



New Directions and Approached to Cancer Treatment:

Imaging

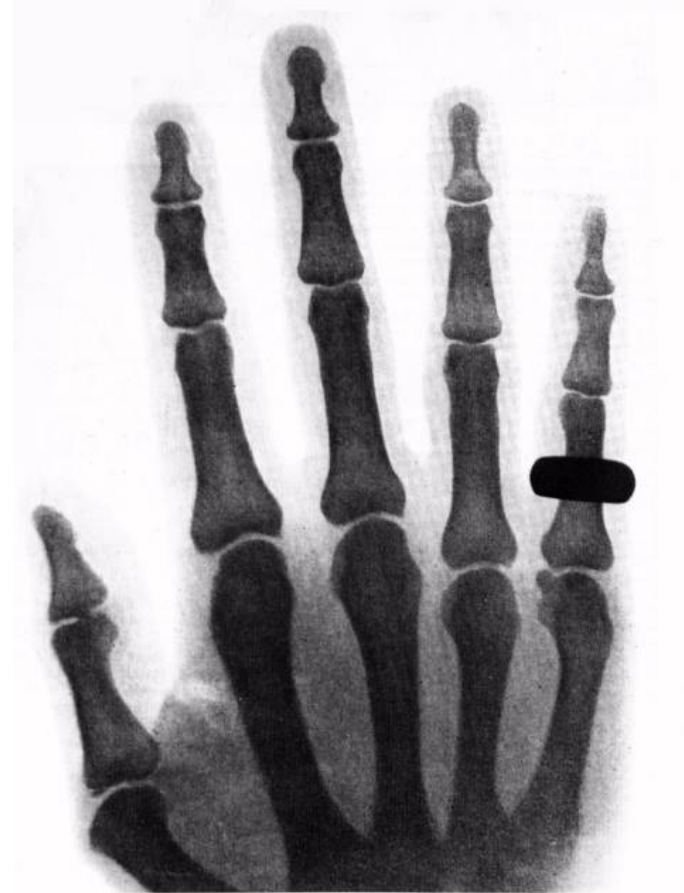
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STFC Workshop, Birmingham, 28th January 2010

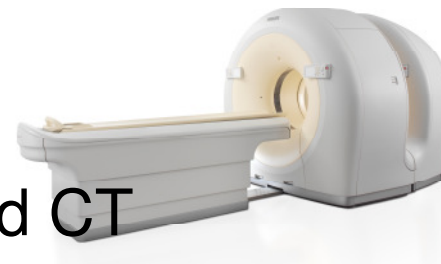
The beginning of medical imaging

- Wilhelm Röntgen's first “medical” x-ray, of his wife Anna’s hand, taken on 22nd December 1895.
- This picture was taken by English Doctor Charles Thurston Holland on the 26th May 1896.



Advances in technology

- CT
 - Multi-slice detectors
 - Cone-beam systems
- MRI
 - Higher field strengths
 - Steeper RF gradients
- PET (& SPECT)
 - Higher spatial resolution
 - Improved signal-to-noise ratio
 - Hybrid scanners with combined CT

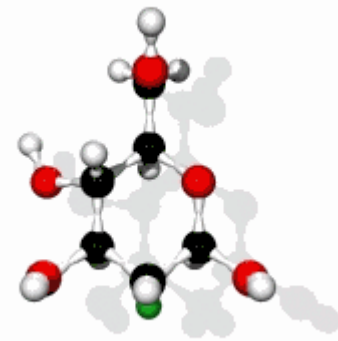


Overview

- Past advances have been based on anatomical images.
- We are beginning to use biological imaging prior to treatment to determine anatomical targets and organs-at-risk.
- A clear next step is to use biological information to change treatment strategy.
- The real future challenge is to measure rapid biological response to therapy and use this information to customise therapy.

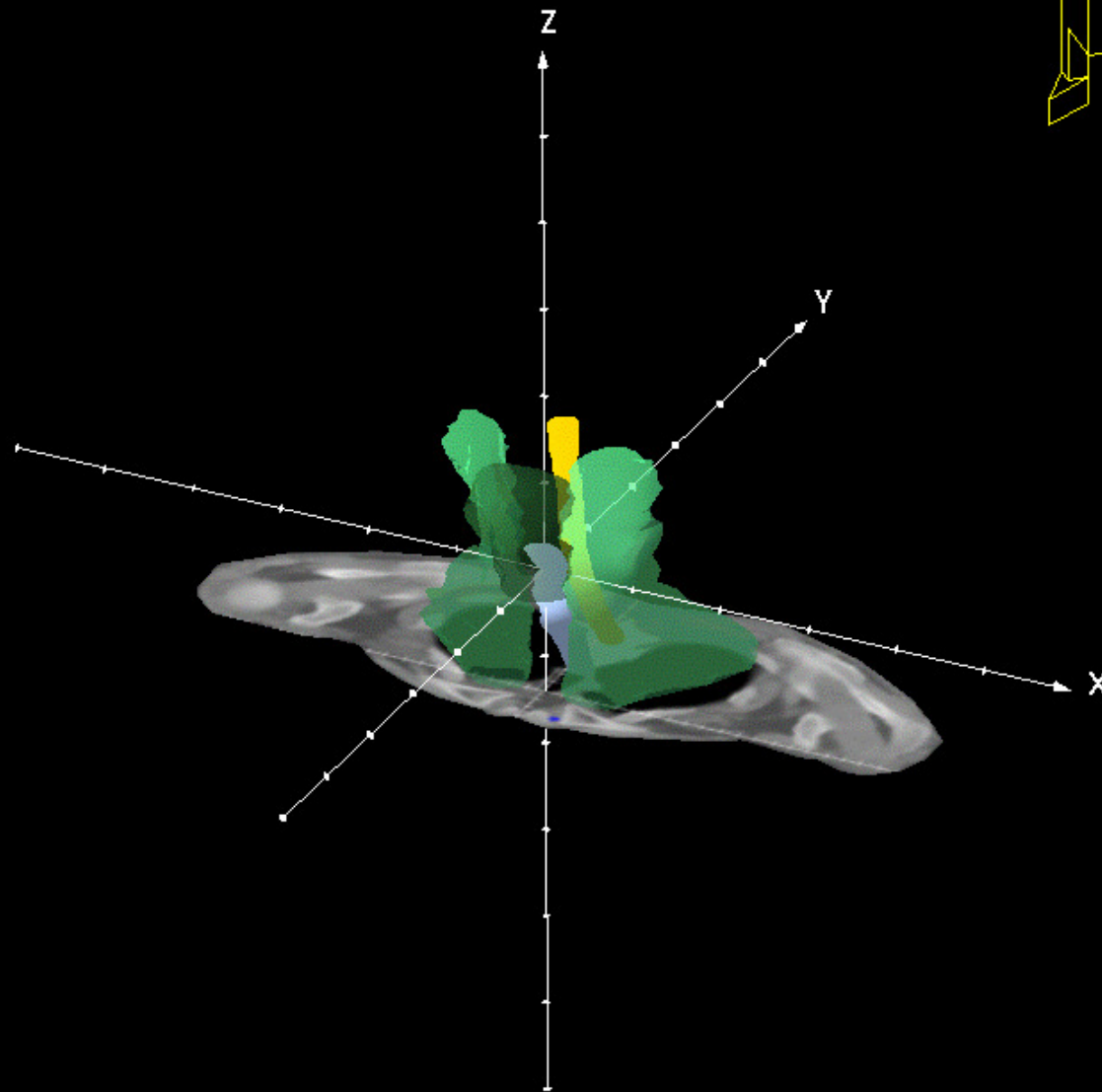
What is Biological Imaging?

- Any image data more than purely anatomical.
- Magnetic Resonance Imaging (MRI)
 - Perfusion / Diffusion
 - Spectroscopic imaging
- Nuclear Medicine
 - ^{18}F -FDG Positron Emission Tomography (PET)
 - Single Photo Emission Computed Tomography (SPECT)



Current uses of imaging

- Identification of tumour nodal target volumes.
(staging of disease)
- Identification of organs-at-risk.
- Monitoring of set-up accuracy and day-to-day anatomical changes in radiotherapy.
- Real-time tracking of moving tumours
(4D imaging)



1) Pink: body contour

2) Dark green: primary target

3) Light green: nodal target

4) Yellow: spinal cord

5) Grey: oesophagus

Head & Neck Radiotherapy

Cyberknife

x-ray source

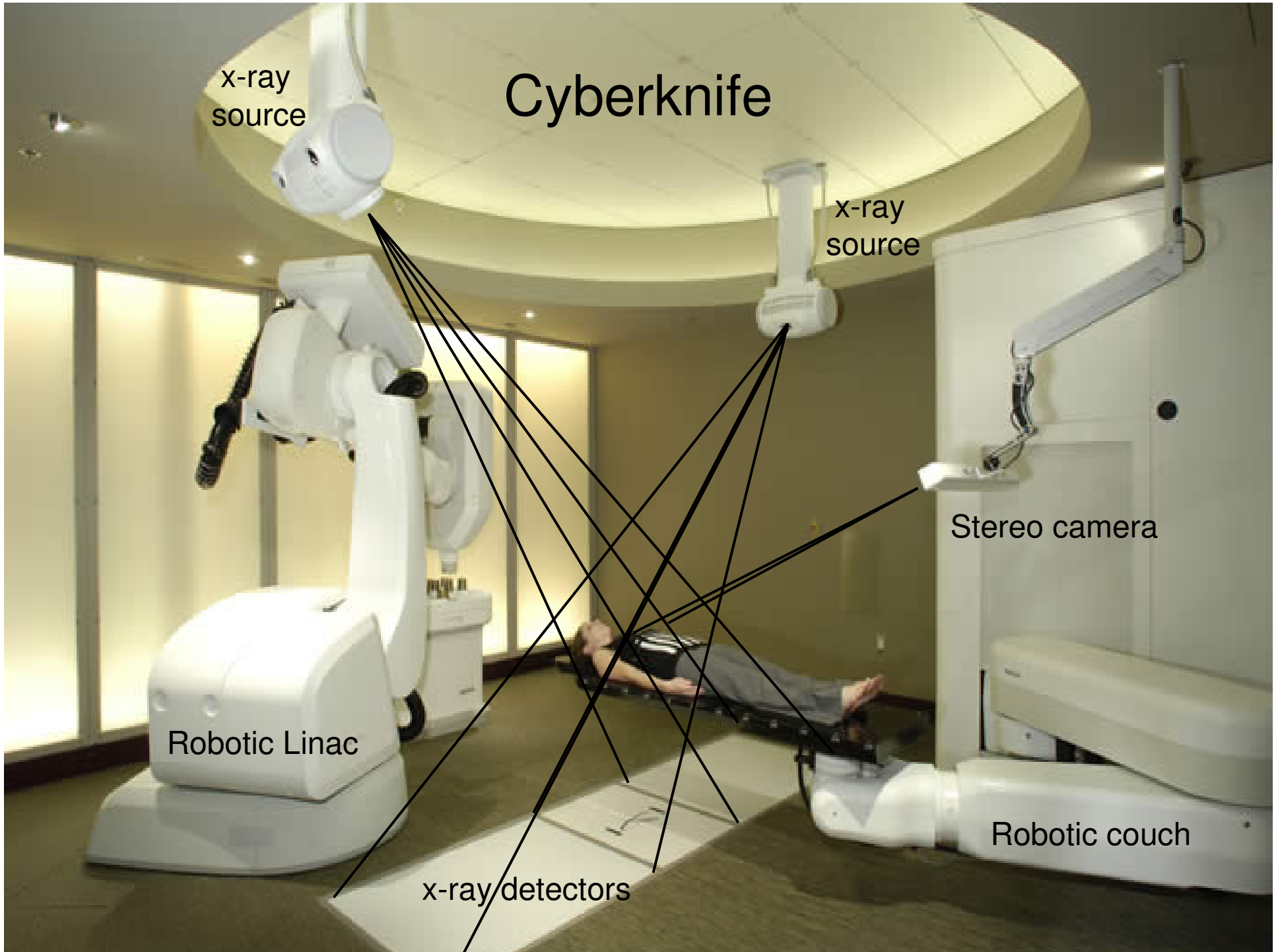
x-ray source

Stereo camera

Robotic Linac

Robotic couch

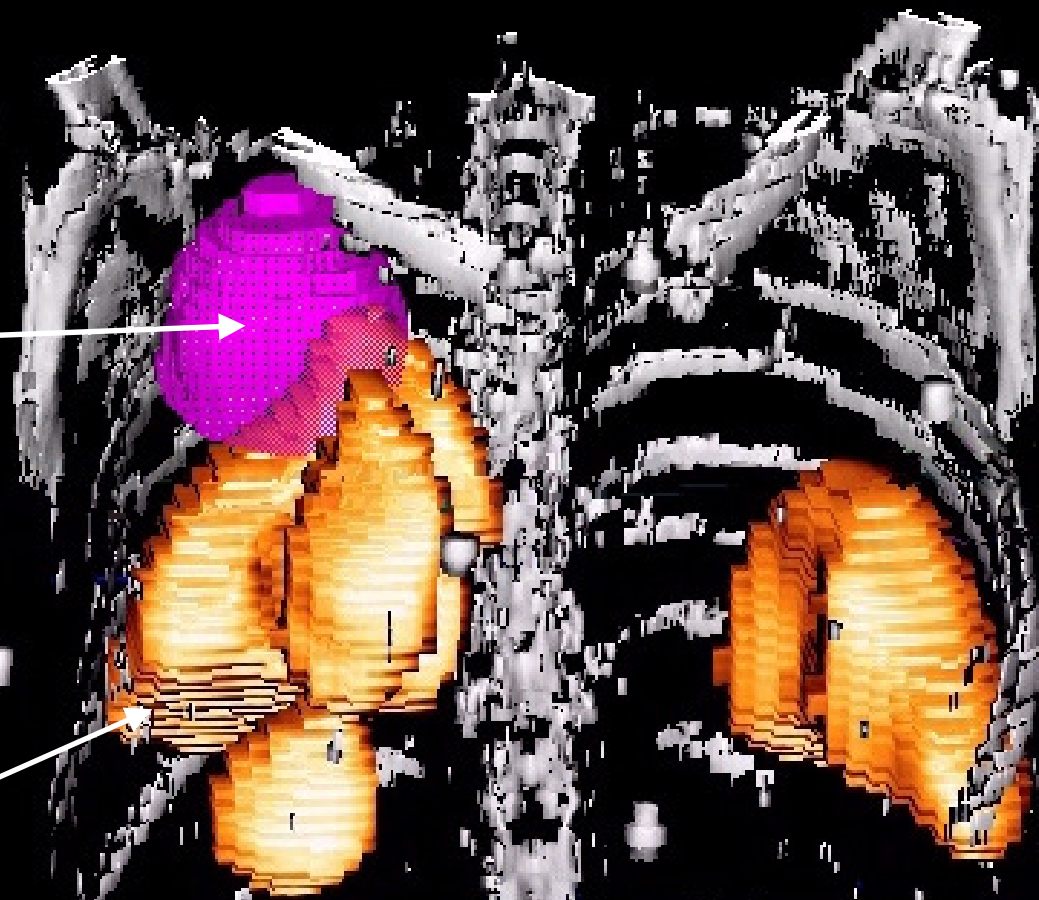
x-ray detectors



Lung Radiotherapy

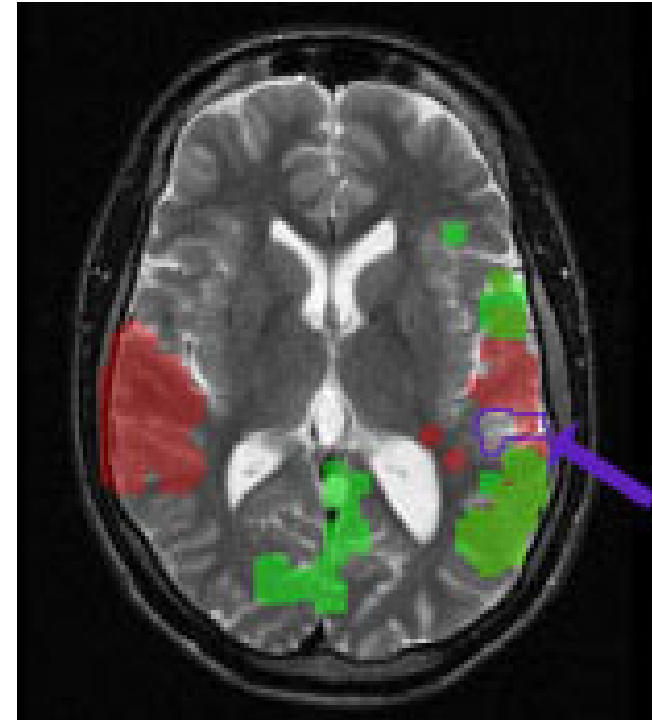
Target

Well-perfused
lung from
SPECT



Functional imaging for surgical planning

- fMRI for surgery planning
 - Green = visual stimulus
 - Red = auditory stimulus
 - Purple = tumour



(tumour identified using methionine PET scan)

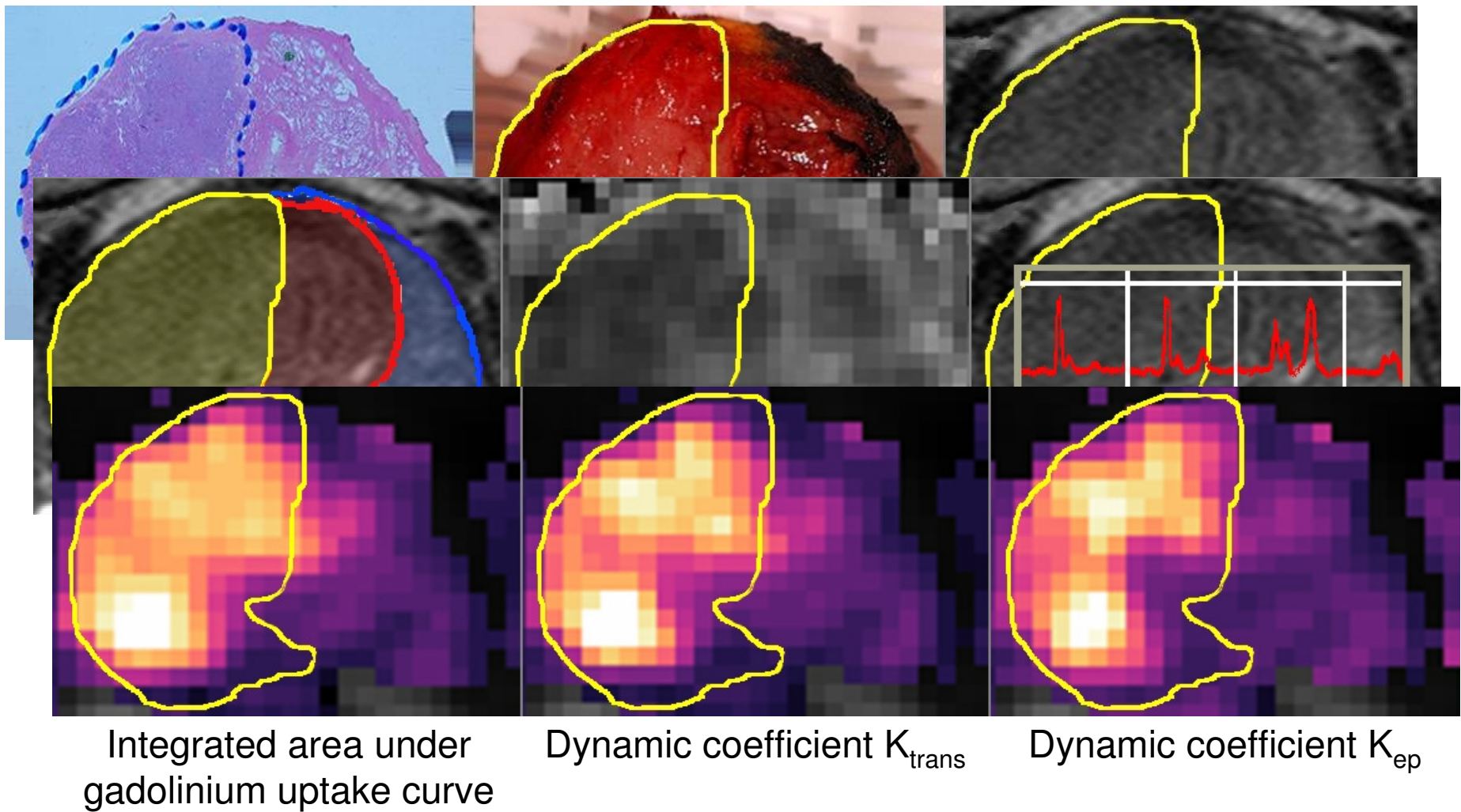
Future imaging developments

- Improved PET quality and speed:
 - New detector technology
 - Time-of-flight & depth-of-interaction
 - More specific and sensitive radiotracers
 - High quality 4D and dynamic imaging
- Higher field strengths and RF gradients
 - Higher sensitivity
 - Improved coil and pulse sequence
 - Spectroscopic imaging
 - Hyperpolarized imaging

Future uses of imaging

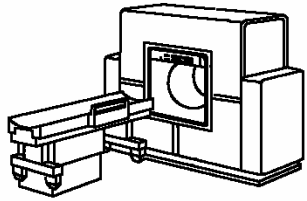
- More accurate biological targeting of disease
 - Studies correlating biological imaging with histopathology.
- Changes in dose prescription directly driven by biological imaging “dose painting”
 - Studies correlating biological imaging with treatment outcomes.
- Adaptation of treatment as a result of biological images of early response.
 - Clinical trials.

MR-guided intraprostatic lesion boost



Current treatment

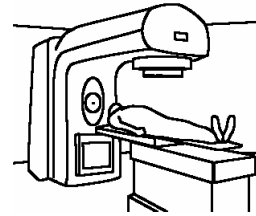
Treatment
planning



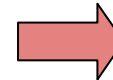
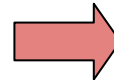
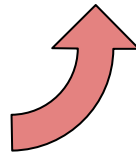
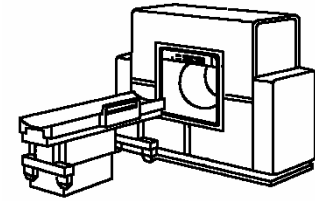
Phase I
treatment



Phase II
treatment

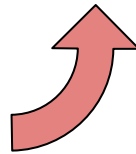
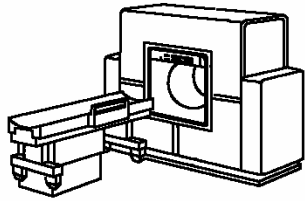


Assessment

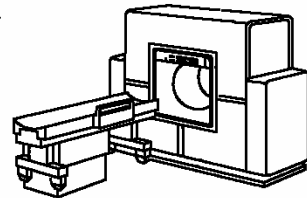


Adaptive treatment

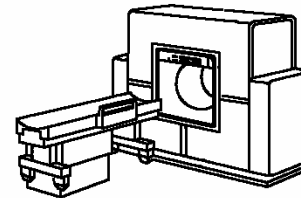
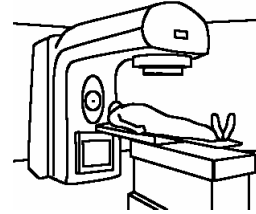
Treatment
planning



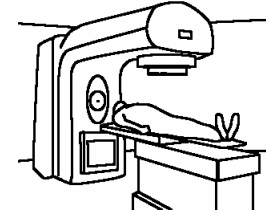
Phase I
treatment



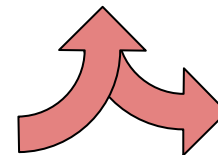
Phase II
treatment



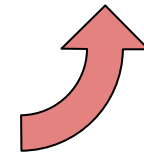
Phase III
treatment



Adapt
treatment



Adapt
treatment



Theoretical framework

By imaging biological response to a 2-phase radiotherapy treatment, we can (in theory) determine patient-specific radiosensitivity α and β and use these to customise the remainder of the treatment:

$$\begin{pmatrix} A^{[1]} D^{[1]} & \frac{B^{[1]} D^{[1]^2}}{n^{[1]}} \\ A^{[2]} D^{[2]} & \frac{B^{[2]} D^{[2]^2}}{n^{[2]}} \end{pmatrix} \begin{pmatrix} \alpha \\ \beta \end{pmatrix} = \begin{pmatrix} \ln \left(\frac{N^{[0]}}{N^{[1]}} \right) \\ \ln \left(\frac{N^{[1]}}{N^{[2]}} \right) \end{pmatrix}$$

Local oxygenation (A & B), dose and fractionation.

number of surviving cancer cells

Patient-specific radiosensitivity

Future Challenges

- Biological imaging that is accurate, quantitative and highly repeatable.
(hardware & software / industry challenge)
- A range of well-understood and clinically validated “imaging biomarkers” covering the major processes in cancer (proliferation, hypoxia, angiogenesis, apoptosis)
(radiochemistry, pre-clinical & clinical challenge)
- Well understood strategies for how to use this new biological information.
(mathematical modelling, radiobiology, physics, clinical trials)

Acknowledgements

RF Mould, A History of X-rays and Radium,
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The Institute
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