

New EARL PET/CT Performance Standards for Oncological PET/CT Studies

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Ronald Boellaard

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Terez Sera received honoraria for data interpretation from EARL.

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Nothing to disclose

Overview

- Brain standardisation
- ^{89}Zr accreditation
- New EARL standards (main part)

Feasibility of a brain PET harmonization program for state of the art PET/CT systems

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Aim: to explore the feasibility of developing a standard for harmonizing performance of FDG PET brain studies on state of the art PET/CT systems

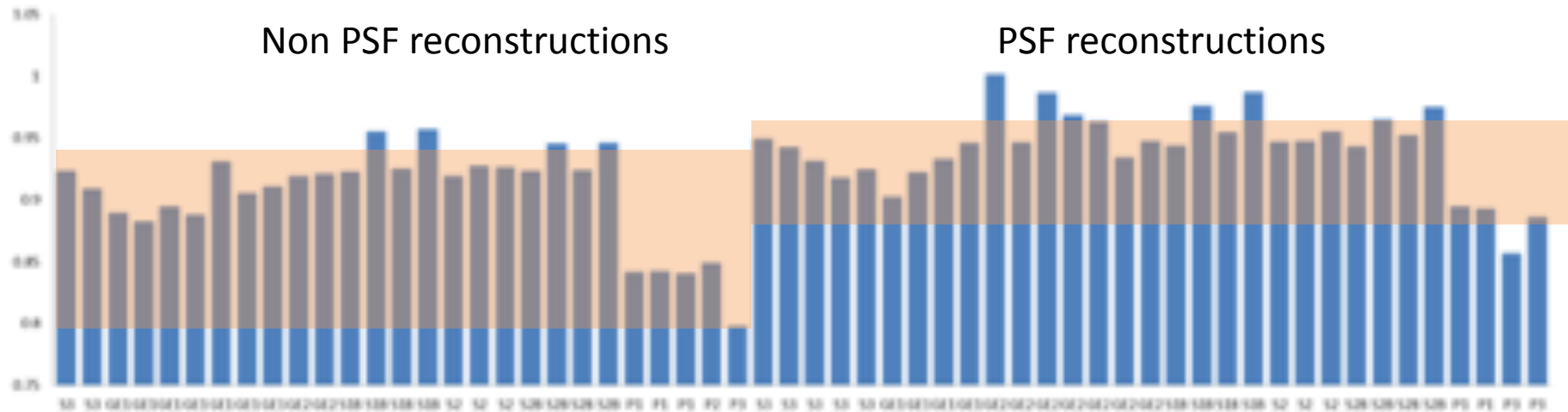
- 11 different state of the art PET/CT systems from 3 vendors
- 30 min Hofman brain phantom PET/CT scans – up to 10 different reconstructions



Variation in image quality and quantitative accuracy across systems:



Grey matter recovery



Harmonized performance (shaded) = at least one reconstruction per system can comply

Conclusion: This pilot study shows that harmonization of PET/CT system performance for FDG brain studies seems feasible within +/-10% (non PSF) and +/- 5% (PSF).

^{89}Zr PET accreditation

^{89}Zr – isotope used for antibody labelling

EJNMMI physics (in press)

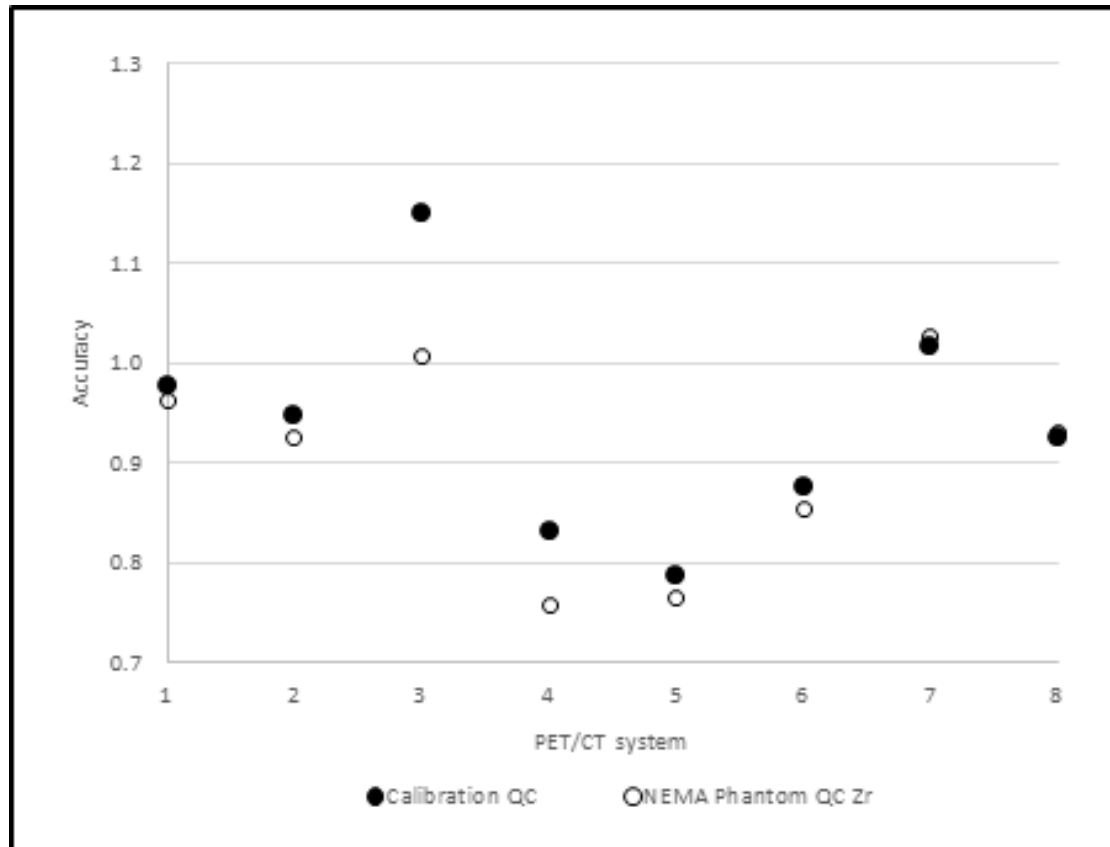
SHORT COMMUNICATION

Open Access

Feasibility of PET/CT system performance harmonisation for quantitative multicentre ^{89}Zr studies

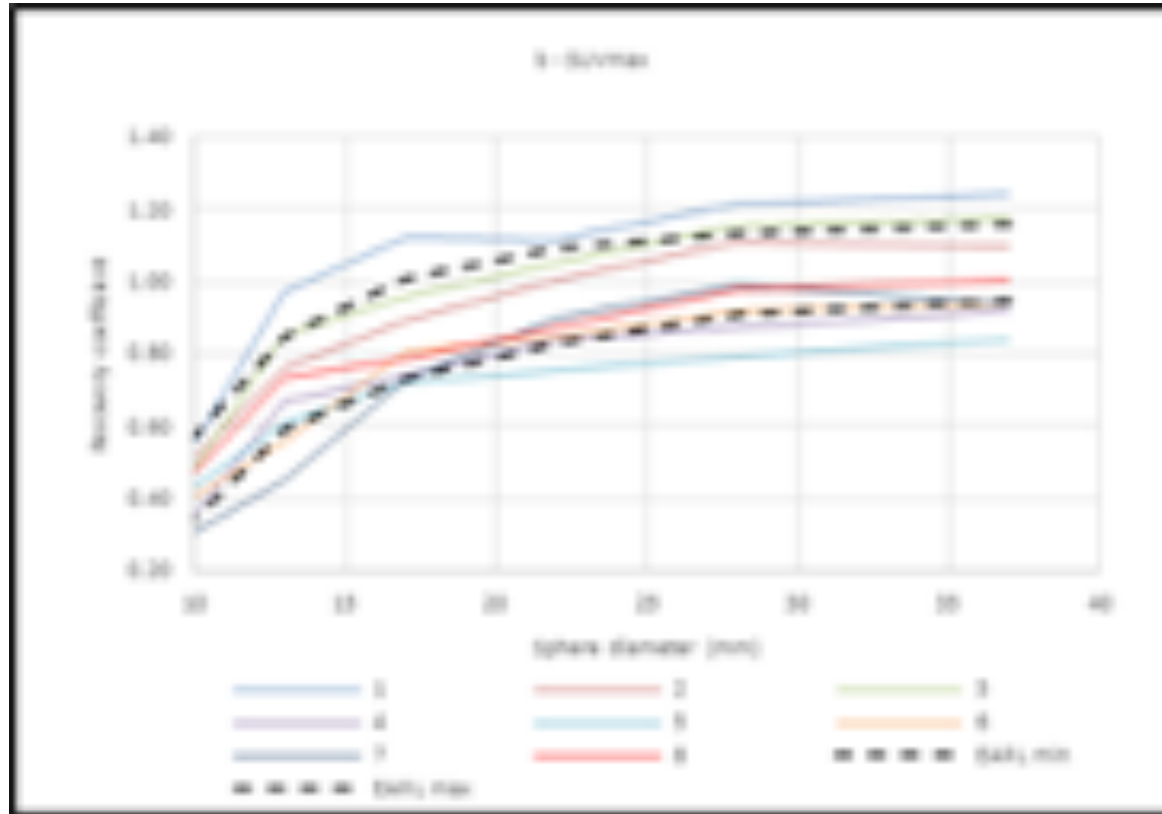
Andres Kaalep^{1*}, Marc Huisman², Terez Sera^{3,5}, Danielle Vugts², Ronald Boellaard^{2,4*}, on behalf of EARL⁵, EATRIS⁶ and the TRISTAN Consortium (#B4SD-116106)⁷

^{89}Zr PET accreditation



4 out of 8 systems show a calibration error of more than 10%

^{89}Zr PET accreditation



^{89}Zr recovery curves are comparable to those seen with FDG (apart from the calibration error)

^{89}Zr PET accreditation

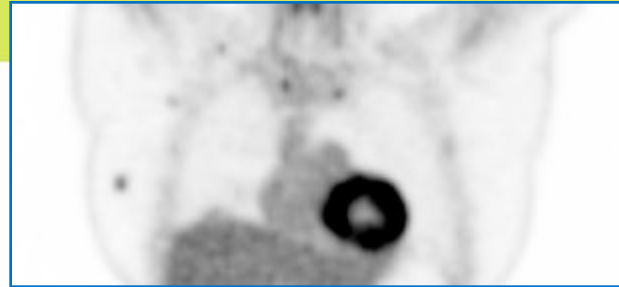
Procedure to obtain ^{89}Zr accreditation:

1. Obtain the ^{18}F accreditation using both phantom QC
 - Calibration using uniform cylinder
 - Image Quality QC
2. ^{89}Zr accreditation is performed on top of ^{18}F
 - Calibration QC using uniform cylinder (with ^{89}Zr solution) only
3. Same calibration criteria as for ^{18}F
 - < 10% deviation

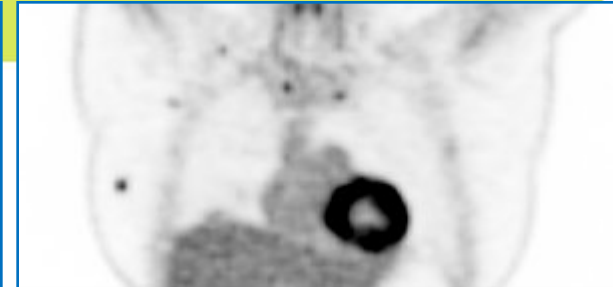
Overview

- Brain standardisation
- ^{89}Zr accreditation
- **New EARL standards (main part)**

Introduction



Conventional
reconstruction



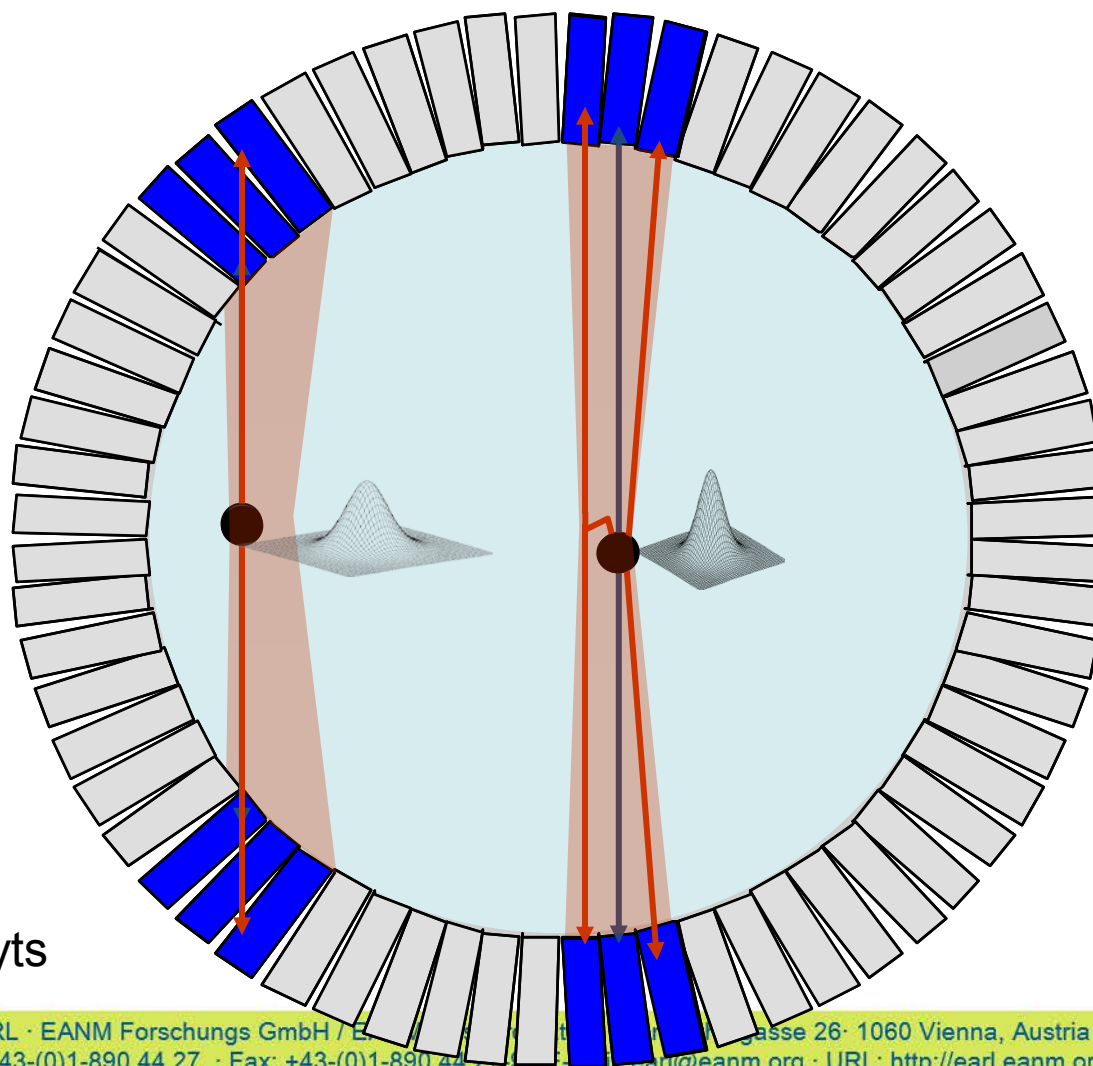
PSF
reconstruction

- PET image reconstruction with point spread function (PSF) modelling aims to,
 - Improve spatial resolution.
- PSF images are being widely used for,
 - Visual assessment.
 - SUV quantification.
- However, prior studies have shown SUV quantification from PSF images is not directly comparable to conventional non-PSF images.

PSF reconstruction

- Users like to use PSF for its improved image quality
- At present about 50% of EARL and of installed systems have PSF reconstructions
- Therefore, a good time to explore update of EARL to allow for PSF reconstructions

Resolution modeling



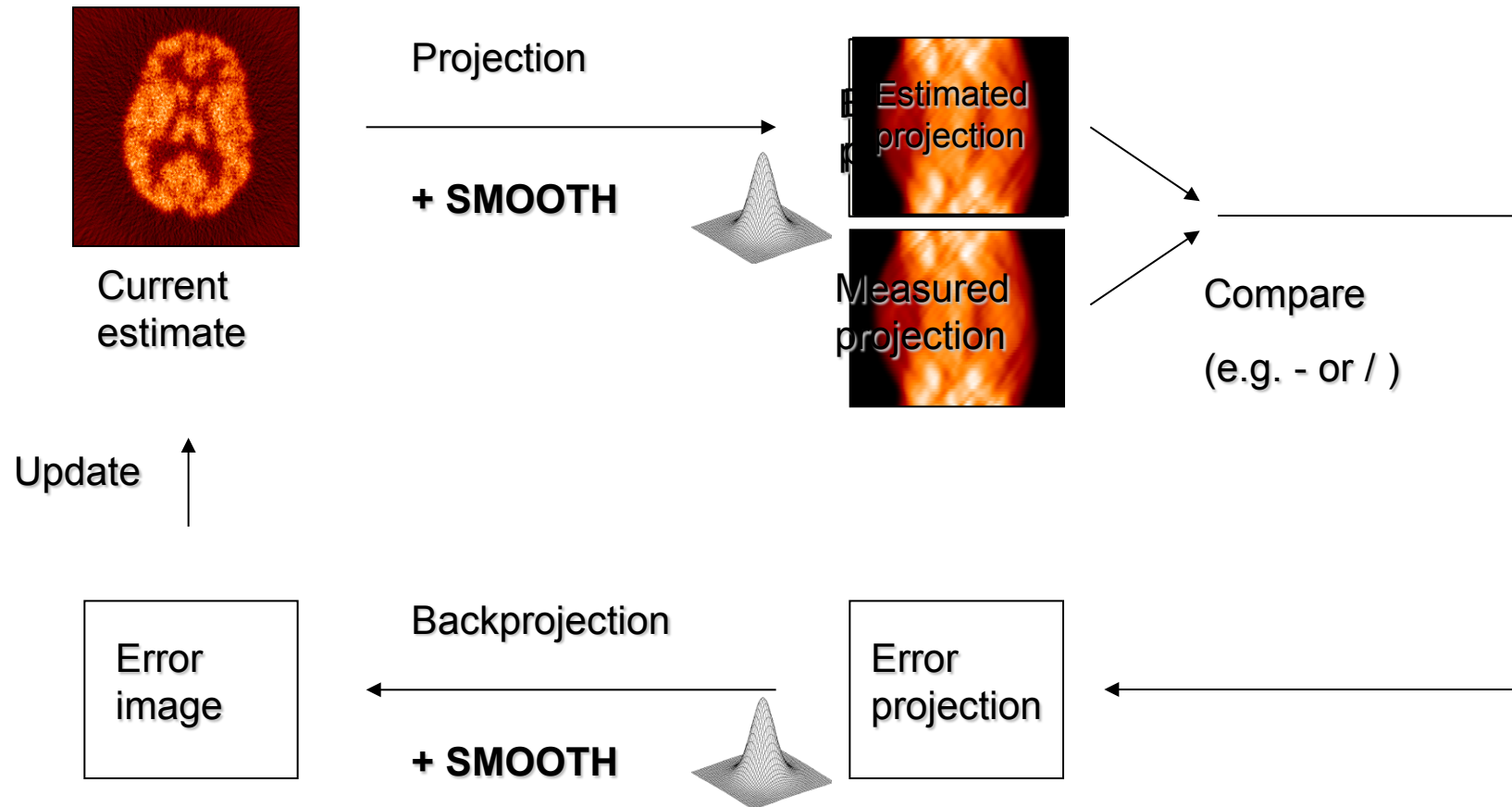
Courtesy of J. Nuyts

Iterative reconstruction with resolution modeling

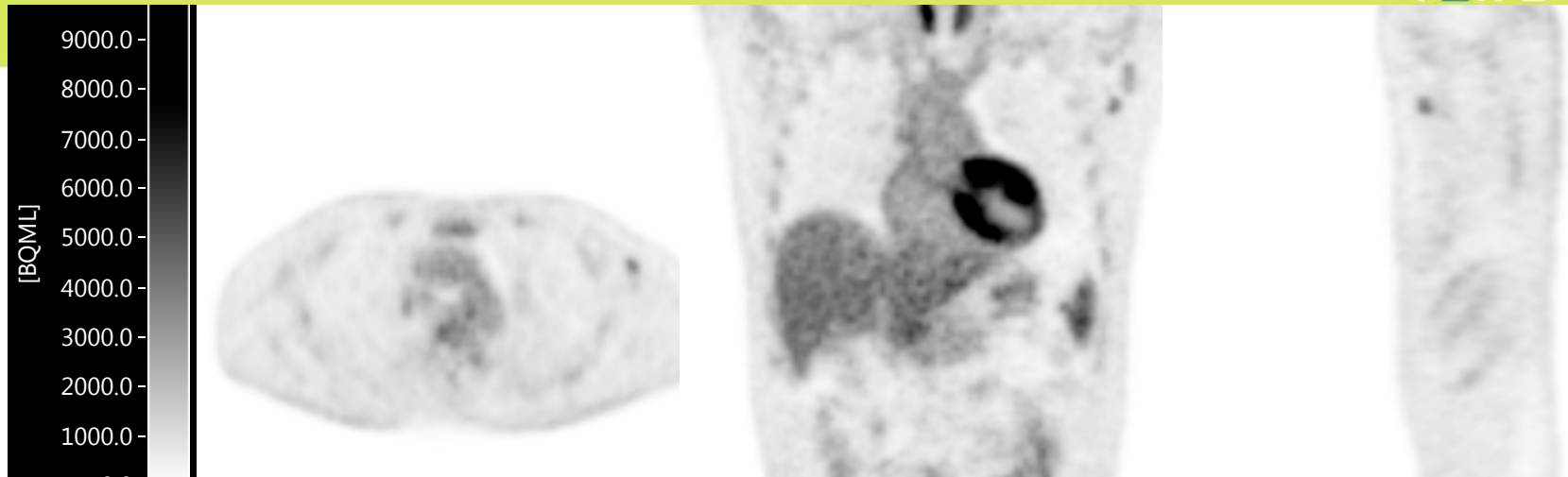
RESEARCH 4LIFE[®]
an EANM initiative

image space

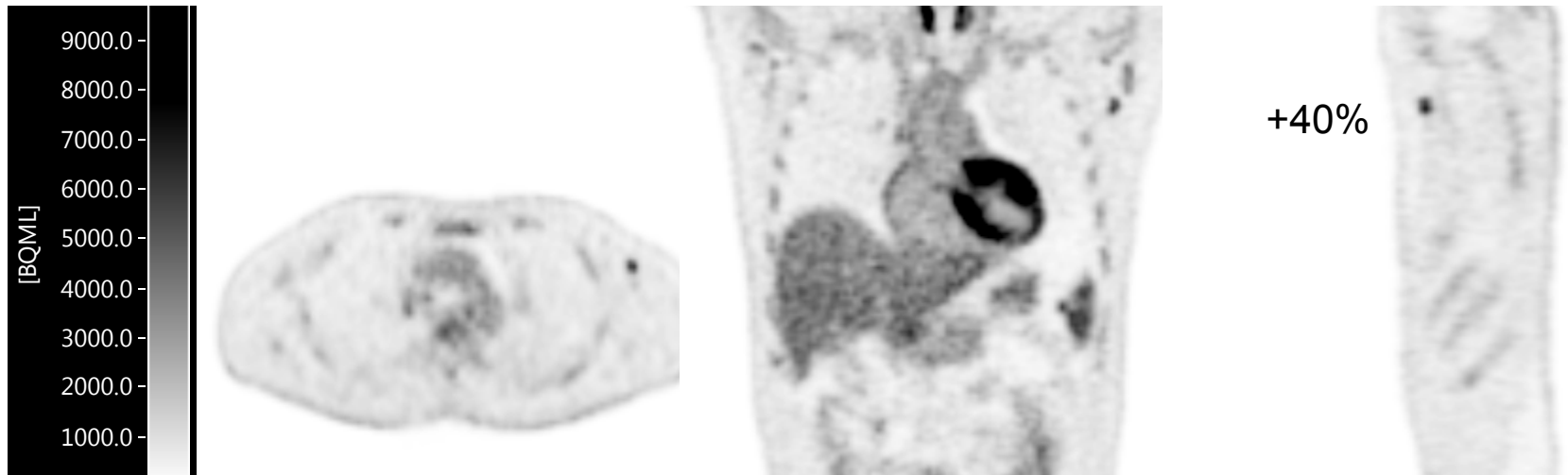
projection space



EARL



PSF

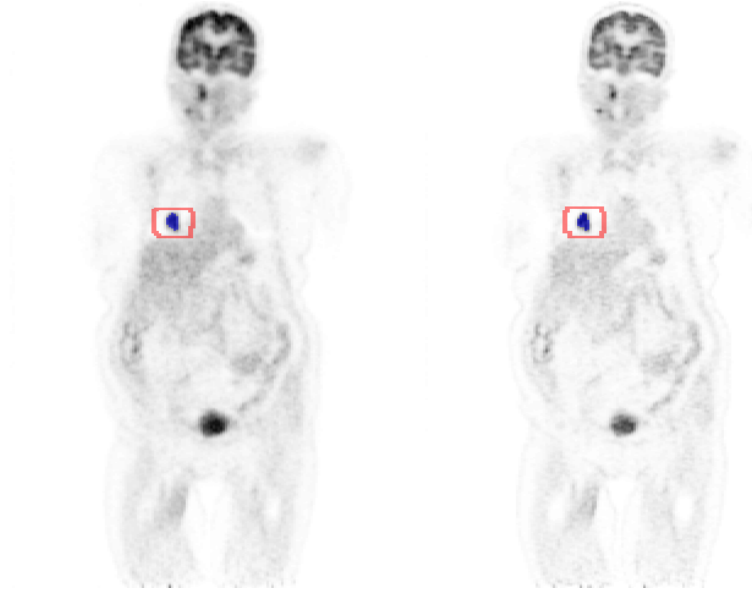


Courtesy of D. Van Assema, ErasmusMC

New technologies

- Use of resolution modeling during reconstruction
 - TOF and digital PET (improvement of TOF by factor 2)
 - Use of smaller voxel sizes
-
- Improved image spatial resolution
 - Better lesion detectability
 - Different (increased) quantitative results !

SUVmax liver ~unaffected by PSF (=DS reference tissue)



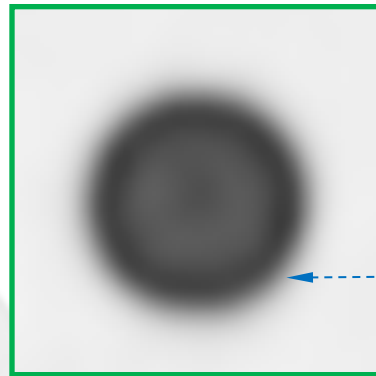
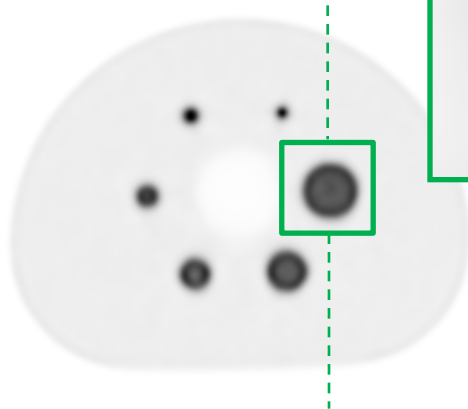
EARL

PSF

SUV _{max} target	=	9.9	13.8	+39%
SUV _{max} liver	=	4.1	4.0	-2.5%

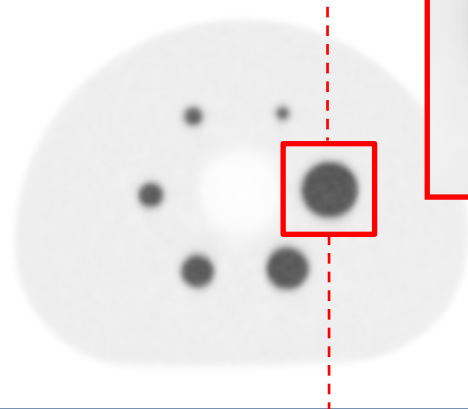
However....edge artifacts

10-to-1 sphere-to-background ratio
0 – 15 SUV display range



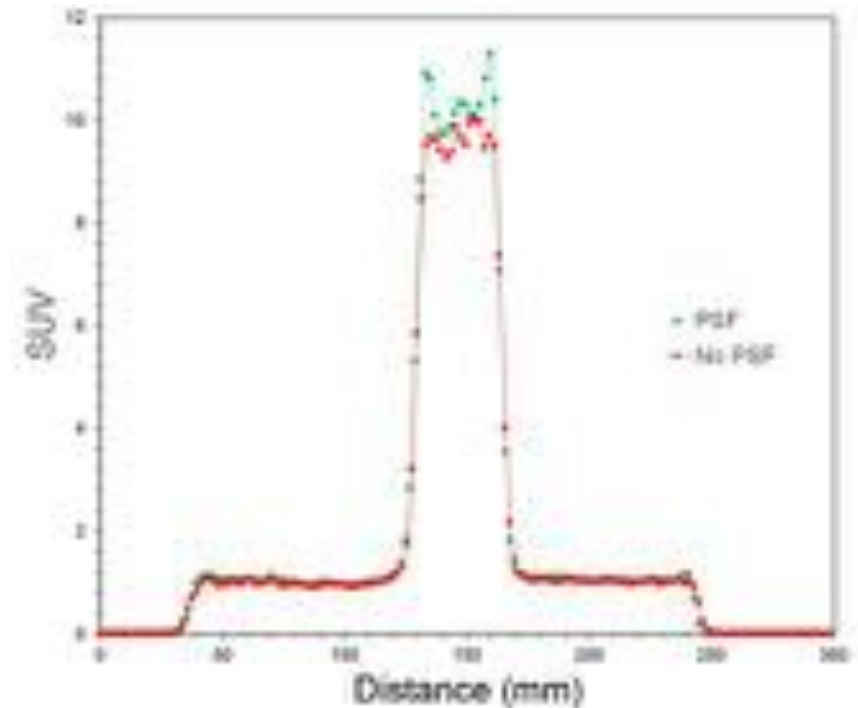
OSEM+TOF+PSF,
2i, 21s,
all pass filter,
2 mm voxels

Edge artifact due to PSF



OSEM+TOF, No-PSF
2i, 21s,
all pass filter,
2 mm voxels

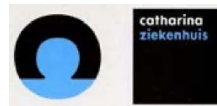
- Image reconstruction with PSF is associated with edge artifacts (Politte & Snyder 1988)



Feasibility of state of the art PET/CT system performance harmonisation

Andres Kaalep¹, Terez Sera^{2,8}, Sjoerd Rijnsdorp³, Maqsood Yaqub⁴, Anne Talsma⁵, Martin A. Lodge⁶, Ronald Boellaard^{4,7,8}

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7. University of Groningen, University Medical Center Groningen, Groningen, The Netherlands
8. On behalf of EANM Research Limited (EARL), Vienna, Austria

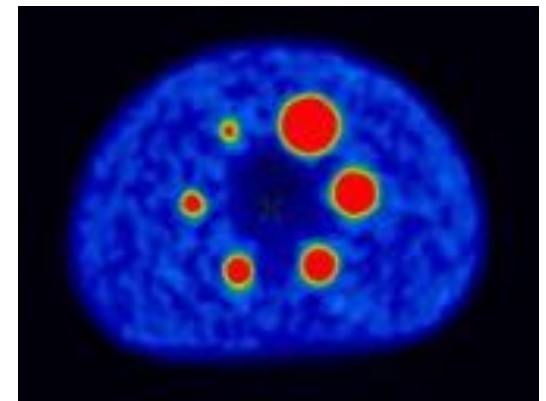
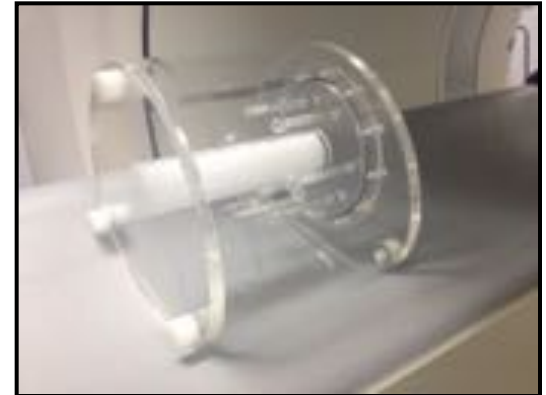


Objective

- To investigate the feasibility of quantitative harmonisation among state-of-the-art PET/CT scanners from major manufacturers
- To produce prototype harmonising criteria for an update of EANM EARL accreditation program

Methods

- Phantom experiments using NEMA image quality phantom
 - Hot spheres of 10, 13, 17, 22, 28, 37 mm diameter
 - Sphere-to-background ratio of 10:1
 - SUVmean, SUVmax & SUVpeak
- 2-phase study
 - 1. Determining harmonising reconstruction settings (development dataset)
 - 2. Validating harmonising capabilities on additional systems (test dataset)



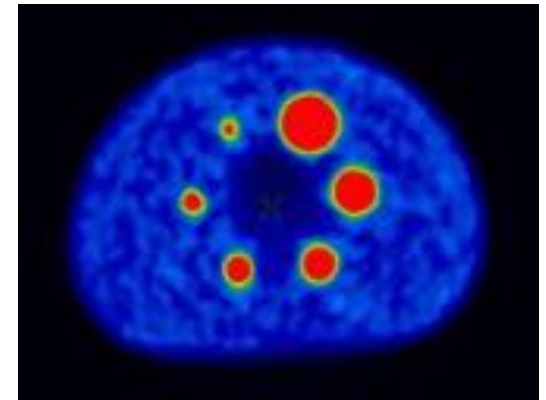
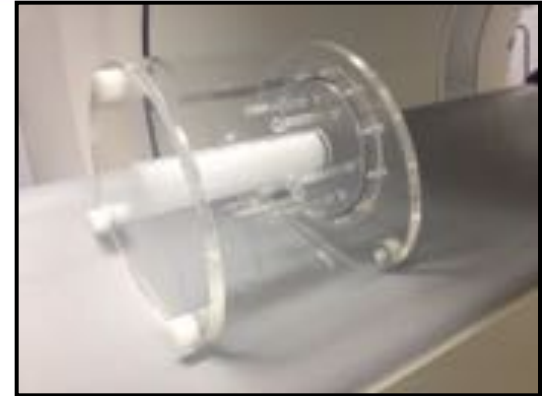
Methods

Phase 1 - Selecting harmonising reconstruction modes

- 15x3 initial datasets from:
 - Siemens Biograph mCT
 - Siemens Biograph mCT Flow
 - GE Discovery 710
 - Philips Ingenuity TF 128
- Variables:
 - voxel size
 - post filter
 - acquisition duration
 - Flow mode / Q.Clear

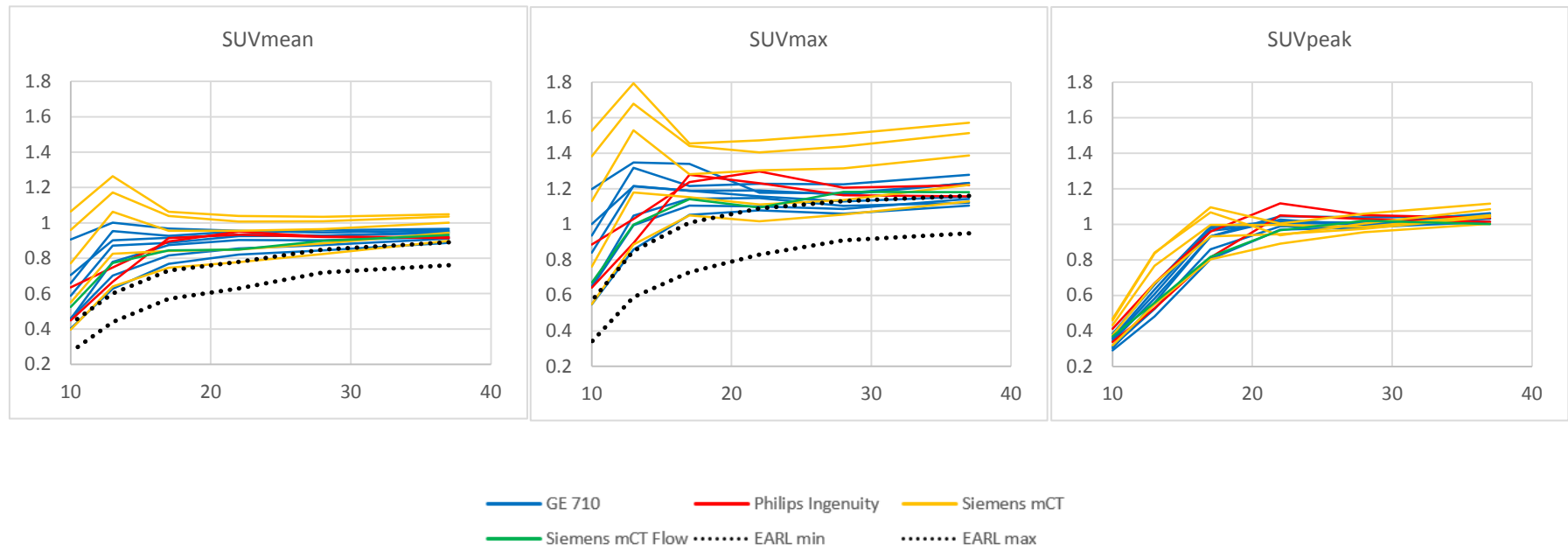
Phase 2 - Validation of harmonising reconstruction modes

- 23 datasets from 18 PET/CT scanners:
 - Siemens Biograph mCT
 - Siemens Biograph mCT Flow
 - GE Discovery 710
 - GE Discovery IQ
 - GE Discovery MI
 - Philips Ingenuity
 - Philips Vereos
- Independent scans by the volunteer sites



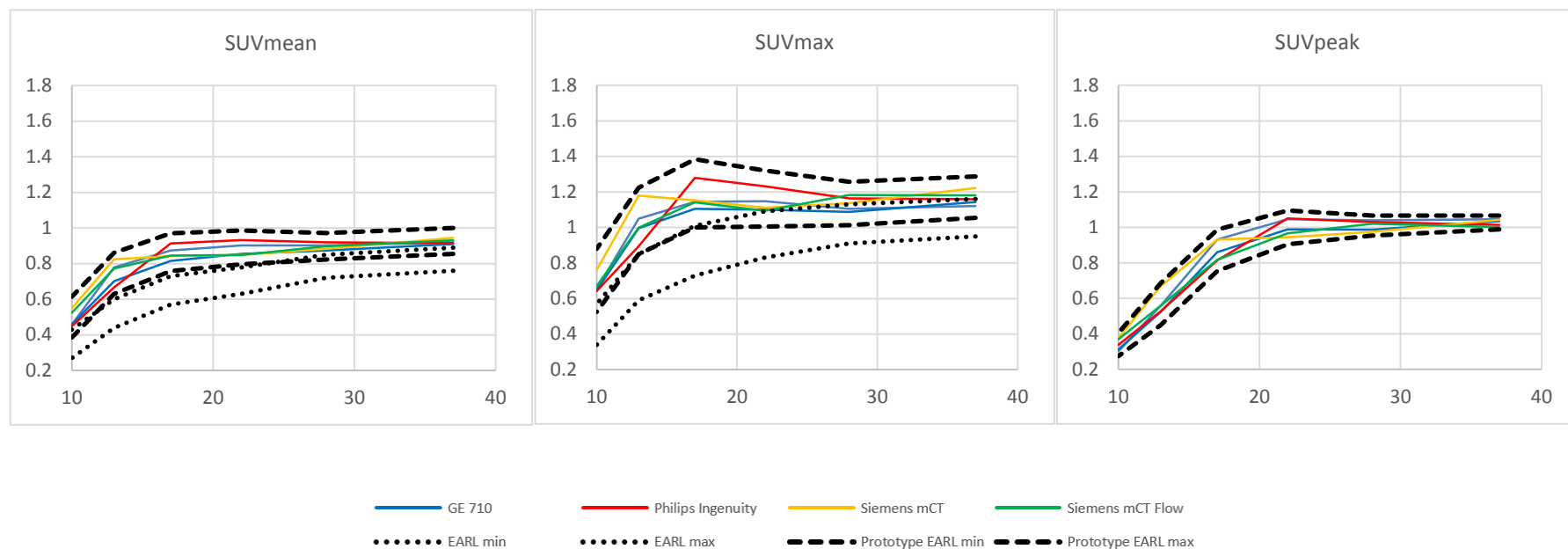
Results - Initial reconstruction modes

- Initially large inter- and intrasystem variability
- RC curves outside current EARL specifications
- SUVpeak shows excellent harmonising capacity, but low RCs for small spheres



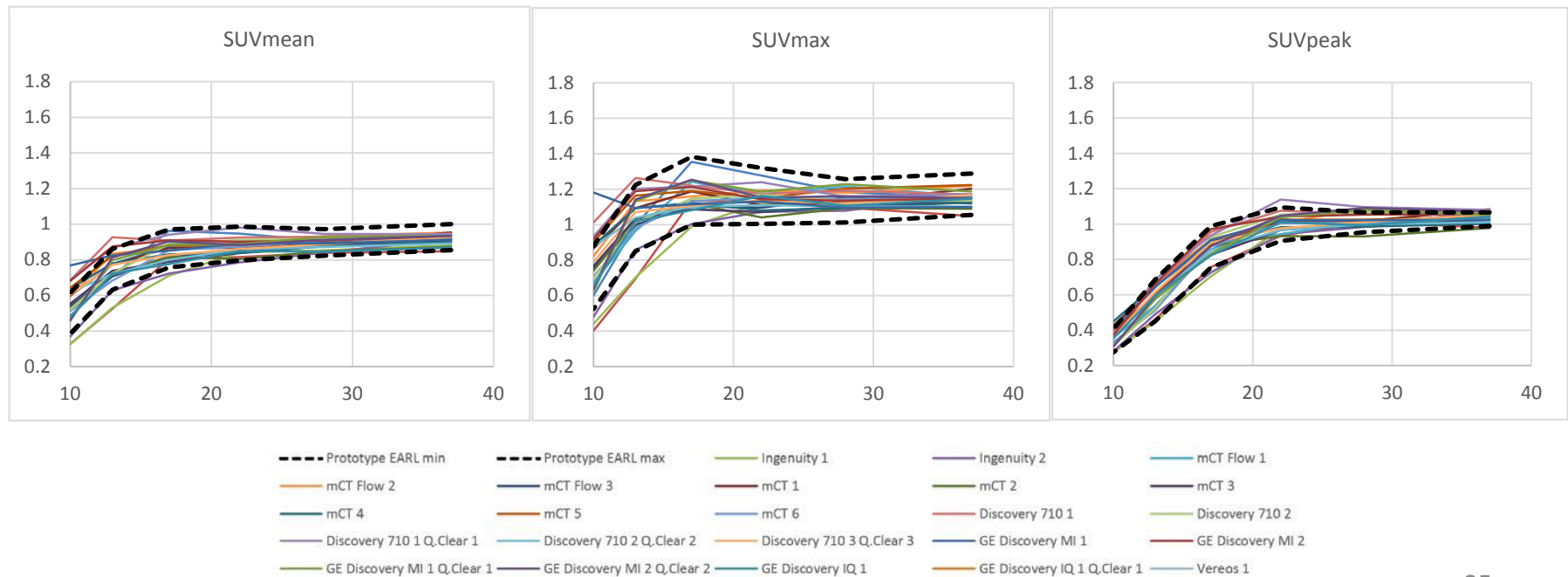
Results - Harmonising reconstruction modes

- Prototype EARL specifications increase overall RC ~25%
- Reconstruction setting - stable in reduced count rate conditions
- Curves become more „flat“



Results - Validation results

- Prospective independent test data from 23 imaging sites
- Majority of results fit within prototype EARL specifications



25

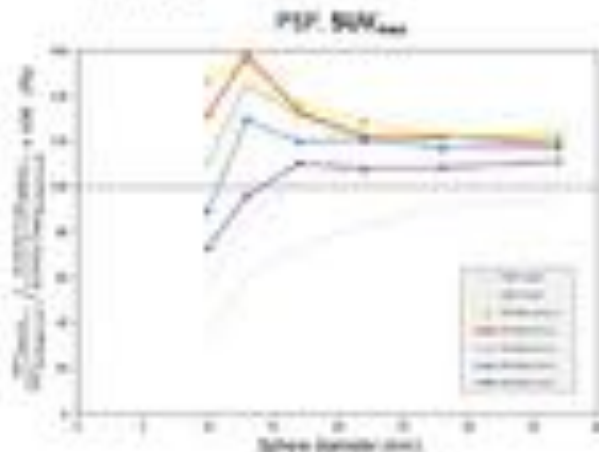
Discussion

- New reconstruction technologies i.e PSF can increase variability among scanners not subjected to harmonisation
- In PSF enabled reconstruction, impact of sphere-to-background ratio on the quantitative results should be further investigated
- Prototype EARL specifications could merge often separate „for quantification“ and „for lesion detection“ reconstructions into one
- SUVmax positive bias of about 10-25% expected for objects >17 mm diameter
- SUVpeak could be used as a robust quantitative metric
 - Low sensitivity to noise
 - Low sensitivity to reconstruction parameters
 - Similar recoveries with current EARL specs of SUVmax
 - Least sensitive to sphere-to-background ratio and Gibbs artefacts

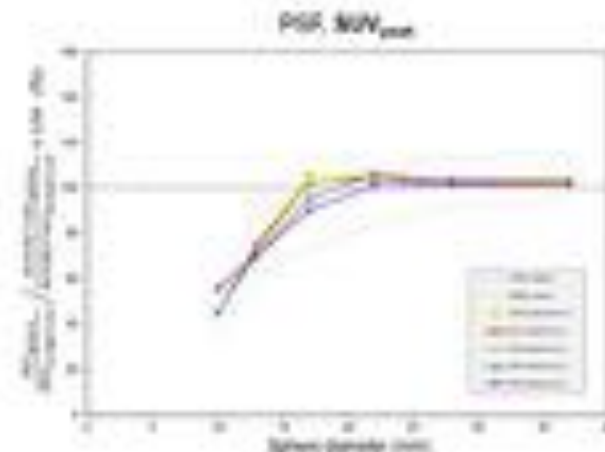
- M.A. Lodge & R. Boellaard have demonstrated that:

PSF & SUV_{peak}

- SUV_{peak} defined as a 1 mL spherical VOI, positioned to maximize mean.
– Incorporates slightly greater volume averaging than SUV_{max}
- SUV_{peak} substantially reduces bias over a range of sphere-to-background ratios.



(a) OSEM+TOF+PSF, 2i, 21s, all pass filter, 2 min voxels



(b) OSEM+TOF+PSF, 2i, 21s, all pass filter, 2 min voxels

Conclusion

- Harmonisation of state of the art PET/CT systems is feasible
 - Results can further improve with adjustment of reconstruction parameters
- Prototype EARL specifications
 - ~25% increased contrast recoveries for SUVmean and SUVmax, effect being larger in smaller (≤ 17 mm) spheres
 - Stable RC curved in low statistics scenarios (≤ 2 min/bed position)
 - SUVpeak is now added to the standard

We thank the contributions of:

- University Clinic for Nuclear Medicine and Endocrinology, Salzburg, Austria
- VU University Medical Centre, Amsterdam, The Netherlands
- GIE Humanitep, Lille, France
- University Hospital of Cologne, Cologne, Germany
- Ghent University Hospital, Ghent, Belgium
- Zentralklinik Bad Berka, Bad Berka, Germany
- University Medical Centre Utrecht, Utrecht, The Netherlands
- Centre Antoine Lacassagne, Nice, France
- VieCuri Medical Centre, Venlo, The Netherlands
- University Hospital Magdeburg, Magdeburg, Germany
- Cancer Institute Nantes-Atlantiques, St. Herblain, France
- Groene Hart Ziekenhuis, Gouda, The Netherlands
- University Hospital of Navarra, Pamplona, Spain
- University Hospital Antwerp, Edegem, Belgium
- Heinrich-Heine University Hospital, Düsseldorf, Germany
- University Hospital Brussels, Jette, Belgium
- Bispebjerg Hospital, Copenhagen, Denmark
- St. Vincent's Hospital PET - CT Centre, Linz, Austria
- Postgraduate Institute of Medical Education and Research, Chandigarh, India
- King's College Hospital NHS Foundation Trust, London, United Kingdom
- Uppsala University Hospital, Uppsala, Sweden.

EARL website <http://earl.eanm.org>

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<https://doi.org/10.1007/s00259-017-3853-7>



ORIGINAL ARTICLE

EANM/EARL FDG-PET/CT accreditation - summary results from the first 200 accredited imaging systems

Andres Kaalep¹ · Terez Sera^{2,3} · Wim Oyen⁴ · Bernd J. Krause⁵ · Arturo Chiti⁶ · Yan Liu⁷ · Ronald Boellaard^{3,8,9}

European Journal of Nuclear Medicine and Molecular Imaging
<https://doi.org/10.1007/s00259-018-3977-4>

ORIGINAL ARTICLE



Feasibility of state of the art PET/CT systems performance harmonisation

Andres Kaalep¹ · Terez Sera^{2,3} · Sjoerd Rijnsdorp⁴ · Maqsood Yaqub⁵ · Anne Talsma⁶ · Martin A. Lodge⁷ · Ronald Boellaard^{3,5,8}

Introduction of new standard:

1. Formally introduced 1-1-2019
2. “EARL2” on top of “EARL1”
3. In case you opt for EARL2, then EARL2 and EARL1 recons will be both required
4. Currently clinical translation of EARL2 SUVs to EARL1 SUVs are explored:
 - A filter is identified to convert EARL2 to EARL1
5. Foreseen transition phase of several (2?) years:
 - Until less than 10% of system do NOT have PSF recons
 - To allow to run out current studies

Overview

- Brain standardisation (WIP)
- ^{89}Zr accreditation
 - start per 1-1-2019
- New EARL standards
 - start per 1-1-2019

Current EARL center of excellence network

FRANCE	43	HUNGARY	4	AZERBAIJAN	1
THE NETHERLANDS	39	SWITZERLAND	4	ESTONIA	1
GERMANY	23	ISRAEL	3	INDIA	1
BELGIUM	18	KUWAIT	3	JORDAN	1
SPAIN	18	PORTUGAL	3	PAKISTAN	1
ITALY	15	SWEDEN	3	SAUDI ARABIA	1
UNITED KINGDOM	9	VIET NAM	3	SLOVAKIA	1
BRAZIL	6	ARGENTINA	2	SOUTH AFRICA	1
DENMARK	6	CANADA	2	TURKEY	1
NORWAY	6	CZECH REPUBLIC	2	URUGUAY	1
UNITED STATES	6	FINLAND	2		
AUSTRIA	4	ROMANIA	2		

