

First Clinical Experience with **Discovery MI Digital PET/CT**

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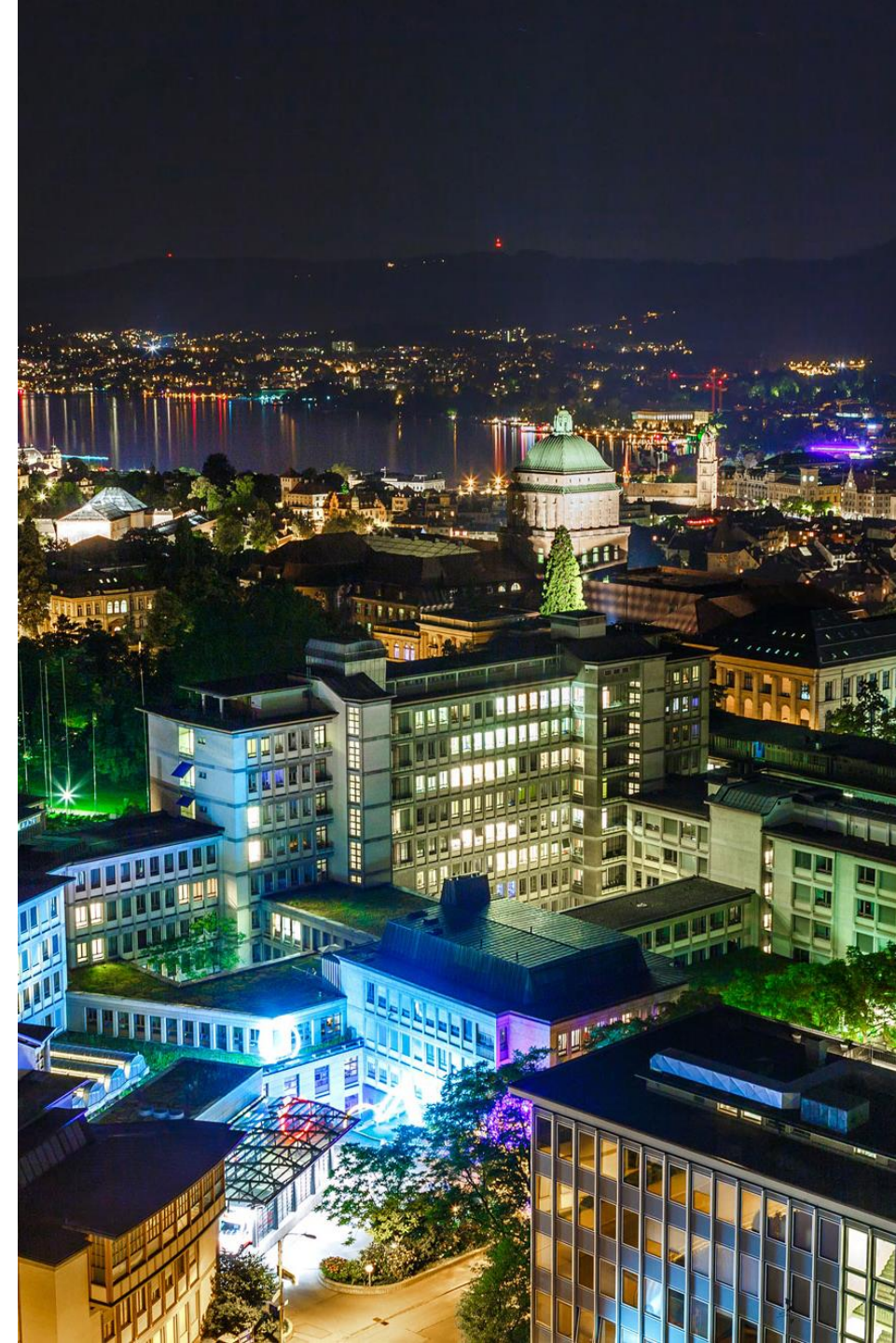


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Agenda

BelNuc GE Symposium

1. **Digital PET detectors**
2. PET image reconstruction
 - Time of flight
 - Q.clear™
 - Impact of radiotracers and dosage
3. Dose reduction
4. Motion correction with PET: Q.freeze™, Q.static™
5. Metal artifact reduction
6. True whole-body acquisition



Digital PET detectors

Comparison with analog PMT

Photomultiplier tubes (PMT):

Used in analog PET/CT, cannot be used with PET/MR.

Silicon photomultipliers (SiPM):

Can be used with PET/MR, allow for time-of-flight reconstruction.

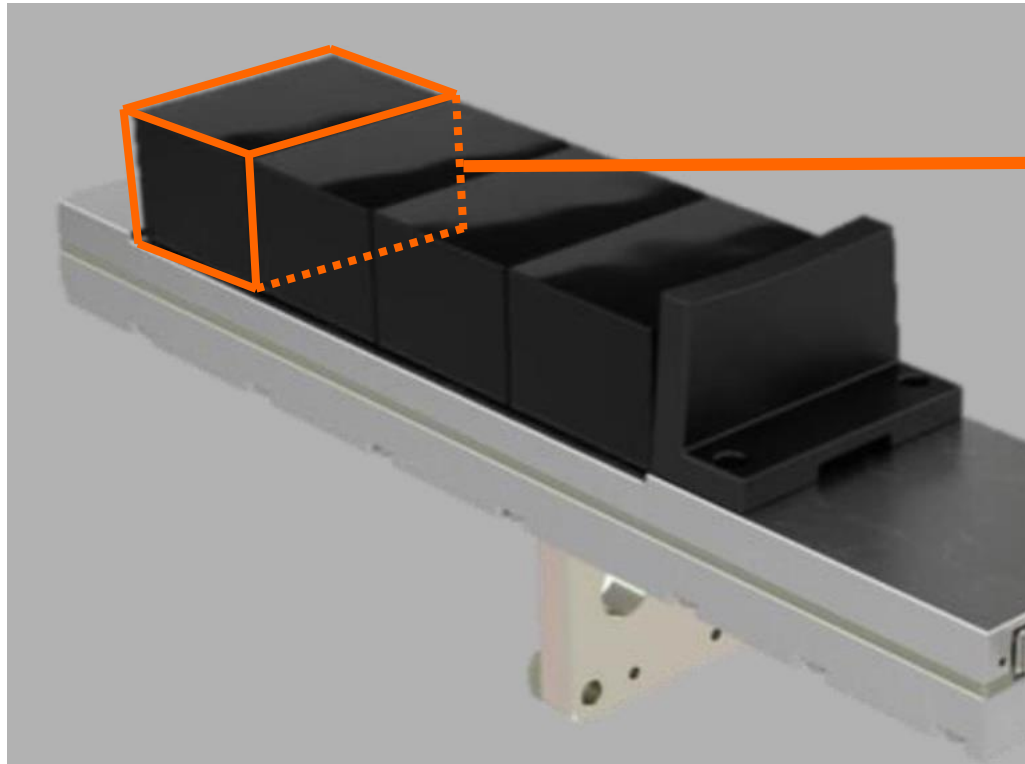
	PMT	SiPM
Detection efficiency	25%	50%
Coincidence timing res.	550 ps	350 ps
Gain	10^6	$10^5 - 10^6$
Sensitivity	7.5 cps/kBq	13.5 cps/kBq
Noise	Low	Low
Profile	100 mm	2 mm
MR compatibility	No	Yes
Technology maturity	40 yrs	8 yrs
Cost	Low	High

Based on EANM 2010 presentation by A. Ganin, former chief engineer, GE Healthcare

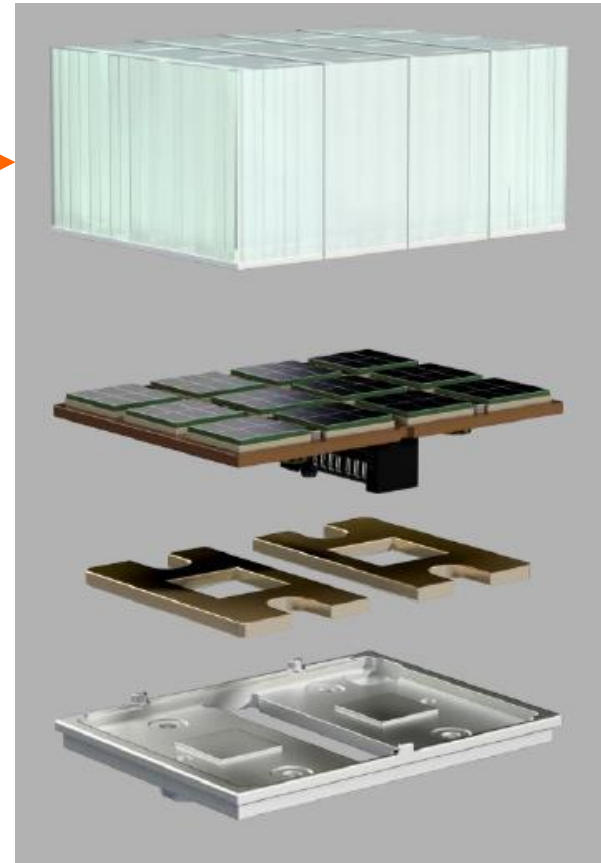


Digital PET detectors

SiPM



Detector array



Detector components

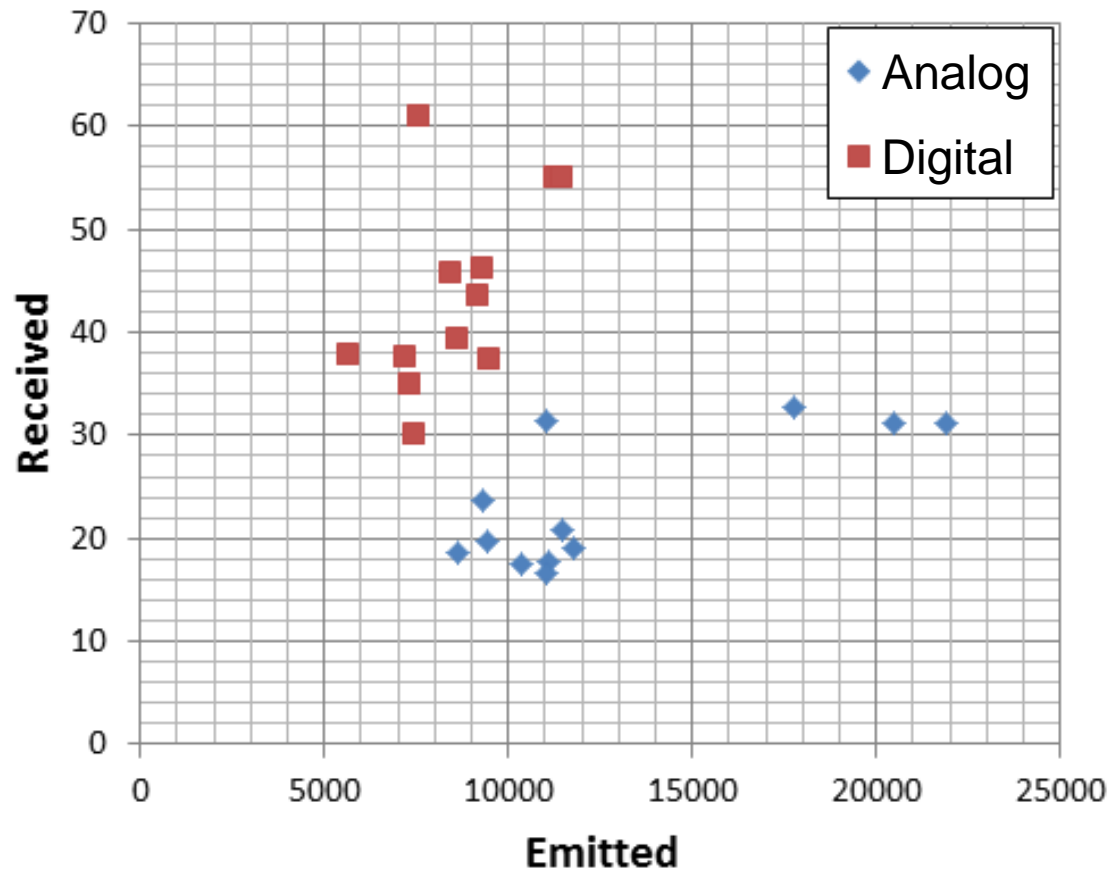
Scintillator crystal array
with light guides and spectral reflectors

Silicon photomultiplier
(SiPM)

Thermal conductive pad

Digital PET detectors

Comparative count data



Digital PET acquired *after* analog PET.

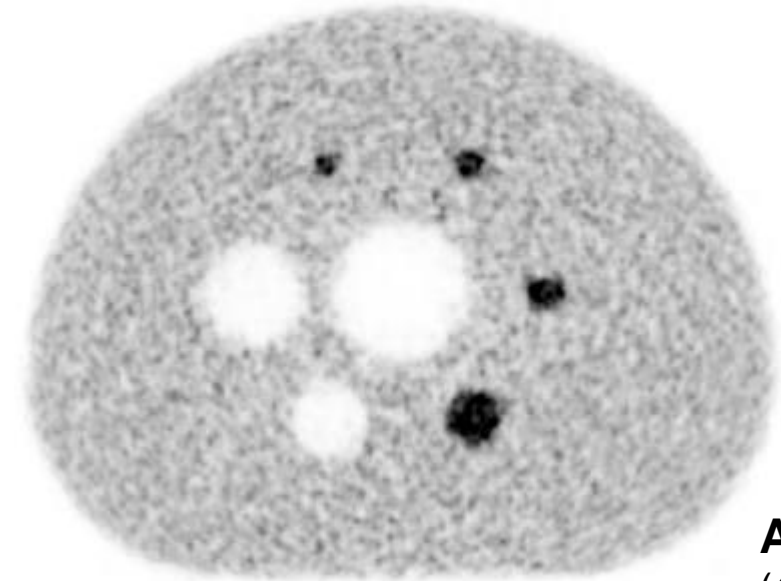
Digital PET detectors

GE Discovery MI

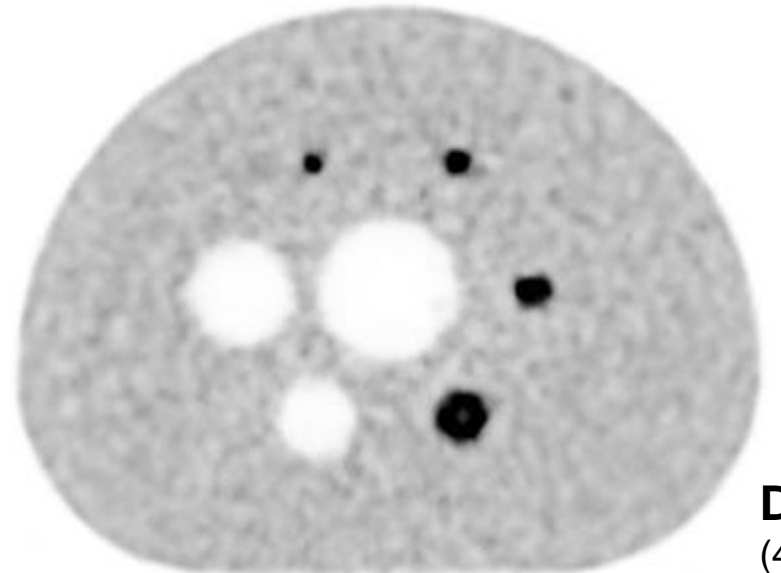
- Highest NEMA sensitivity of any TOF-PET/CT system*
- Highest NECR of any TOF-PET/CT system*
- Up to 2x improved volumetric resolution**

* ITN comparison charts

** Phantom tests



Analog
(4 iterations)



Digital
(4 iterations)



Digital PET detectors

Image quality - Body



Analog



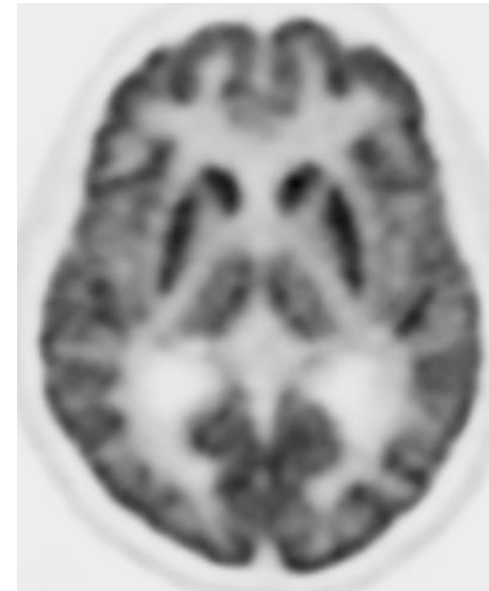
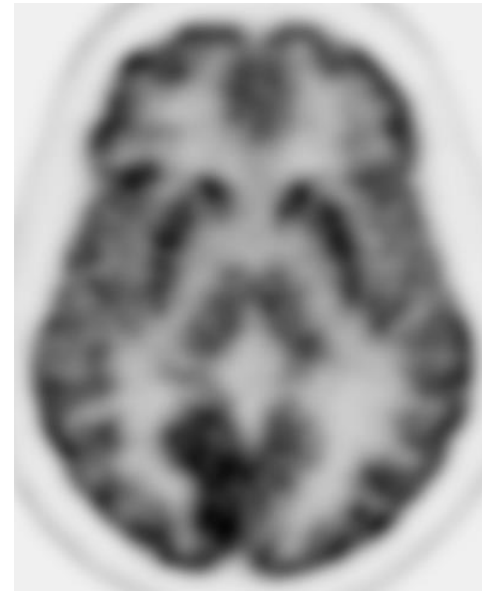
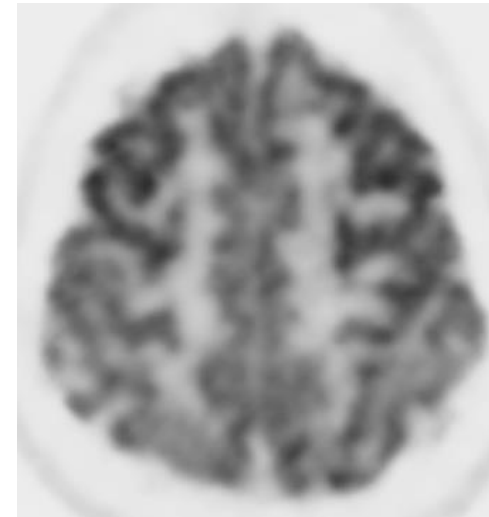
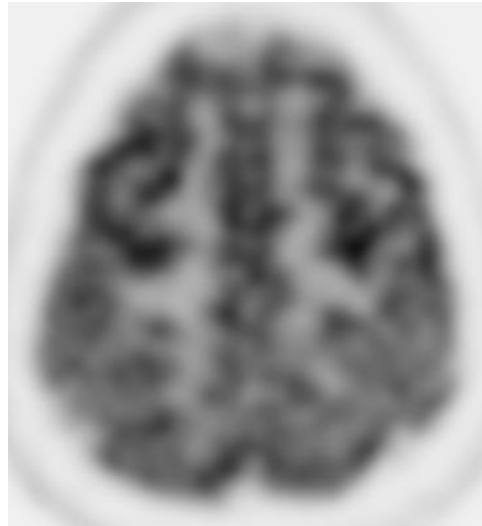
Digital

¹⁸F-FDG
56yo male
T cell lymphoma
Complete remission



Digital PET detectors

Image quality - Brain



^{18}F -FDG
49yo female
Memory disorders

Analog

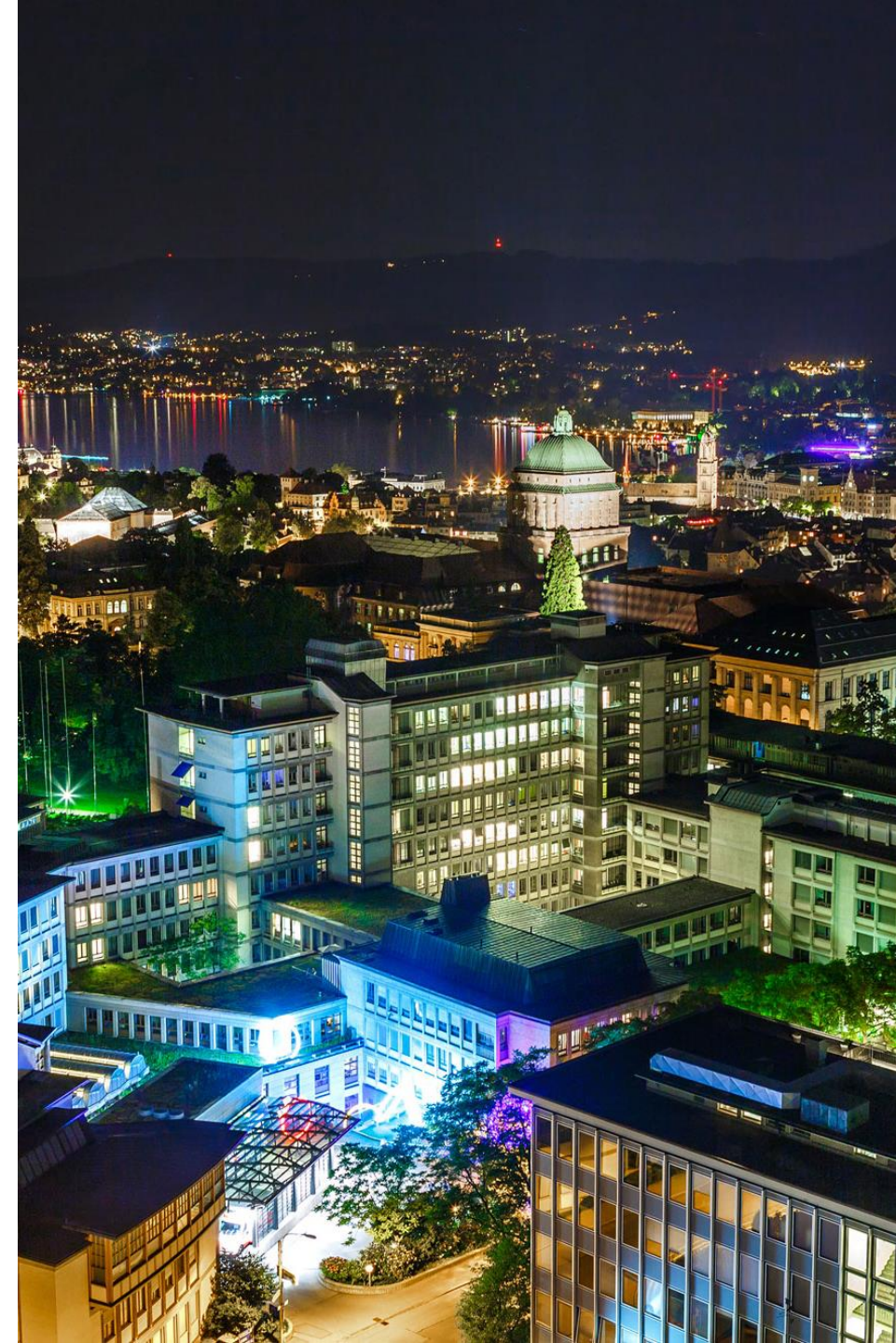
Digital



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PET image reconstruction

The goal of PET/CT imaging:

Detect harmful things that might otherwise be unnoticed.

60 cm poisonous snake on image



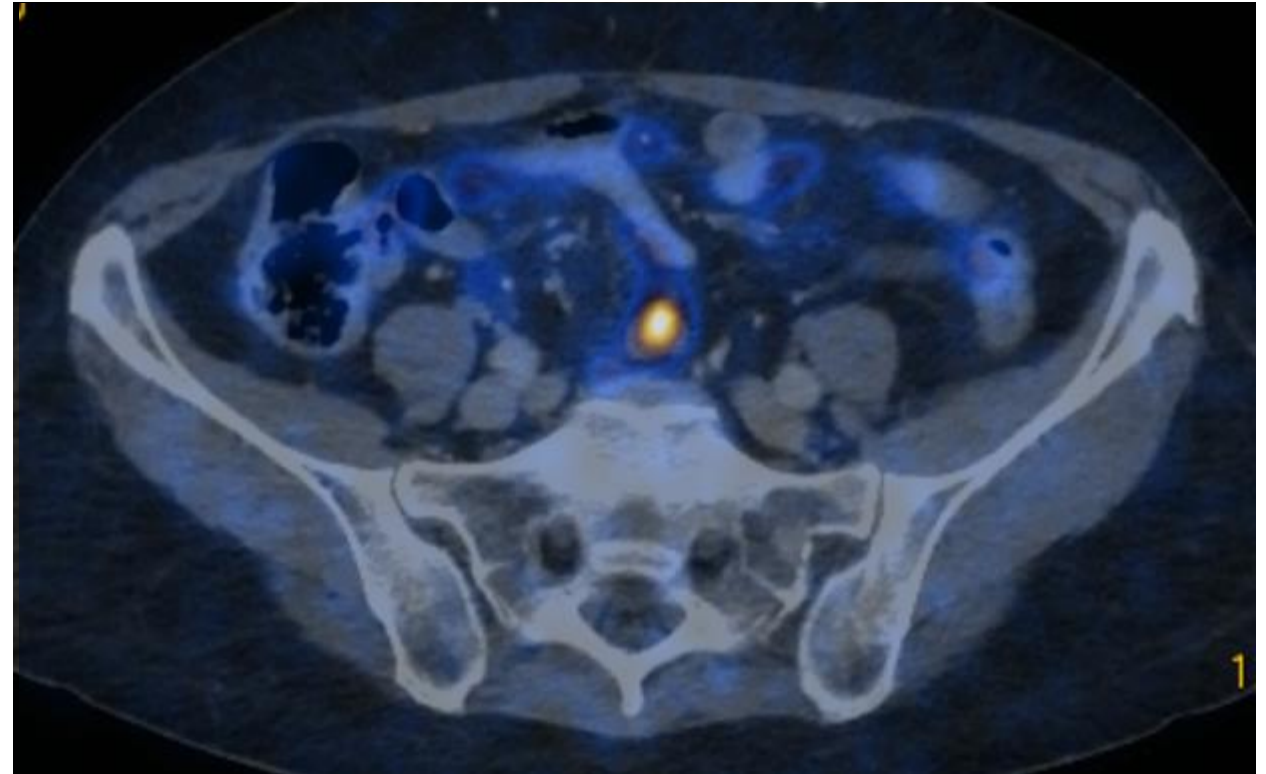
PET image reconstruction

The goal of PET/CT imaging:

Detect harmful things that might otherwise be unnoticed.

Reconstruction utilities:

- Time of flight imaging
- Novel iterative reconstruction (Q.clear™)
- Accounting for different radiotracers and dosage



3 cm long bowel tumor on image

⁶⁸Ga-DOTATATE (Q.clear 450)

PET image reconstruction

Time of flight PET

- **Higher image quality** with TOF reconstruction than with non-TOF reconstruction
- **More accurate attenuation correction**
- TOF information **reduces artifacts**:
 - Caused by respiratory mismatch between emission and attenuation data
 - Caused by metal implants

Barbosa et al., Q J Nucl Med 2016

Sekine et al., JNM 2016

Delso et al., Radiology 2016

ter Voert et al., EJNM 2017



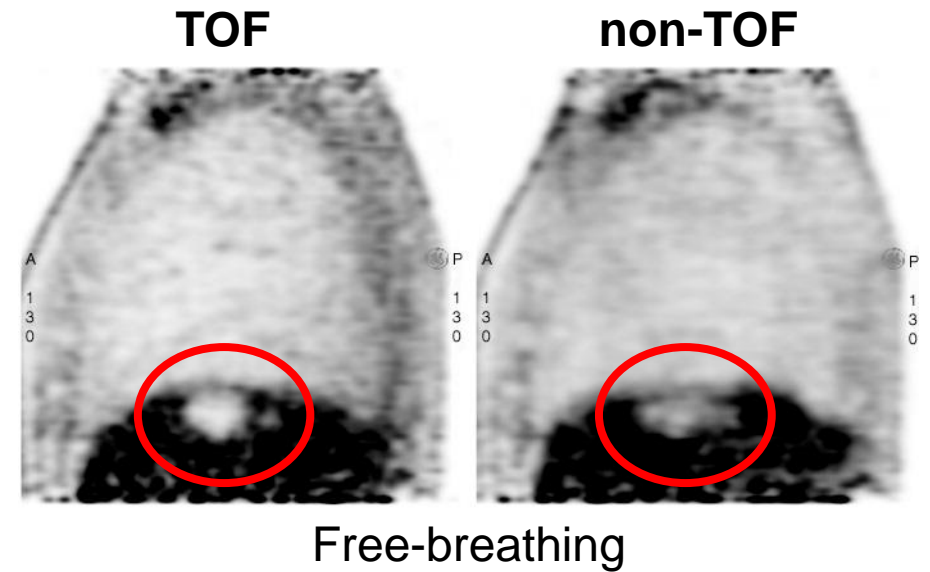
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PET image reconstruction

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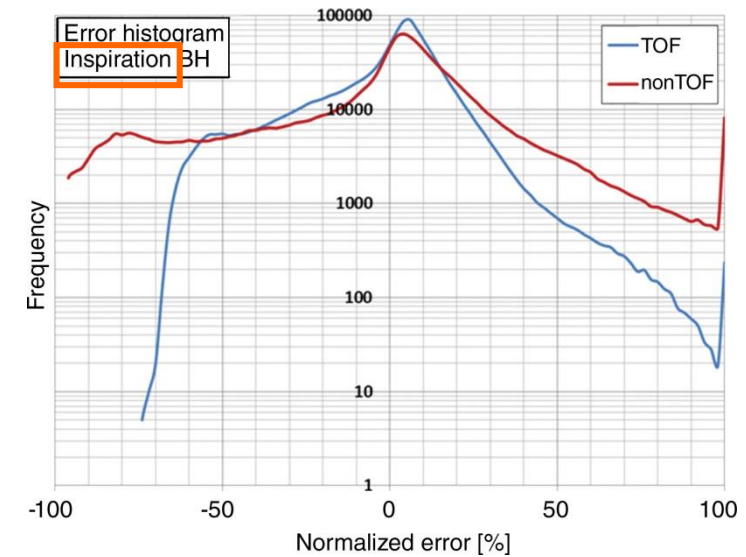
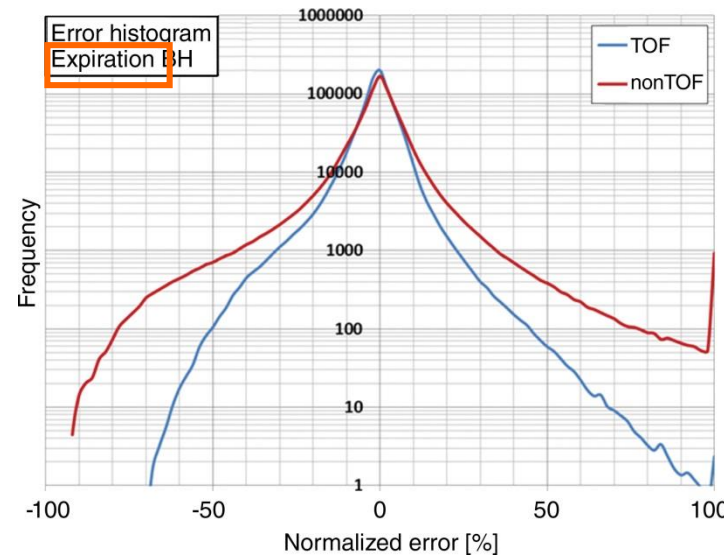
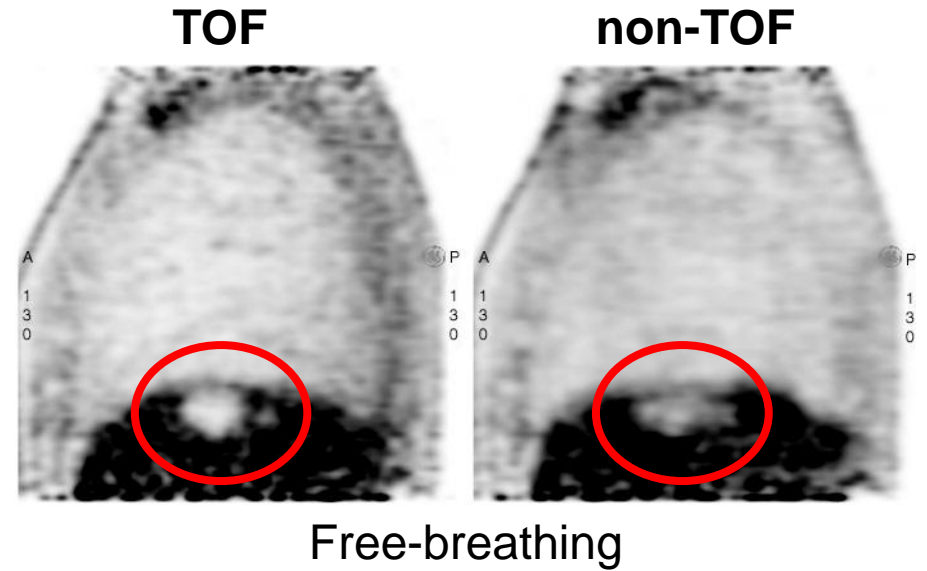


Barbosa et al., Q J Nucl Med 2016
Sekine et al., JNM 2016
Delso et al., Radiology 2016
ter Voert et al., EJNM 2017

PET image reconstruction

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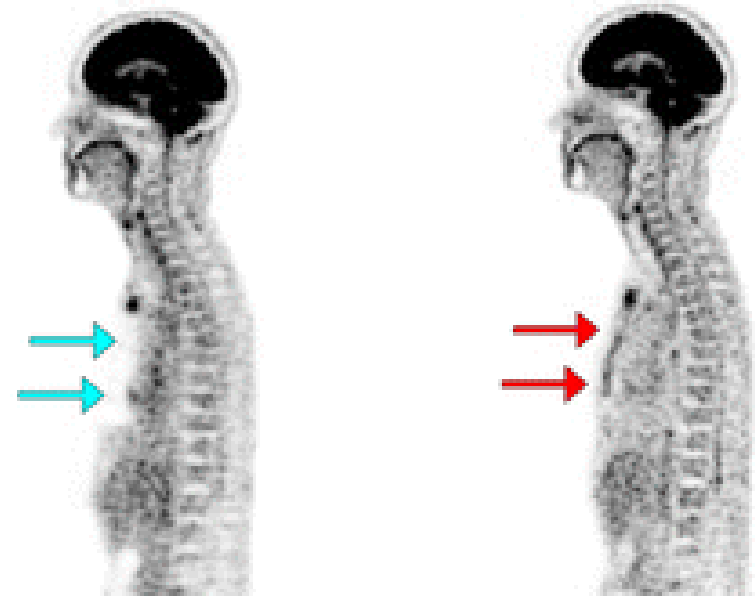


Barbosa et al., Q J Nucl Med 2016
Sekine et al., JNM 2016
Delso et al., Radiology 2016
ter Voert et al., EJNM 2017

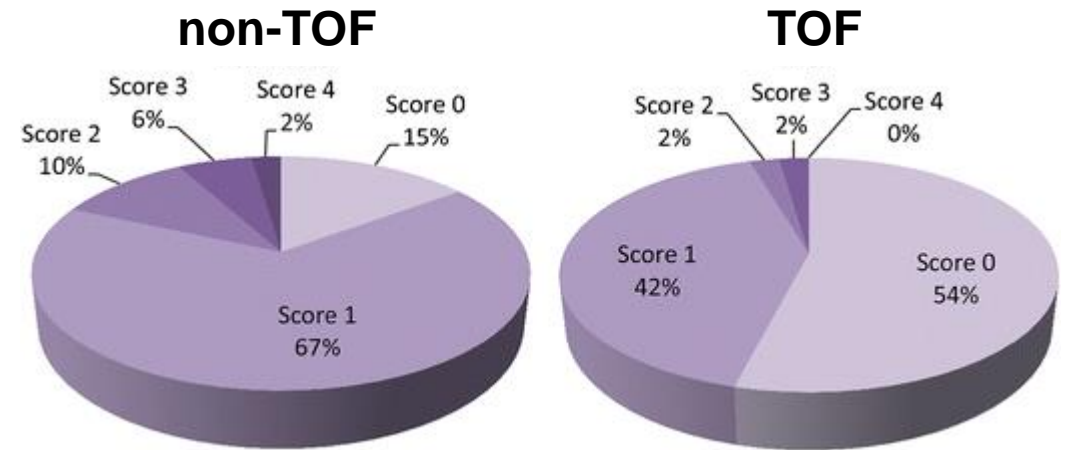
PET image reconstruction

Time of flight PET

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Metal artifacts



Barbosa et al., Q J Nucl Med 2016

Sekine et al., JNM 2016

Delso et al., Radiology 2016

ter Voert et al., EJNM 2017



PET image reconstruction

Q.clear™

- Bayesian penalized likelihood reconstruction
- Controls noise as part of regularization process inside the IR

PL objective function: $\hat{x} = \arg \max_{x \geq 0} \sum_{i=1}^{n_d} y_i \log[Px]_i - [Px]_i - \beta R(x)$

$$R(x) \equiv \sum_{j=1}^{n_v} \sum_{k \in N_j} w_j w_k \frac{(x_j - x_k)^2}{(x_j + x_k) + \gamma |x_j - x_k|}$$

beta: Controls strength of regularizing term

R(x): Penalty to control noise

Subtraction: Reduces objective function as noise increases → steers algorithm away from noisier images

Activity-dependent noise control

Chen TC et al., IEEE TNS1990
Mumcuoglu EU et al., IEEE TMI 1994
Nuyts J et al., IEEE TNS 2002
De Pierro AR et al., IEEE TMI 2001
Ahn S et al, IEEE TMI 2003

PET image reconstruction

Q.clear™



¹⁸F-FDG
64yo female
Metastasizing
colorectal cancer



PET image reconstruction

Q.clear™



¹⁸F-FDG
64yo female
Metastasizing
colorectal cancer



SharpIR



Q.Clear 450



Would you call this lymph node?

„No way.“

„Probably... yes.“



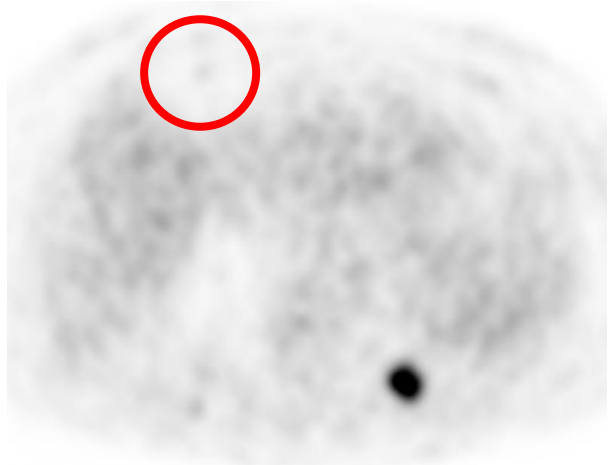
PET image reconstruction

Q.clear™

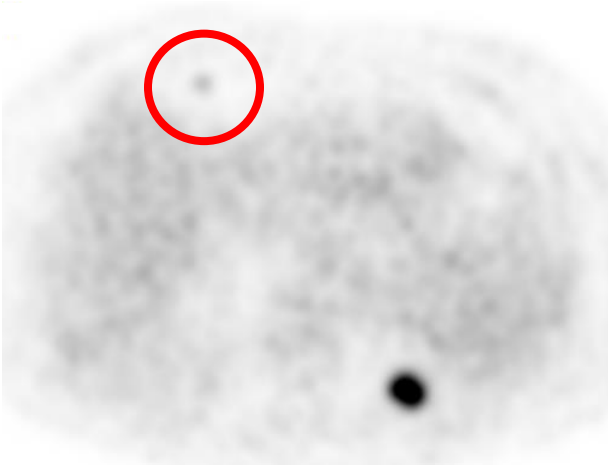


76yo female
Metastasizing tongue carcinoma

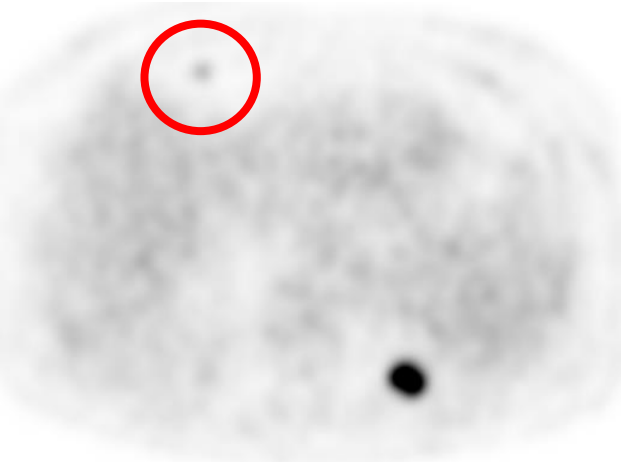
TOF off



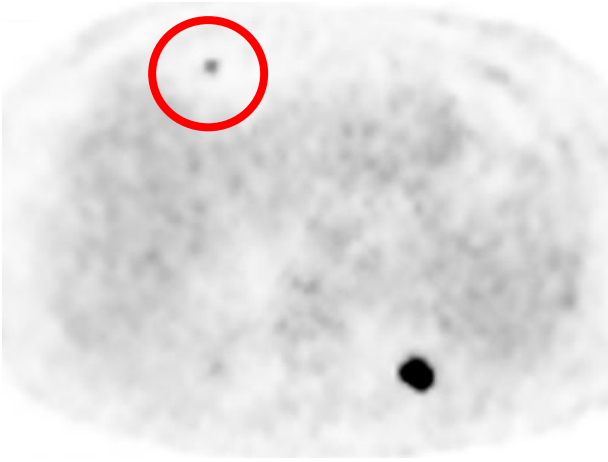
TOF on / SharpIR off



TOF on / SharpIR on



TOF on / Q.clear 600



PET image reconstruction

Q.clear™

- Full convergence reconstruction (without deterioration of IQ by noise)
- Up to 2x improvement in **PET accuracy** (SUV_{mean}) and **image quality** (SNR)
- SUV_{max} is higher than with OSEM / SharpIR

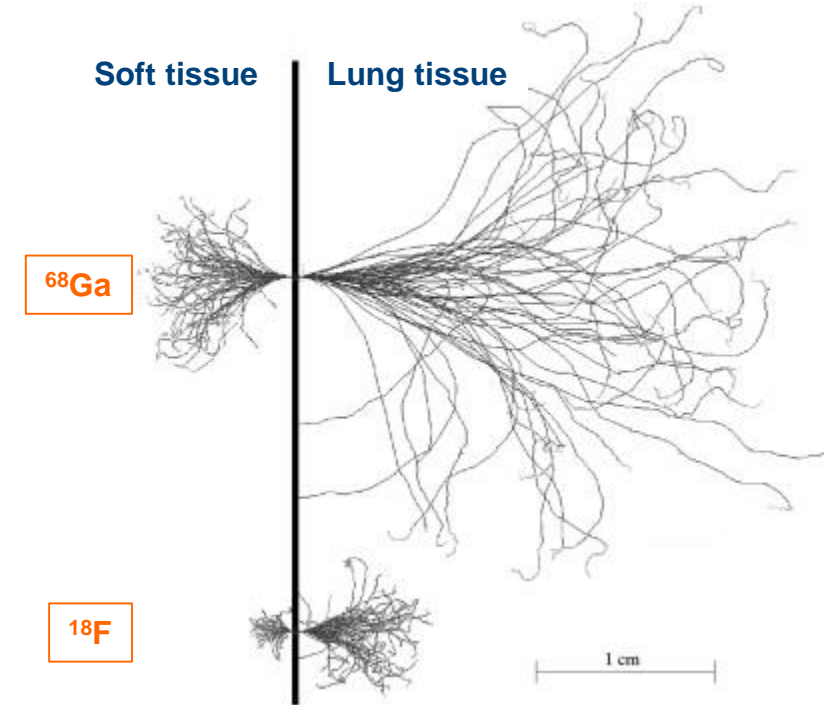
Chen TC et al., IEEE TNS1990
Mumcuoglu EU et al., IEEE TMI 1994
Nuyts J et al., IEEE TNS 2002
De Pierro AR et al., IEEE TMI 2001
Ahn S et al, IEEE TMI 2003



PET image reconstruction

Q.clear™ - Implications for different radiotracers

- Average **positron energy**: ^{18}F : 0.25 MeV, ^{68}Ga : 0.89 MeV, ^{15}O : 0.80 MeV
Longer positron range \rightarrow lower resolution with high energy positron emitters
- **Lower positron yield** of ^{68}Ga than ^{18}F
- Reconstruction design optimized for ^{18}F
- Different background (e.g. higher background with ^{68}Ga -DOTATATE in the body, or with ^{18}F -FDG in the brain)



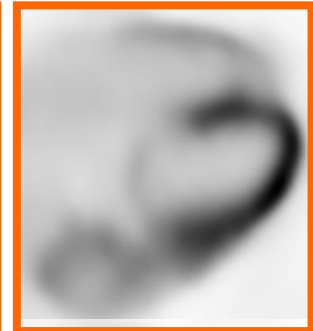
\rightarrow *Different Q.clear β -factors necessary for:*

- *Different radiotracers*
- *Different types of studies*
- *Different dosage*

Sánchez-Crespo et al., EJNM 2004
Sánchez-Crespo, Appl Radiat Isot 2012

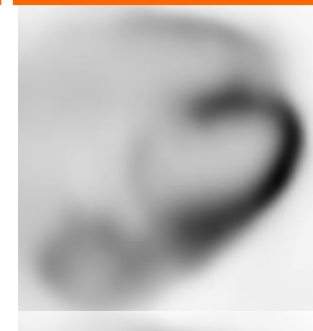
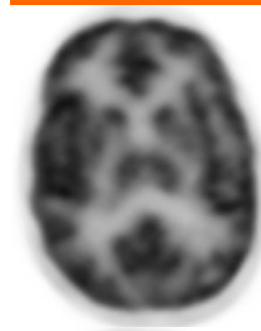
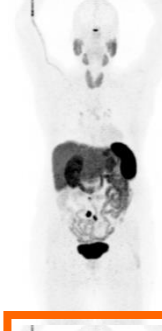
$^{18}\text{F-FDG}_{\text{Body}}$ $^{18}\text{F-FDG}_{\text{Brain}}$ $^{68}\text{Ga-PSMA}$ $^{68}\text{Ga-DOTATATE}$ H_2^{15}O $^{13}\text{N-Ammonia}$

Q.clear
b200



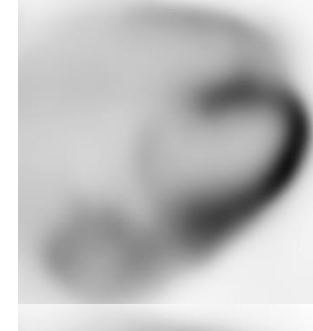
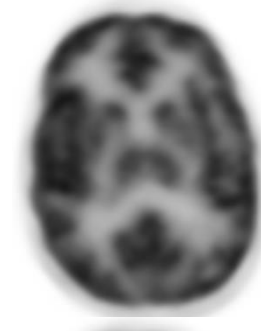
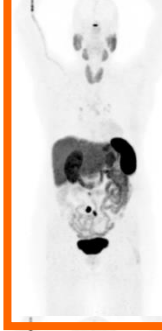
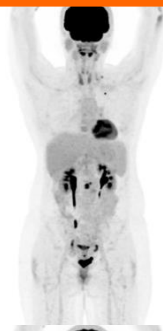
Q.clear
b200

Q.clear
b450



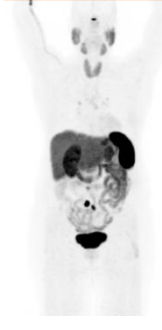
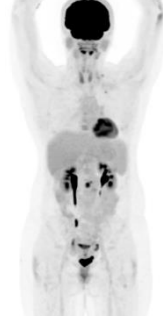
Q.clear
b450

Q.clear
b600



Q.clear
b600

Q.clear
b1200



Q.clear
b1200

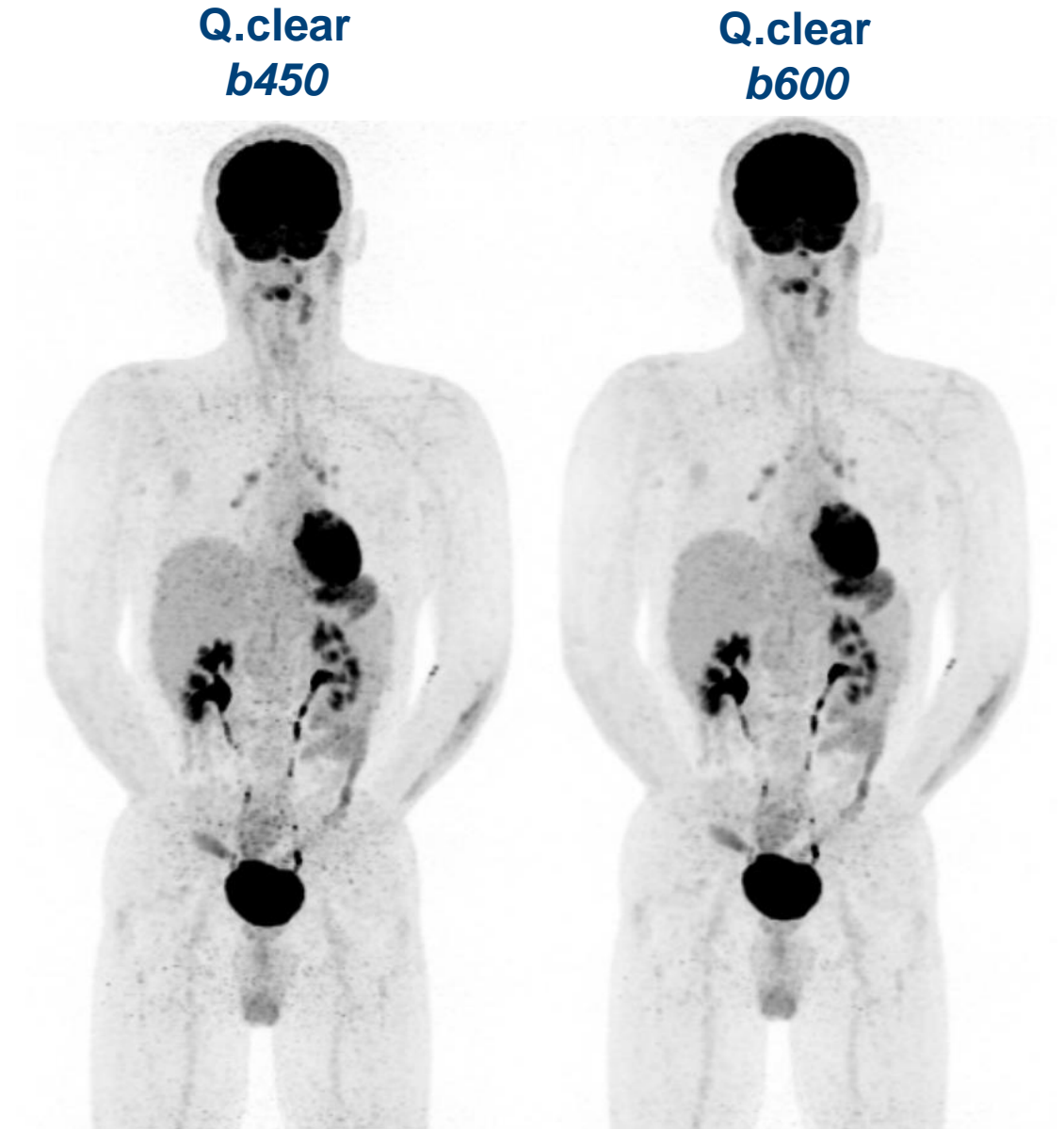


PET image reconstruction

Q.clear™ – Impact of dosage

- Lower dose → more noise
- Higher b-value → less noise

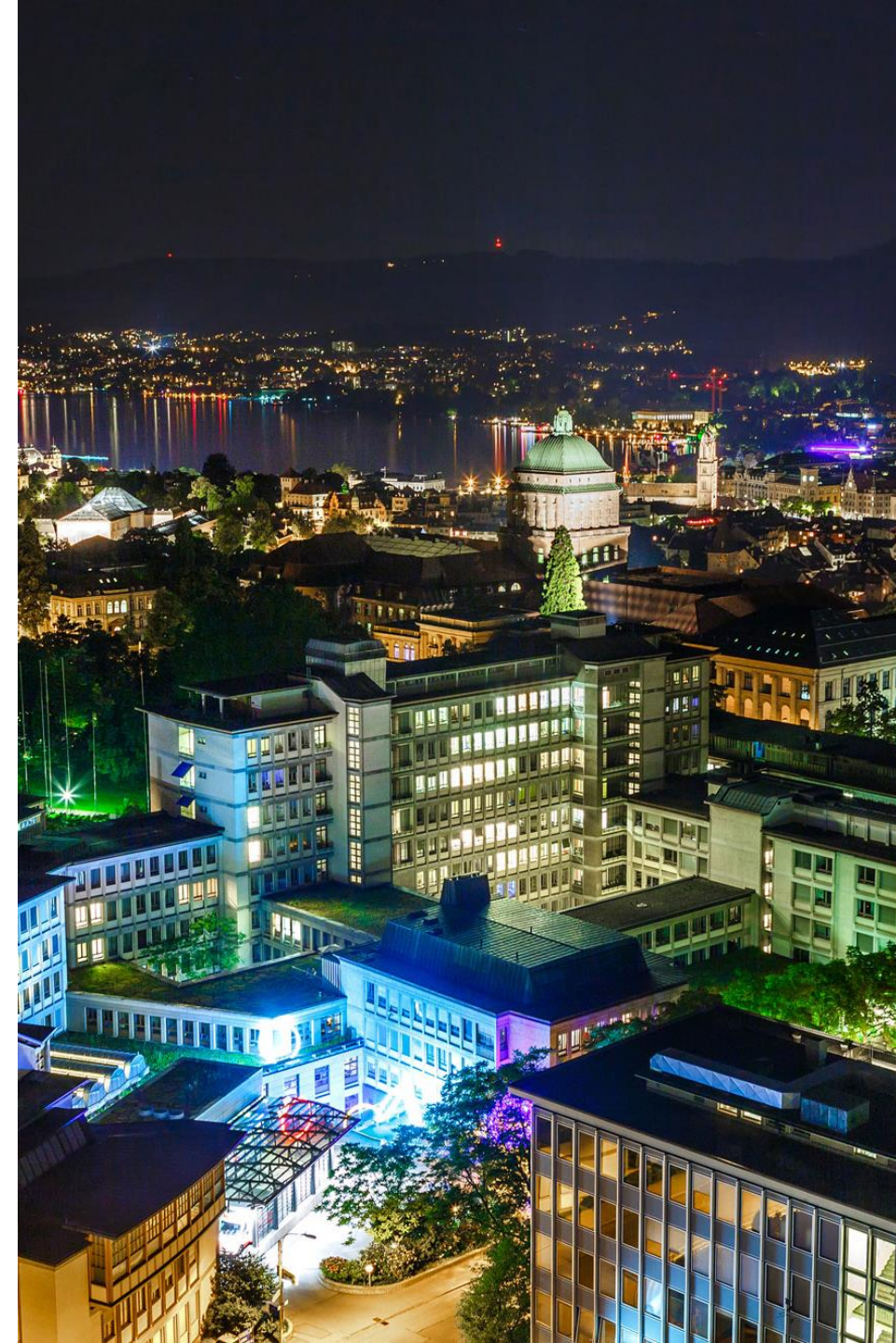
→ Higher b-value preferred in „low dose“ scans



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4. Motion correction with PET: Q.freeze™, Q.static™
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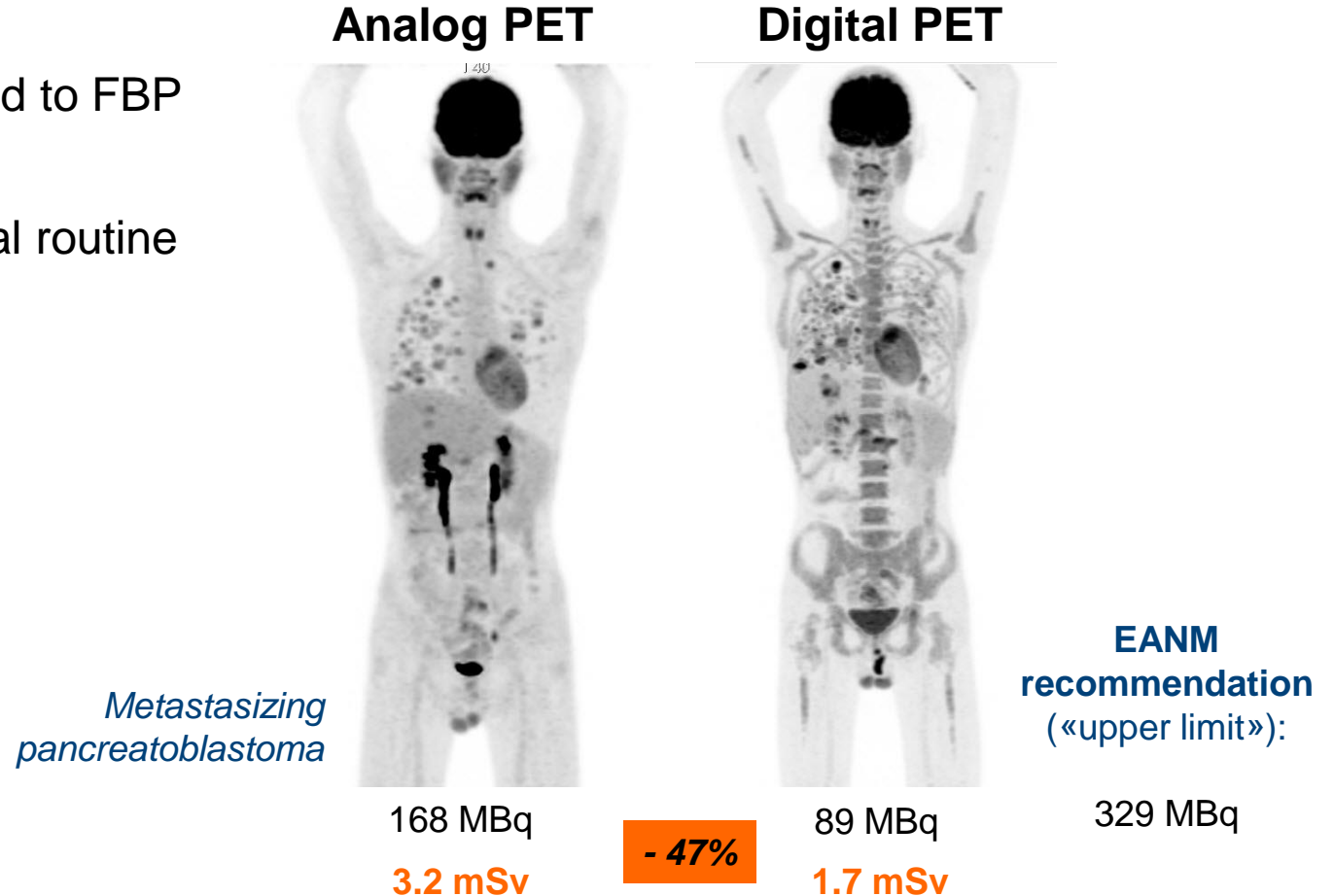


Dose reduction

GE Discovery MI

- **CT:** ASiR-V™ up to **80%** dose reduction compared to FBP in phantom study (MITA CT IQ)
- **PET:** Approximately **40%** dose reduction in clinical routine (¹⁸F-FDG)

Sekine T et al., Radiology 2017 (ahead of print)



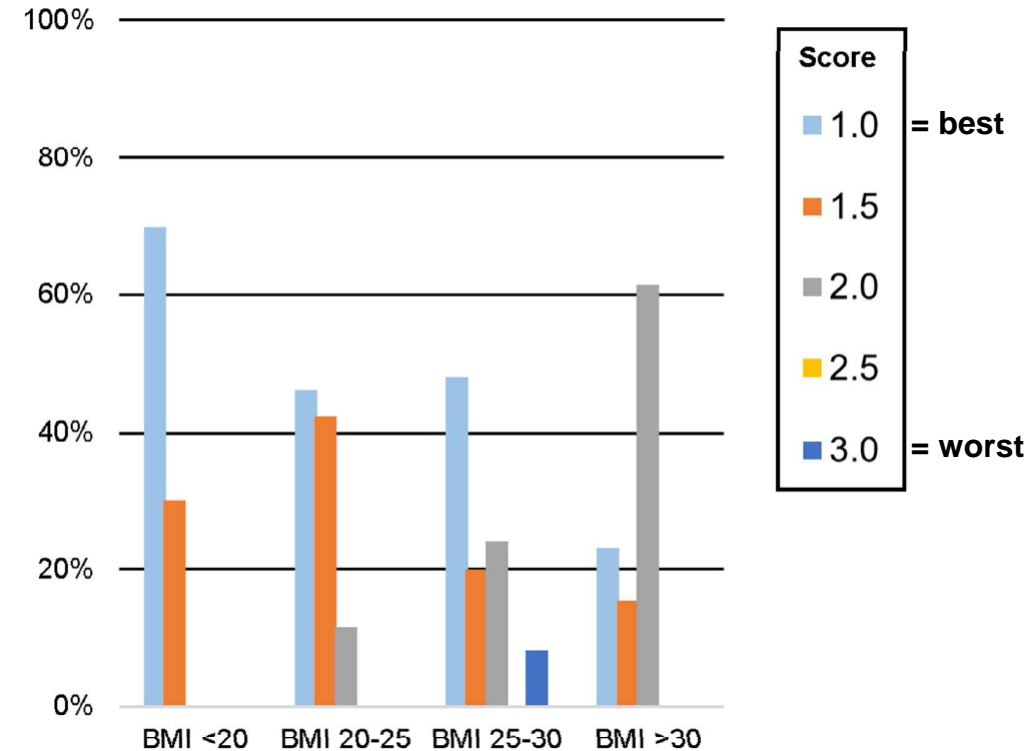
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PET image quality



Dose reduction

GE Discovery MI

- BMI-adjusted dosage regimen for ^{18}F -FDG
- Dose reduction: 40% in BMI >25, 50% in BMI <25

^{18}F -FDG	BMI	Dosage [MBq / kg]
	< 20	1.5
	20 – 25	2.0
	> 25	2.8

(Max.: 320 MBq)

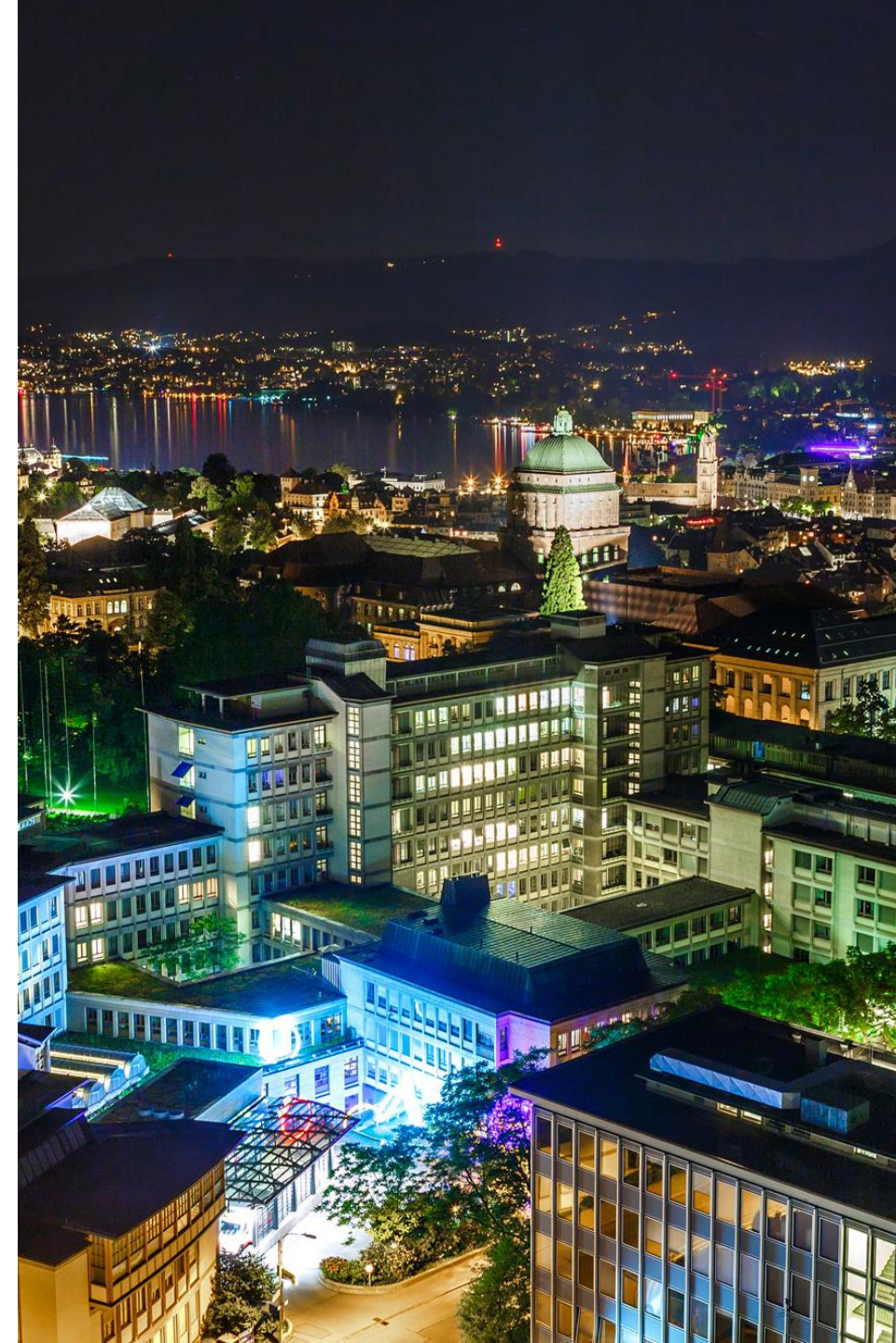
Sekine T et al., Radiology 2017 (ahead of print)



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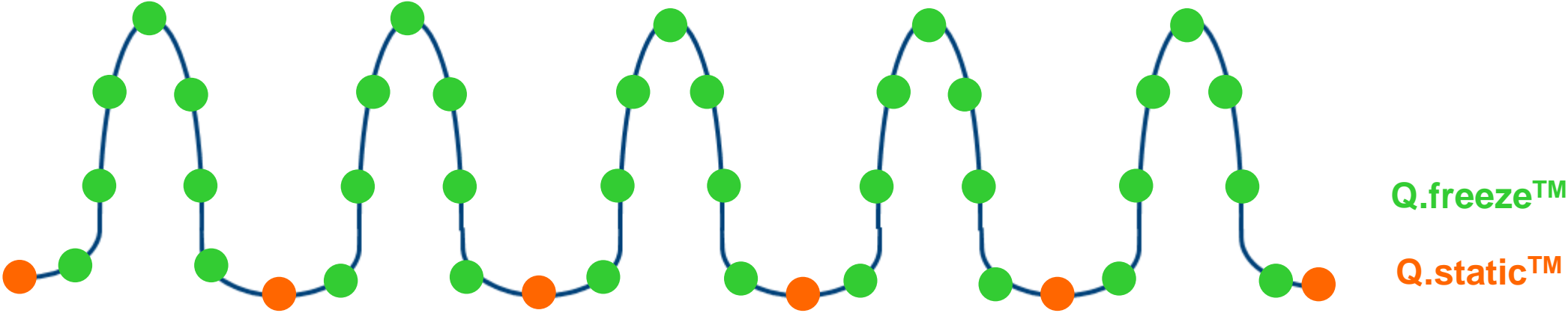
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Motion correction

Q.static™, Q.freeze™

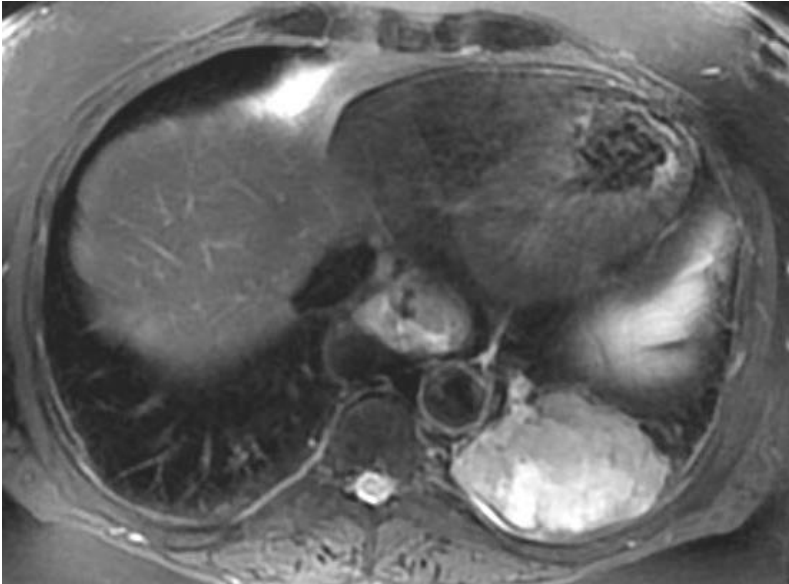


Respiration curve

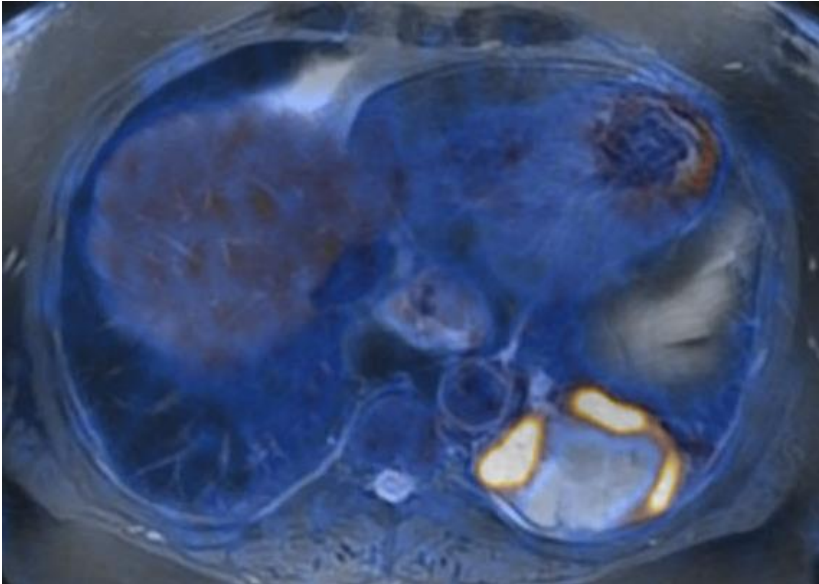
Motion correction

Q.static™, Q.freeze™

Bronchial carcinoma



T2w Propeller®



FDG-PET/MR

Without motion correction
Q.static™

Motion correction

Q.static™, Q.freeze™



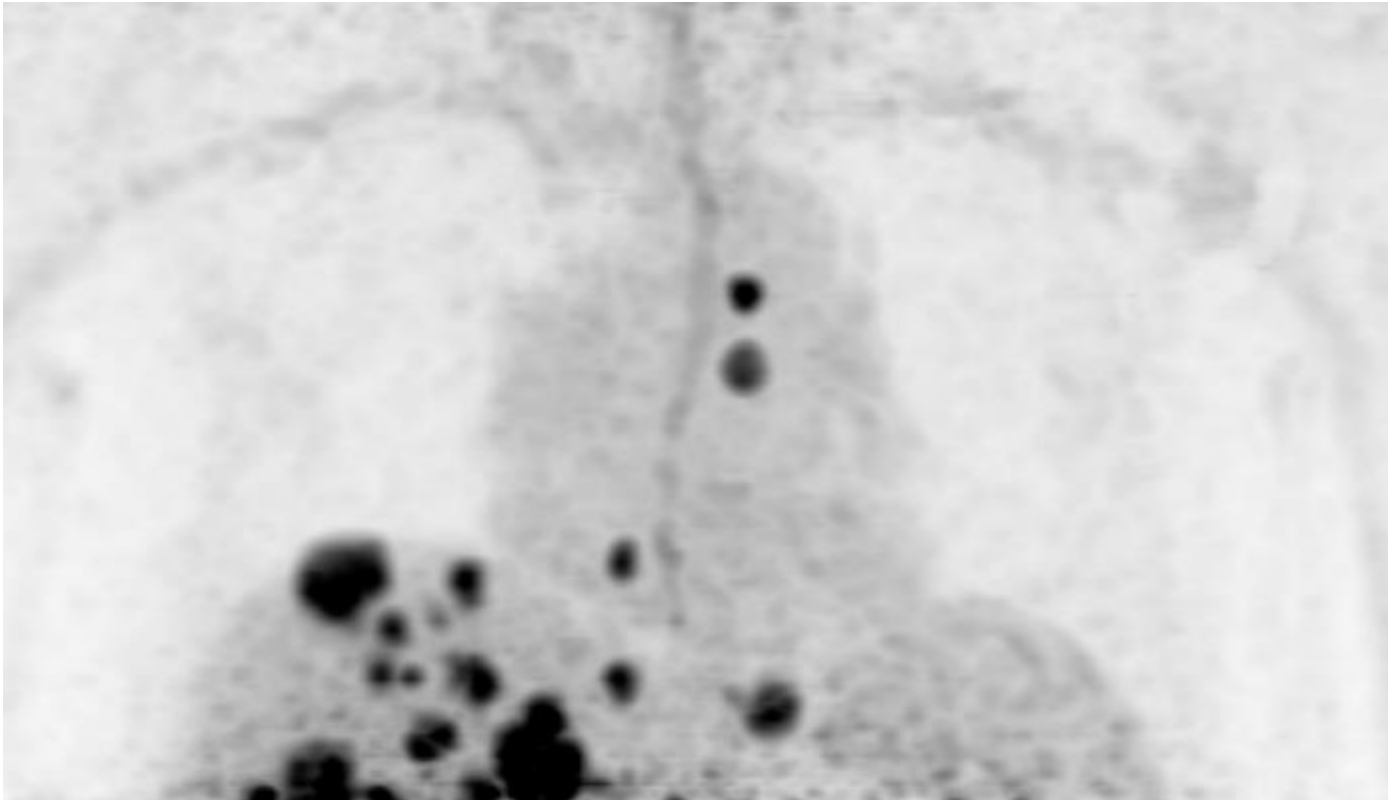
Bronchial carcinoma

Q.static™



Motion correction

Q.static™, Q.freeze™



Liver metastases

Motion correction:

- Higher image quality
- Reduction of artifacts
- More accurate SUV

Catana C, Semin Nucl Med 2016

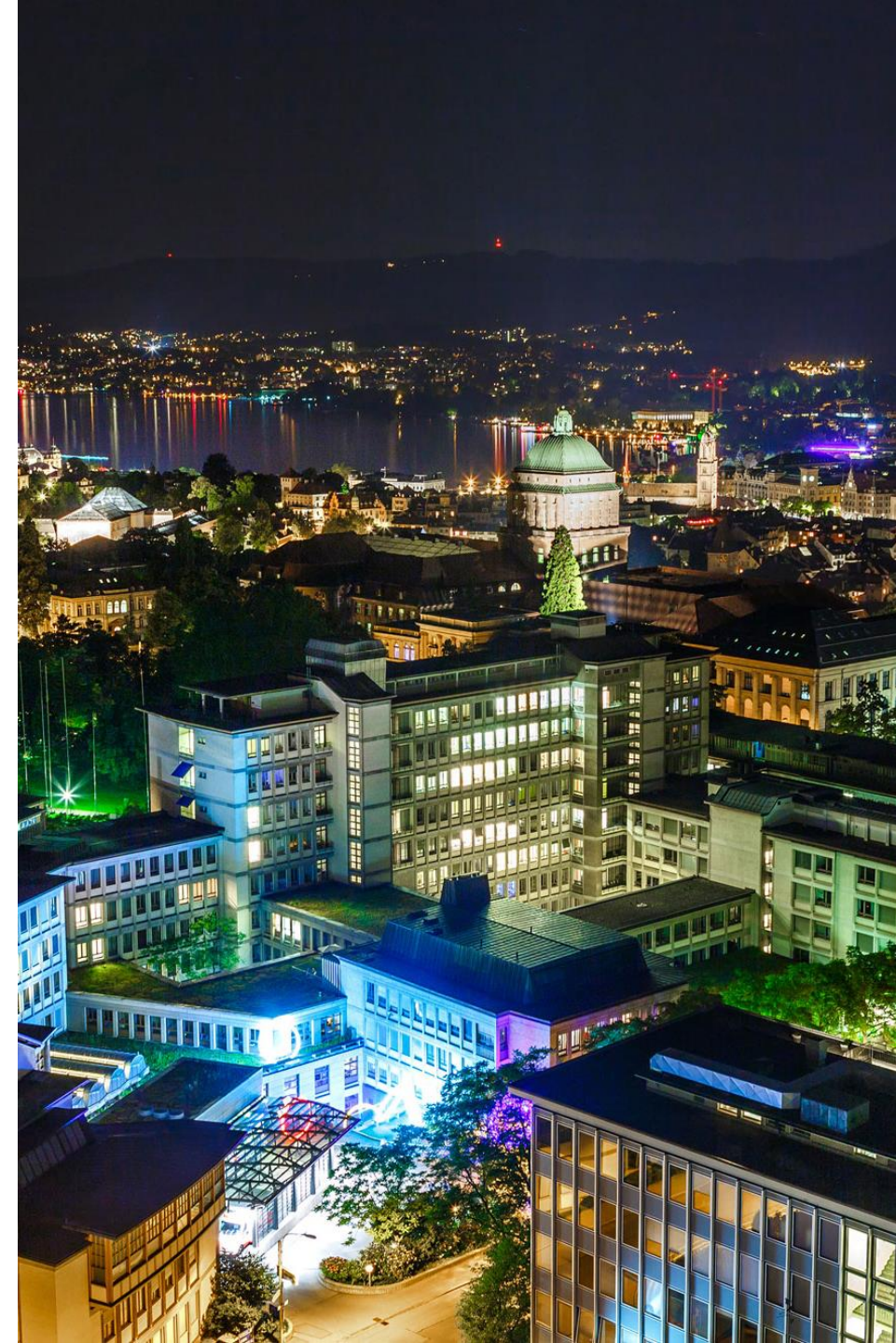
Without
motion correction

Q.static™

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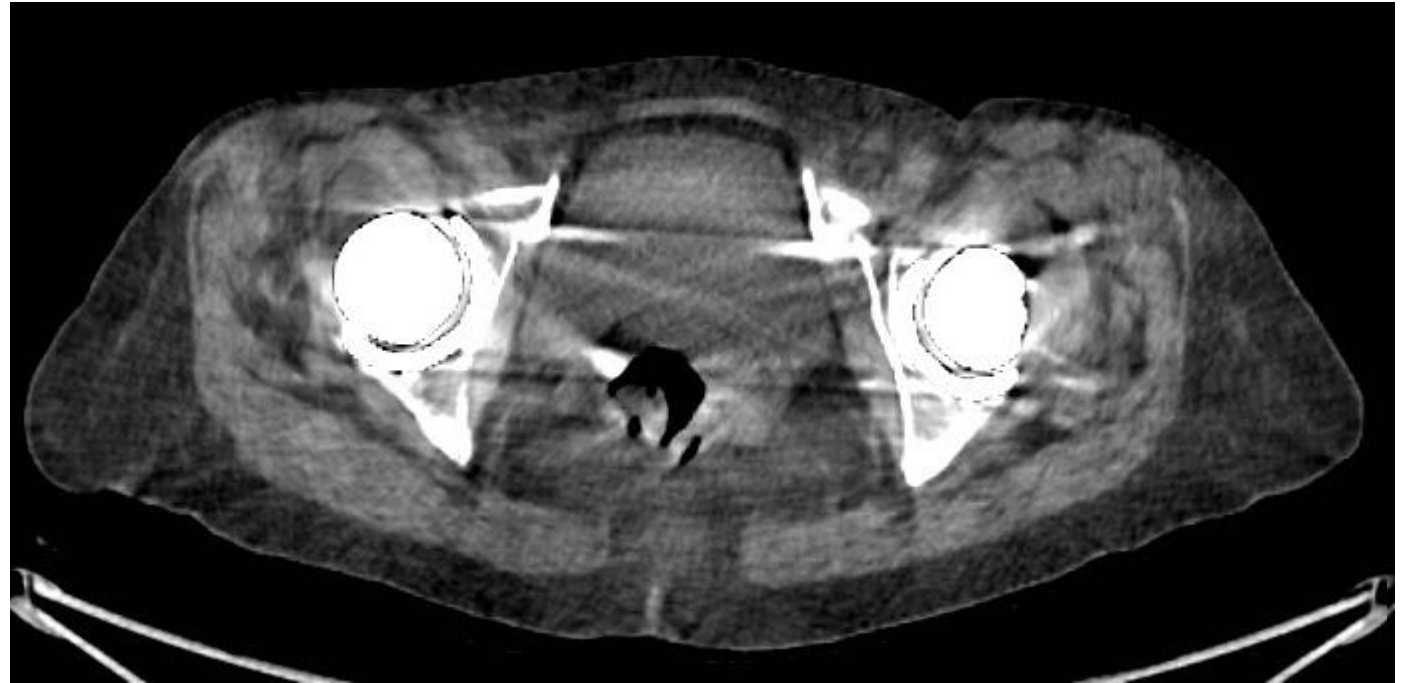


Metal artifact reduction

Smart MAR

- Real-time reconstruction
- Projection-based technique
 - No separate scan required
 - Particularly useful in PSMA studies

Without
MAR

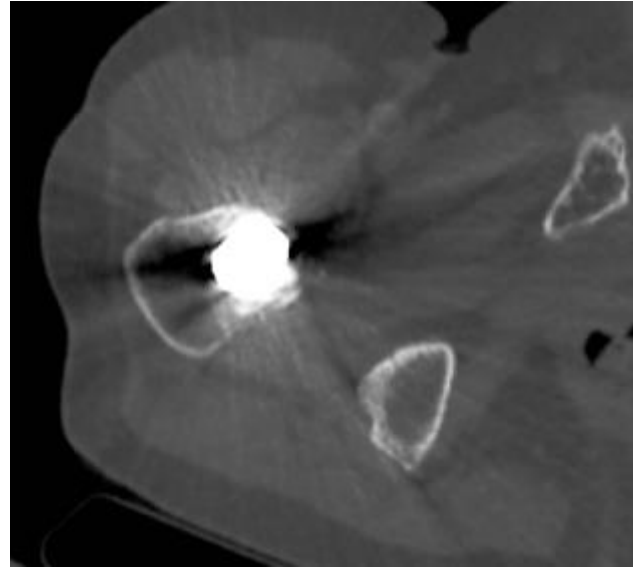


Metal artifact reduction

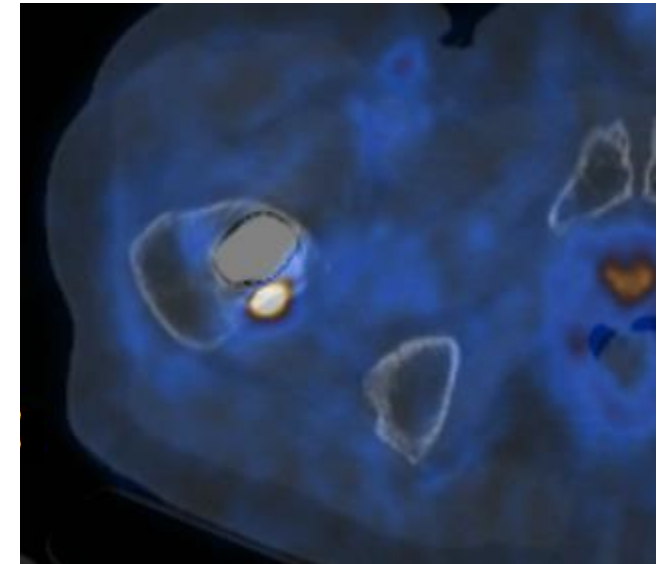
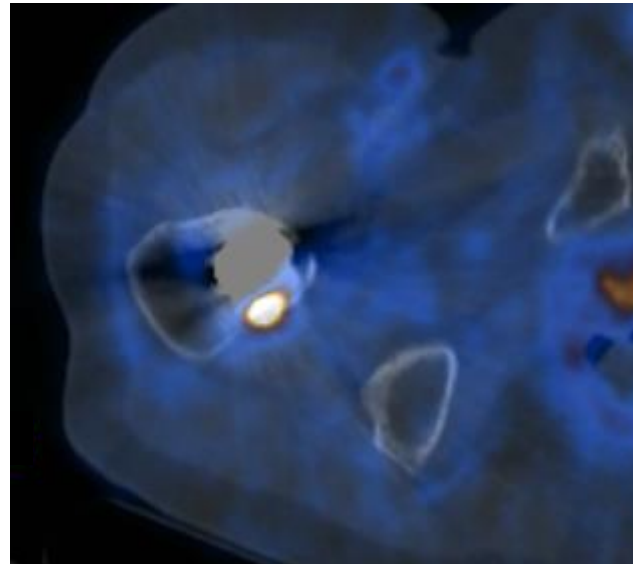
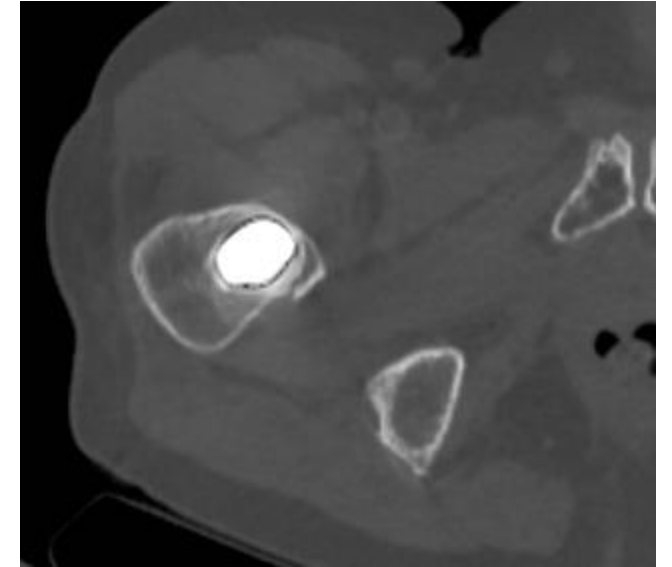
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no MAR



MAR

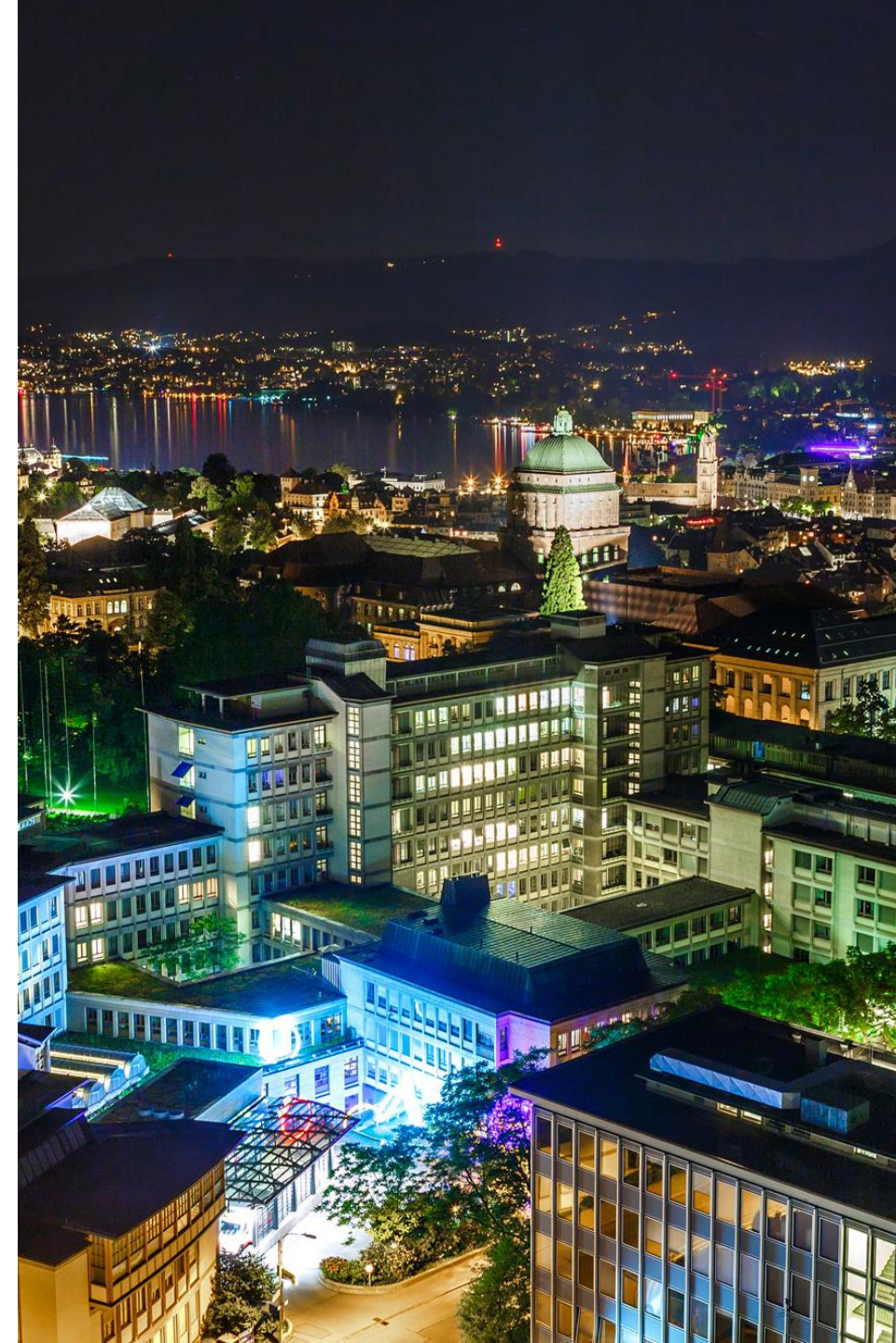


⁶⁸Ga-PSMA
*Prostate carcinoma,
bone metastasis*

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6. **True whole-body acquisition**



True whole-body* acquisition

* Patients <2.00m height

What the techs love most about Discovery MI...

1. Dose reduction
2. Dose reduction
3. Dose reduction
4. **True whole-body acquisition**

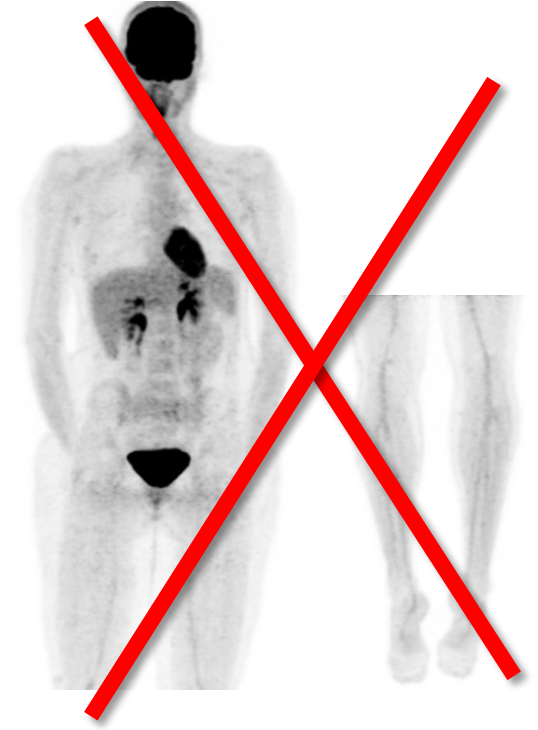
→ ***No patient repositioning
for whole-body scan***



Digital PET



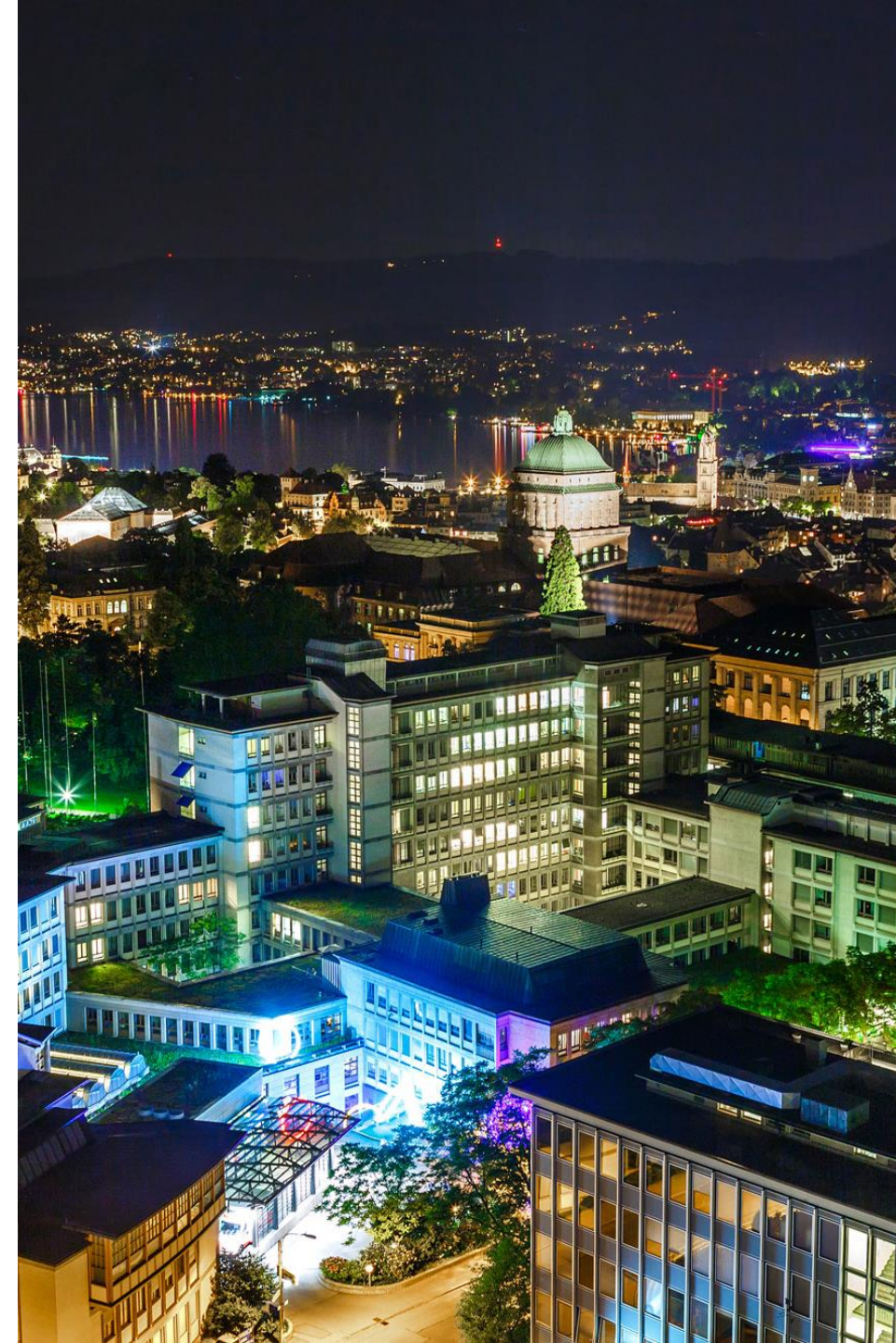
Analog PET



Summary

Clinical advantages of new digital PET/CT scanners

- Time of flight
- Q.clear™, beta adaption for different radiotracers and dosage
- **Dose reduction:** approximately by 40%
- Nice to have:
 - Motion correction capability
 - Metal artifact reduction capability
 - True whole-body acquisition





Thank you!

