Fusion in Medical Imaging:
Two Case Studies

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Summary

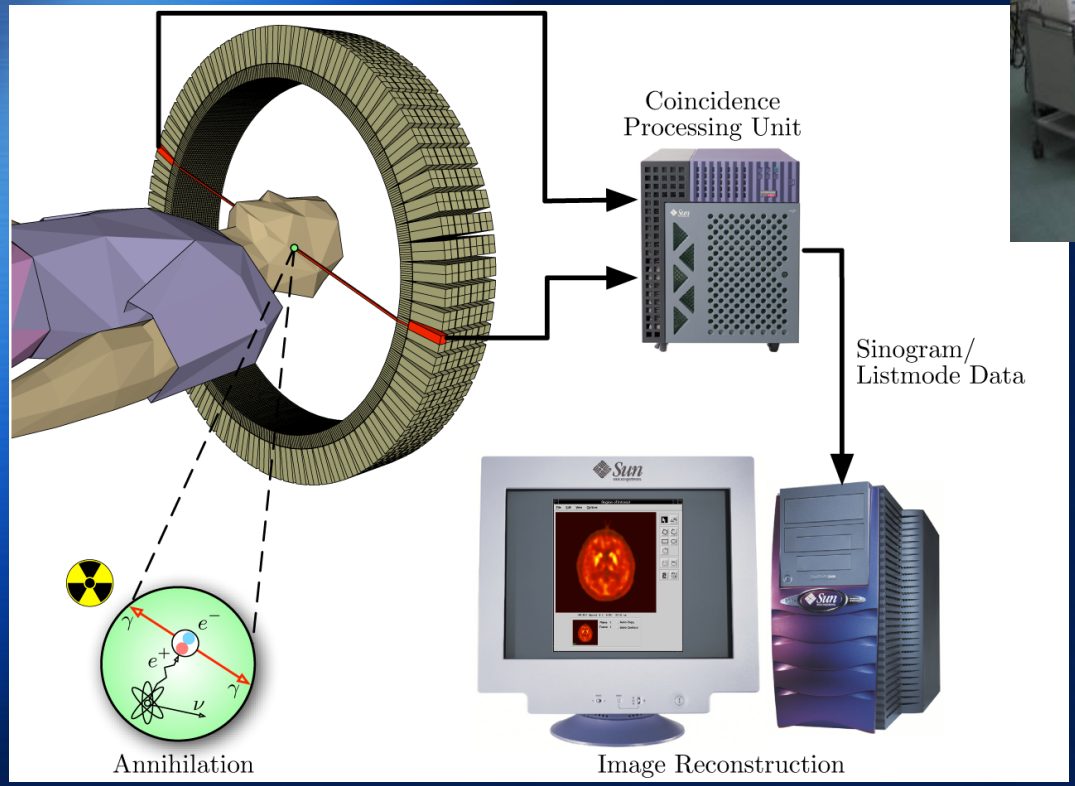
- Two case studies:
  - PET versus PET-CT
  - Triage of Acute Coronary Syndrome (ACS) patients in ERs
- PET-CT
  - There was considerable a priori justification why a fused system would be beneficial
    - Better registration, correlation between structure and function, attenuation correction, quantitation
  - PET-CT fusion were being done manually before hybrid systems came on the market
- ACS
  - While ACS triage continues to evolve, there is a priori justification why fusion of disparate sources of information is beneficial
    - Permits individualized assessment of the patient
    - Results in significantly better outcomes of patients

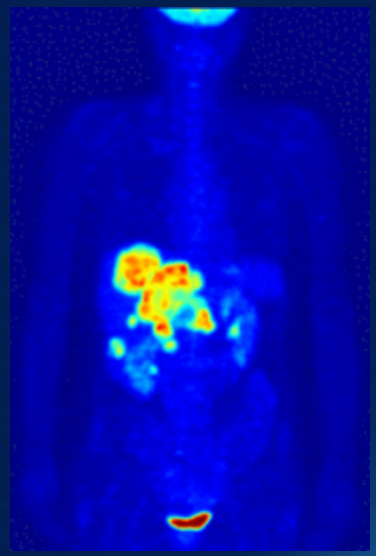
PET Imaging

Positron emitting water

Positron emitting glucose

Radionuclide	Half-life	Common forms
^{15}O	2 min	$^{15}O_2$, $C^{15}O_2$, $C^{15}O$
^{13}N	10 min	$^{13}NH_3$, $^{13}N_2$
^{11}C	20 min	$^{11}CO_2$, ^{11}CO, ^{11}CH
^{18}F	1.8 h	$^{18}F_2$, $H^{18}F$
^{76}Br	16.2 h	$^{76}Br_2$
^{124}I	4 days	$Na^{124}I$





FDG uptake

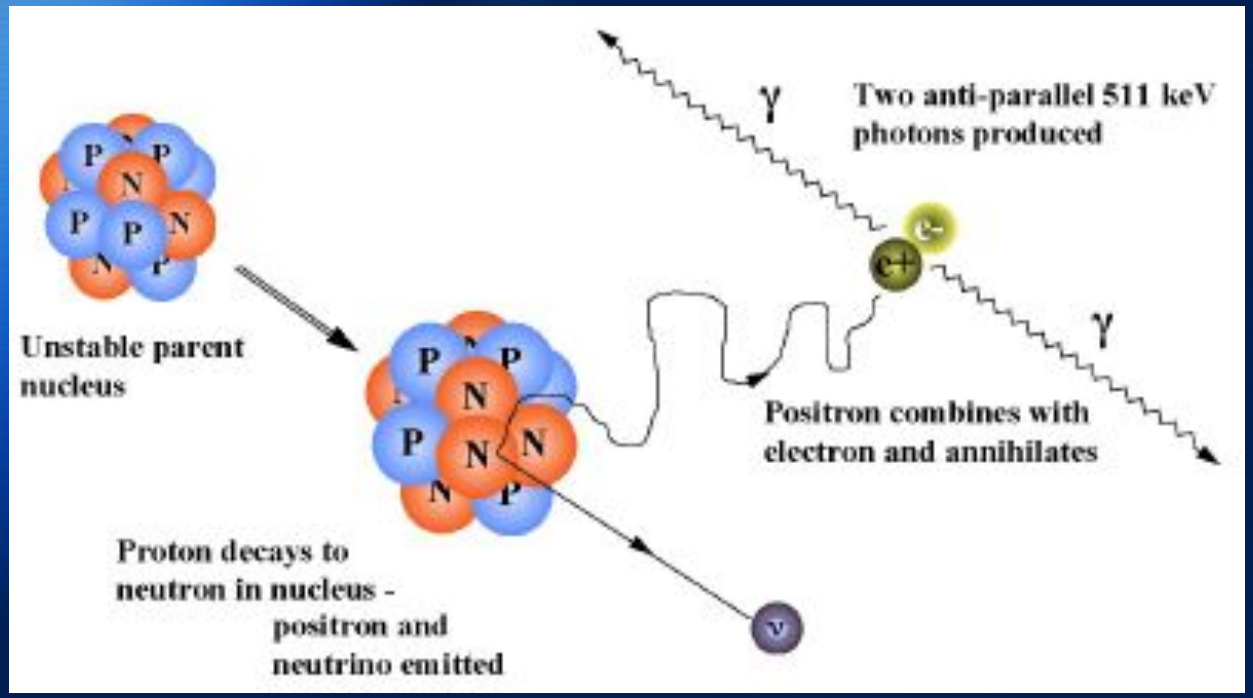
Pictures from Wikipedia

Brief History of PET

- 1950's
  - Gordon Brownell at MGH
  - First positron image – brain tumor localization (1951)
    - 2 decades before MRI and CT
- 1960's and 1970's
  - Emissions computed tomography and Mark-II scanner
  - Chesler's FBP 3-D recon applied to CT and PET
  - First commercial PET scanner (1970)
  - Phelps and the PETT-III (1974) – 2-cm resolution
  - Tracers: O15-water (1970) and FDG (1976)

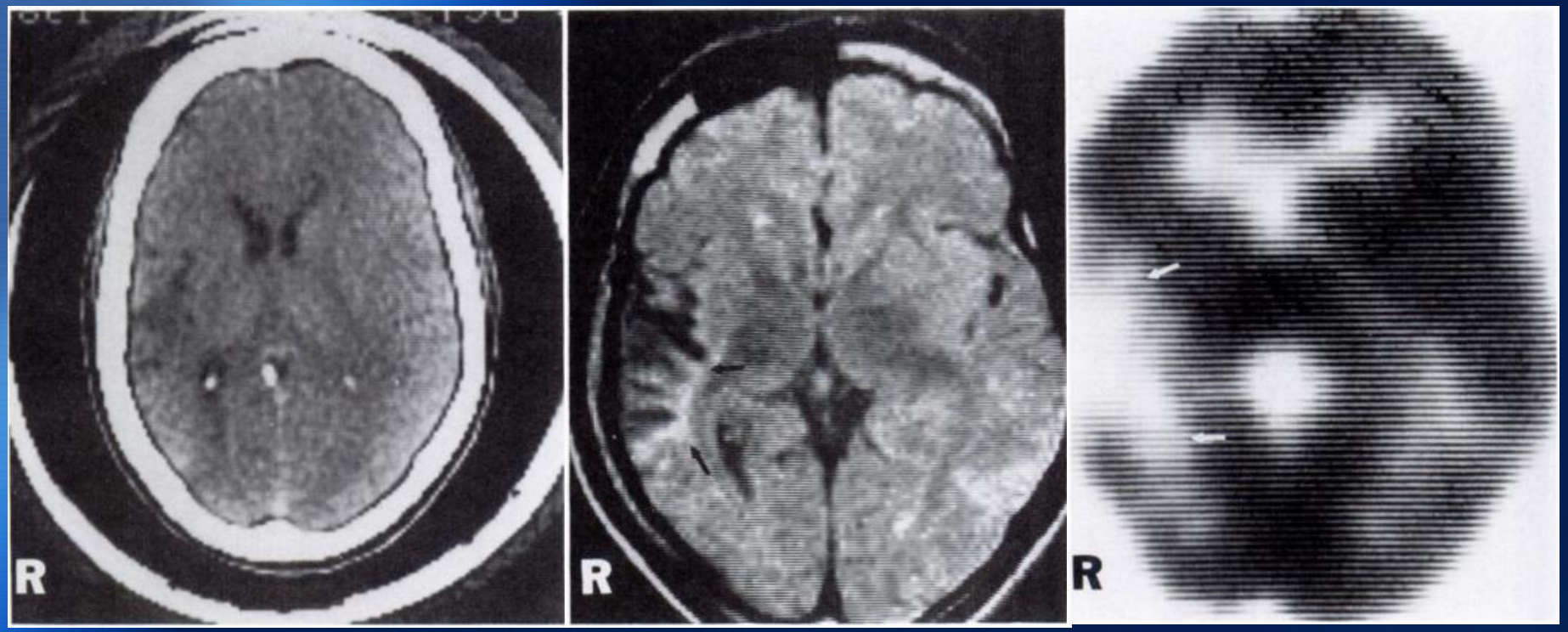
Linton, *Radiology at Massachusetts General Hospital: 1896-2000*
Wacholtz, "History and development of PET," Cewebsource.com

Positron annihilation

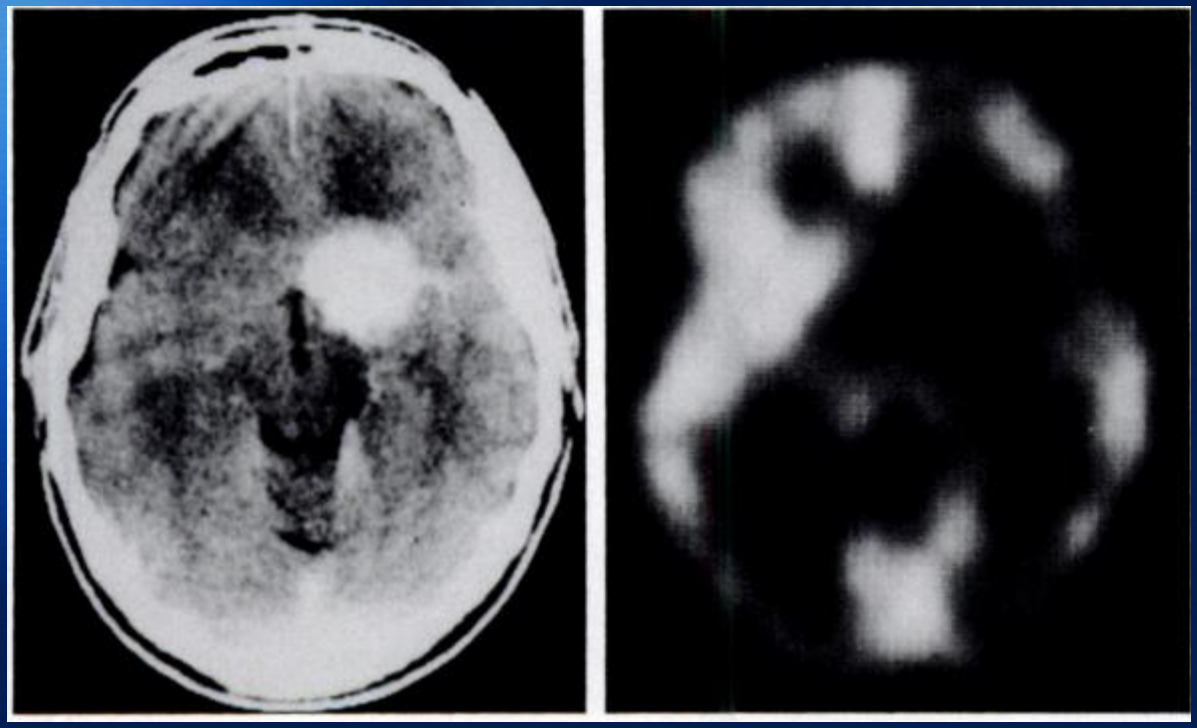


http://depts.washington.edu/nucmed/IRL/pet_intro/intro_src/section2.html

CT MRI PET



Latack et al, “Patients with partial seizures: evaluation by MR, CT, and PET imaging,” Neuroradiology, 1986



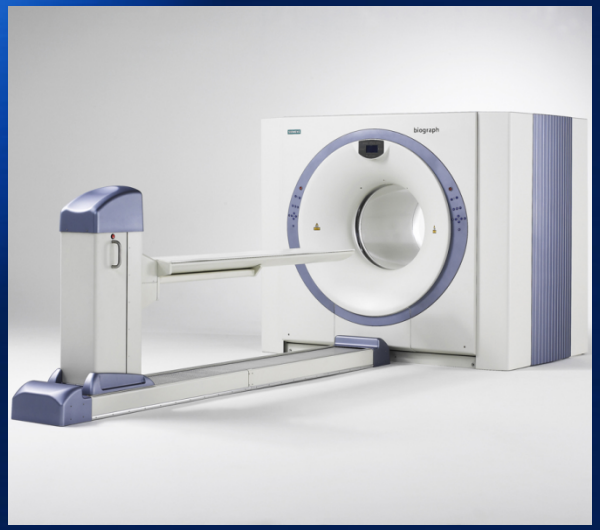
Di Chiro et al, “glucose utilization by intracranial meningiomas as an index of tumor aggressivity …” *Radiology* 164 1987.

1980's and 1990's

- PET transitioned from research to clinical tool
- It was well recognized that PET, by itself, did not provide sufficient resolution or anatomic details
  - Used in conjunction with CT and MR to provide structural information to complement PET's functional information
- Separate PET and CT scans were performed, but patient movement made image registration an issue
- Also recognized that PET was not quantitative
  - Needed to properly account for vast attenuation differences between bone, tissue, and air

PET-CT

- Introduced in 2000
- Time Magazine's Invention of the Year
  - Dec 2000



Siemens Biograph 64 PET-CT

Nuclear Medicine

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Martin P. Sandler, MD

Index terms:
Fluorine, radioactive
Neoplasms, PET
Positron emission tomography (PET), comparative studies

Radiology 2001; 218:163–171

Abbreviations:
AC = attenuation correction
COSEM = coincidence-ordered subsets expectation maximization
FBP = filtered back projection
FDG = 2-[fluorine-18]fluoro-2-deoxy-D-glucose

[1] From the Section of Nuclear Medi-

Value of Iterative Reconstruction, Attenuation Correction, and Image Fusion in the Interpretation of FDG PET Images with an Integrated Dual-Head Coincidence Camera and X-Ray–based Attenuation Maps[1]

PURPOSE: To compare lesion detectability on 2-[fluorine-18]fluoro-2-deoxy-D-glucose (FDG) positron emission tomographic (PET) images obtained with a dual-head coincidence (DHC) gamma camera equipped with an integrated x-ray tube–based transmission system (*a*) with images reconstructed with filtered back projection (FBP) and those reconstructed with an iterative reconstruction algorithm based on coinci-

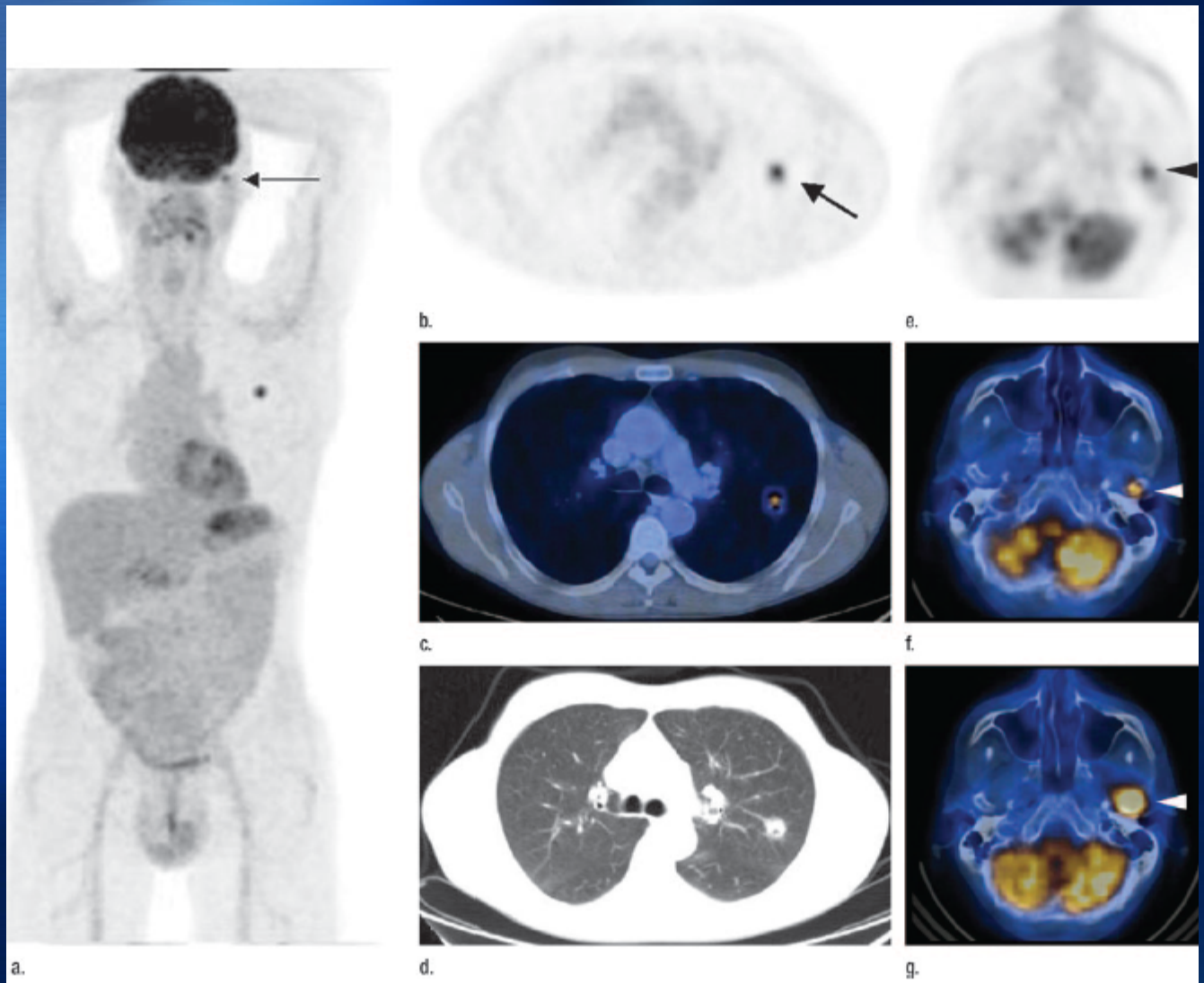


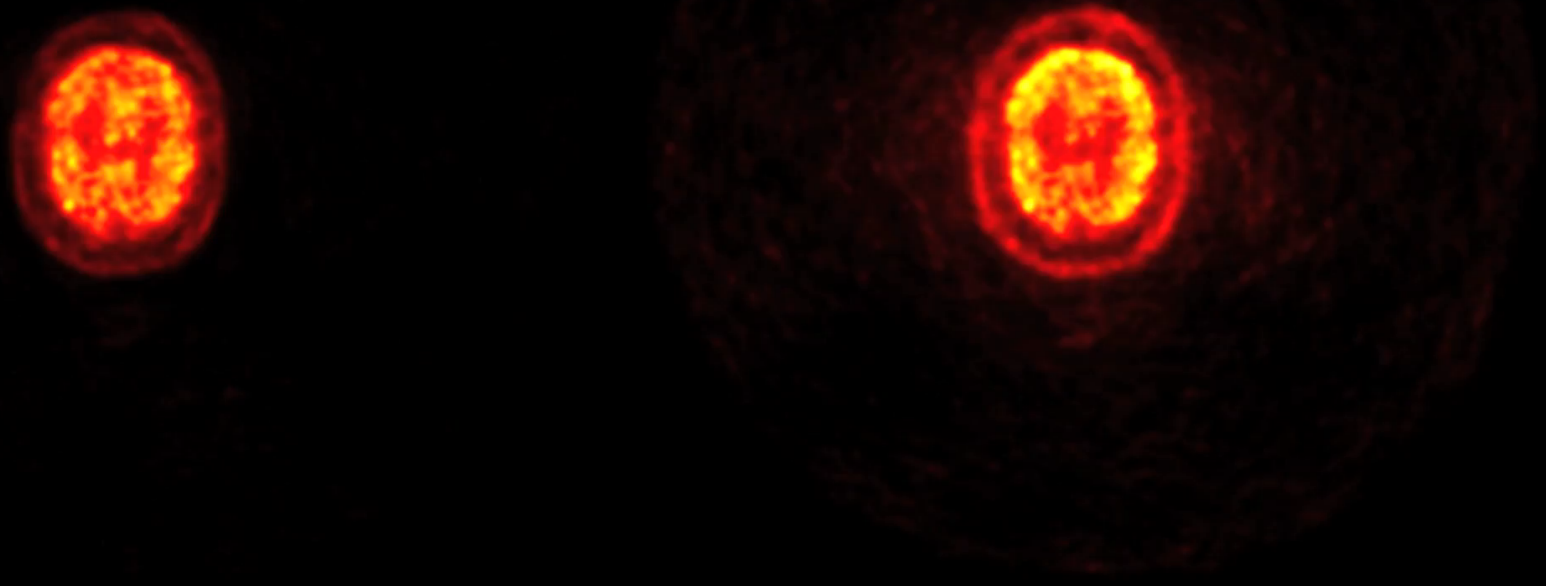
Figure 1: Non–small cell lung cancer (arrow in **b**) in the left upper lobe is shown in **(a)** coronal PET maximum intensity projection (MIP) and **(b)** transverse PET image, **(c)** transverse PET/CT image, and **(d)** transverse CT lung window image. **(e)** Transverse PET image shows small focus at left skull base (arrowhead, arrow in **a**); **(f)** on transverse PET/CT scan, focus appears to be a bone metastasis (arrowhead) in the mandibular condyle, which was not noted at CT alone (not shown). **(g)** This was confirmed with follow-up transverse PET/CT, where interval growth of the lesion (arrowhead) was seen. Osseous metastasis was confirmed at histologic examination.

Von Schulthess et al, "Integrated PET/CT: current applications and future directions," Radiology, 328, 2006.

Attenuation Correction

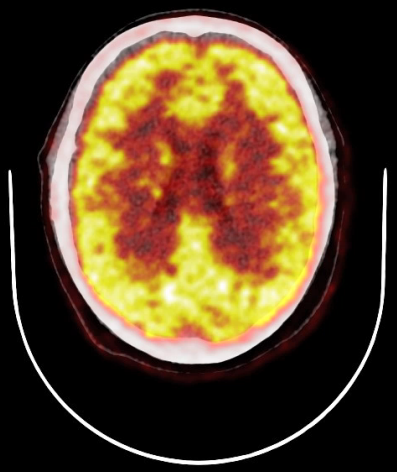
Attenuation Corrected

Uncorrected

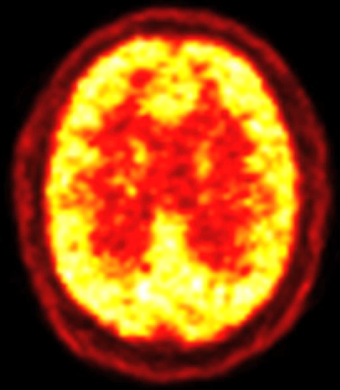


PET-CT Registration

PET-CT



PET only

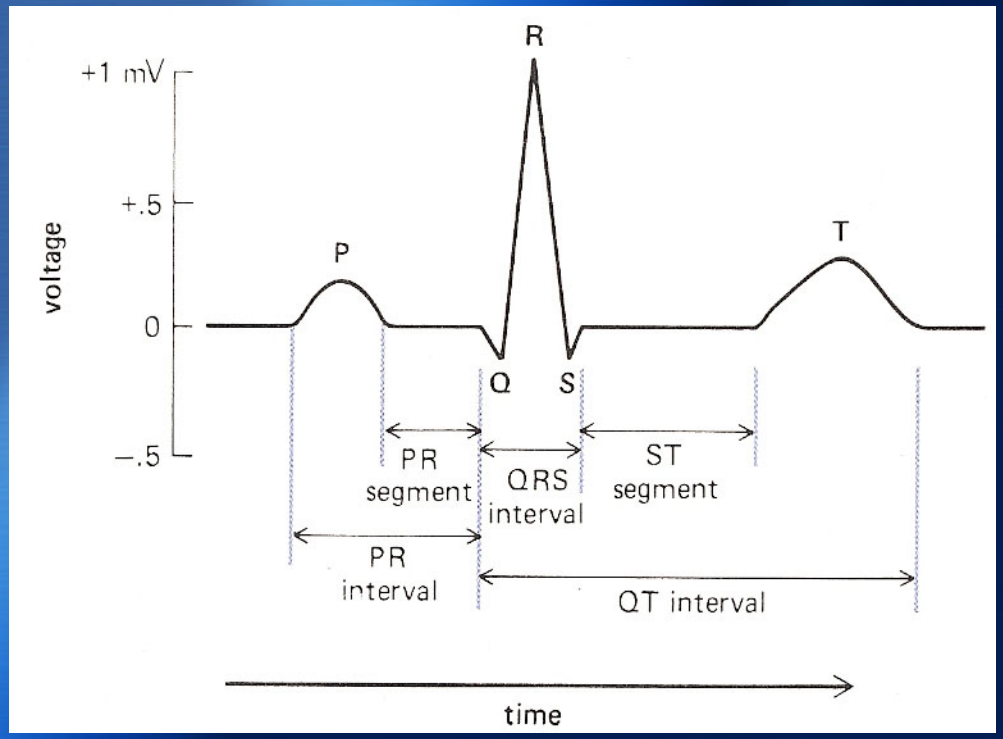


Problem

ACUTE CORONARY SYNDROME (ACS)

- Patient enters the Emergency Room complaining of sharp chest pains
- How should the ER triage the patient?

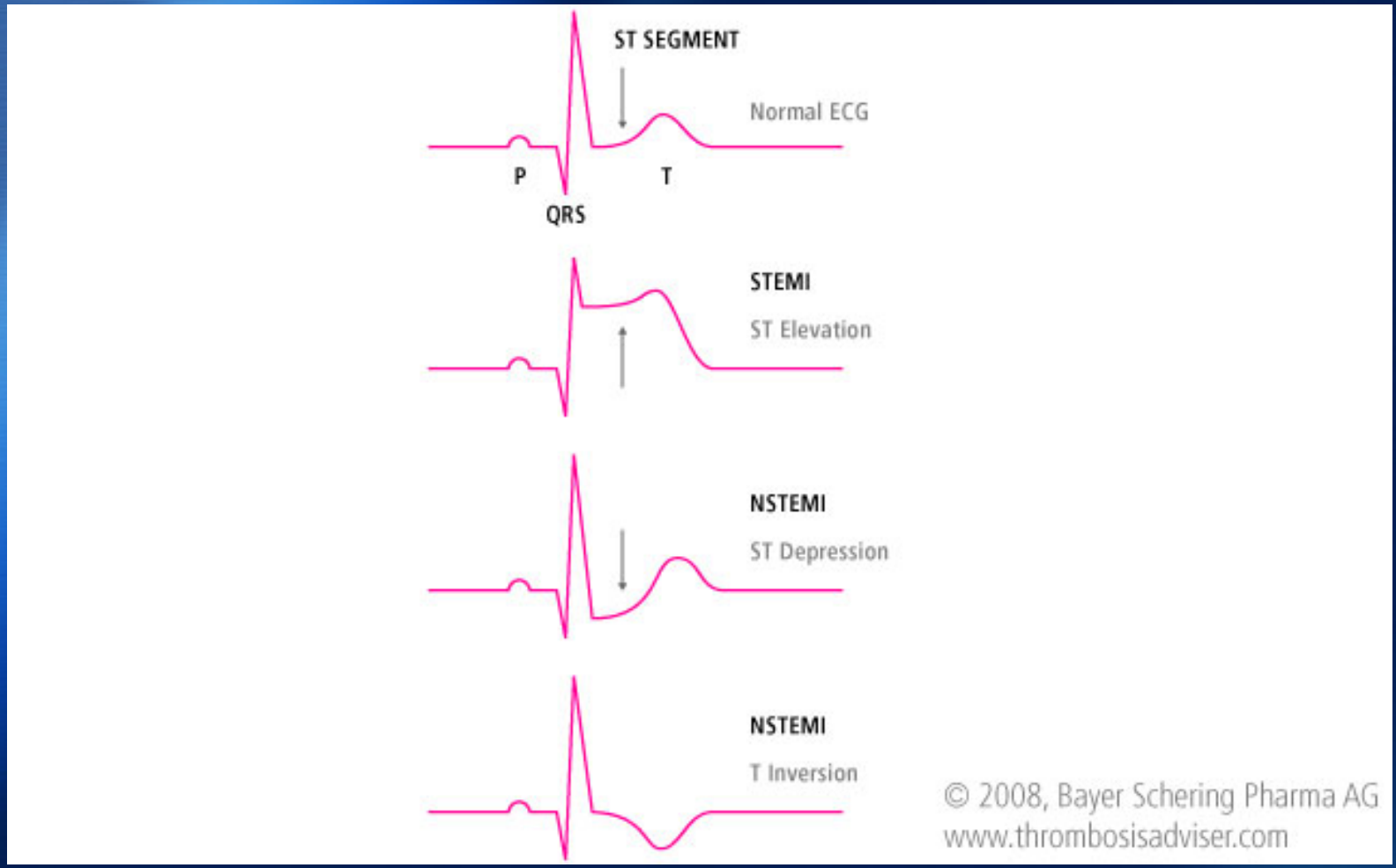
EKG



- QRS complex
  - Ventricular depolarization
- T
  - Ventricular repolarization
- ST
  - STEMI
  - NSTEMI

Mohrman and Heller, Cardiovascular Physiology, McGraw Hill, 2006.

EKG


ST SEGMENT
Normal ECG
P
T
QRS
STEMI
ST Elevation
NSTEMI
ST Depression
NSTEMI
T Inversion
© 2008, Bayer Schering Pharma AG
www.thrombosisadviser.com

ACS Triage- 1988

Triage decisions based on case history, symptoms, and EKG

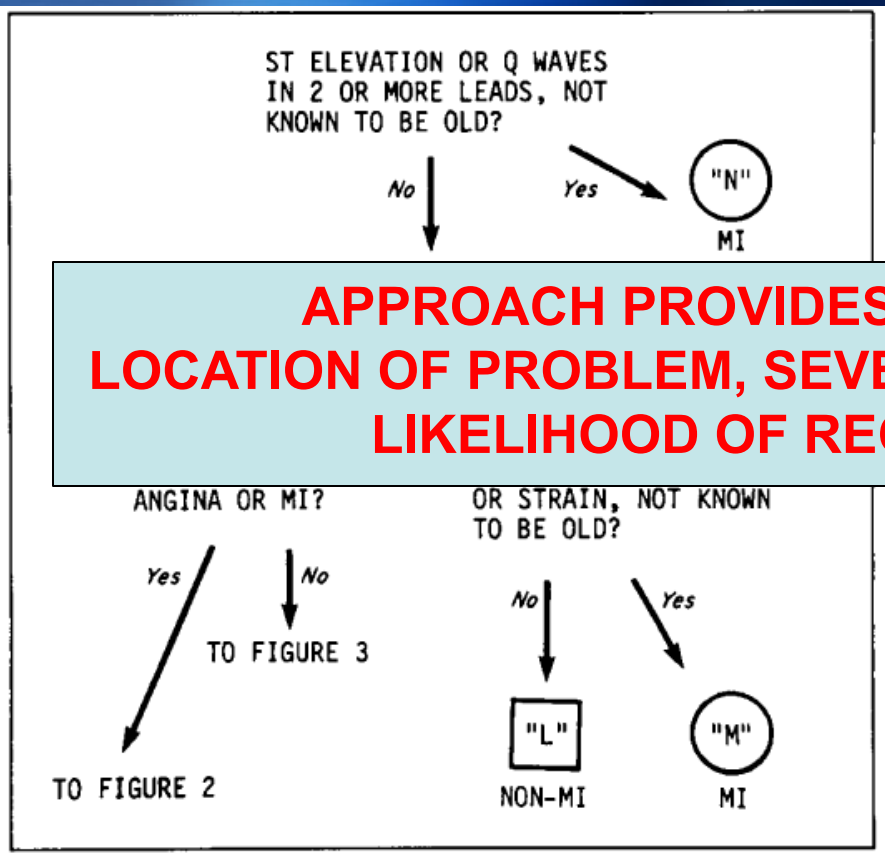


Figure 1. Computer Protocol for the Evaluation of Patients with Acute Chest Pain in the Emergency Department.

APPROACH PROVIDES NO INSIGHTS INTO LOCATION OF PROBLEM, SEVERITY, EXTENT OF DAMAGE, LIKELIHOOD OF RECURRENCE, ETC.

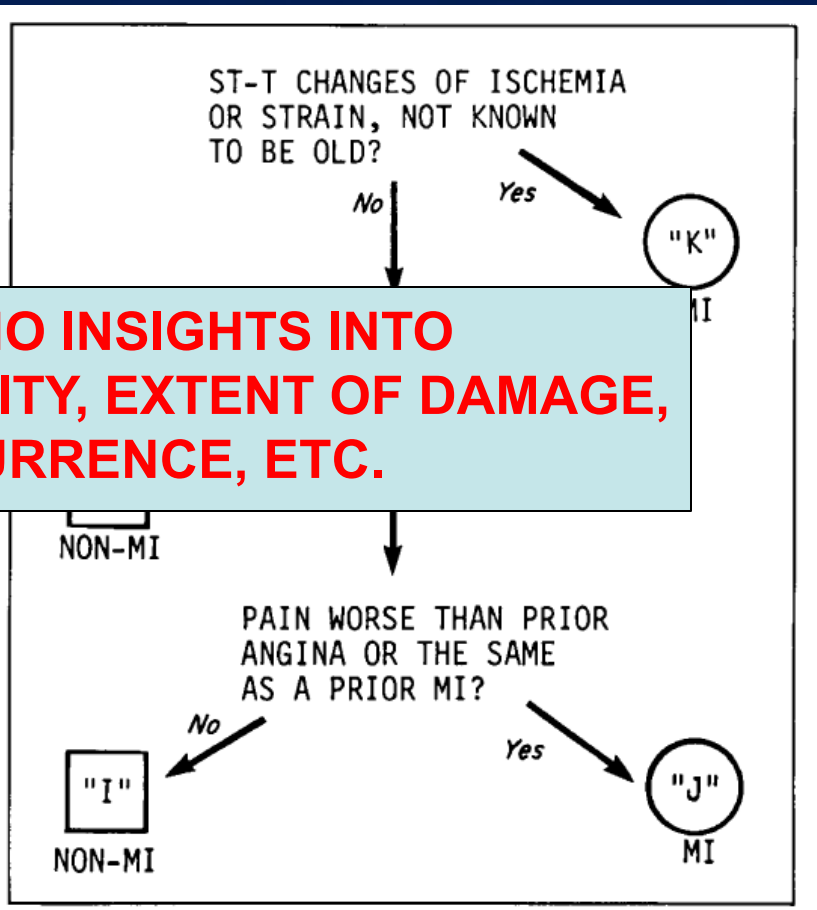
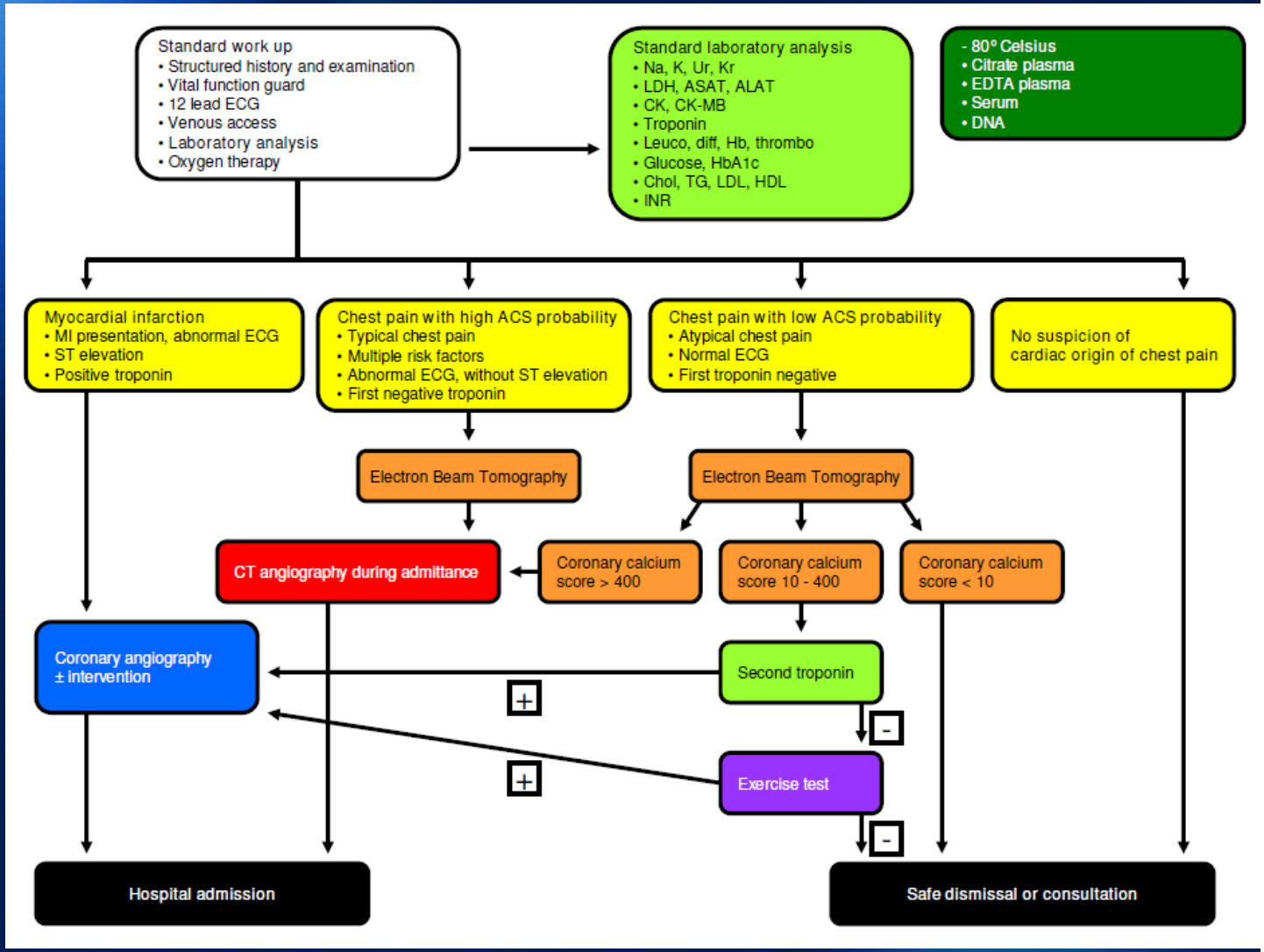


Figure 2. Questions to Be Asked of Patients with a History of Angina or Myocardial Infarction (MI) Who Do Not Have New ST Elevation or Q Waves and Whose Pain Began Less Than 48 Hours Previously.

Goldman et al, NEJM, 3/31/1988

ACS Triage - 2009

Triage now consists of:
- **History / risk factors**
- **Blood test / enzymes**
- **EKG**
- **Symptoms**
- **Imaging**
- **Progression of enzymes**



Willemsen et al, BMC Cardiovascular Disorders, 2009

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