Symposium 2, April 13
New Frontiers of Fusion Imaging

Fusion Imaging in Nuclear Medicine

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☑ The author has no conflict of interest to disclose with respect to this presentation.

FUSION OF PHYSYOLOGIC AND ANATOMICAL IMAGING

- Structural and functional images are increasingly understood as complementary rather than competing imaging modalities.

- When functional images can be fused with anatomical images the strengths of the individual modalities can be exploited and the limitations minimised.

IMAGES with RADIOPHARMACEUTICALS clinical and research applications

Imaging and Molecular Medicine

- ✓ Radiopharmaceuticals for DIAGNOSIS
- ✓ Radiopharmaceuticals for THERAPY
- ✓ Radiopharmaceuticals for ASSESSMENT and MONITORING response to THERAPY
- ✓ Radioligands for R & D – new THERAPIES (pharmacokinetics and pharmacodynamics)

THERANOSTICS

Combination of two words:

- Therapeutic + Diagnostic
- Sometimes interchangably refered to as Theragnostics
- Use of radionuclide-labeled agents that specifically permit us to diagnose disease in individuals and then use identical or closely related agents to treat these diseases

HYBRID DEVICES

- SPECT/CT
- PET/CT
- PET/MR
- SPECT/MR

Hybrid SPECT/CT: a new era for SPECT imaging?

Orazio Schillaci[1]

[1] Department of Biopathology and Diagnostic Imaging, University "Tor Vergata", Rome, Italy

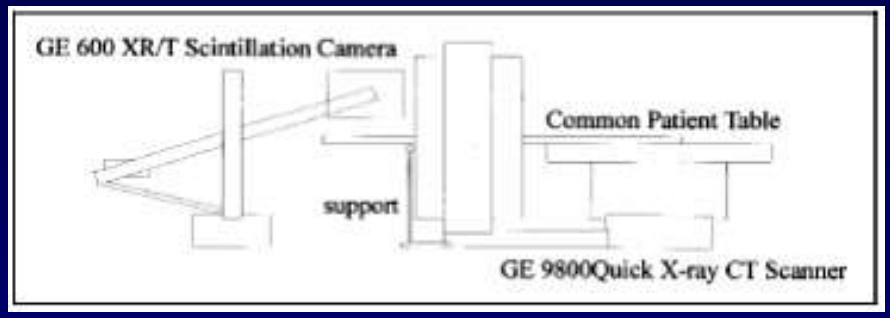
Published online: 3 March 2005

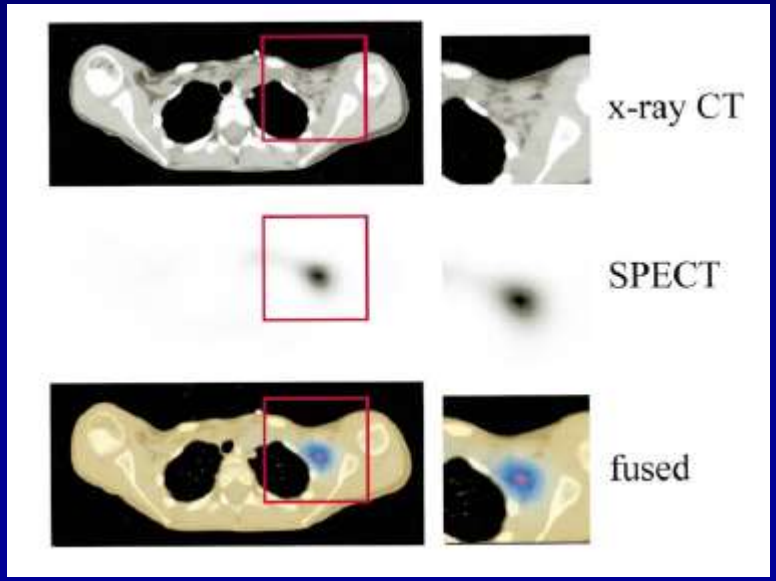
Eur J Nucl Med Mol Imaging (2005) 32:521–524
DOI 10.1007/s00259-005-1760-9

dose X-ray tube, attached to the same gantry. This system enables, in a sequential interchangeable sequence, the acquisition, together with SPECT data, of cross-sectional X-ray transmission images, which accurately locate the

Hybrid systems are opening up a new era in SPECT imaging; we do not know whether this will substantially change our routine clinical practice, but it certainly will improve the accuracy of SPECT studies and, of paramount importance, patient care.

SPECT/CT: the first prototype





B. Hasegawa et al, UCSF

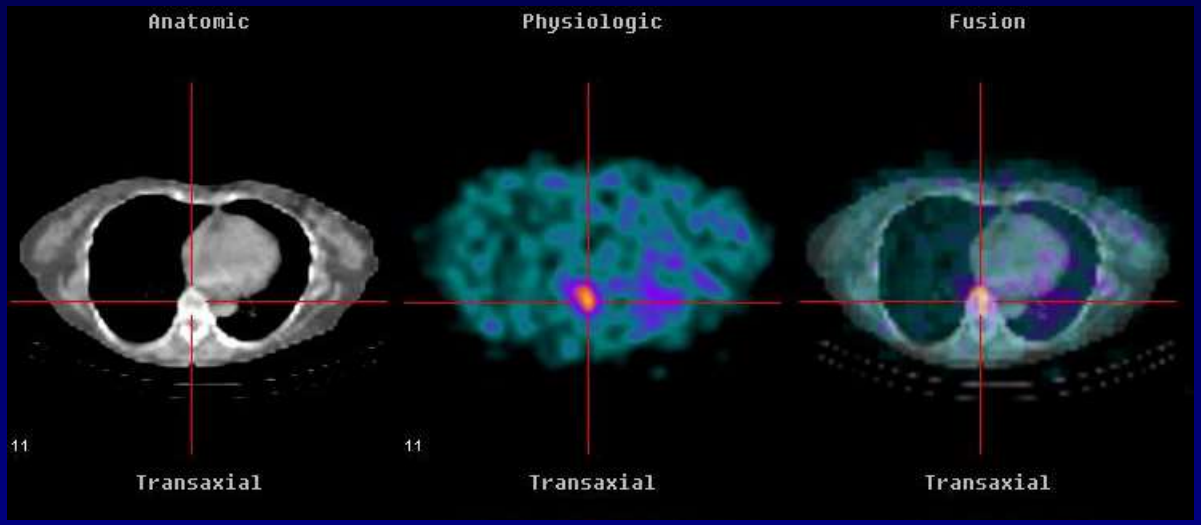
IS SPECT/CT WITH A HYBRID CAMERA USEFUL TO IMPROVE SCINTIGRAPHIC IMAGING INTERPRETATION?

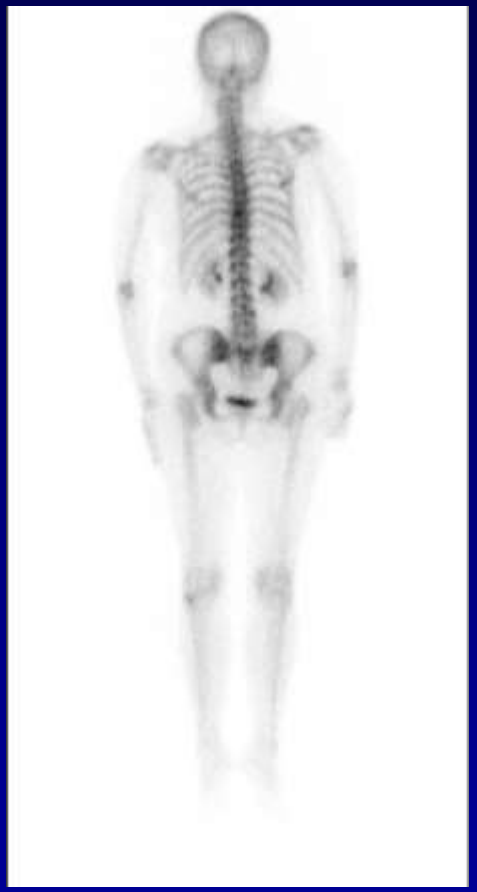
FAM improved image interpretation in 33 out of 81 patients (40.7%):

- providing a correct anatomical localisation of SPECT findings (with the determination of the involved organs or with an accurate relationship between lesions and neighbouring structures) --> 23 cases;
- allowing the definition of functional significance of CT lesions --> 2 cases;
- providing the exclusion of disease in sites of physiologic radiopharmaceutical uptake --> 8 cases.

O. Schillaci et al, Nucl Med Commun 2004

G.M., 62 y, M, previously resected ileal carcinoid

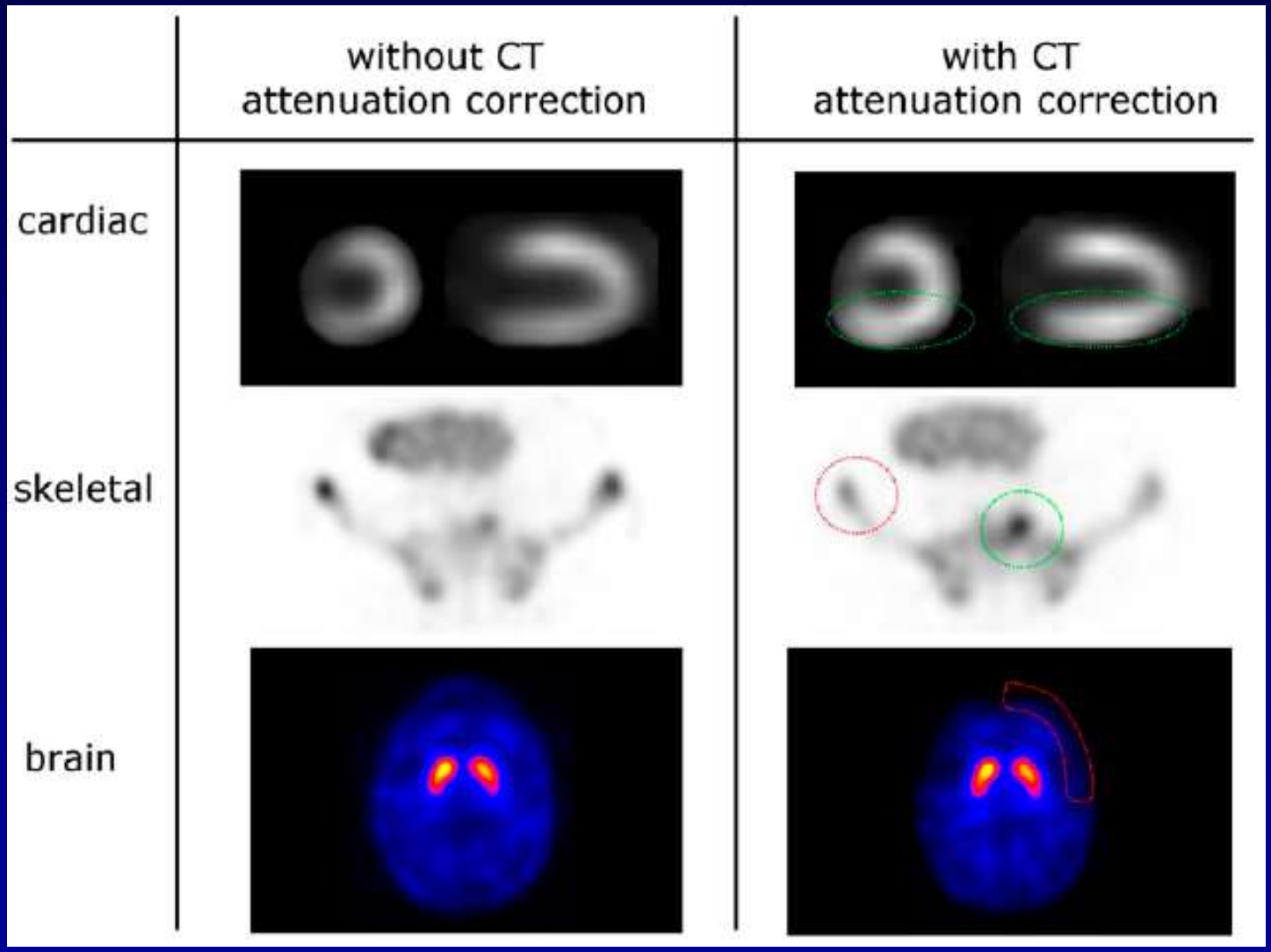




In-111 pentetreotide SPECT shows a focal uptake in the chest, which **FAM precisely localizes** in T8 vertebra. MR confirmed finding.

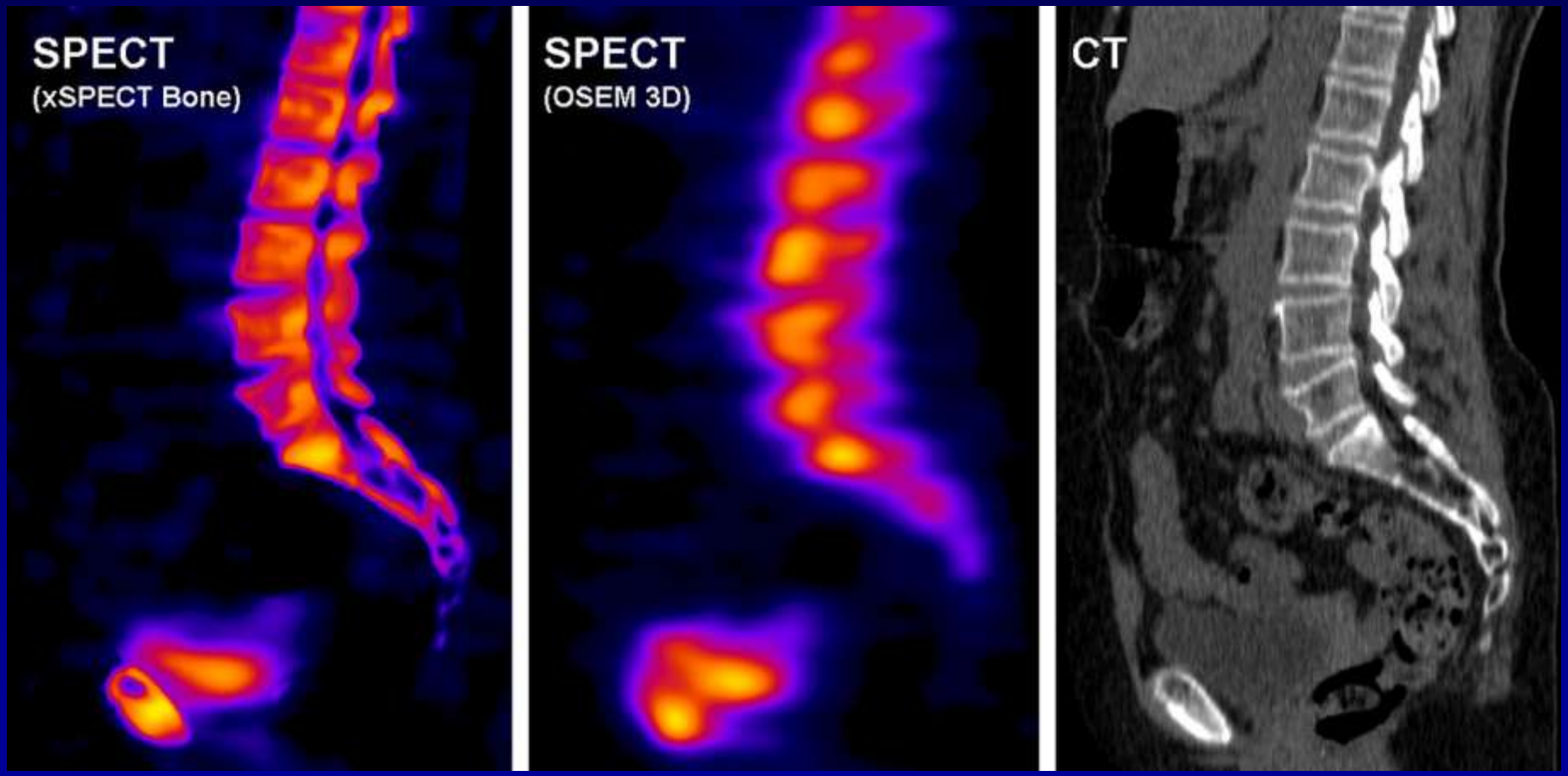
Bone scan is negative.

Impact of CT attenuation correction



from A.K. Buck et al, J Nucl Med 2008

The use of CT data: improve the spatial resolution of reconstructed SPECT images and obtain higher quantitative accuracy



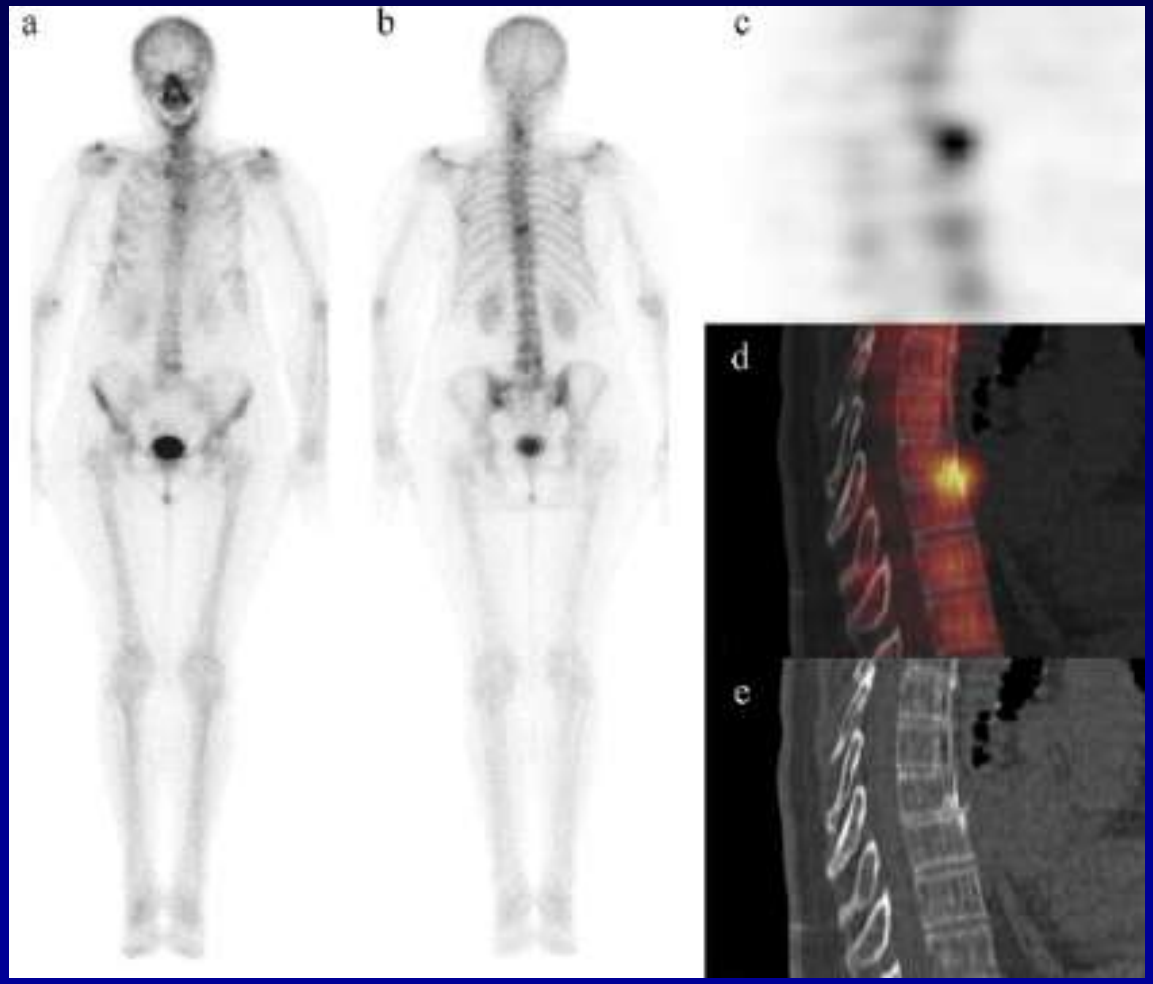
from P. Ritt et al, Clin Trans Imaging 2014

SPECT/CT in indeterminate foci of increased bone metabolism on SPECT in cancer patients

- 272 consecutive patients; 112 (41%) required further workup by SPECT because a definite diagnosis could not be established using WB planar scintigraphy. In 57 of these patients, SPECT was accompanied by inline CT over the region of interest.
- 52 lesions in 44 patients were rated as indeterminate on SPECT: 33 (63%) could be correlated with benign findings on CT, involving mostly osteochondrosis, spondylosis, and spondylarthrosis of the spine; 15 lesions (29%) could be correlated with osteolysis or sclerotic metastases on CT; 4 lesions (8%) remained indeterminate, they were in the ribs and the scapula.
- SPECT-guided CT was able to clarify more than 90% of SPECT findings classified as indeterminate.

W. Romer et al, J Nucl Med 2006

SPECT/CT and bone scan in oncology



from D. Papathanassiou et al, Joint Bone Spine 2009

Clinical SPECT/CT in oncology

- SPECT/CT allows a better definition of organs involved in radiotracer uptake and their precise relationship with adjacent structures, it defines the functional significance of CT lesions and improves the specificity of SPECT excluding disease in sites of physiologic uptake (vascular structures) or excretion (urinary or gastrointestinal tracts).
- Clinically, it is particularly useful in the more difficult cases, often solving complex questions, especially in tumour imaging with radiotracers lacking the structural delineation of the pathologic processes they detect.
- SPECT/CT correlative data could aid not only diagnosis, but also the selection and planning of the appropriate therapeutic option.

PERSPECTIVES

Is there still a role for SPECT–CT in oncology in the PET–CT era?

Rodney J. Hicks and Michael S. Hofman

established by Gordon Brownell, has lead to devices that are now widely used in the diagnosis, staging and therapeutic response assessment of cancer. The principles of SPECT and PET, both molecular imaging techniques that can evaluate physiological,

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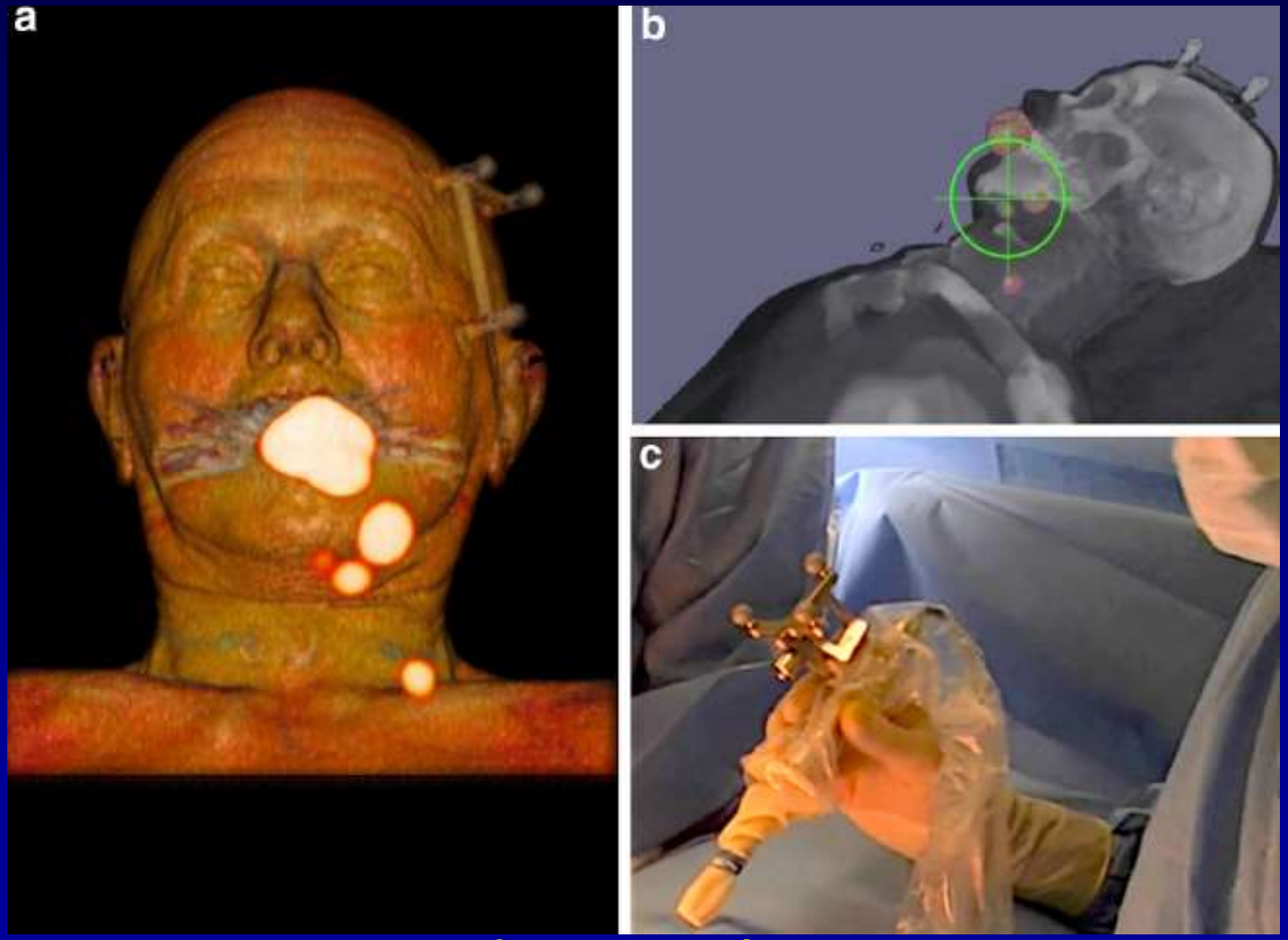
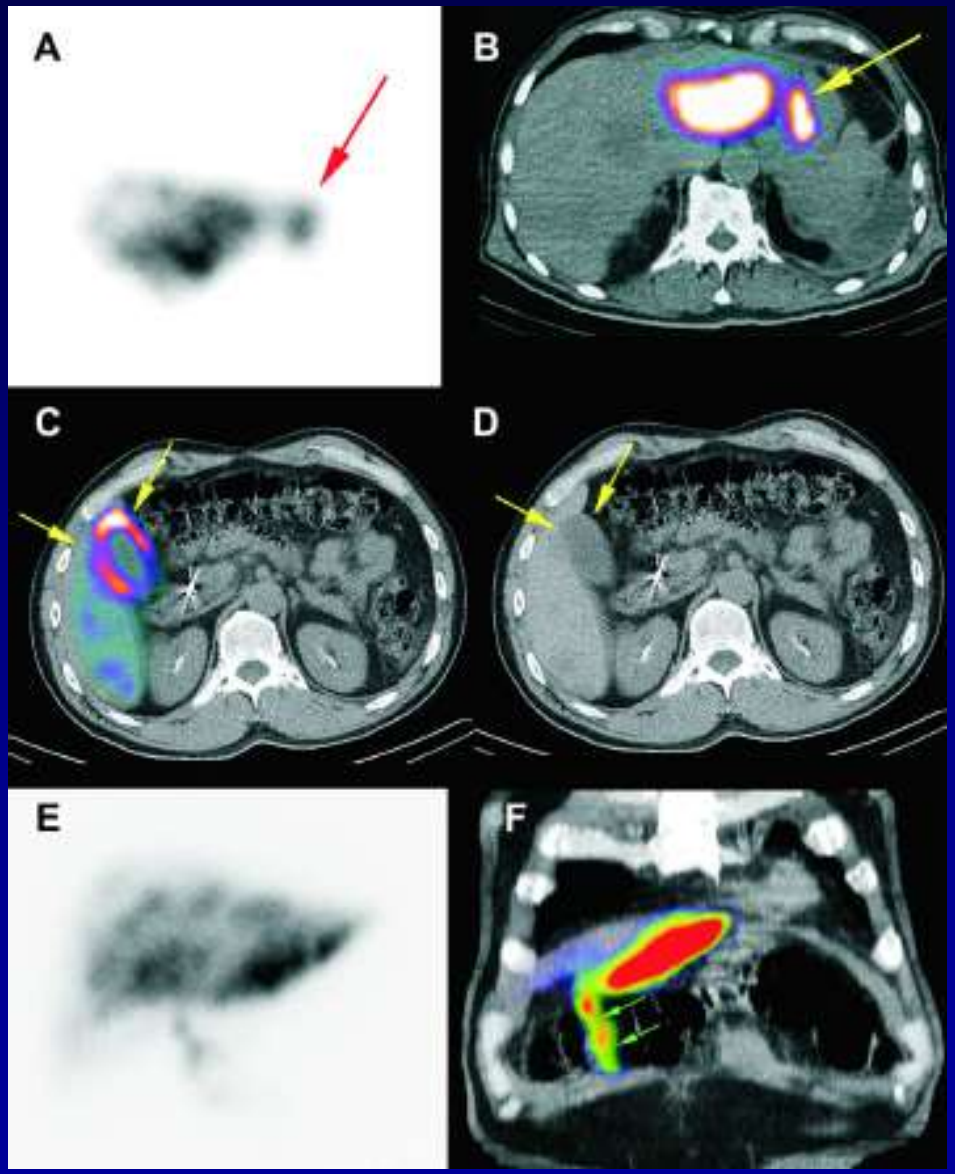
SPECT/CT as the basis for new technological approaches in the SN procedure



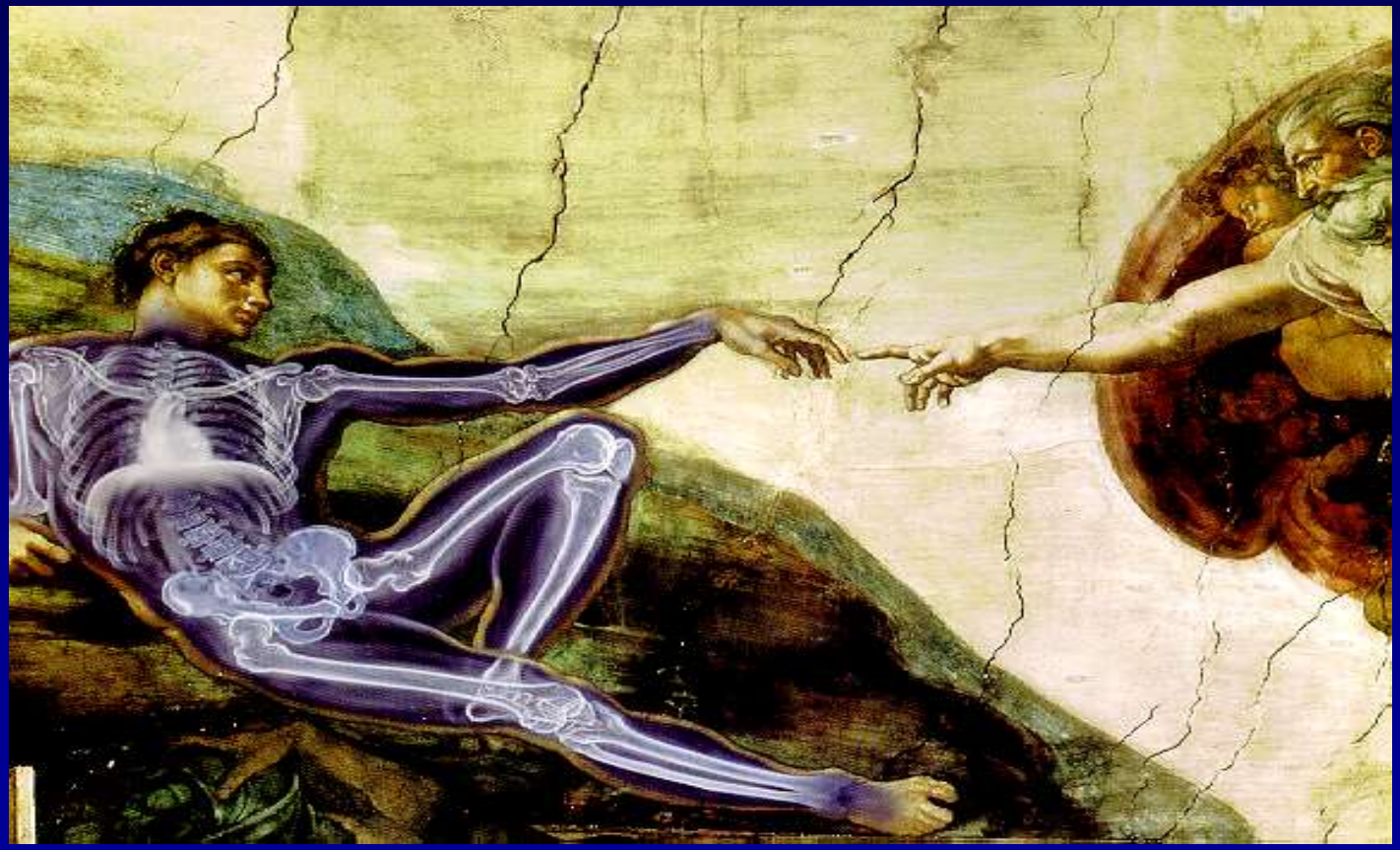
from R.A. Valdès Olmos et al, Clin Trans Imaging 2014

The role of SPECT/CT in radioembolization of liver tumours



from H. Ahmadzadehfar et al, Eur J Nucl Med Mol Imaging 2014

Hybrid PET/TC



The creation of a masterpiece

Why hybrid imaging with PET/CT?

- to image different aspects of disease
- to acquire complementary information
- to increase accuracy of interpretation
- to compensate for non-specificity of tracers
- to provide unique additional information

1 + 1 = 3

TIME Magazine, December 2000

Clinical impact of PET/CT

- **Improvement of lesion detection on both CT and FDG-PET images.**
- **Improvement of the localization of foci of FDG uptake resulting in better differentiation of physiologic from pathologic uptake.**
- **Precise localization of the malignant foci, for example in the skeleton versus soft tissue, or liver versus adjacent bowel or node.**

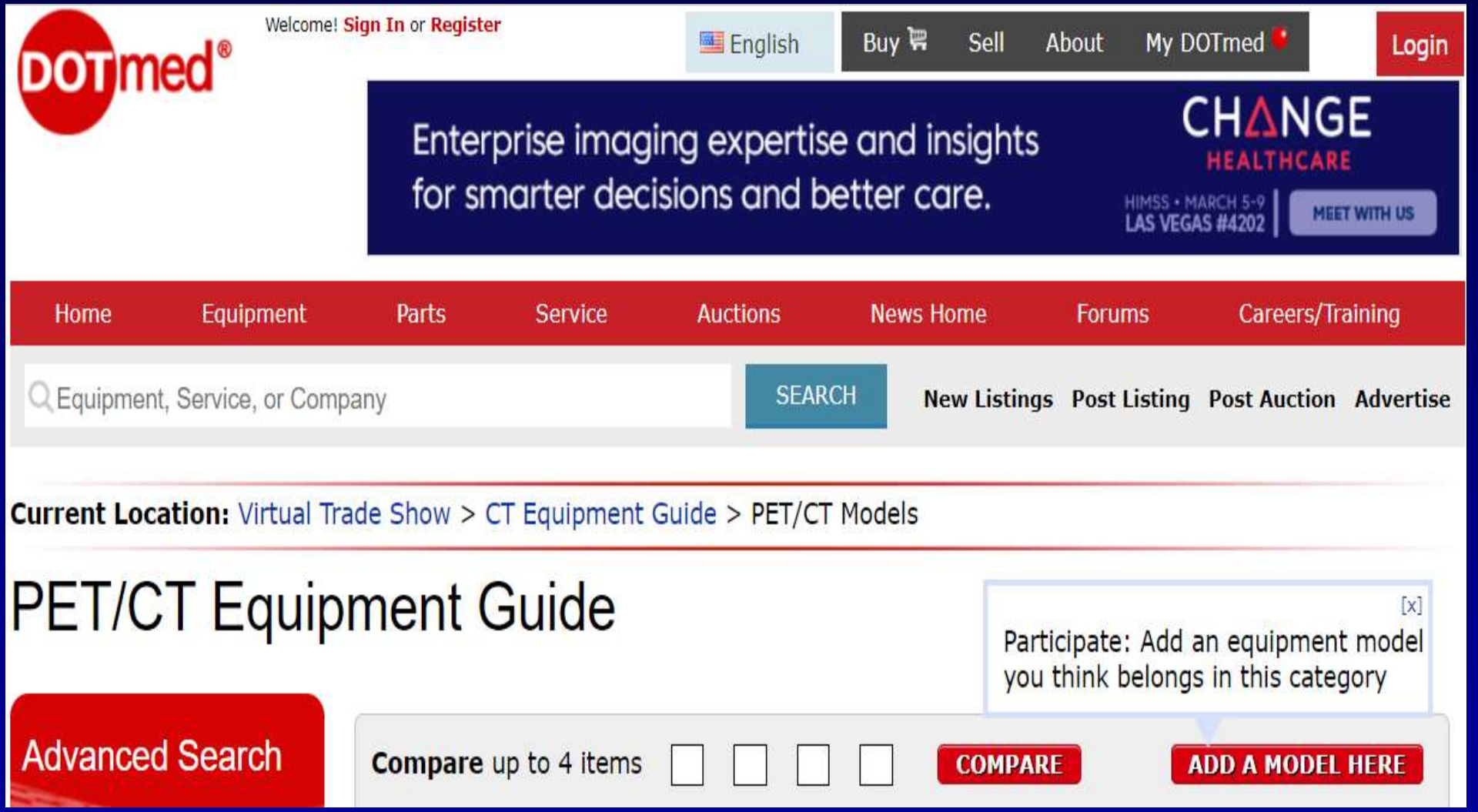
Concurrent PET/CT fusion images affect the clinical management by guiding further procedures, excluding the need of further procedures, and changing both inter- and intramodality therapy.

O. Schillaci et al, CB&R 2004

Relationship between cancer type and impact of PET/CT on intended management: findings of the National Oncologic PET Registry

Testing indication	No. of scans	% of cases with change in management*	95% CI
Initial staging	14,365	39.8	39.0–40.6
Restaging	14,584	35.9	35.1–36.7
Detection of suspected recurrence	11,914	38.5	37.6–39.3
Total	40,863	38.0	37.6–38.5

B.E. Hillner et al, J Nucl Med 2008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PET/CT Equipment Guide
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Participate: Add an equipment model you think belongs in this category
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COMPARE
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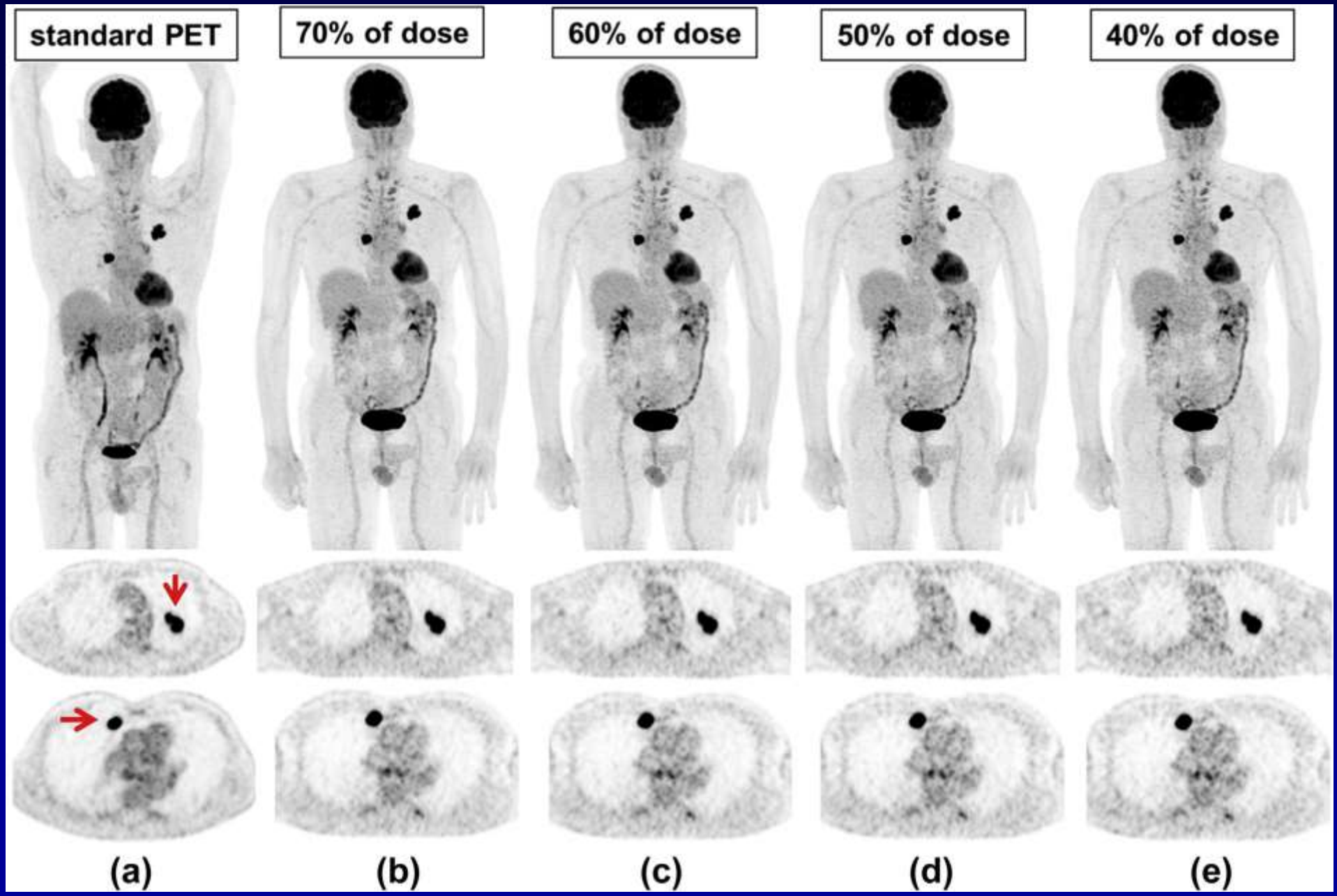
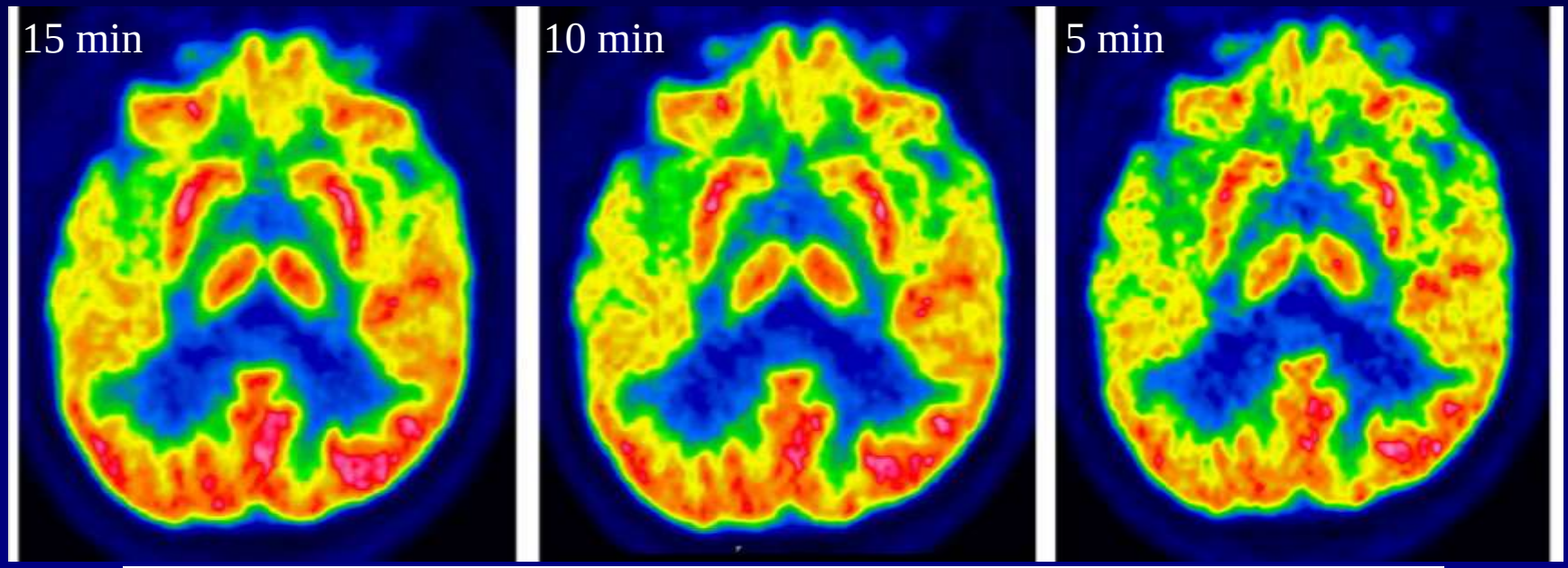
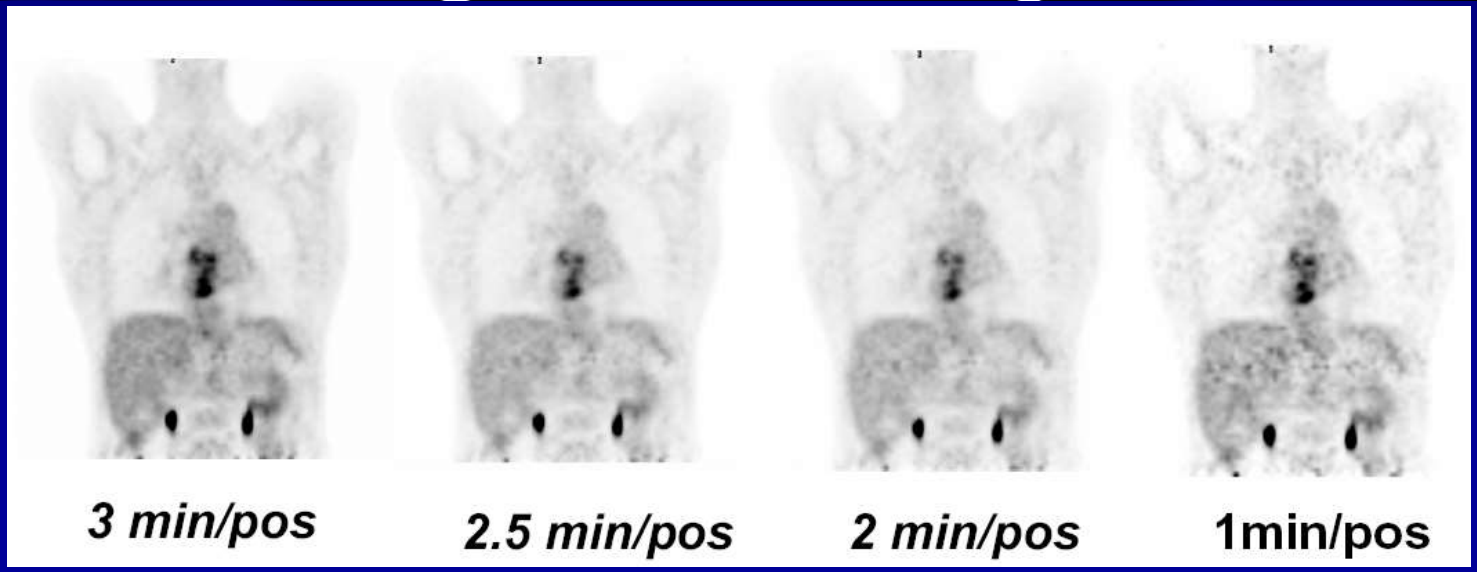

standard PET
70% of dose
60% of dose
50% of dose
40% of dose
(a)
(b)
(c)
(d)
(e)

PET scan duration and time per bed position





European Journal of Radiology 73 (2010) 449–451

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Editorial

PET/CT: More than the sum of two established imaging modalities?

European Journal of Radiology 73 (2010) 470–480

Contents lists available at ScienceDirect

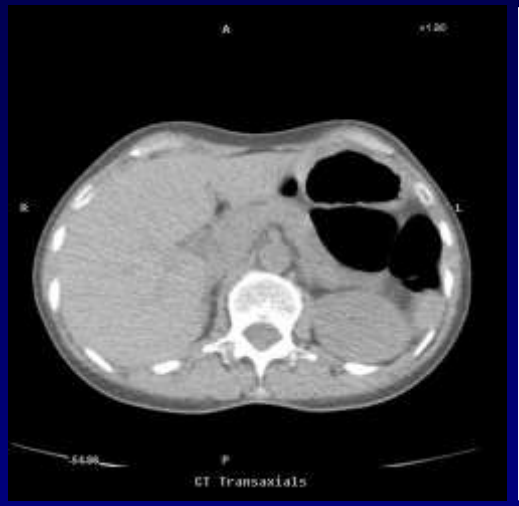
European Journal of Radiology

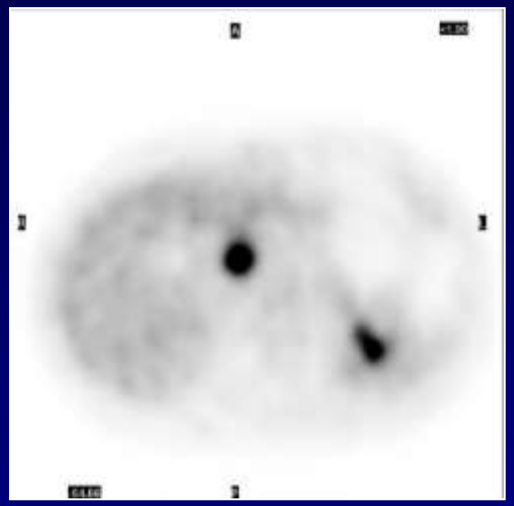
journal homepage: www.elsevier.com/locate/ejrad

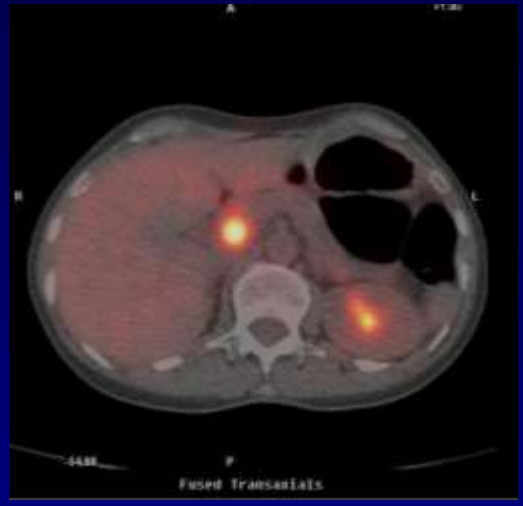
Review

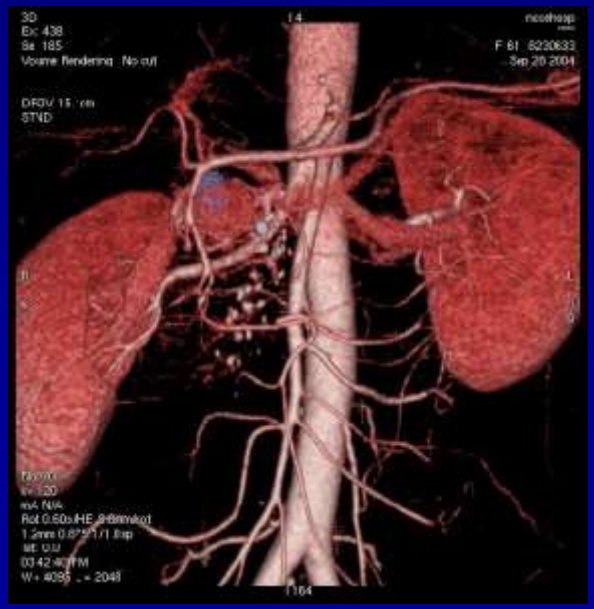
PET/CT imaging: The incremental value of assessing the glucose metabolic phenotype and the structure of cancers in a single examination

Contrast-enhanced FDG-PET/CT: 1-stop-shop imaging in oncology









What was PET-CT originally intended to be ?

- "It is to be emphasized that the documented objectives of this development was to offer *clinical CT* and *clinical PET* scans from a single device; the intended purpose of the CT was to provide clinical patient information and not just attenuation correction and localization alone."

David Townsend, Co-Inventor of PET/CT

CT in PET/CT: essential features of interpretation

Categories of Potentially Important or Significant CT Findings in a PET/CT Study

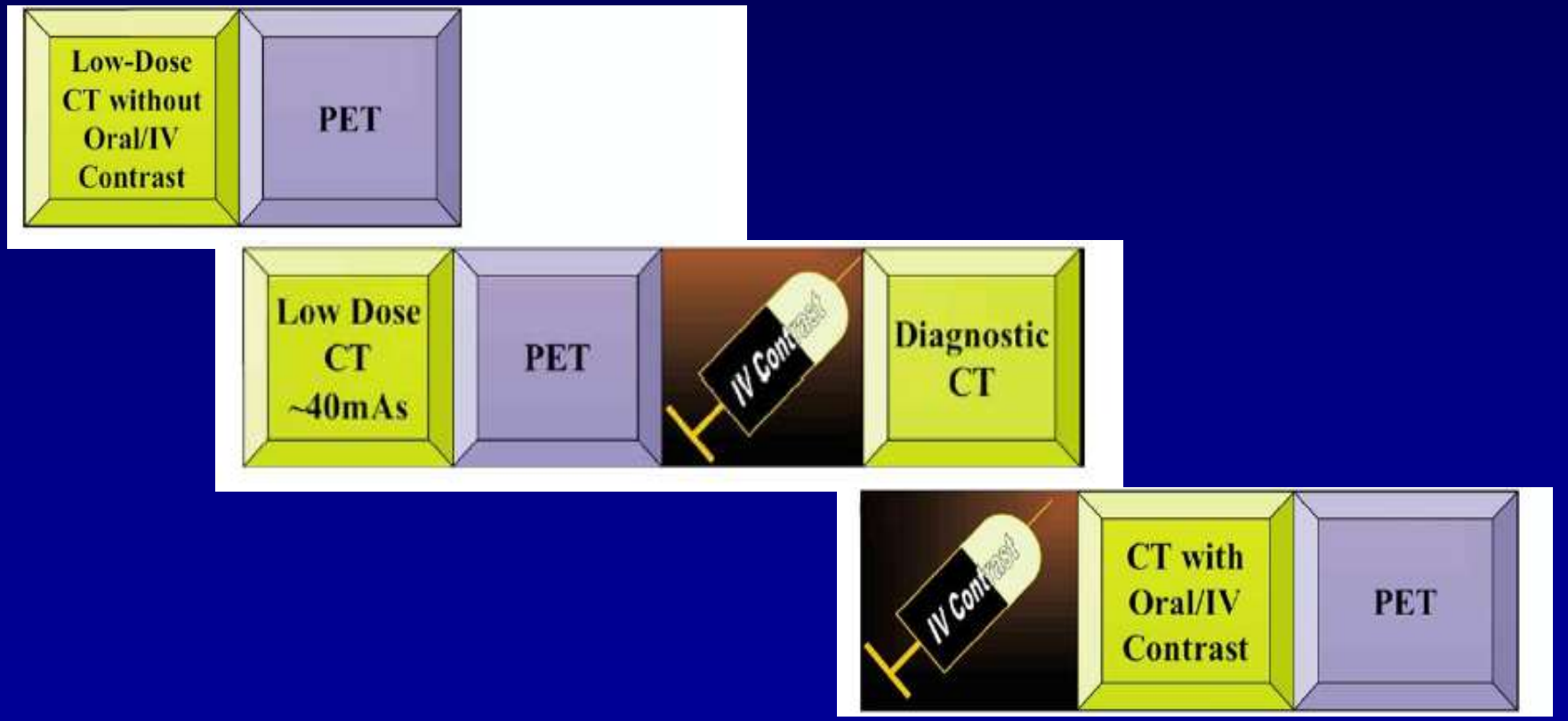
Category	Definition	Examples
Major	A finding that may require medical or surgical intervention immediately or within a short time	Abdominal aortic aneurysm, pneumothorax, pneumoperitoneum, tumor invasion/compression of airways, massive pleural/pericardial effusion, large osteolytic lesions with impending fracture, tumor invasion of spinal canal (usually also noted on PET/CT images)
Intermediate	A finding that is potentially important or helpful in PET interpretation	Lung nodules without ^{18}F-FDG uptake, pulmonary consolidation, cystic abdominal lesions (renal, hepatic, adnexal), ascites, massive bile duct dilatation, aerobilia, diverticulosis, surgical defects (especially in the head and neck), postsurgical changes (pneumonectomies, percutaneous endoscopic gastrostomy tubes, colostomy, urinary diversions, surgical clips, prosthetic devices, and fluid collections not associated with abnormal ^{18}F-FDG uptake)
Minor	A finding that is not seen on PET, does not affect PET interpretation, but may provide relevant medical information	Gallstones and renal stones, vascular calcifications (especially coronary and renal arteries), myomatous uterus, emphysema, prostate enlargement, extremity edema

H. Schoder et al, J Nucl Med 2005

If a physician does not review the CT portion of the PET/CT scan, then that physician is extremely vulnerable to legal consequence: ignorance is not a viable defense.

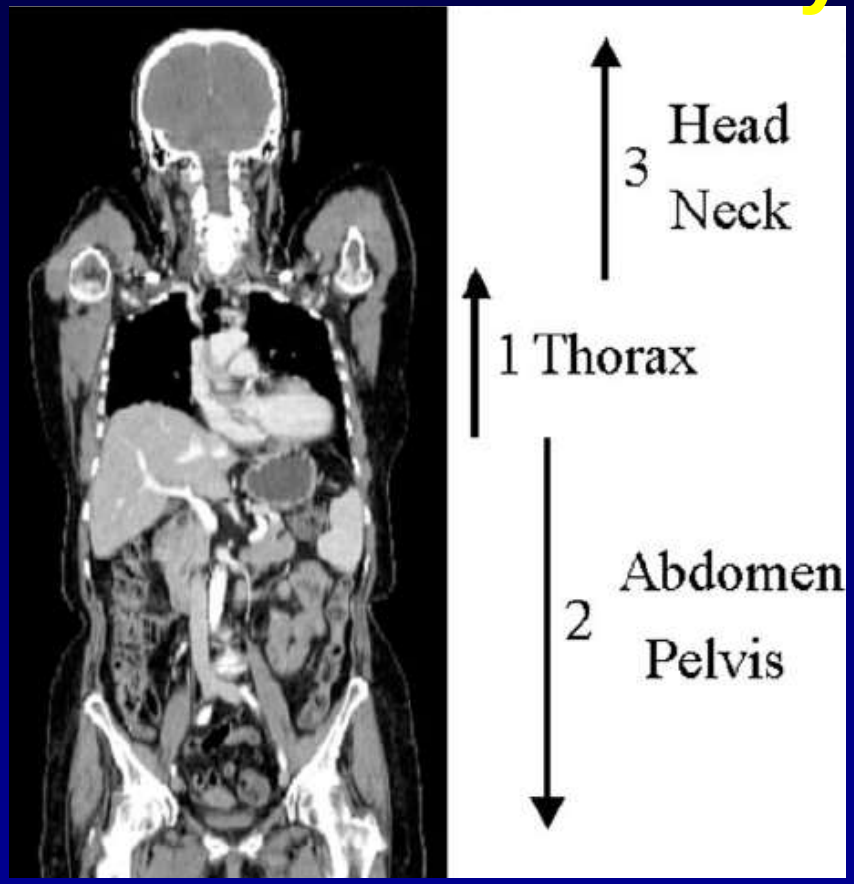
J.A. Brink, AJR 2005

To enhance or not to enhance?



T.M. Blodgett et al, Semin Nucl Med 2006

CT protocol to optimize contrast enhancement in each body region



Desired contrast enhancement is arterial in thorax, portal-venous in upper abdomen, venous in pelvis, and late-venous in neck and head. To meet these requirements, PET/CT scanners need to allow whole-body acquisition starting with thorax (scanned in caudocranial direction), followed by abdomen and pelvis (craniocaudal direction), and by neck and head (caudocranial scanning).

G. Antoch et al, J Nucl Med 2004

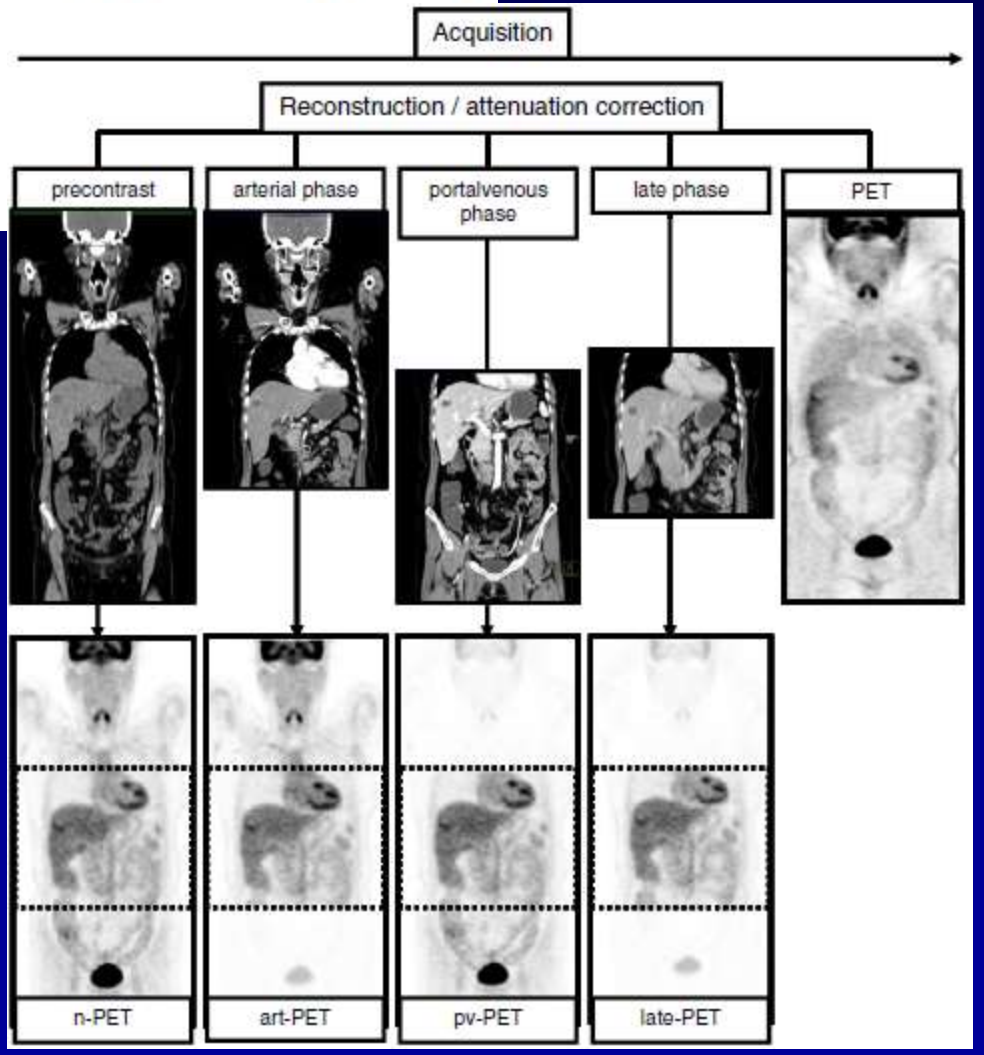
Eur J Nucl Med Mol Imaging (2012) 39:316–325
DOI 10.1007/s00259-011-1919-5

ORIGINAL ARTICLE

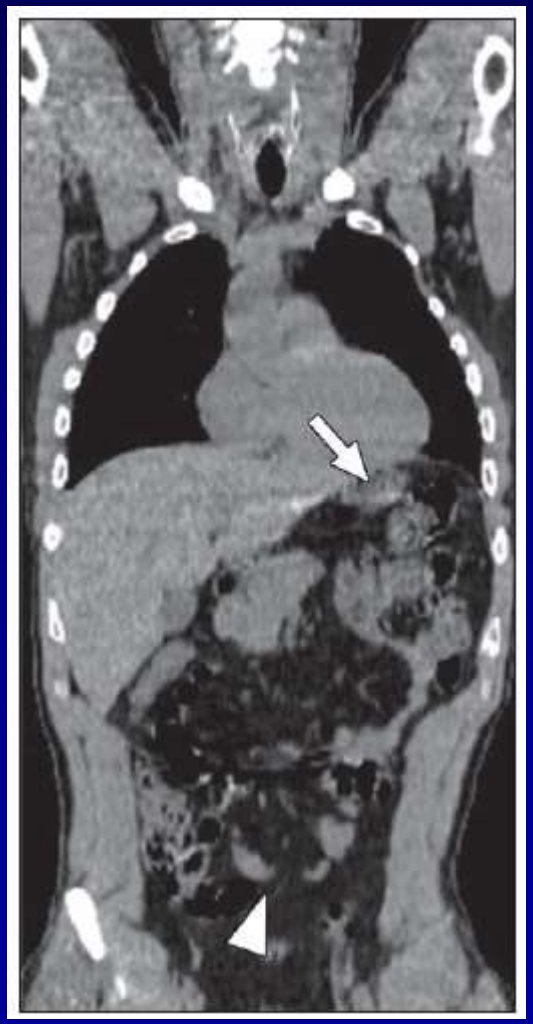
Multiphase contrast-enhanced CT with highly concentrated contrast agent can be used for PET attenuation correction in integrated PET/CT imaging

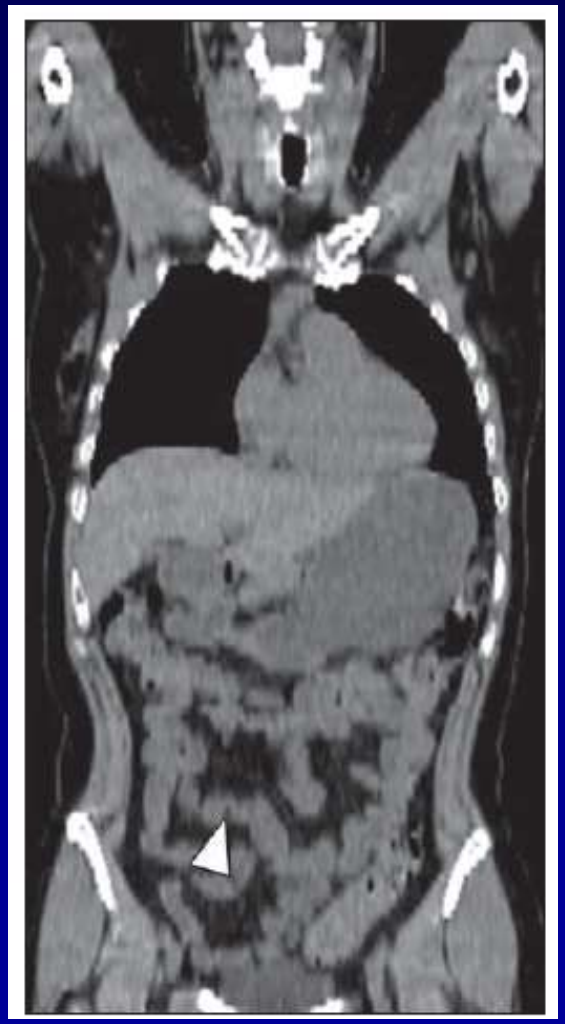
Philip Aschoff · Christian Plathow · Thomas Beyer · Matthias P. Lichy · Gunter Erb · Mehmet Ö. Öksüz · Claus D. Claussen · Christina Pfannenberg

Conclusion Multiphase CT data acquired with the use of highly concentrated CM can be used for qualitative assessment of liver lesions in torso FDG PET/CT. The influence on quantification of FDG uptake is small and negligible for most clinical applications.



Evaluation of low-density neutral oral contrast material in PET/CT for tumor imaging: results of a randomized clinical trial





The use of low-density neutral oral contrast material for CT during combined FDG-PET/CT studies significantly improves visualization of the bowel structures compared with no contrast material without causing side effects or clinically detectable errors in the attenuation correction of the FDG-PET study.

H.J. Otero et al, AJR 2009

Radiol med (2014) 119:283–289
DOI 10.1007/s11547-013-0340-5

RESOURCE MANAGEMENT AND HEALTH ECONOMICS

PET–CT in oncological patients: analysis of informal care costs in cost–benefit assessment

Antonio Orlacchio · Anna Micaela Ciarrapico · Orazio Schillaci · Fabrizio Chegai · Daniela Tosti · Fabrizio D'Alba · Manlio Guazzaroni · Giovanni Simonetti

Table 2 Medical costs arising from CECT, PET–CT and PET–CT with CECT

Medical cost (€)			
	ceTC	PET-TC	PET-TC + ceTC
Doctors	25.16	75.47	150.94
Technicians	11.32	15.09	17.01
Nurses	6.71	8.39	10.02
Auxiliary operator	3.62	3.624	3.62
Machine's depreciation	51	198.6	198.62
Consumables	65	226	276
Secretarial expenses	6.4	10.66	10.66
Fixed costs	73.55	134.48	134.48
Total	247.02	672.314	801.3
Total	919.33		801.3

Nonmedic	
Patient pr loss (€)	
3,575	

	Total (€)
	12,448

PET with FDG in ONCOLOGY
UTILITY in CLINICS

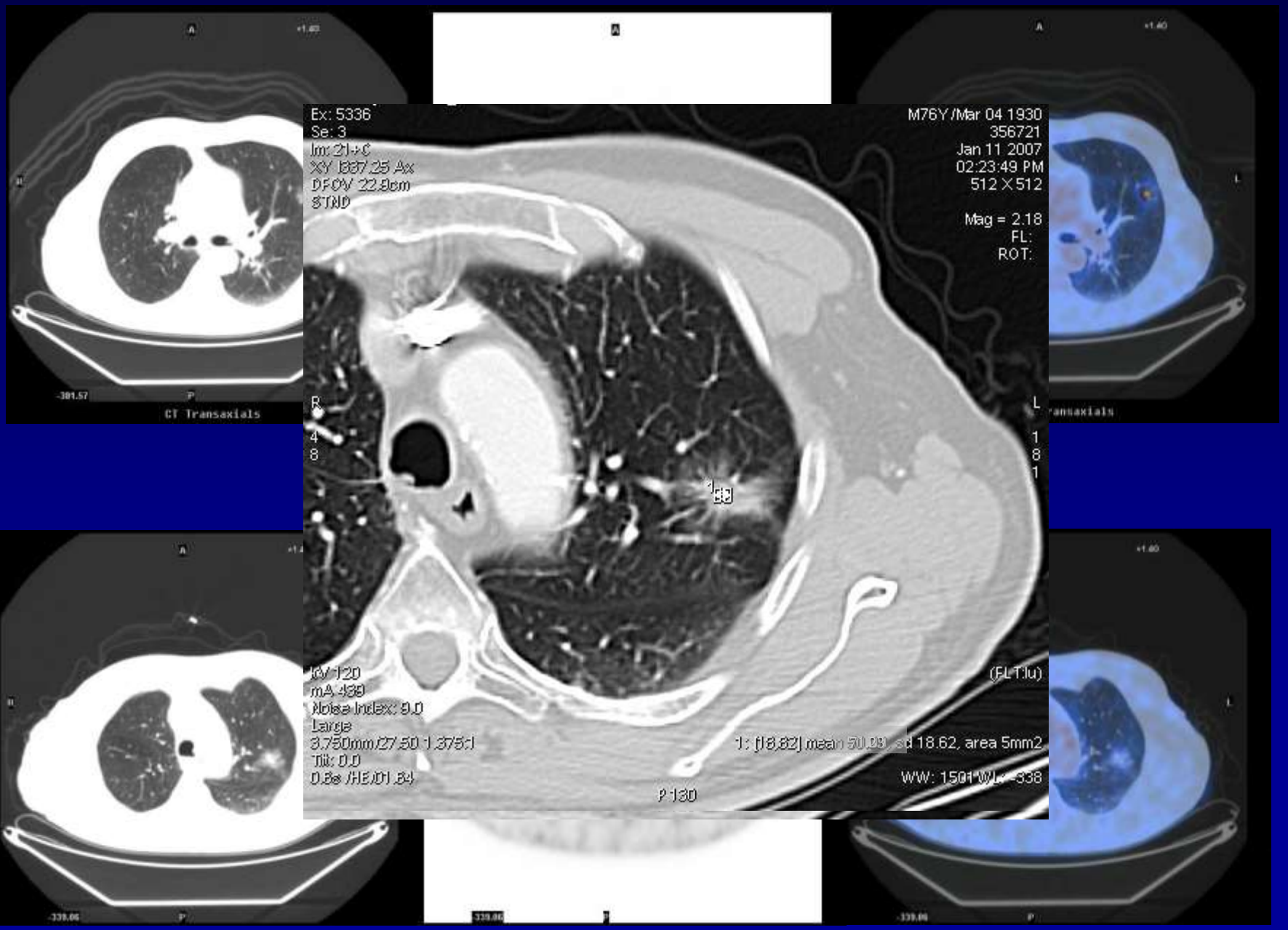
1. Diagnosis and "grading" of malignant disease
2. Definition of disease extent
   staging and restaging
3. Identification and localisation of disease foci
   unknown primary (paraneoplastic syndromes)
4. Evaluation and monitoring of response to therapy
5. Identification of recurrent disease in comparison with "raising" tumour markers and anatomic/structural changes (CT and MR)
6. Guide for biopsy
7. Therapy guidance and "management"

Preliminary study on the correlation between grading and histology of solitary pulmonary nodules and contrast enhancement and [^{18}F]fluorodeoxyglucose standardised uptake value after evaluation by dynamic multiphase CT and PET/CT

J Clin Pathol 2011

Salvatore Cappabianca,[1] Annamaria Porto,[1] Mario Petrillo,[1] Barbara Greco,[1] Alfonso Reginelli,[1] Francesco Ronza,[1] Francesca Setola,[1] Giovanni Rossi,[2] Andrea Di Matteo,[2] Roberto Muto,[2] Maria Luisa De Rimini,[3] Sergio Piccolo,[3] Mara Catalano,[3] Pietro Muto,[3] Nicoletta De Rosa,[4] Enrica Barra,[4] Ilaria De Rosa,[4] Francesca Antinolfi,[4] Giuseppe Antinolfi,[4] Mario Caputi,[5] Luca Brunese,[6] Roberto Grassi,[1] Antonio Rotondo[1]

- CT net enhancement (NE) well explains the growing characteristics of solitary pulmonary nodules (SPNs), which are strictly related to their angiogenesis activity.
- G3-graded SPNs showed reduced CT NE compared with G2 lesions; this behaviour reflects a structural anarchy in vascularisation that is pronounced in G3 lesions.
- Similar trends in [^{18}F]fluorodeoxyglucose (^{18}F-FDG) standardised uptake value (SUV) and CT NE values can be identified between G1/G2 and G3 lesions; although each technique strictly defined a different phenomenon, respectively vascularisation and metabolic activity, such behaviours show the close relationships that link contrast medium delivery and ^{18}F-FDG consumption in SPNs.
- A comprehensive evaluation of NE and ^{18}F-FDG SUV in clinical routine would probably lead to an accurate evaluation of potential SPN aggressiveness.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Noise Index: 9.0
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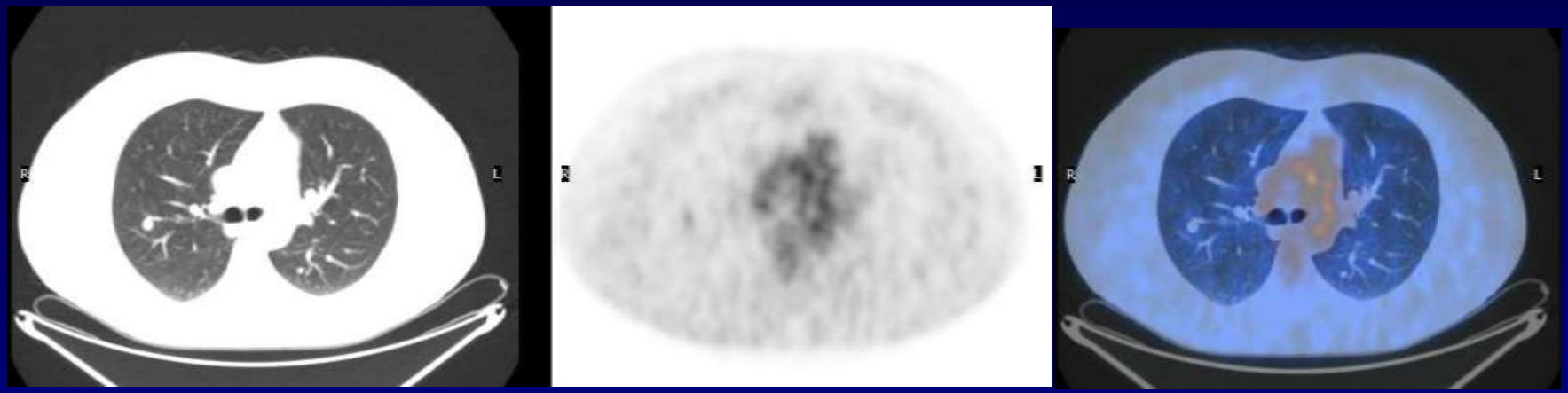
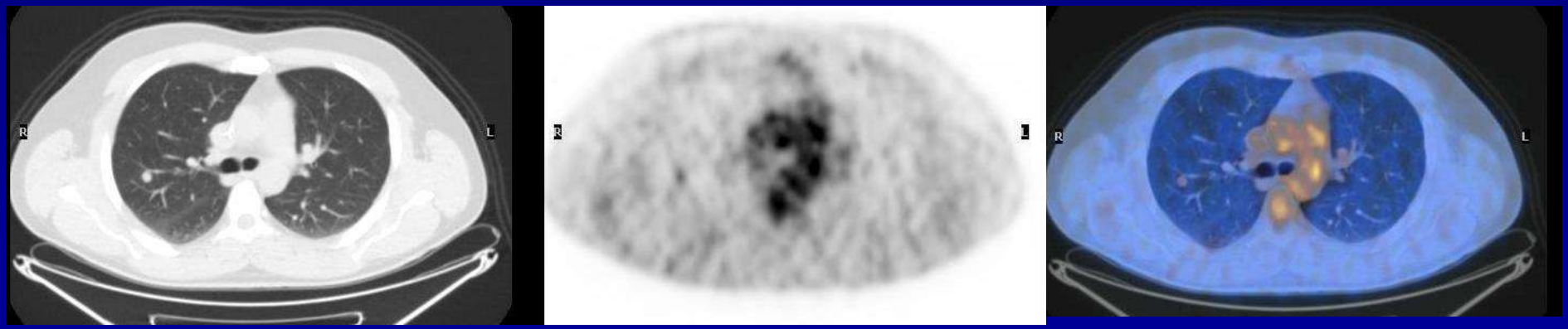
(FLT:lu)
WW: 1501 WL: 338
P 130

SPN: dual time FDG-PET/TC



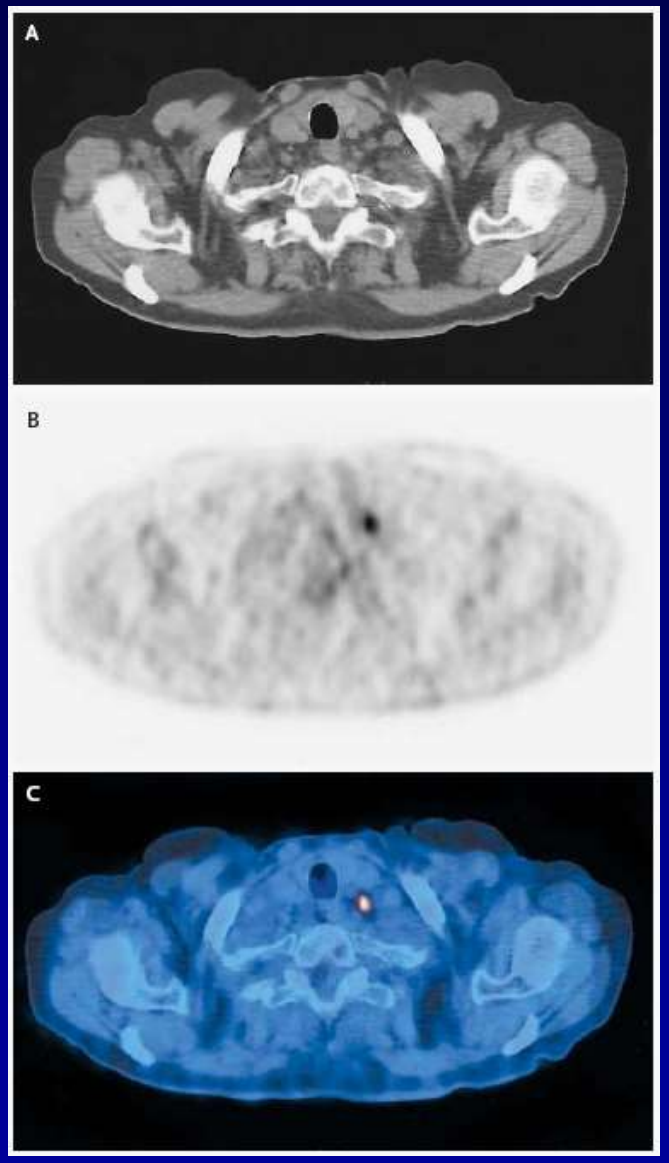
Early SUV 1.4

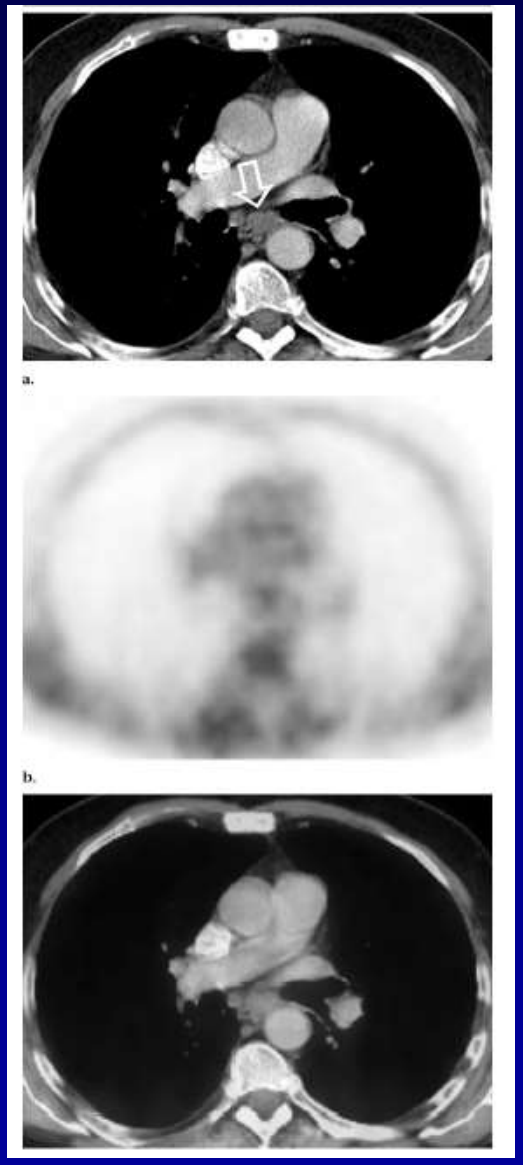


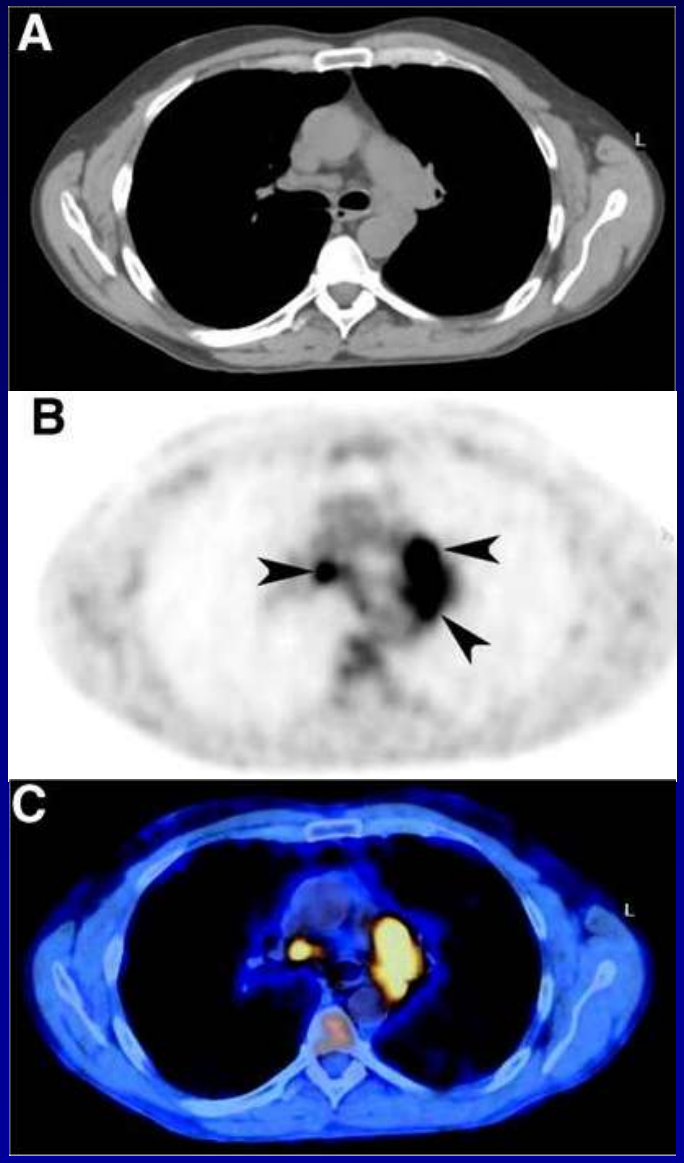
Delay SUV 2.1

O.Schillaci et al, Radiol med 2009

NSCLC: N-staging





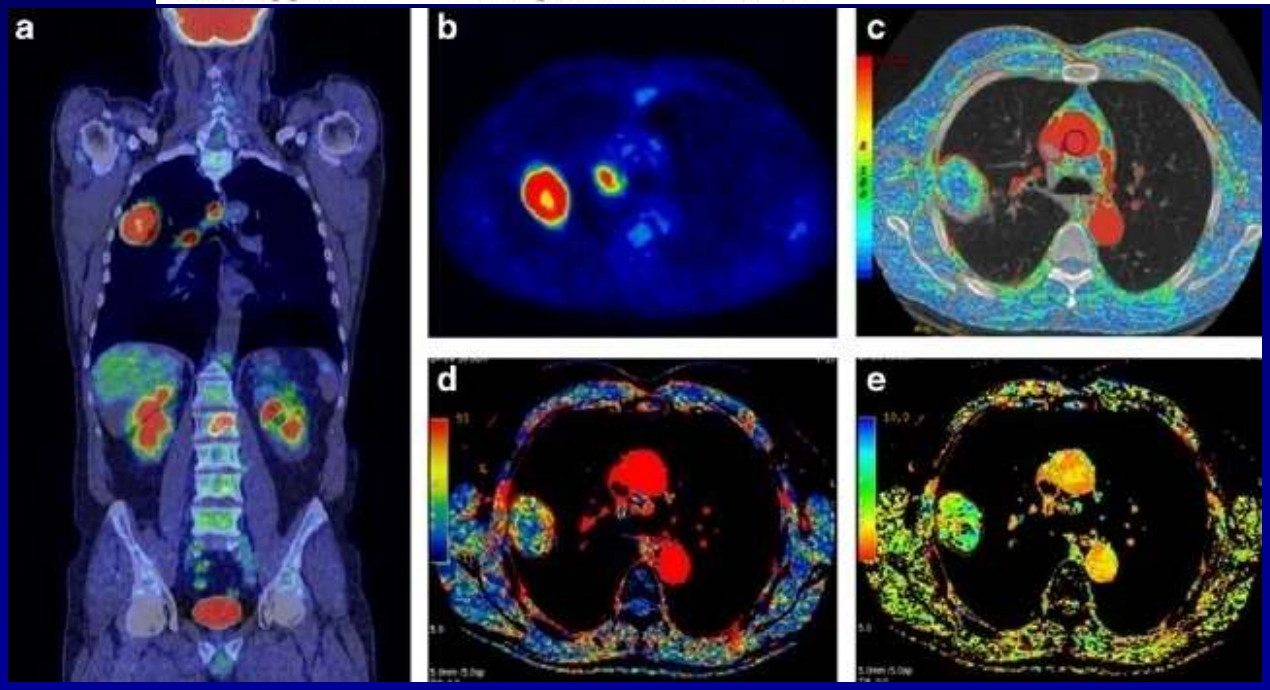


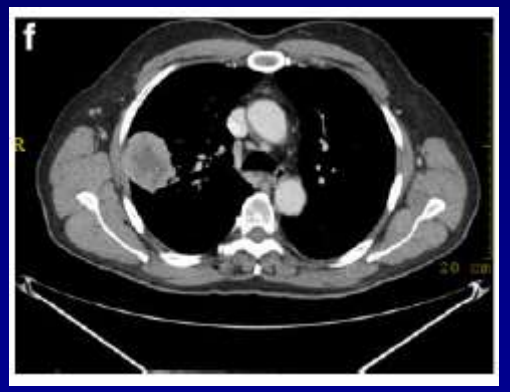
Eur J Nucl Med Mol Imaging (2013) 40:156–165
DOI 10.1007/s00259-012-2273-y

ORIGINAL ARTICLE

Feasibility of perfusion CT technique integrated into conventional ^{18}FDG/PET-CT studies in lung cancer patients: clinical staging and functional information in a single study

Davide Ippolito · Cristina Capraro · Luca Guerra ·





Perfusion CT combined with PET/CT is feasible technique that may provide additional functional information about vascularity and tumour aggressiveness as a result of lower perfusion and higher metabolism shown by larger lesions.

Contrast-enhanced FDG PET/CT: 1-stop-shop imaging for assessing the resectability of pancreatic cancer

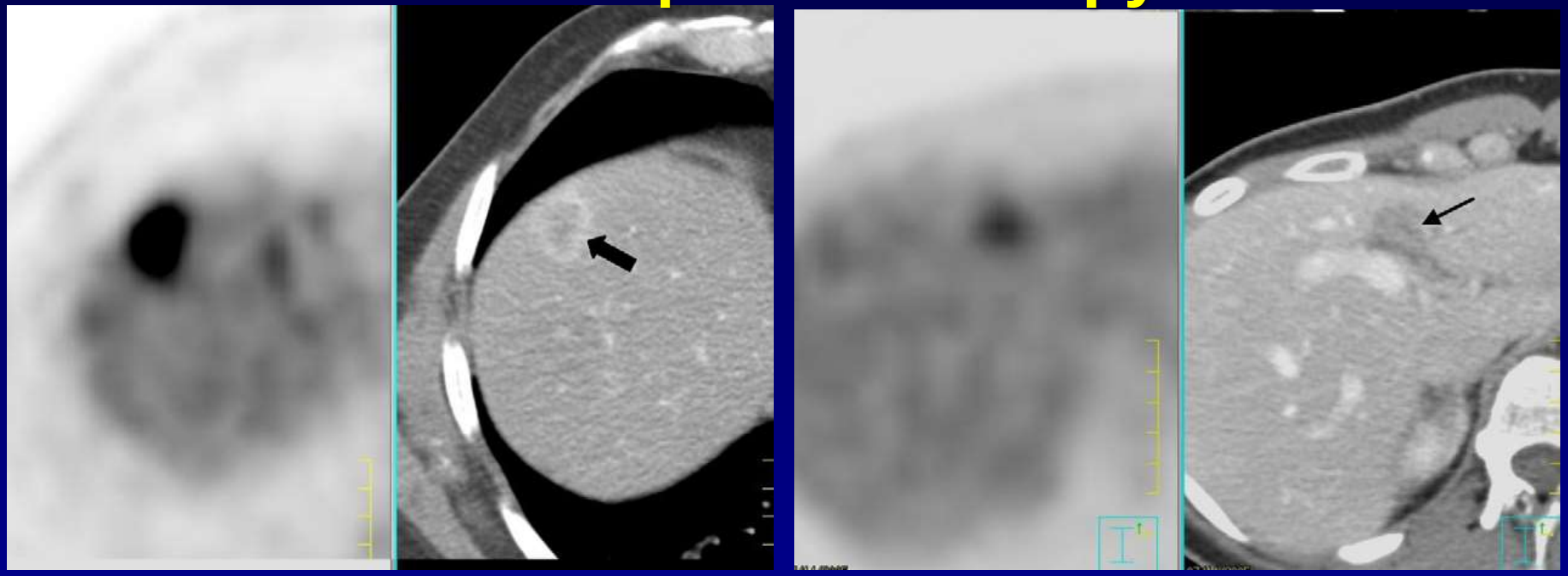
Fifty patients with biopsy-proven pancreatic adenocarcinoma underwent FDG PET/CT for the evaluation of resectability.

Criteria for unresectability were distant metastases, peritoneal carcinomatosis, arterial infiltration, or invasion of neighboring organs other than the duodenum. The performance of enhanced PET/CT regarding resectability

Index	PET	Unenhanced PET/CT	Enhanced PET/CT
Sensitivity	100% (23/23)	100% (23/23)	96% (22/23)
Specificity	44% (12/27)	56% (15/27)	82% (22/27)
Accuracy	70% (35/50)	76% (38/50)	88% (44/50)
PPV	61% (23/38)	66% (23/35)	82% (22/27)
NPV	100% (12/12)	100% (15/15)	96% (22/23)

K. Strobel et al, J Nucl Med 2008

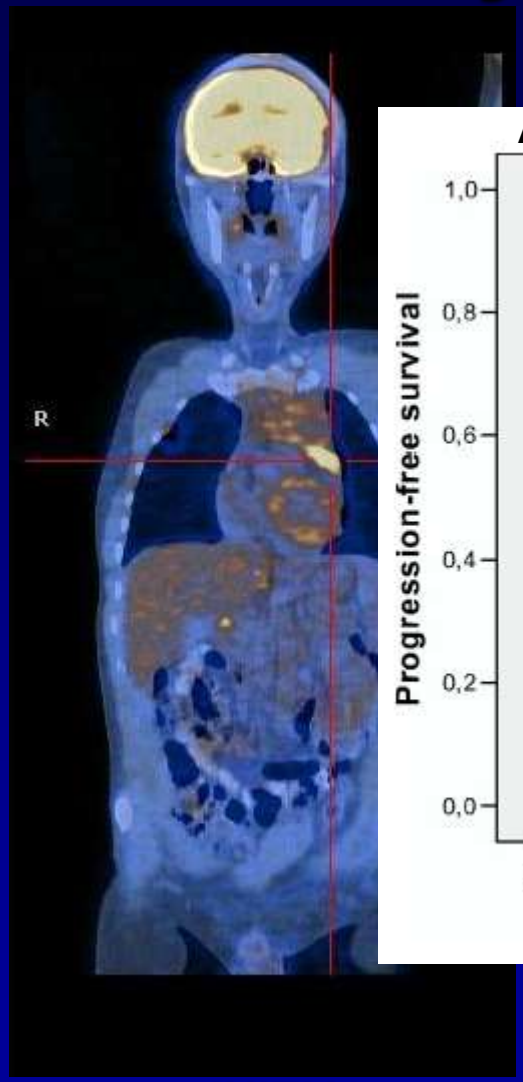
Evaluation of contrast medium enhancement and FDG uptake of liver metastasis in PET/CT prior to therapy

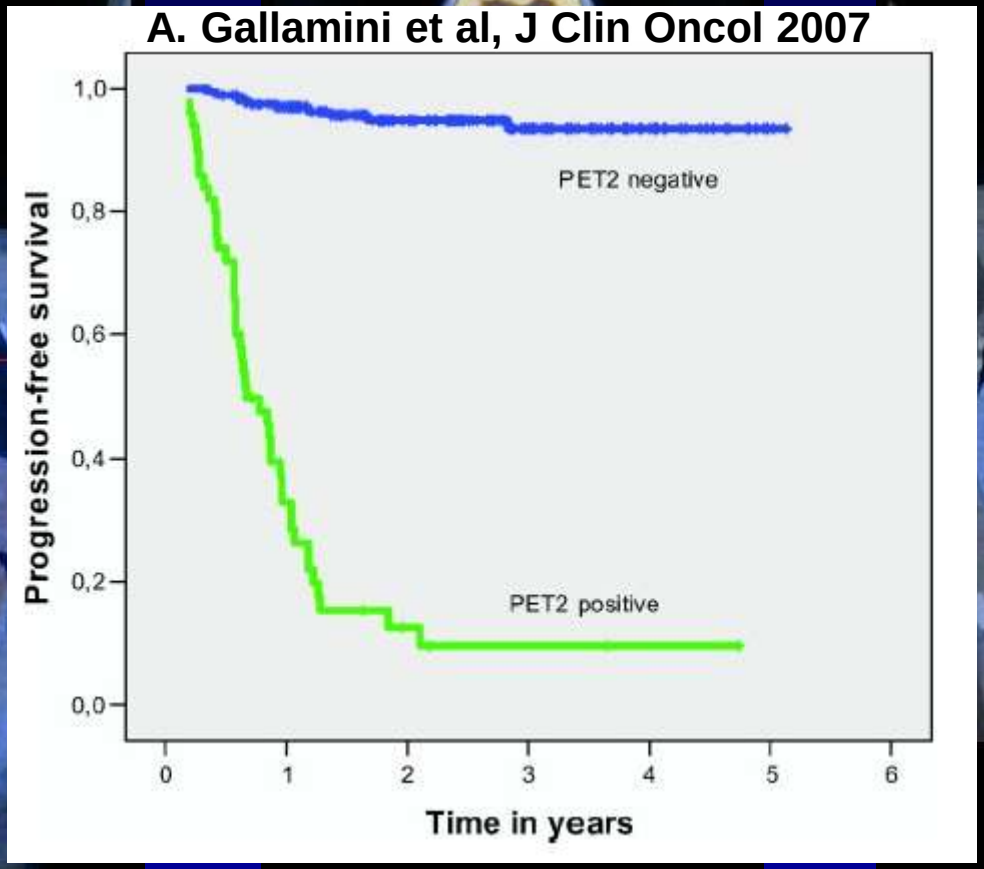


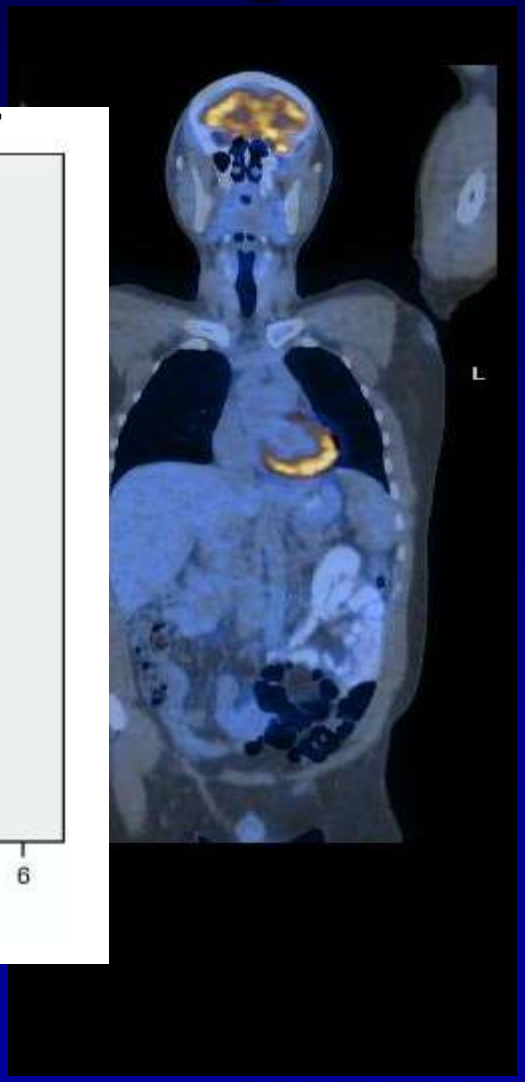
Significant differences between the SUVs and HU values of liver lesions in colon and breast carcinoma exist. The rim enhancement of the lesion in colon carcinoma indicate a significant higher SUV of the lesion; no differences were seen in lesions of breast carcinoma. Only moderate correlations between the area size, the SUVs and HU values were seen. The information given by one modality cannot be replaced by the other modality. To assess the disease in its whole extent it is necessary to have the information of both methods.

W. Hundt et al, Eur J Radiol 2012

FDG PET/CT in lymphoma: early therapy monitoring





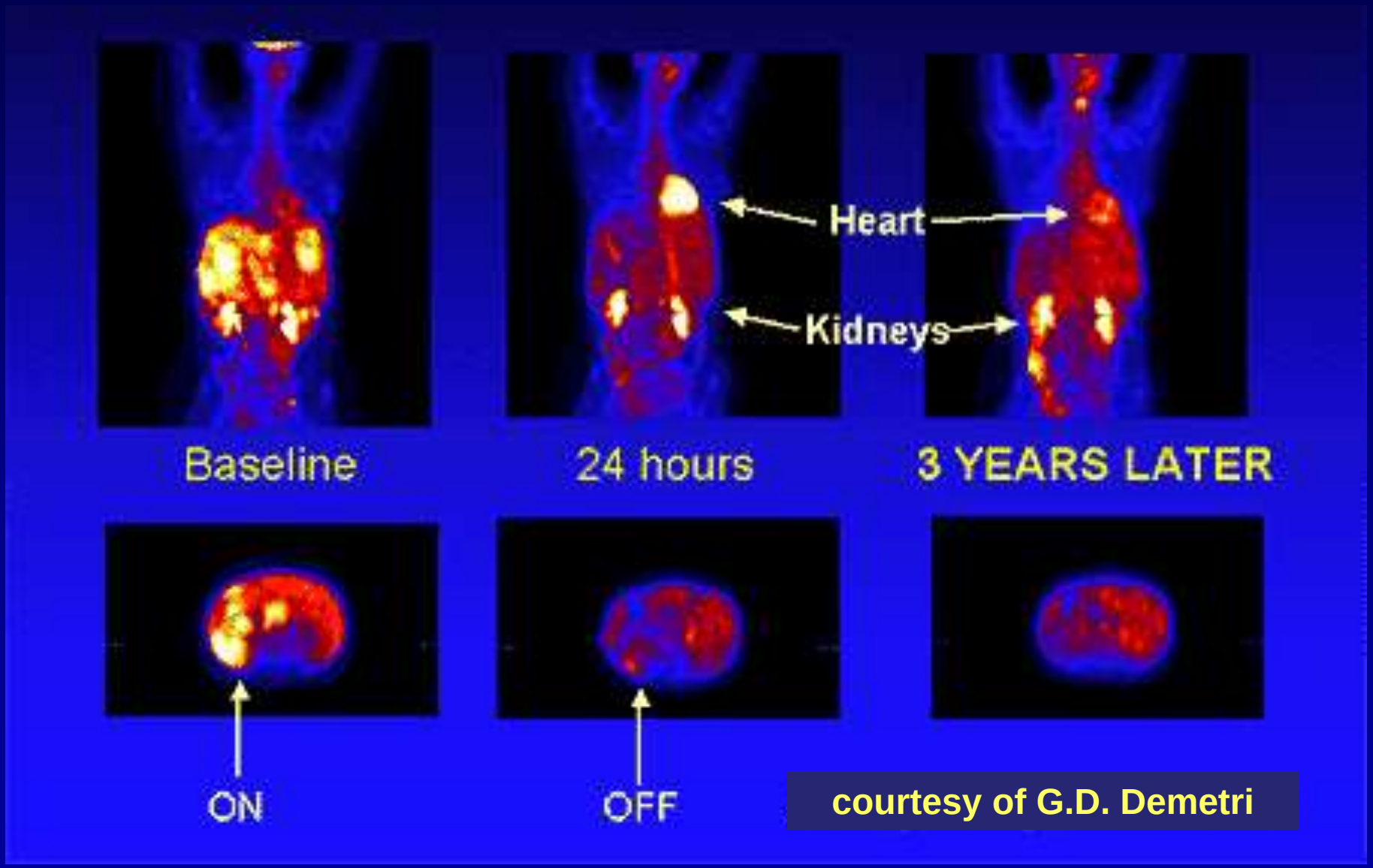


INITIAL

AFTER 2 CYCLES

6 MONTHS

PET in evaluating treatment response to imatinib in GIST



The Impact of Positron Emission Tomography (PET) on Expected Management During Cancer Treatment

Findings of the National Oncologic PET Registry

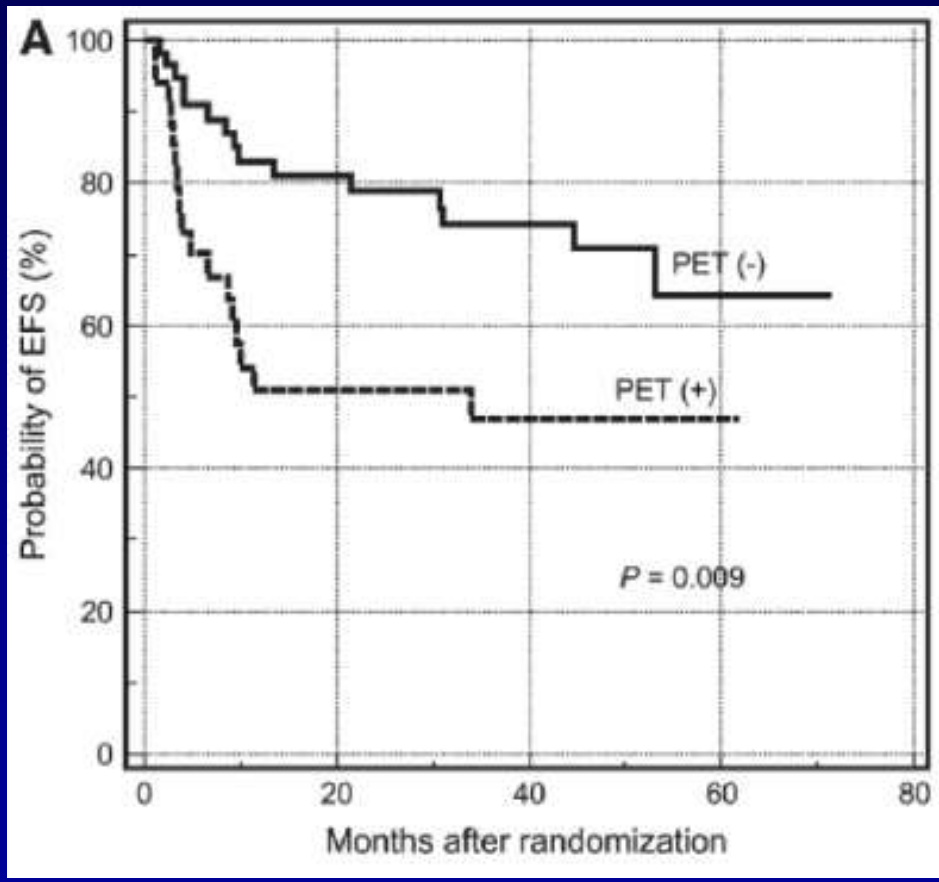
Variable	No. of Scans (%)				
	Treatments	Imaging	Biopsy	Observation or Supportive Care	All
Pre-PET Plan					
No. of scans	4299 (41)	5523 (52.6)	231 (2.2)	444 (4.2)	10,497
Post-PET plan					
No change in therapy	1667 (38.8)	3212 (58.2)	136 (58.9)	306 (68.9)	5321 (50.7)
Switch to another therapy	1208 (28.1)	1432 (25.9)	65 (28.1)	73 (16.4)	2778 (26.5)
Adjust the dose or duration of therapy	800 (18.6)	857 (15.5)	28 (12.1)	59 (13.3)	1744 (16.6)
Switch from therapy to observation or supportive care	624 (14.5)	22 (0.4)	2 (0.9)	6 (1.4)	654 (6.2)

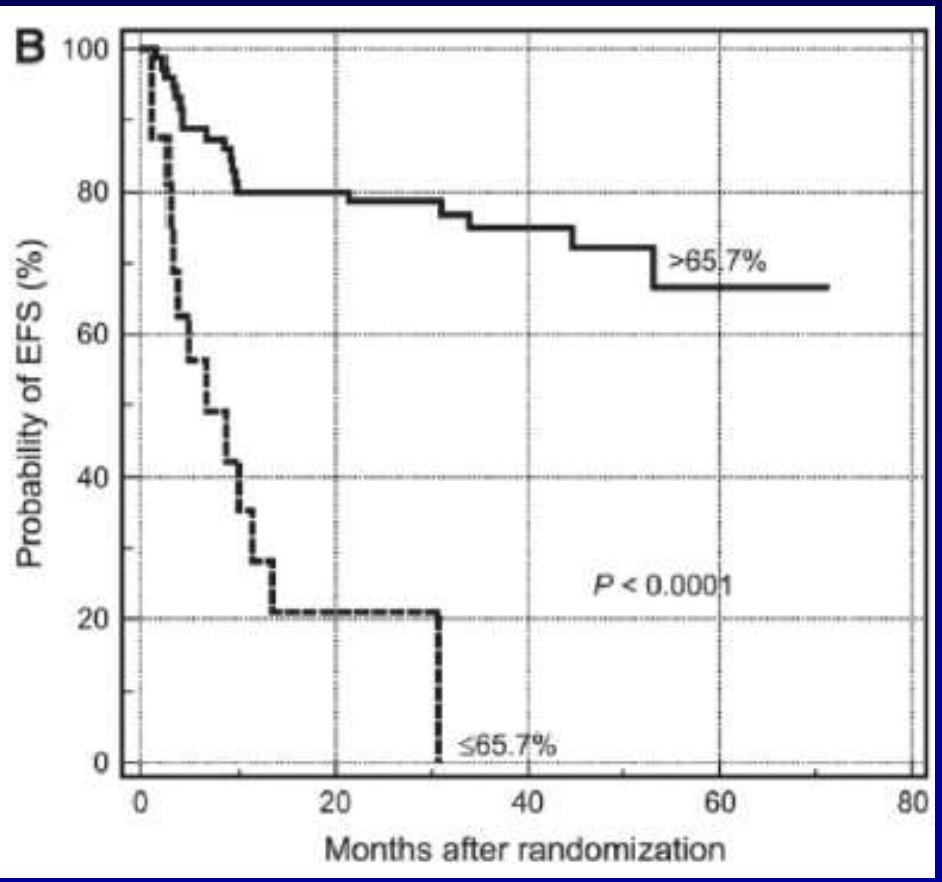
B.E. Hillner et al, Cancer 2009

PET/CT is a qualitative and quantitative method

- *Most applications to date have been qualitative.*
- *In treatment response assessment, especially if looking for small induced changes, quantitation will be needed.*
- *Quantitation requires grater attention to technical details than qualitative imaging.*
- *Standardization of methods is required for quantitation.*

PET tumour quantification improves prediction of patient survival





C. Lin et al, J Nucl Med 2007

Standardization of PET-based response evaluation

- Determining the appropriate timing of response measurement: which therapy and when to measure—recognition of "metabolic flare" and "hormonal flare" and "metabolic stunning" in the context of radiotherapy, hormonal therapy, and chemotherapy.[17–19]
- The optimal and clinically most appropriate approach for quantification of FDG uptake.[20,21]
- Which thresholds are to be used to define response as complete metabolic response, partial metabolic response, stable metabolic disease, and progressive metabolic disease?
- How should it be used judiciously for varying uptake by different tumors or in heterogeneous tumors?[22]
- Need for standardization of PET methodology: patient preparation, injection dose, imaging time, and attenuation correction and imaging reconstruction algorithm.

S. Basu et al, Pet Clin 2015

From RECIST to PERCIST: Evolving Considerations for PET Response Criteria in Solid Tumors

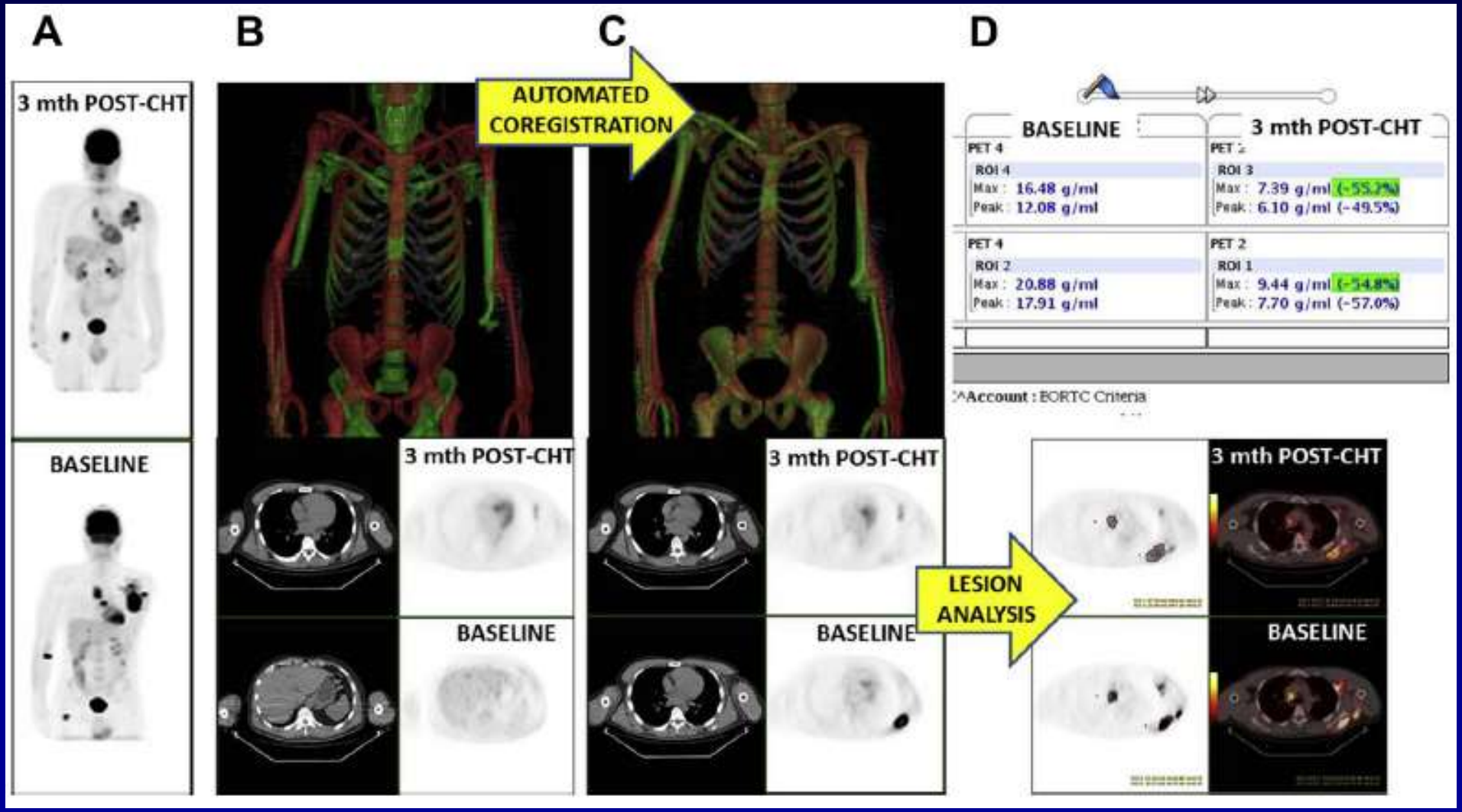
Richard L. Wahl[1,2], Heather Jacene[1], Yvette Kasamon[2], and Martin A. Lodge[1]

[1]*Division of Nuclear Medicine, Department of Radiology, Johns Hopkins University School of Medicine, Baltimore, Maryland; and*
[2]*Department of Oncology, Johns Hopkins University School of Medicine, Baltimore, Maryland*

The purpose of this article is to review the status and limitations of anatomic tumor response metrics including the World Health Organization (WHO) criteria, the Response Evaluation Criteria in Solid Tumors (RECIST), and RECIST 1.1. This article also reviews qualitative and quantitative approaches to metabolic tumor response assessment with ^{18}F-FDG PET and proposes a draft framework for PET Response Criteria in Solid Tumors (PERCIST), version 1.0. **Methods:** PubMed searches, including searches for the terms *RECIST, positron, WHO, FDG, cancer* (including specific types), *treatment response, region of interest,* and derivative references, were performed. Abstracts and articles judged most relevant to the goals of this report were reviewed with emphasis on limitations and strengths of the anatomic and PET approaches to treatment response assessment. On the basis of these data and the authors' experience, draft criteria were formulated for PET tumor response to treatment. **Results:** Approximately 3,000 potentially relevant references were screened. Anatomic imaging alone using standard WHO, RECIST, and RECIST 1.1 criteria is widely applied but still has limitations in response assessments. For example, despite effective treatment, changes in tumor size can be minimal in tumors such as lymphomas, sarcoma, hepatomas, mesothelioma, and gastrointestinal stromal tumor. CT tumor density, contrast enhancement, or MRI characteristics appear more informative 3-cm-diameter region of interest in the liver, using a consistent PET protocol, using a fixed small region of interest about 1 cm^3 in volume (1.2-cm diameter) in the most active region of metabolically active tumors to minimize statistical variability, assessing tumor size, treating SUV lean measurements in the 1 (up to 5 optional) most metabolically active tumor focus as a continuous variable, requiring a 30% decline in SUV for "response," and deferring to RECIST 1.1 in cases that do not have ^{18}F-FDG avidity or are technically unsuitable. Criteria to define progression of tumor-absent new lesions are uncertain but are proposed. **Conclusion:** Anatomic imaging alone using standard WHO, RECIST, and RECIST 1.1 criteria have limitations, particularly in assessing the activity of newer cancer therapies that stabilize disease, whereas ^{18}F-FDG PET appears particularly valuable in such cases. The proposed PERCIST 1.0 criteria should serve as a starting point for use in clinical trials and in structured quantitative clinical reporting. Undoubtedly, subsequent revisions and enhancements will be required as validation studies are undertaken in varying diseases and treatments.

Key Words: molecular imaging; oncology; PET/CT; anatomic imaging; RECIST; response criteria; SUV; treatment monitoring

J Nucl Med 2009; 50:122S–150S
DOI: 10.2967/jnumed.108.057307


A
B
C
D
3 mth POST-CHT
BASELINE
AUTOMATED COREGISTRATION
3 mth POST-CHT
BASELINE
3 mth POST-CHT
BASELINE
BASELINE
3 mth POST-CHT
PET 4
ROI 4
Max : 16.48 g/ml
Peak : 12.08 g/ml
PET 2
ROI 3
Max : 7.39 g/ml (-55.2%)
Peak : 6.10 g/ml (-49.5%)
PET 4
ROI 2
Max : 20.88 g/ml
Peak : 17.91 g/ml
PET 2
ROI 1
Max : 9.44 g/ml (-54.8%)
Peak : 7.70 g/ml (-57.0%)
Account : EORTC Criteria
LESION ANALYSIS
3 mth POST-CHT
BASELINE

(^{18}F)Fludeoxyglucose Positron Emission Tomography and Computed Tomography as a Prognostic Tool Before Liver Transplantation, Resection, and Loco-Ablative Therapies for Hepatocellular Carcinoma

Liver Transpl 2015

Yael Asman,[1] Amy R. Evenson,[3] Einat Even-Sapir,[2] and Oren Shibolet[1]

TABLE 3. Role of [^{18}F]FDG PET-CT in Predicting Prognosis After OLT

Author, Institution, Year	Patient Number	Group Division: PET-Positive/ PET-Negative (n)*	Principal Study Results: Recurrence-Free Survival Among PET-Positive and PET-Negative Groups (%)	Recurrence-Free Survival Among Patients Within and Outside Milan Criteria (%)
Yang et al.,[37] Seoul National University College of Medicine, 2006	38	13/25	2 years: 46 versus 85	2 years: 84.6 versus 41.7
Lee et al.,[38] Seoul National University College of Medicine, 2009	59	21/38	1 year: 57 versus 97 2 years: 42 versus 97	79 versus 71† $P > 0.05$ (0.75)
Kornberg et al.,[39] Friedrich-Schiller-University, Jena, Germany, 2009	42	16/26	3 years: 35 versus 93	3 years: 94 versus 63‡
Kornberg et al.,[40] Friedrich-Schiller-University, Jena, 2009	55	19/36	3 years: 46.9 versus 93.3	95 versus 80†‡ $P > 0.05$ (0.13)
Kornberg et al.,[41] Technical university of Munich, 2012	91	35/56	45.7 versus 96.4†	5 years: 86.2 versus 47.4
Lee et al.,[42] National Cancer Centre, Goyang-si, Gyeonggi-do, 2013	191	55/136	1 year: 62 versus 94 2 years: 60 versus 88 3 years: 57 versus 87	92 versus 52†§

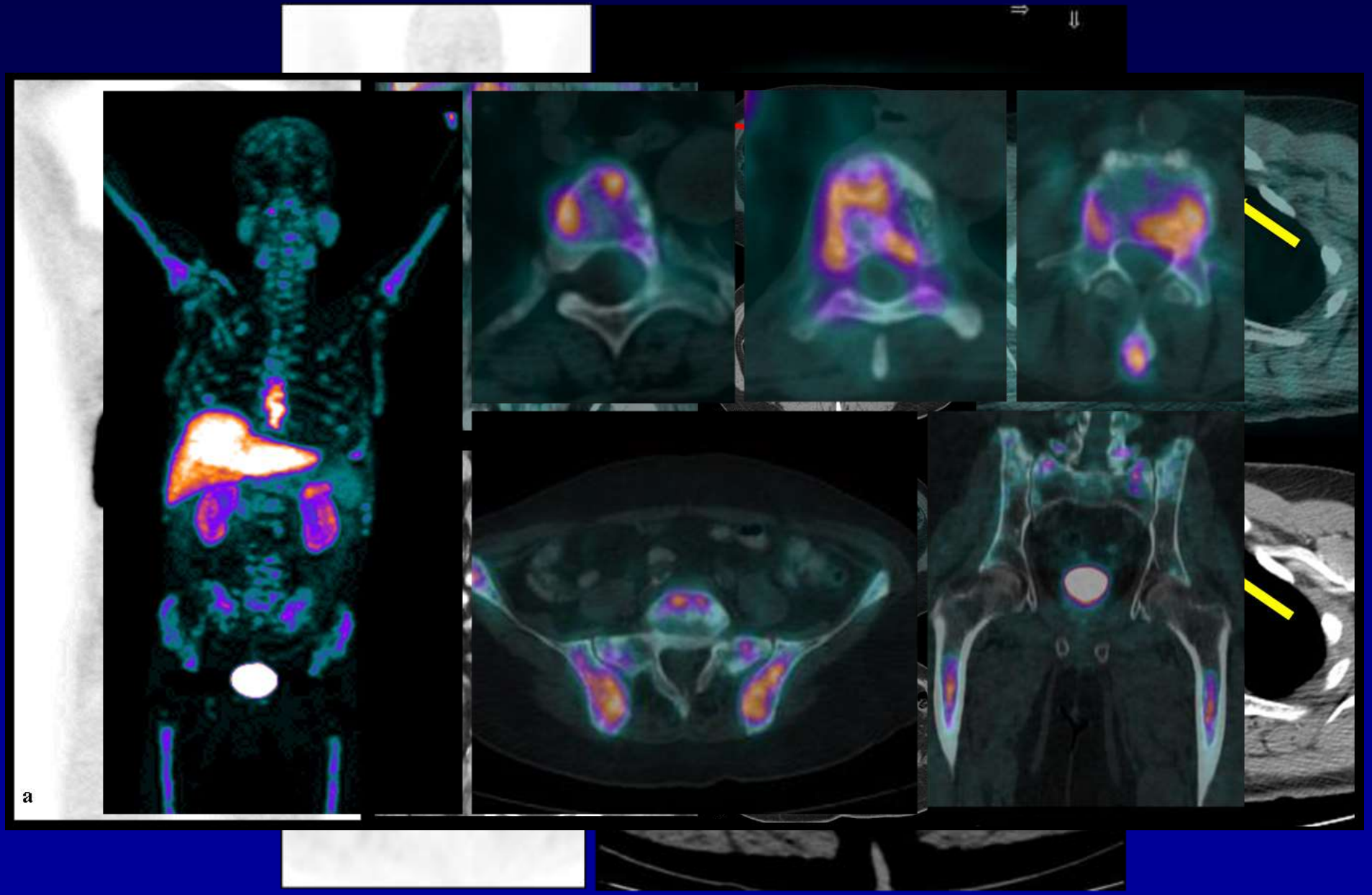
NOTE: If not stated otherwise, P is <0.05.
*PET-positive/negative refers to the group with SUV ratios higher/lower than a preset cutoff level.
†During entire research period.
‡Milan status determined histologically.
§Calculated data; P not stated.

81.2%; PET-positive, 50%

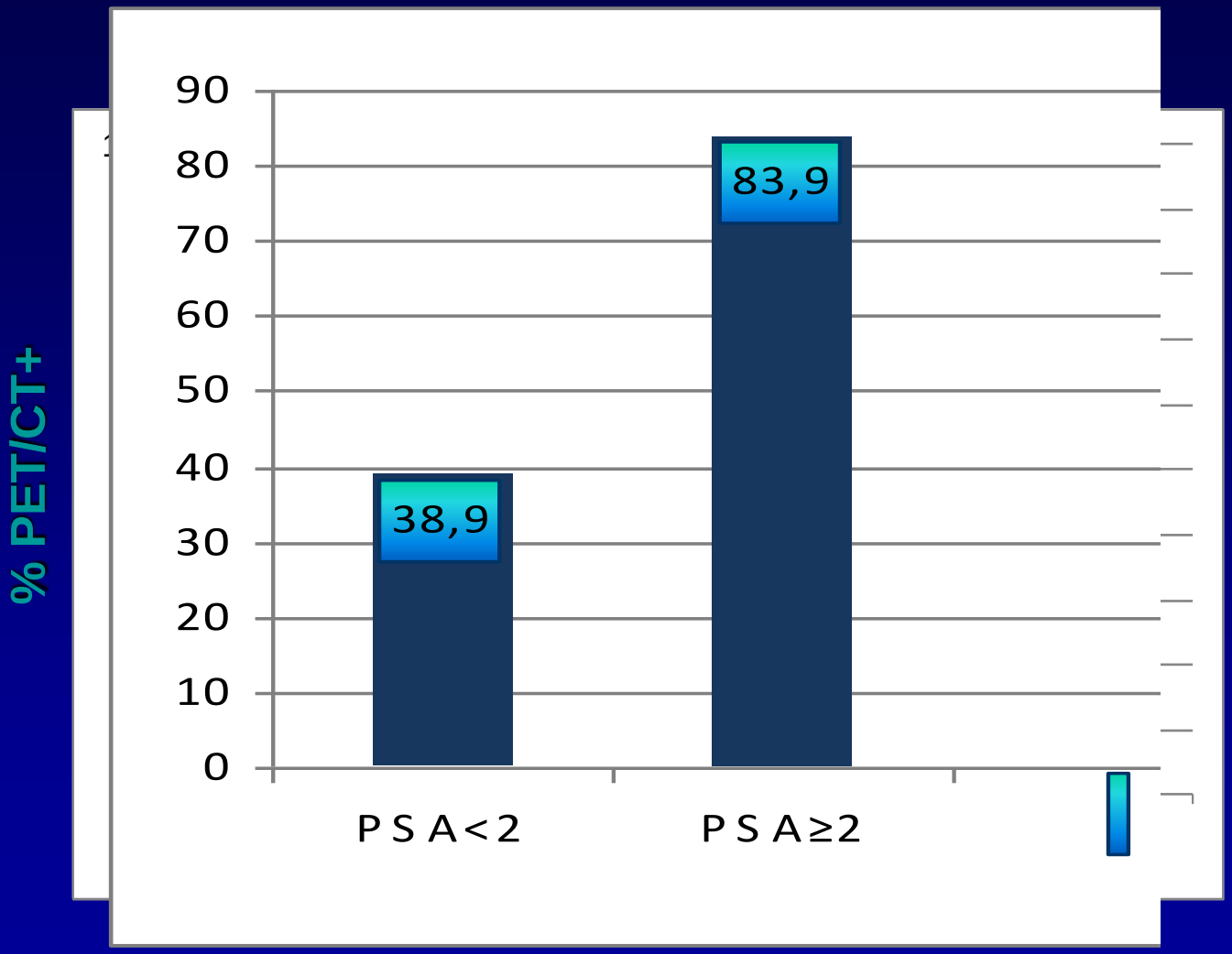
not correlate with survival.

*PET-positive: TSUVmax to LSUVmean ratio larger than 1.9.
†Postprocedural response: a reduction of at least 30% in tumor size assessed by triphasic CT.
‡PET-positive: TSUVmax to LSUVmean ratio ≥ 1.7.

Why choline?



PET/CT vs PSA



Eur J Nucl Med Mol Imaging (2012) 39:589–596
DOI 10.1007/s00259-011-2030-7

ORIGINAL ARTICLE

Influence of PSA, PSA velocity and PSA doubling time on contrast-enhanced ^{18}F-choline PET/CT detection rate in patients with rising PSA after radical prostatectomy

Orazio Schillaci · Ferdinando Calabria ·

No. (%) of patients	PSAdt (months)
21/25 (84)	≤6
12/24 (50)	>6

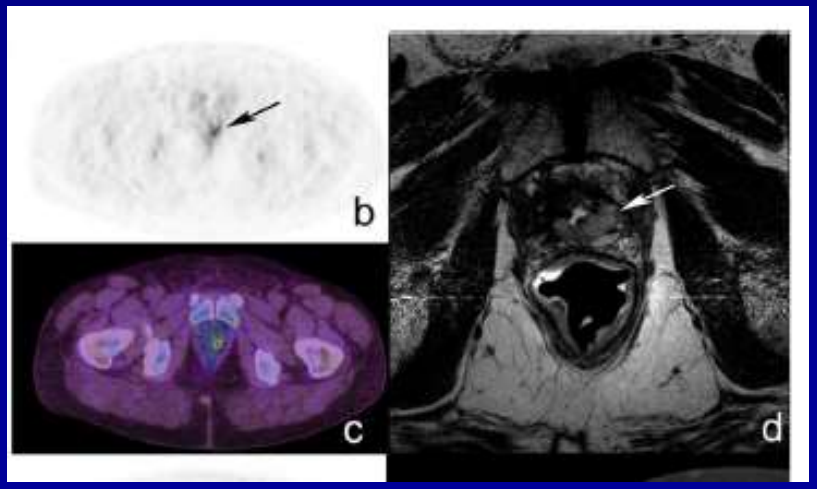
No. (%) of patients	PSAve (ng/ml/year)
7/19 (36.8)	≤2
26/30 (86.7)	>2

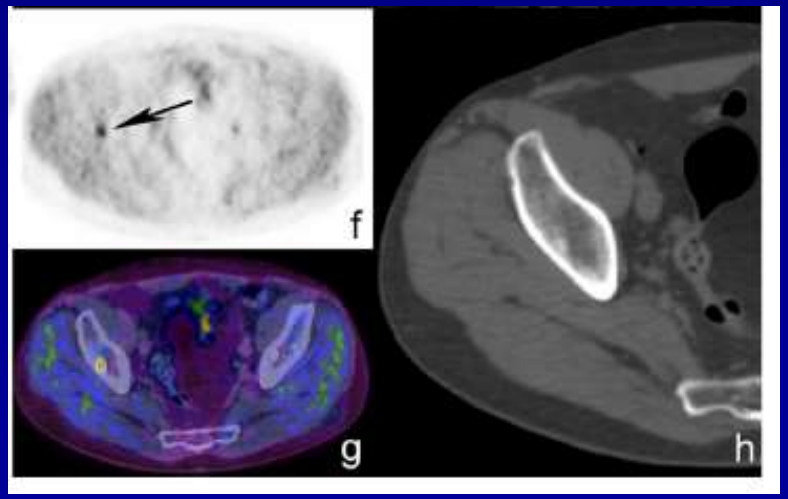
PET/CT with ^{18}F-choline after radical prostatectomy in patients with PSA ≤2 ng/ml. Can PSA velocity and PSA doubling time help in patient selection?

Agostino Chiaravalloti[1] · Daniele Di Biagio[1] · Mario Tavolozza[1] · Ferdinando Calabria[2] · Orazio Schillaci[1,3]

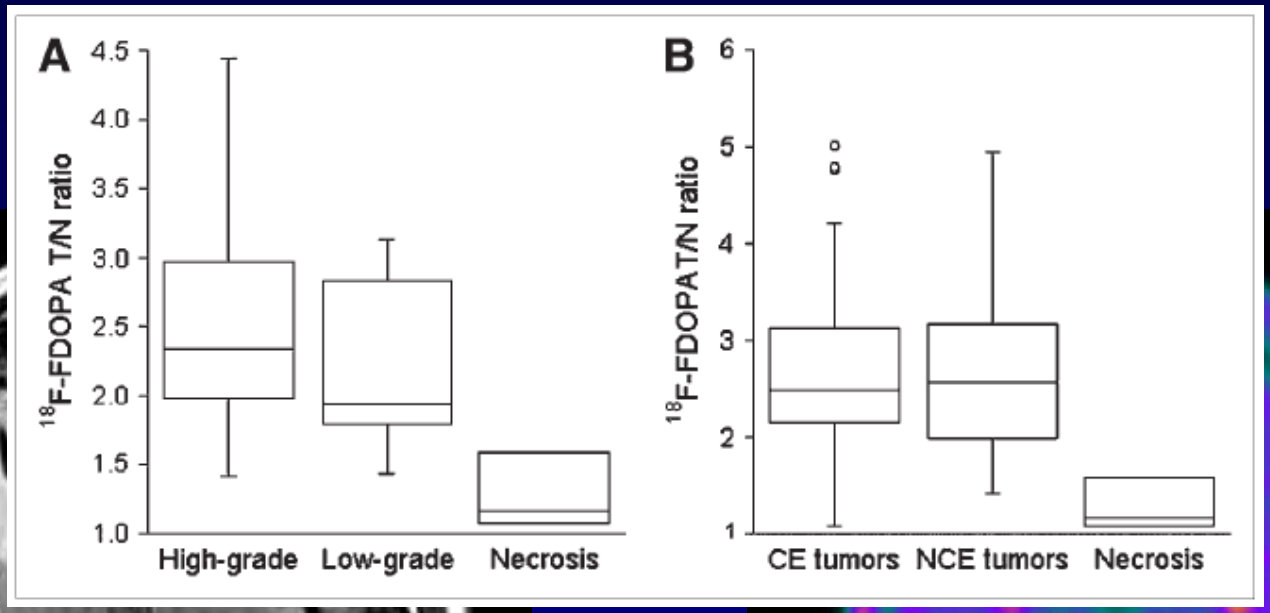
Eur J Nucl Med Mol Imaging. 2016

	Whole population (n = 79)	PET/CT-positive (n = 44)	PET/CT-negative (n = 35)	P value (positive vs. negative)
Age (years), mean ± SD	70 ± 7	69 ± 6	71 ± 5	>0.05
Gleason score (mean)	7	7	7	P = 0.89; F = 0.02
PSA (ng/ml), mean ± SD	1.36 ± 0.44	1.38 ± 0.39	1.34 ± 0.51	0.84
PSAdt (months), mean ± SD	10.04 ± 16.67	7.12 ± 8.28	13.71 ± 22.93	0.031
PSAve (ng/ml per year), mean ± SD	2.75 ± 3.11	3.35 ± 3.28	2.01 ± 2.45	0.006





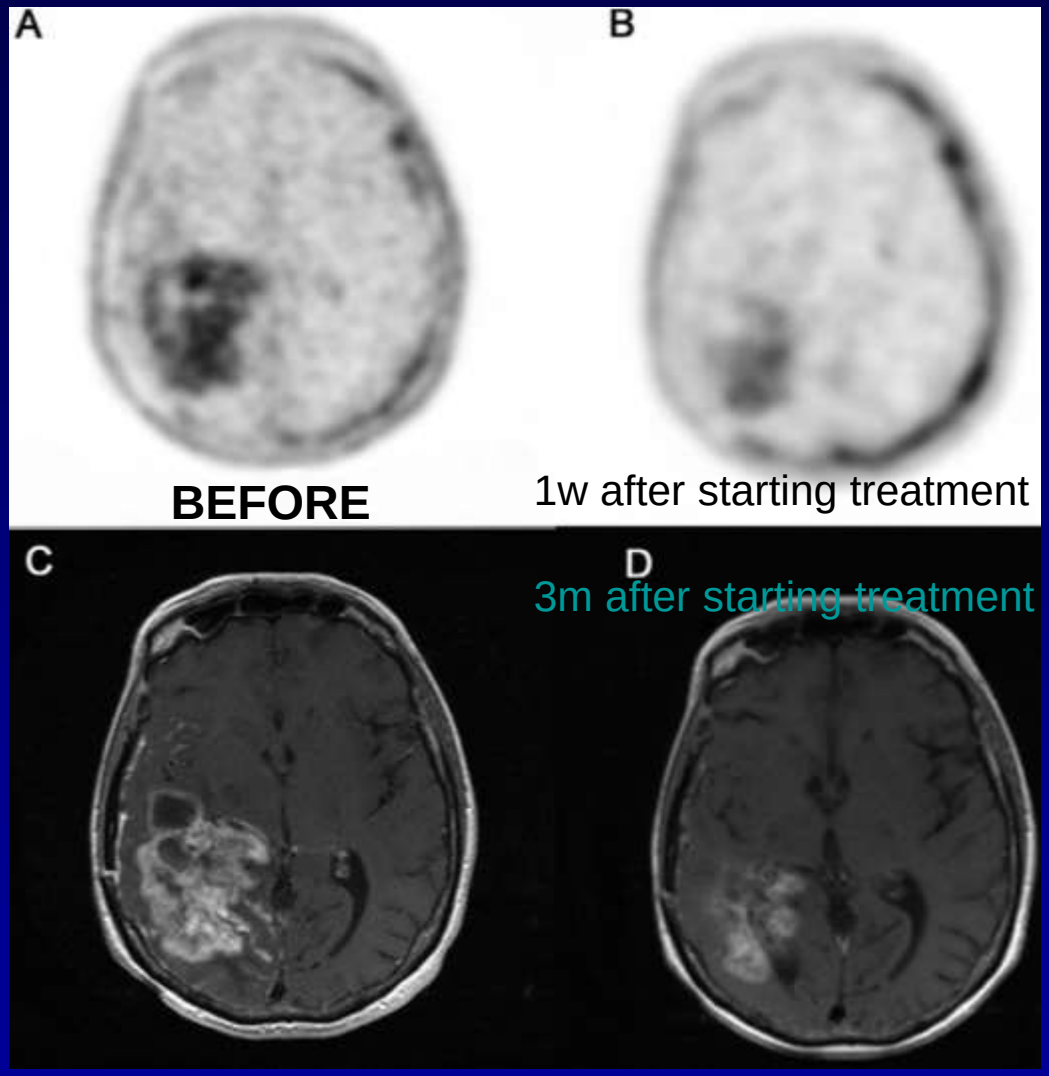
F-18 DOPA in brain tumours



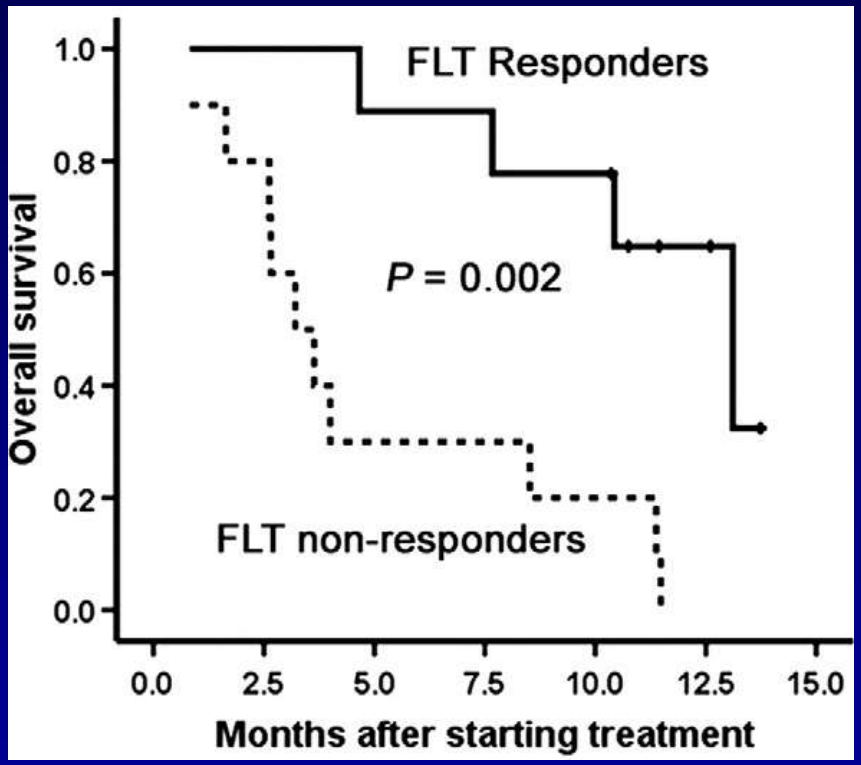
Parameter (%)	Group 1 patients (n = 30)	Group 2 patients (n = 51)	Combining 2 groups (n = 81)
Sensitivity	100	97	98
Specificity	86	86	86
Accuracy	97	94	95
PPV	96	95	95
NPV	100	92	95

W. Chen et al, J Nucl Med 2006

Predicting treatment response of malignant gliomas to bevacizumab and irinotecan by imaging proliferation with FLT PET

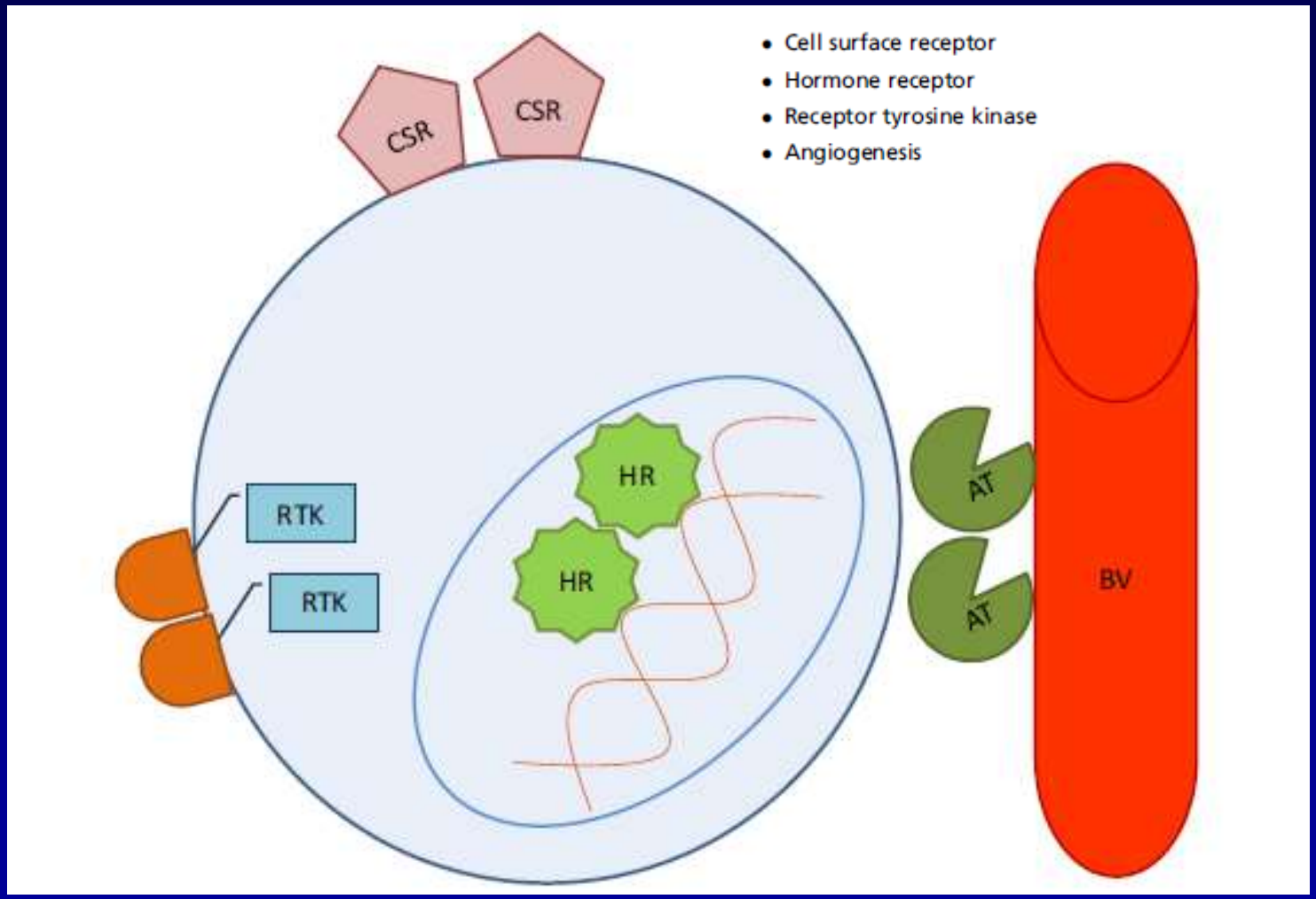


RECURRENT GLIOBLASTOMA



W. Chen et al, Semin Nucl Med 2008

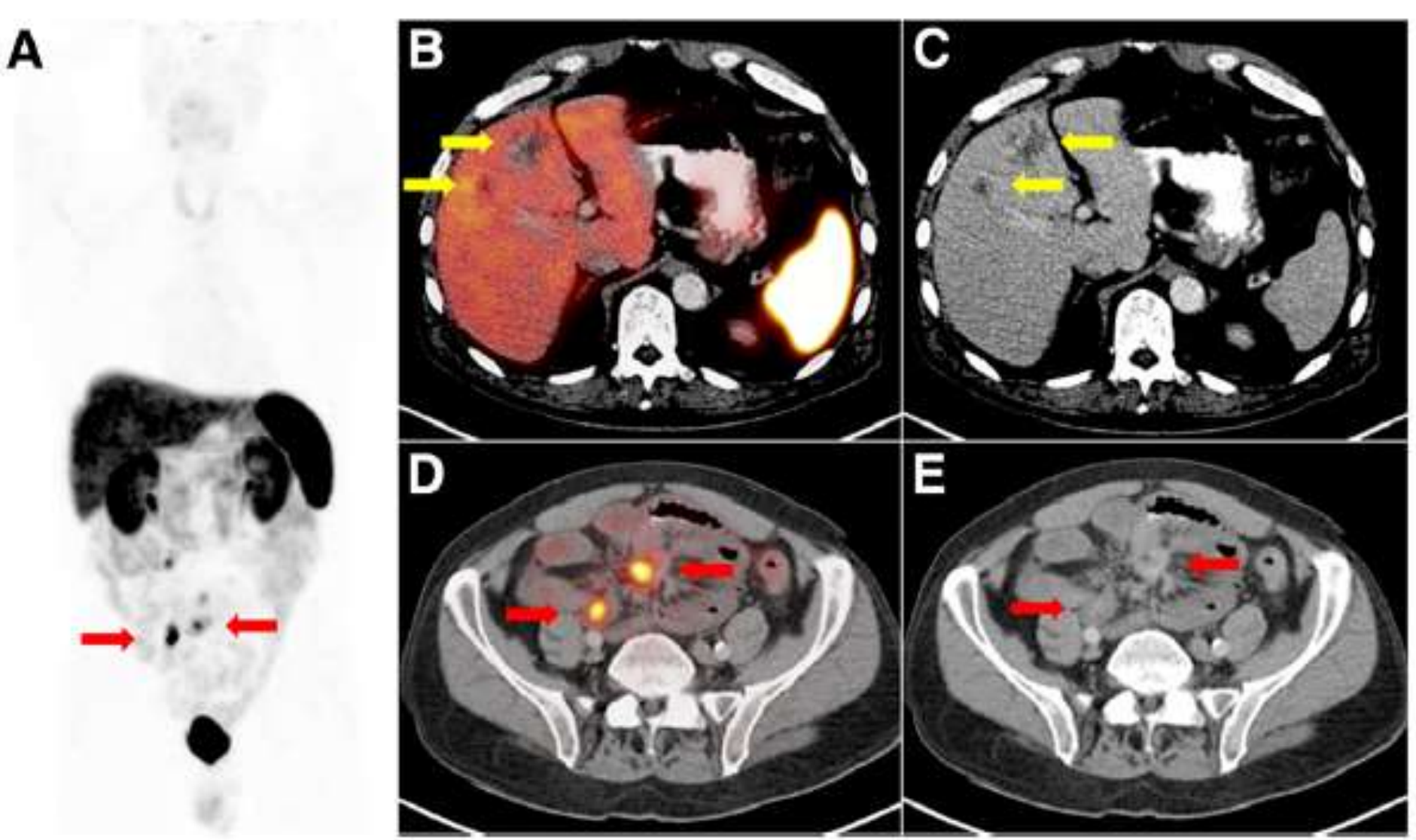
Cellular and extracellular for targeted anticancer therapies that can be used in PET/CT molecular imaging



Radiolabelled target anticancer therapies for PET molecular imaging

Class	Target	PET Agent	Animal Studies	Human Studies	Clinical Role
Cell surface receptor	Somatostatin receptors	^{68}Ga-DOTATOC	+	+	Established
		^{68}Ga-DOTANOC	+	+	Established
		^{68}Ga-DOTATATE	+	+	Established
		^{64}Cu-DOTATATE	+	+	Under Evaluation
	PSMA	^{68}Ga-PSMA-HBED-CC	+	+	Established
		^{64}Cu-PSMA	+	+	Under Evaluation
		^{18}F-DCFBC	+	+	Under Evaluation
	FR	^{68}Ga-deferoxamine-folate	+	–	Under Evaluation
		^{18}F-fluorobenzylamine-folate	+	–	Under Evaluation
		^{18}F-oligoethyleneglycole-folate	+	–	Under Evaluation
		^{18}F-polyethyleneglycole-folate	+	–	Under Evaluation
Hormone receptor	ER	^{18}F-FES	+	+	Established
	AR	^{18}F-FDHT	+	+	Under Evaluation
Receptor tyrosine kinase	EGFR	^{11}C-erlotinib	+	+	Under Evaluation
		^{11}C-geftinib	+	–	Under Evaluation
		^{18}F-geftinib	+	–	Under Evaluation
		^{64}Cu-cetuximab	+	–	Under Evaluation
		^{86}Y-cetuximab	+	–	Under Evaluation
		^{89}Zr-cetuximab	+	+	Under Evaluation
		^{64}Cu-panitumumab	+	–	Under Evaluation
		^{86}Y-panitumumab	+	–	Under Evaluation
		^{89}Zr-panitumumab	+	–	Under Evaluation
	BCR-ABL	^{11}C-imatinib	–	–	Under Evaluation
	EGFR, HER2	^{18}F-lapatinib	–	–	Under Evaluation
	HER2	^{64}Cu-trastuzumab	+	+	Under Evaluation
		^{89}Zr-trastuzumab	+	+	Under Evaluation
Angiogenesis	VEGFR	^{64}Cu-bevacizumab	+	–	Under Evaluation
		^{86}Y-bevacizumab	+	–	Under Evaluation
		^{89}Zr-bevacizumab	+	+	Under Evaluation
	VEGFR, PDGFR	^{11}C-sorafinib	+	–	Under Evaluation
		^{18}F-sunitinib	–	–	Under Evaluation
		^{11}C-vandetinib	–	–	Under Evaluation
	Integrin $\alpha v\beta 3$	^{68}Ga-NODAGA-c(RGDfK)	+	–	Under Evaluation
		^{68}Ga-NOTA-RGD	+	+	Under Evaluation
		^{68}Ga-TRAP $(RGD)_3$	+	–	Under Evaluation
		^{18}F-galacto-RGD	+	–	Under Evaluation
		^{18}F-FPRGD2	+	+	Under Evaluation
		^{18}F-alfatide	+	+	Under Evaluation
		^{64}Cu-NODAGA-c(RGDyK)	–	–	Under Evaluation

Most of the Intended Management Changes After ^{68}Ga-DOTATATE PET/CT Are Implemented



patients (75%).

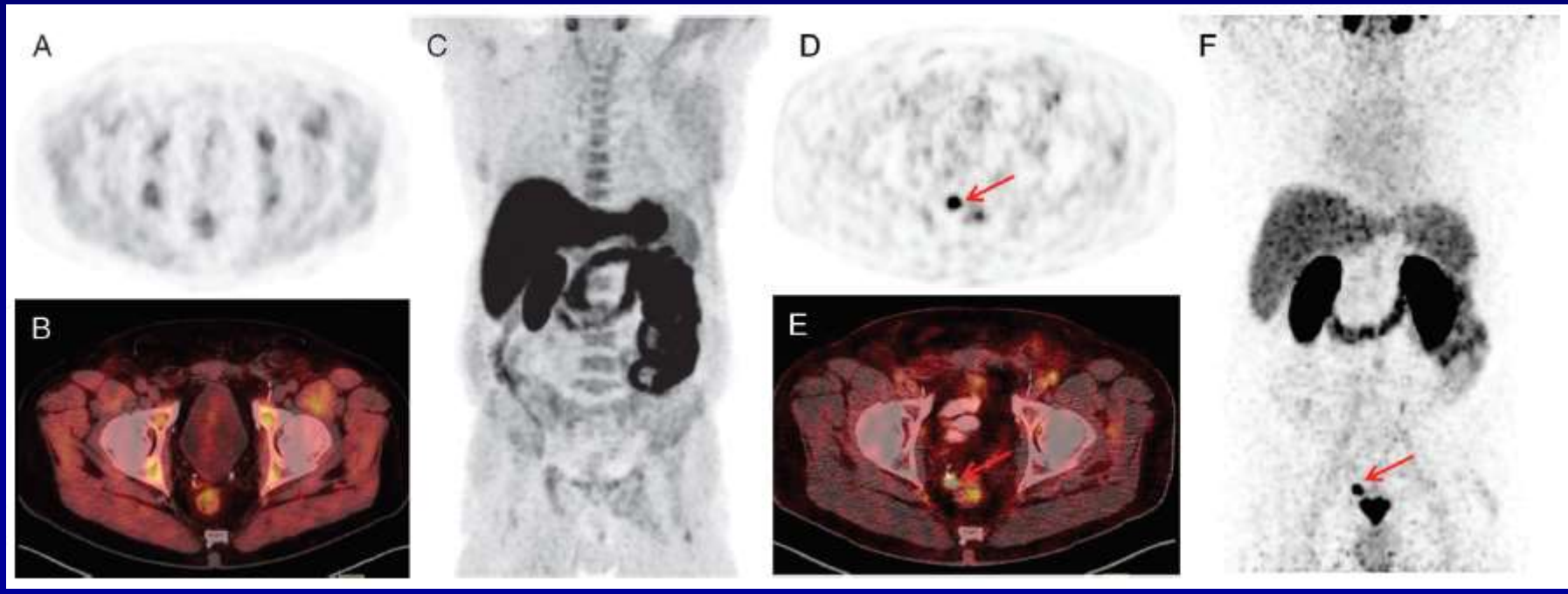
J. Calais et al, J Nucl Med 2017

^{68}Ga-PSMA-PET/CT in Patients With Biochemical Prostate Cancer Recurrence and Negative ^{18}F-Choline-PET/CT

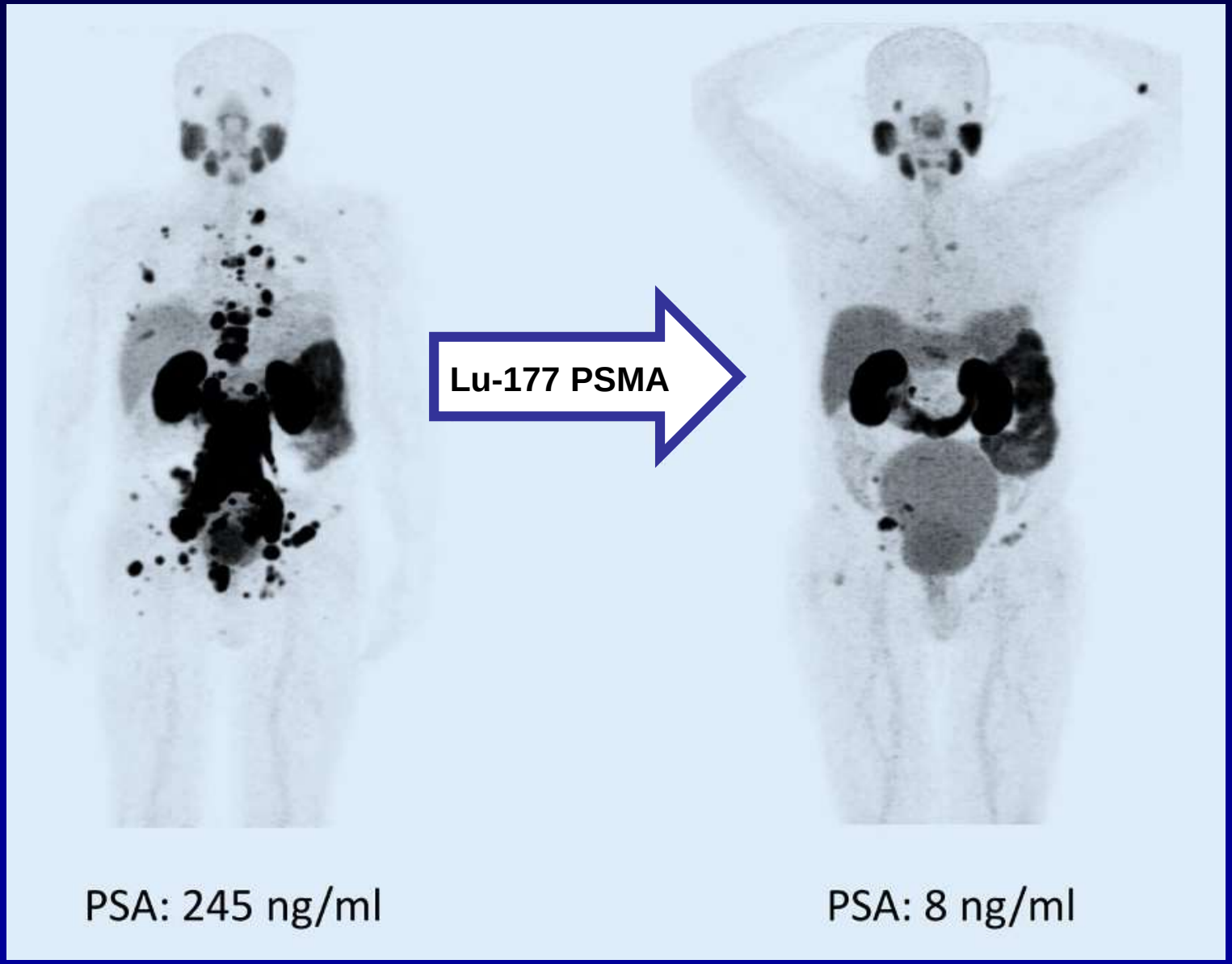
(*Clin Nucl Med* 2016;00: 00–00)

Christina Bluemel, MD, Markus Krebs, MD,† Bülent Polat, MD,‡*

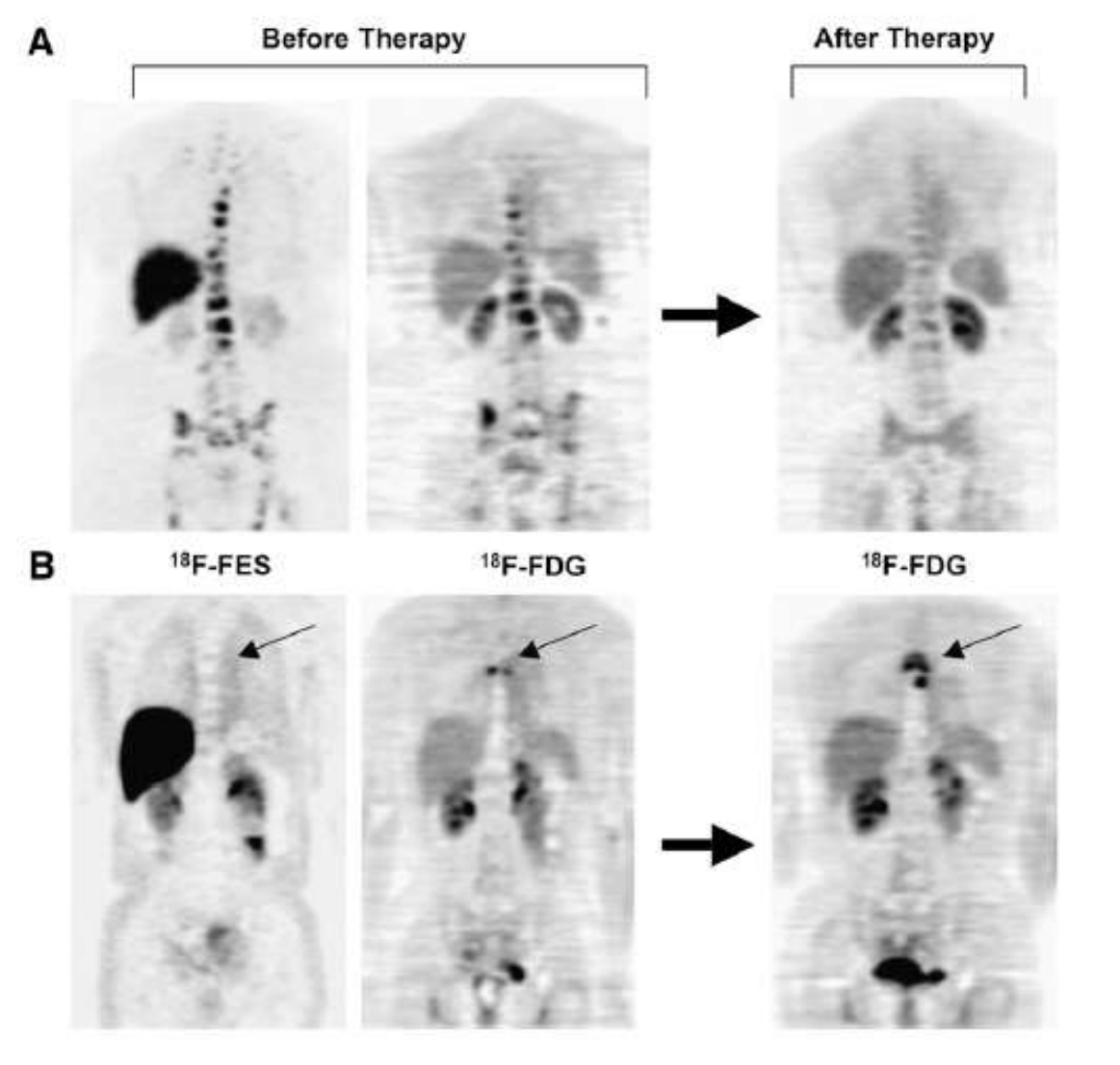
	n	Sequential Imaging Approach Positive, n (%)	^{18}F-Choline Positive, n (%)	^{68}Ga-PSMA Positive, n in Choline-Negative Patients (%)
Overall	125	107/125 (85.6%)	93/125 (74.4%)	14/32 (43.8%)
PSA level (ng/mL)				
≥0.2– < 1	26	16/26 (61.5%)	12/26 (46.1%)	4/14 (28.6%)
1–2	33	27/33 (81.8%)	22/33 (66.7%)	5/11 (45.5%)
>2	66	64/66 (97.0%)	59/66 (89.4%)	5/7 (71.4%)



Theranostics: PSMA



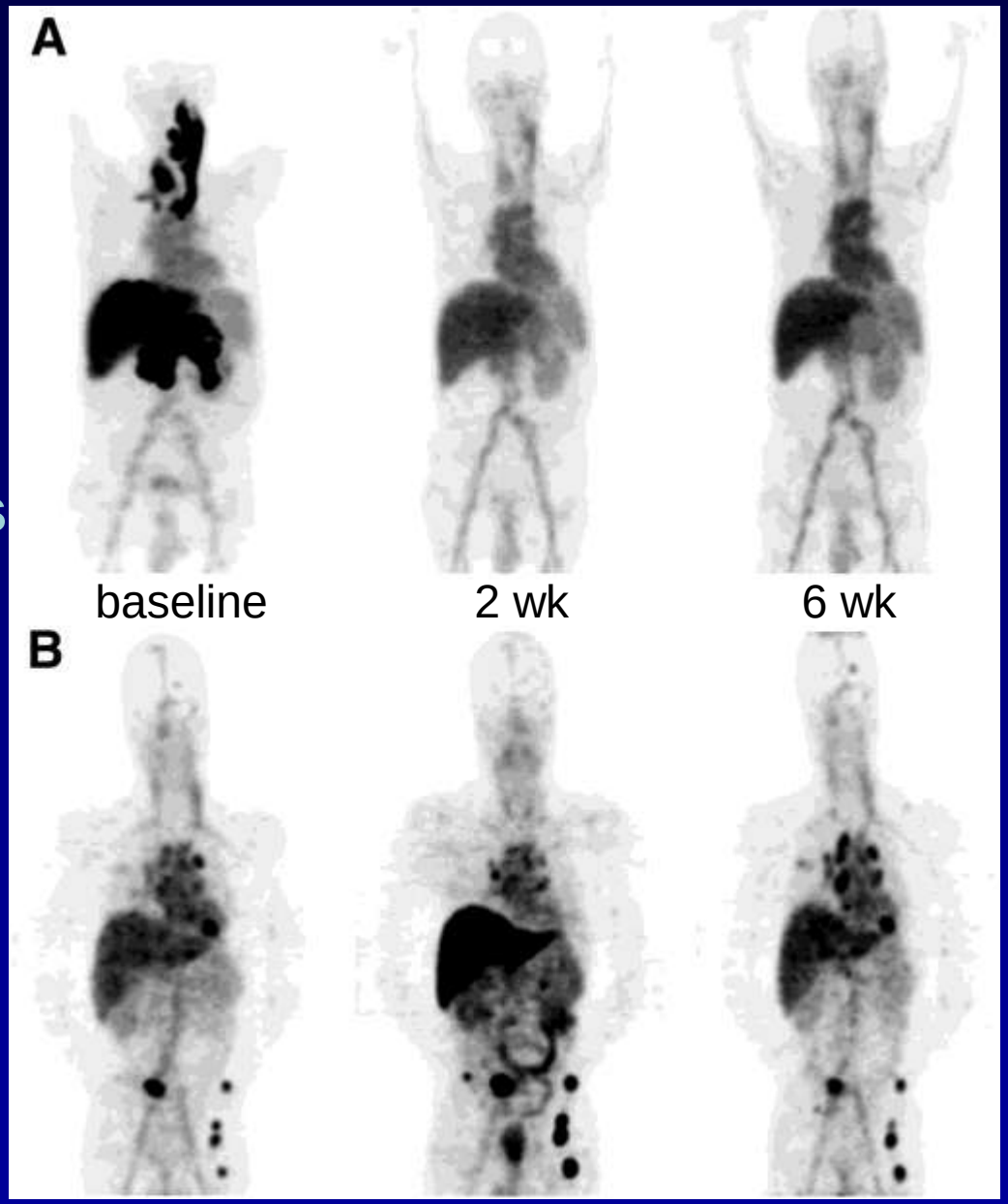
PET/CT: estrogen receptors expression



from H.M. Linden et al, J Clin Oncol 2006

Serial 89Zr-bevacizumab PET scans

22 patients with renal cell carcinoma metastases



S.F. Oosting et al, J Nucl Med 2015

CONTINUING EDUCATION

^{18}F-FDG PET/CT and PET/MRI Perform Equally Well in Cancer: Evidence from Studies on More Than 2,300 Patients

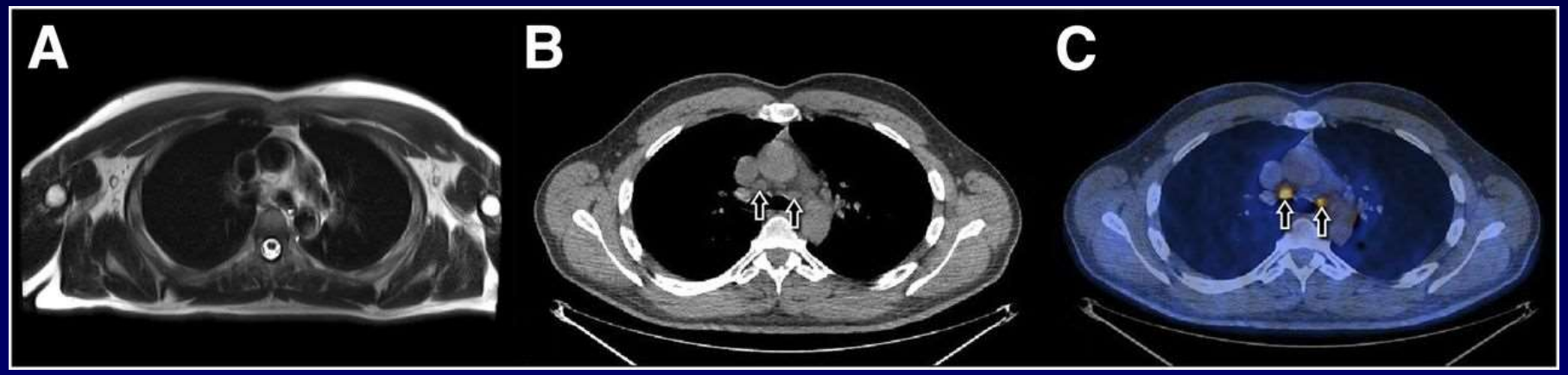
Claudio Spick[1], Ken Herrmann[1,2], and Johannes Czernin[1]

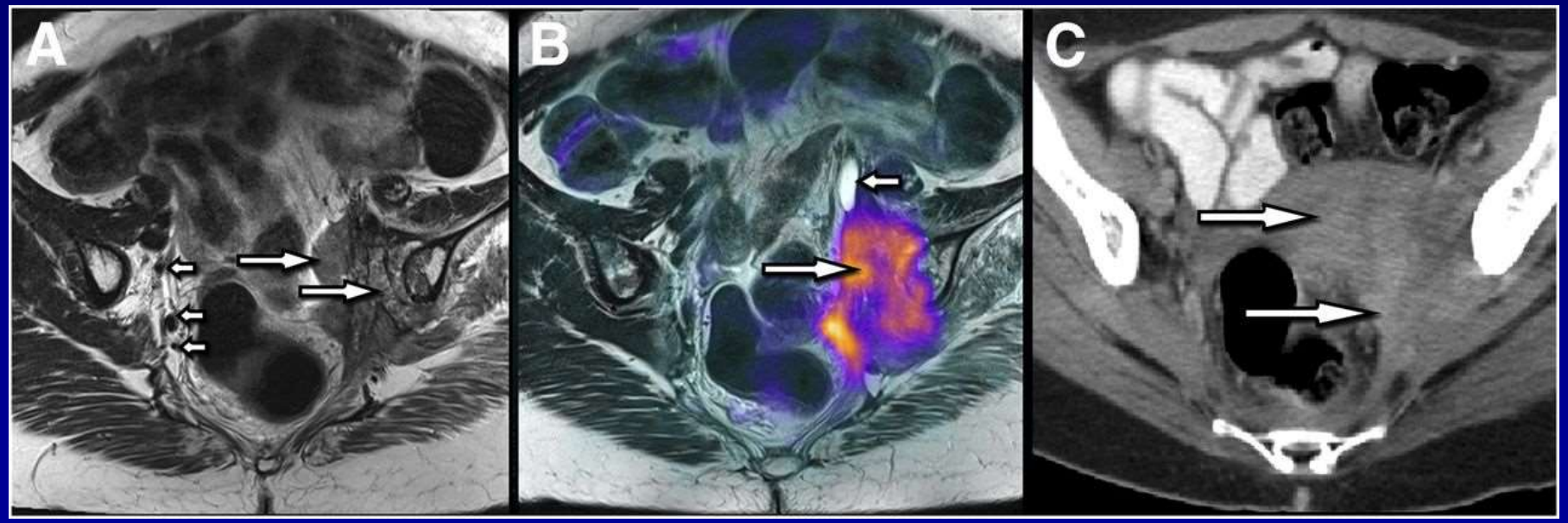
J Nucl Med 2016

Clear diagnostic advantages of PET/MR, when used mainly for providing the anatomic framework, have not been established and will be difficult to demonstrate given the high accuracy of PET/CT.

Multiparametric but not standard PET/MR may have advantages for better allocation of bone metastases and for localizing intraprostatic sites of disease involvement. Conversely, the superiority of PET/CT for lung assessment is relevant across many types of cancer.

It seems reasonable to use PET/MR for those types of cancer routinely imaged with MR when the addition of PET (with various probes) can provide added value.





from K. Z. Al-Nabhani et al, J Nucl Med 2014

Variations in PET/MR operations: results from an international survey among 39 active sites

- The duration of a typical PET/MR protocol (45 to 60 min) was about two times longer and weekly throughput (8 to 12 patients) about 5 times lower than in typical PET/CT operations, despite similar number of staff employed.
- Protocols are not well-defined, mostly due to varying MR protocols.
- The interpretation of PET/MR images is more challenging than that of PET/CT studies.

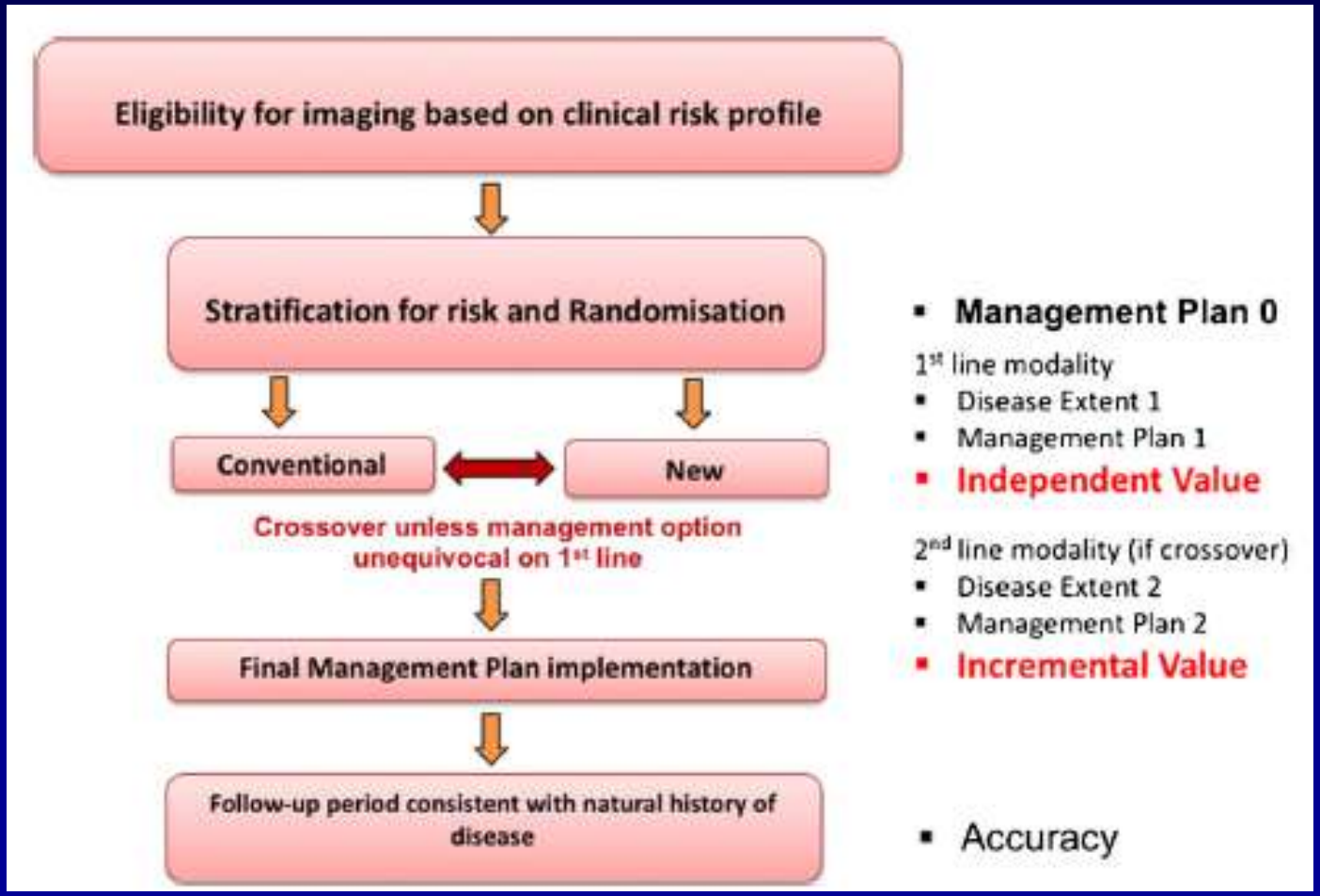
W.E. Fendler et al, J Nucl Med 2016

Requirements for PET/MR to move into mainstream clinical practice

- Optimisation of PET/MR protocols to achieve a balance between an abundance of image-based information and realising this in a practical imaging protocol (total examination time ≤45 min).
- Collaboration between the vendors and the users to achieve optimised acquisition protocols and software for analysis.
- Development of specific guidelines for PET/MR investigations.
- Development of a suitable evidence base for the appropriate use of PET/MR using appropriately designed trials acceptable to regulators and health technology agencies.
- Exploitation of added clinical value combining multiparametric PET/MR data with multi-scale clinical, laboratory, histopathologic, and “-omics” data.

D.A. Bailey et al, Mol Imaging Biol 2016

Flow diagram of proposed randomised control trial for evaluating novel imaging paradigms



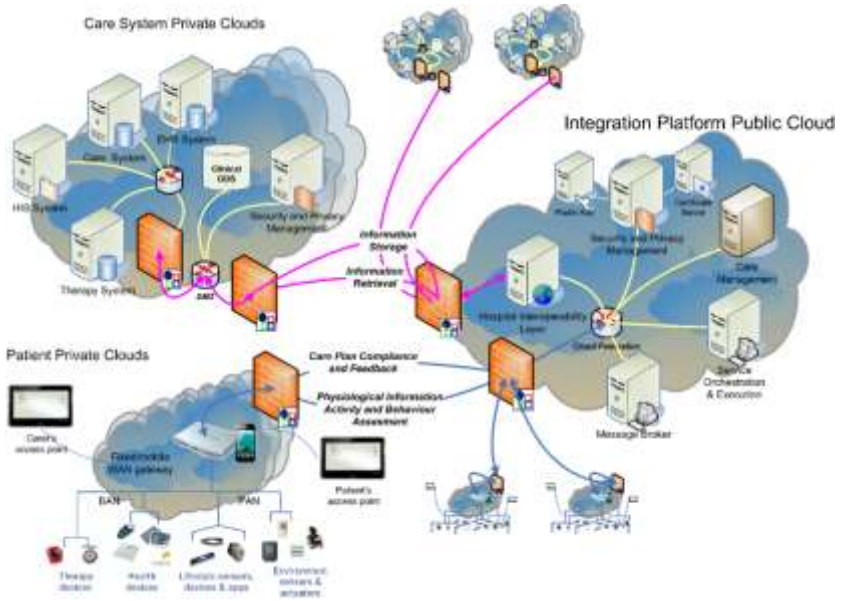
courtesy of R. Hicks, Peter Mac Cancer Centre Melbourne, Australia

PET/CT was a medical revolution and a technical evolution

PET/MR seems to be a technical revolution and a medical evolution

PICASO

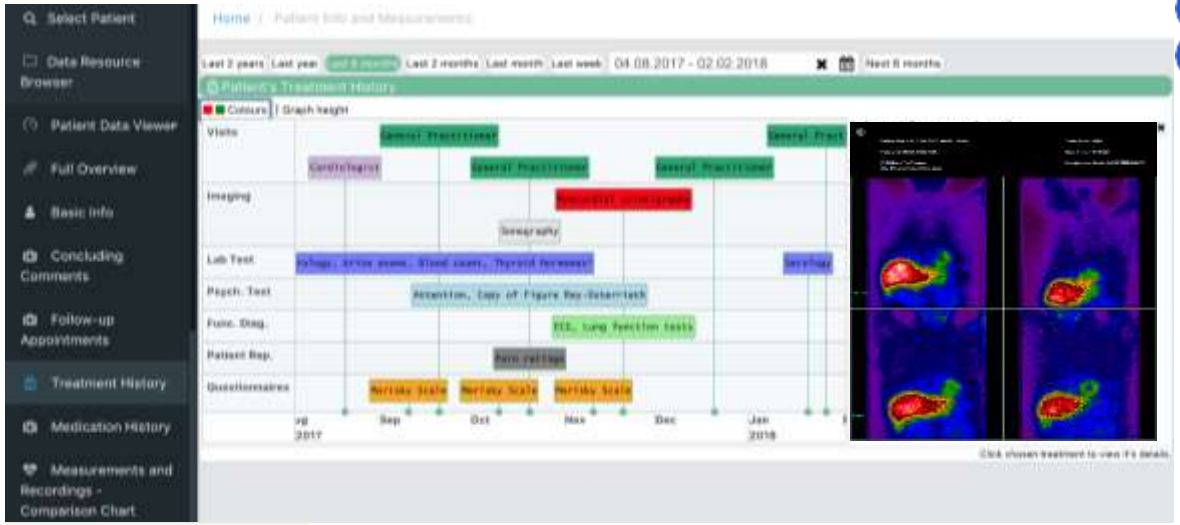
- Aims: Develop a set of Integrated Tools for Care Management of patients with multi-morbidities



A Personalised Integrated Care Approach for Service Organisations and Care Models for Patients with Multi-Morbidity and Chronic Conditions

Clinician Dashboard:

Integrated overview of Imaging, laboratory and other clinical data with home monitoring data



Patient Dashboard:

Integrataed overview of A daily diary for drug Intake and health Parameters

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