Harmonized PET Reconstructions for Cancer Clinical Trials

Sunderland JJ [1], Kinahan PE [2], Karp JS [3], Boellaard R [4], Byrd D [2], Scheuermann J [3], Panetta J [3], Sensoy L [1], Casey MW [5], Stearns CW [6], Shao L [7], Clarke BN [8]

University of Iowa [1], University of Washington [2], University of Pennsylvania [3], VU University, Netherlands [4], Siemens Molecular Imaging [5], GE Healthcare [6], Philips Healthcare[7], Society of Nuclear Medicine and Molecular Imaging Clinical Trials Network [8]

Abstract

This 5 year project, begun in September of 2012, will identify and implement harmonized PET reconstruction parameters for all PET/CT scanners for use in clinical trial scenarios where quantitative accuracy is critical.

The project has 4 specific goals:

1) Accurately calibrate the PET/CT systems from the three major scanner manufacturers using NIST traceable ^{68}Ge/^{68}Ga sources to measure the lowest achievable global calibration variability.
2) Identify and implement manufacturer and model specific reconstruction parameter sets for all late and current model PET/CT systems to harmonize quantitative PET image measurements for clinical trials
3) Test the effectiveness and impact of the harmonized image reconstruction by reprocessing anonymized data already acquired in ongoing multi-center clinical trials using PET imaging.
4) Provide dissemination and long-term sustainability beyond the time frame of this project through the RSNA Quantitative Imaging Biomarkers Alliance (QIBA).

Outcomes This project will provide a sustainable approach to specify reconstruction parameters for generation of quantitatively harmonized PET image data on a manufacturer and model specific basis. These parameters can be chosen to reduce variability or optimize quantitative accuracy, as the needs of the clinical trial dictate. This project will also provide critical information on the residual errors of measurement due to image reconstruction, needed for optimal trial design.

This project is designed to leverage efforts of the Quantitative Imaging Network

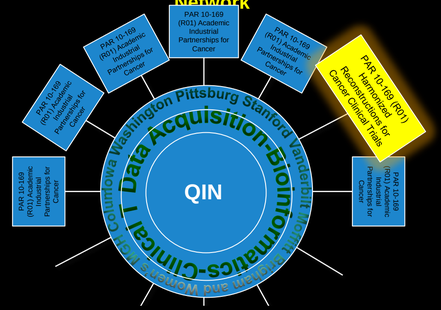


Figure 1: The QIN hub and spoke model. The Harmonized Reconstructions for Cancer Clinical Trials project has direct overlap with work being done in the Data Acquisition, Image Analysis, and Clinical Trials Workgroups.

Industry and Society Involvement

The Clinical Trials Network (CTN) of the SNMMI is coordinating the project, providing administrative support for the considerable logistics, and contributing necessary image server and software infrastructure.

NIST is providing expertise associated with the ^{68}Ge-^{68}Ga NIST traceable sources used in this project. Rad-Qual is manufacturing the NIST traceable sources used in this project.

GE, Philips, and Siemens are each contributing access to their physics and engineering leadership for scientific collaboration, while also contributing personnel and hardware infrastructure necessary to perform the controlled image reconstructions for the project.

EANM Research Limited (EARL) is collaborating to assure that harmonization efforts associated with this project are performed as much in concert with parallel efforts by EANM as possible.

RSNA and its QIBA initiative provide a long-term sustainability mechanism for project results

Primary Goals for Year 1

1) Testing strategies to tie PET scanner calibration to a NIST traceable positron emitting PET radionuclide measurement, thereby minimizing absolute PET scanner measurement variability across scanners and across sites.

1) Developing methodologies to make quantitatively precise Recovery Coefficient (RC) measurements across a number of different make and model PET scanners (Table 1, below) reconstructed using a spectrum of clinically available and relevant reconstruction parameters. The goal is to identify an "optimal" RC curve achievable by all reasonably current make and model PET/CT scanners, and to identify *make and model specific* reconstruction parameters that will achieve that harmonized RC curve

GE	Siemens	Philips
Discovery STE	Biograph True Point	Gemini TF
Discovery RX	Biograph True Point Hi-Rez	Gemini TF Big Bore
Discovery 600	Biograph mCT	Ingenuity TF
Discovery 690		Gemini TF Select
Discovery 710		
Optima 560		

Table 1. Tentative working list of included scanner models. New models will be included as introduced.

NIST Traceable ^{68}Ge/^{68}Ga Source Scanner Calibration Strategies

In an effort to minimize absolute scanner calibration bias, two strategies using NIST traceable quantities of positron emitting ^{68}Ge/^{68}Ga are being tested on multiple PET/CT platforms from different vendors.

Figure 2. Method 1 -Calibration with Rad-Qual's X-Cal system being co-developed with author (PK). The system has ^{68}Ge/^{68}Ga NIST traceable scanner, dose calibrator, and well counter sister sources.

Figure 3. Method 2 - Calibration with 20 cm diameter, 30 cm length implicitly traceable ^{68}Ge/^{68}Ga cylindrical phantom.

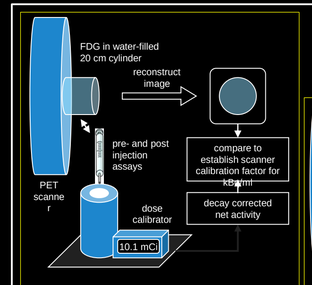


Figure 4. Standard calibration procedure

Method 1: Using the X-Cal System (Also QIN DAWG demonstration project)

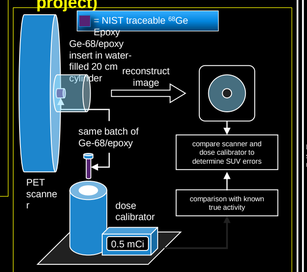


Figure 5. X-Call Calibration.

Method 2: Using a 20 cm Diameter NIST Traceable ^{68}Ge Epoxy Calibration Phantom

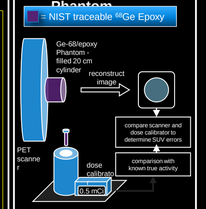


Figure 6. The 20 cm Calibration Phantom method.

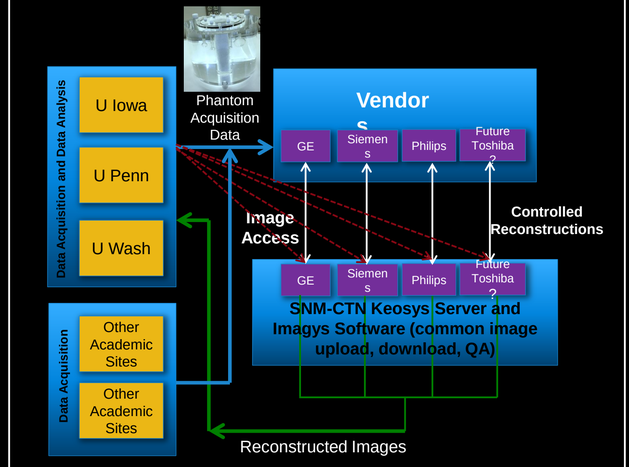
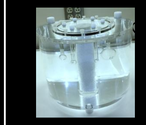


Figure 7. Acquisition, reconstruction and analysis workflow



To define the Recovery Coefficient curves for this project, the NEMA IEC Image Quality phantom is being used with 13 different sized spherical inserts ranging from 8.5 to 44 mm in diameter to measure more continuously the recovery coefficient space.

The group is defining the RC curves with very high statistics acquisitions so that we can achieve harmonization with as little variability as possible.

We are not only varying reconstruction parameters, but also measuring the measurement noise and variance associated with several common metrics including SUV_{max}, SUV_{mean}, and SUV_{peak}

Early Sample Data

Figure 8. Recovery coefficient curves measured from two 9.7:1 lesion:background 30 minute high statistics acquisitions with two different sphere sets (a total of 12 different sized spheres). These lower noise scans are used to define the RC curves for a spectrum of different reconstructions for the Siemens Hi-Rez PET/CT scanner platform. Similar data sets are being acquired for all recent vintage scanner models. From these data sets, optimal harmonized reconstruction parameters for each make and model scanner will be identified.

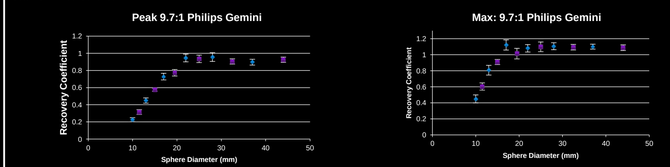


Figure 9. Recovery coefficient curves measured from two 9.7:1 lesion:background 30 minute acquisition with two different sphere sets (a total of 12 different sized spheres). In this experiment the 30 minute scan was broken into 10 x 3 minute scans (roughly clinical duration). Peak and Max values were measured for each reconstruction. The mean with standard deviation from the 10 different reconstructions is plotted.. It is another of the goals of the project to characterize the noise associated with measurements of several different quantitative metrics

Near and Long Term Interfacing between QIN and the Harmonized Reconstruction Project

1) **The first PET DAWG demonstration project includes testing of the modified X-Cal system for global PET scanner calibration. Primary academic sites (Iowa, Washington, and Penn) will be testing this methodology rigorously as part of the Reconstruction Harmonization project.**
2) **Rigorously quantitative phantom studies based upon NIST traceable measurements performed with the NEMA IEC IQ phantom, and CTN oncology phantom will be made available to QIN sites working on segmentation and analysis software.**
3) **Results from the Reconstruction Harmonization projects will be available to be applied to QIN clinical trials.**

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