From Physics to Daily Life

Detection and Imaging

David W. Townsend

CERN, Main Auditorium
26.09.2014, from 8.45 a.m.

Applications in Biology, Medicine, and Healthcare
Physics in medical imaging

X-rays

Radiology

CT scanner

Tracer technique

Nuclear Medicine

Gamma camera

SPECT

PET

26/09/2014
Statistics of cancer: impact on daily life

**Prostate**
- Estimated New Cases in 2014: 233,000
- % of All New Cancer Cases: 14.0%
- Estimated Deaths in 2014: 29,480
- % of All Cancer Deaths: 5.0%
- Metastatic 5-year survival: 28%

**Breast**
- Estimated New Cases in 2014: 232,670
- % of All New Cancer Cases: 14.0%
- Estimated Deaths in 2014: 40,000
- % of All Cancer Deaths: 6.8%
- Metastatic 5-year survival: 22%

**Lung**
- Estimated New Cases in 2014: 224,210
- % of All New Cancer Cases: 13.5%
- Estimated Deaths in 2014: 159,260
- % of All Cancer Deaths: 27.2%
- Metastatic 5-year survival: 1%

**Baseline cancer rate:**
- Male: 1 in 2 will develop cancer and 1 in 4 will die
- Female: 1 in 3 will develop cancer and 1 in 5 will die
In the beginning... Positron Emission Tomography (PET)

Multiwire Proportional Chamber

1992

1977 when PET started at CERN

Georges Charpak 1924 - 2010

The first HIDAC PET camera that was installed in Nuclear Medicine at HCUG in 1980 to image thyroids with $^{124}$I flown in from Manchester

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PET: how it works

Parallel projections

Positron range (r)

Neutron-deficient isotope

Detector

Coincidences

Injection of labeled pharmaceutical

$^{18}\text{FDG}$

$\text{HO-CH}_2$

$\text{HO}$

$\text{HO}$

$\text{HO}$

$\text{H}$

$\text{H}$

$\text{H}$

$\text{H}$

$\text{H}$

$\text{H}$

$\text{H}$

$\text{CH}_2$
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Funding: FNS

- HD MWPC (HIDACs)
- Rotating gantry (RT)
- CAMAC electronics
- 3D PET reconstruction
- $^{124}$I: thyroid; $^{55}$Co: tumor

1979 HIDAC

Funding: CERS; citations: 36

1989 PRT-1

Funding: NIH; citations: 867

1999 PET/CT

- BGO block detectors
- Rotating gantry (UCLA)
- CTI PET electronics
- 3D PET reconstruction
- $^{18}$FDG for brain
- BGO block detectors
- Rotating gantry (Siemens)
- CTI PET electronics
- 3D PET reconstruction
- $^{18}$FDG for oncology

Geneva

Geneva

Pittsburgh
Why combine anatomy and function?

P. Brueghel

X-ray CT: anatomy

PET: function

CT + PET: anatomy + function

Best of both worlds!
First PET/CT device: 1995 - 1998

PET/CT imaging, 1998-2001

University of Pittsburgh
PET/CT imaging in the clinic

4000 PET/CT scanners operational worldwide

PET/CT	
imaging	
in	
the	
clinic

Renal Cell

Non-Hodgkin Lymphoma

18F-fluorodeoxyglucose

Recurrent Nasopharyngeal Carcinoma

Liver metastasis

Pelvic lymph nodes

68Ga-DOTA-NOC (courtesy R. Baum)

Bone metastasis

Metastatic Lung Cancer
A PET/CT scan acquired each week during chemo maps a decreasing SUV in responders compared to patients who do not respond that demonstrate an unchanging or increasing SUV. For these patients with stage IIIb lung cancer, the PET/CT determined that if the patient did not respond to the chemotherapy by week 3 they would not respond to that treatment.
Cancer Survivor Numbers Triple From 40 Years Ago: Report
By Kelly Gilblom | September 16, 2014

- Sensitive diagnostic and screening procedures
- Accurate staging of disease by using imaging
- Better understanding of cancer genetics
- Targeted drug therapies based on tumour type
- Monitoring therapy using molecular imaging
- Accurate radiation therapy (IMRT), low toxicity
- Hadron therapy (protons) for certain tumours
Projection of healthcare expenditure by disease (Australia): 2003 - 2033

Population Growth

Ageing Population

Obesity

Diabetes
Mental Illness
Cardiovascular Disease
Cancer
Joint Disorders

520%
342%
142%
190%
223%

Developing Countries

Annual cost of mental illness

2010

Source Goss J. 2008

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As much as new ideas are fundamental to the advancement of science, technological innovations are the engine of scientific progress.

Professor Shirley Tilghman
President, Princeton University

The history of medicine has been defined by advances born of bioscience. Never before has it been driven to this degree by technology.

Professor Hedi Hricak
Chair, Department of Radiology
Memorial Sloan Kettering Cancer Center