ESRF, Grenoble, France

RECENT ADVANCES IN MEDICAL APPLICATIONS
ID17 ESRF – INSERM U647

Medical Beamline ID 17 at ESRF

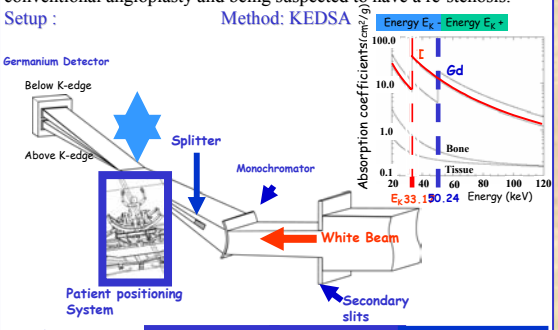
Synchrotron radiation imaging and radiation therapy programs for pre-clinical and potentially clinical applications

IMAGING

INTRAVENOUS CORONARY ANGIOGRAPHY

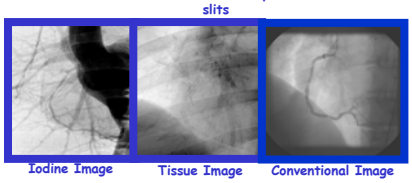
Goal : Validation of the low invasive Synchrotron Radiation angiography for the follow-up of patients who have undergone conventional angioplasty and being suspected to have a re-stenosis.

Setup : Method: KEDSA



Results :

- 64 patients
- Low invasivity
- Low X ray dose (0.2 Sv)

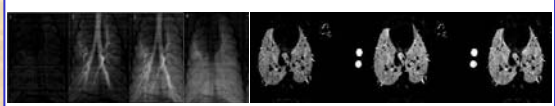


BRONCHOGRAPHY

Goal : experimental study of small airway pathophysiology, of the role of local mediators and that of pharmaceutical agents, and development of models of obstructive lung diseases such as asthma.

Method :
- Rabbits inhale stable Xe gas
- Monochromatic Synchrotron X rays tuned at Xe K-edge
- Projections or Quantitative CT images

Results :



Sequential chest images in rabbit. The bronchial tree is visible on frames 2 and 3

Tomograms in rabbit. Xenon enhancement in the airways is visible

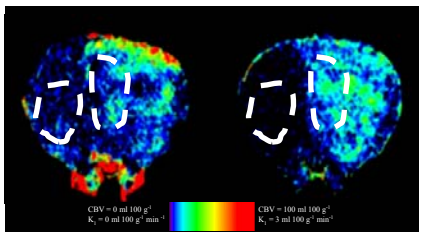
COMPUTED TOMOGRAPHY

Goal : Monochromatic Synchrotron X-ray beams allows quantitative computed tomography and hence *in vivo* high resolution brain vasculature parameters assessment (cerebral blood volume, blood brain barrier permeability)

Procedure :
- Rats with brain glioma model
- Injection of iodine or gadolinium contrast agent
- Reconstruction of transverse slices from acquisition of projected intensity profiles

Results : Accurate quantification of the brain haemodynamic changes between healthy and pathological small animals.

SRCT coronal slice of a rat head expressed in absolute iodine concentration obtained with the "FRELON" CCD camera . The tumor invades the whole right hemisphere.



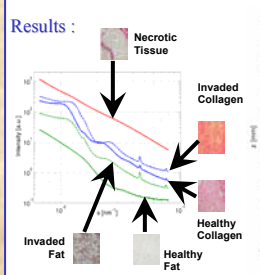
High-resolution cerebral blood volume parametric map and BBB permeability coefficient K parametric map for a rat bearing an advanced stage F98 glioma.

DEI + SAXS for MAMMOGRAPHY

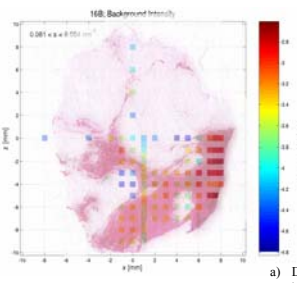
Goal : Early detection of cancer invaded breast tissues

Method : SAXS and diffraction enhanced imaging, which can sense phase gradients in the diffraction plane of the analyser crystal that is introduced behind the tissue sample

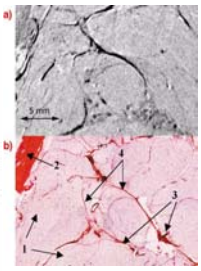
Results :



Increase of intensity of scattering in cancer invaded tissues, either fatty or collagen-rich.



The collagen *d*-spacing is larger in the invaded zones



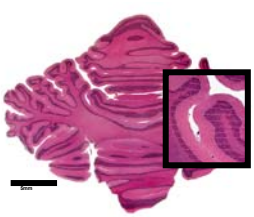
a) DEI-CT image of cancerous breast tissue showing excellent correspondence with the histological section b) taken at the same position. [1] adipose tissue [2] skin and muscular tissue [3] cancer cells embedded in collagen [4] collagen strands

THERAPY

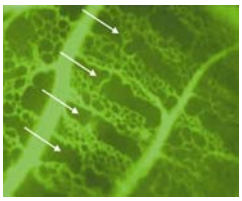
MICROBEAM RADIATION THERAPY

Goal : MRT takes advantage of the "DOSE-VOLUME-EFFECT". Only cells and nuclei are destroyed in the beam path, while no tissue destruction is present. If the dose values between the microbeams are low enough, we can observe a rapid repair of microscopic lesions by unirradiated adjacent cell. Potentially tumoricidal MRT doses could be better tolerated than those used in conventional radiotherapy. The architecture of the vascularisation between healthy and tumor tissue can be substantially different, which might provide a method to control the tumor by the destruction of its vascularisation and the repair in the vicinity of larger blood vessels might enable the healthy tissue to survive. Studying the repair effect of blood vessels illustrated below is part of the MRT research program.

Results :



Horizontal section of the piglet cerebellum. The 25 µm-wide stripes indicate the path of the microbeam with the cells and nuclei destroyed only in the beam-path, but no signs of hemorrage and no tissue destruction are visible



The Chorio-Allantoic Membrane (CAM) of a chicken egg, irradiated with microbeams of 300 Gy (24 hours after irradiation). The capillaries along the beam path have been destroyed, while larger vessels have survived, and in some areas new capillaries are bridging the gaps.

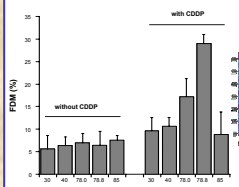
PAT-Plat

Goal: Selective excitation with monochromatic X rays of a high-Z compound located in tumor cells DNA.

Method :
- Cisplatinum chemotherapy drug
- Pt K-edge excitation
- In vitro study of molecular damages
- Animal model: rats with F98 brain glioma

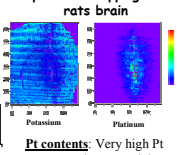
Results :

DNA double strand breaks levels in F98 cells exposed to 0 and 30 µM CDDP for 6 h and irradiated



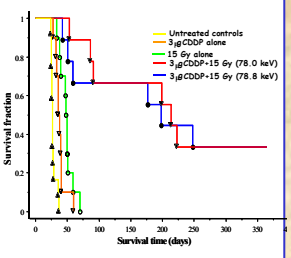
Molecular results: above Pt K-edge : evidence of an extra-number of slowly repairable DNA double-strand breaks

Potassium and platinum mapping on rats brain



Pt contents: Very high Pt concentration around the needle pathway, at the injection site.

Survival curves of rats with F98 brain glioma



Survival curve: Very large difference ($p<0.0001$) between irradiated alone and rats treated with CDDP *and* radiation (best result for this tumor model), however, no difference between the 2 energies