Measurement of the linear attenuation coefficient of breast tissues by synchrotron radiation computed tomography

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1. Introduction

- ✓ SYRMA-CT/SYRMA-3D (SYnchrotron Radiation MAmmography) collaboration aims to perform the world's first in vivo breast computed tomography (BCT) with synchrotron radiation (SR) [1].
- ✓ The high spatial coherence of SR allows to detect phase effects.
  - When radiation freely propagates, as in propagation-based phase-contrast imaging (PPCI), edge enhancement is observed (see Fig 1).

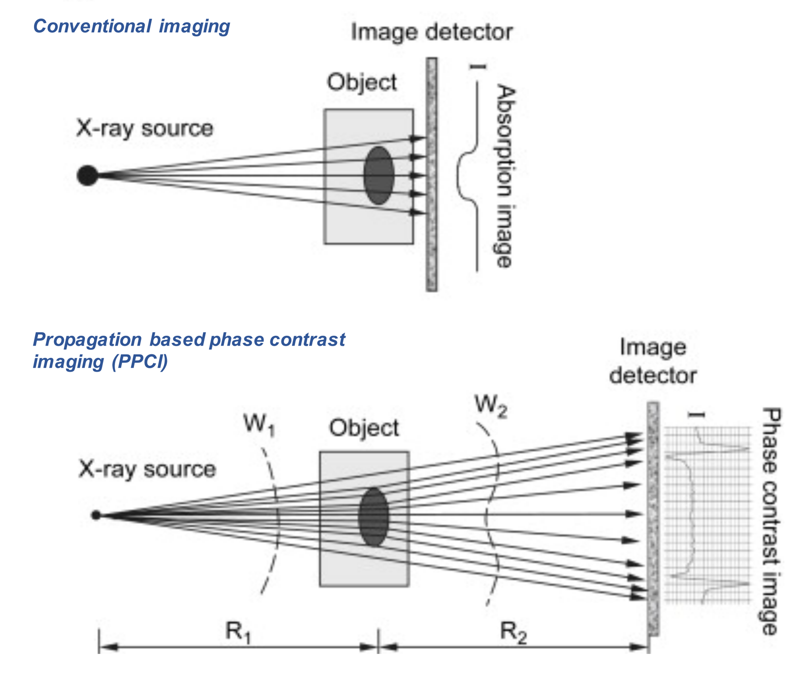

Fig 1. Conventional imaging compared to propagation based phase contrast imaging. In PPCI the detector is not placed just behind the object and the beam freely propagates before being detected. As a result, the edges of details are enhanced. From [2].

- ✓ Due to SR beam monochromaticity the tomographic image is a map of linear attenuation coefficients.

2. Aim of the work

The goal of this work is the measurement of linear attenuation coefficients of breast tissues (adipose tissue, glandular tissue and tumor) by synchrotron radiation BCT images.
For this purpose an image calibration is needed.

3. Materials and methods

- ✓ Images of three surgical breast specimens fixed in formalin, together with three small test tubes filled with ethanol, water and glycerol are analyzed.
- ✓ CT images are acquired at Elettra synchrotron radiation facility in Trieste, Italy, with a monochromatic laminar beam
  - cross section:
    220 (horizontal) mm × 3 mm (vertical, Gaussian shape, FWHM).
- ✓ Measurements are performed at different energies (between 24 keV and 38 keV) and with two mean glandular doses (MGD) (5 mGy and 20 mGy) . Thanks to the negligible beam divergence, projection are collected only over 180°. 1200 projections are acquired for each slice.
- ✓ Data are collected with a direct conversion CdTe photon counting detector (PIXIRAD-8) with a 60 μm pixel size [1].
- ✓ Projections are firstly pre-processed with an *ad hoc* procedure; then a phase retrieval filter is applied to preprocessed data and finally images are reconstructed via a filtered back projection with a standard Shepp-Logan filtering [3].
  - The phase-retrieved image results in a remarkable CNR increase with respect to the absorption image [4].
  - A resolution loss significantly lower than the one obtained by applying common de-noising filters is observed [4].

4. Results

An example of the dependence of the theoretical linear attenuation coefficients of the three reference materials upon the measured voxel values derived from the CT images at 32 keV is depicted in Fig 2.
For each energy a different calibration equation is obtained. No significant differences are observed among calibration equations calculated with varying doses or samples.

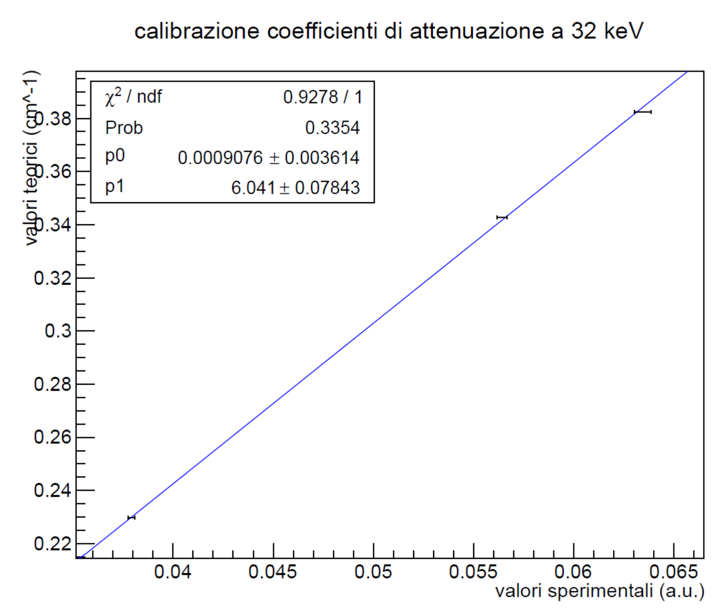

Fig 2. Example of calibration at 32 keV and MGD of 5 mGy. Three reference materials (ethanol, water and glycerol) are used. Theoretical values are taken from [5] while experimental values are evaluated, for each sample, as the average signal intensity, over several slices, of homogeneous ROIs. One sigma error bars.

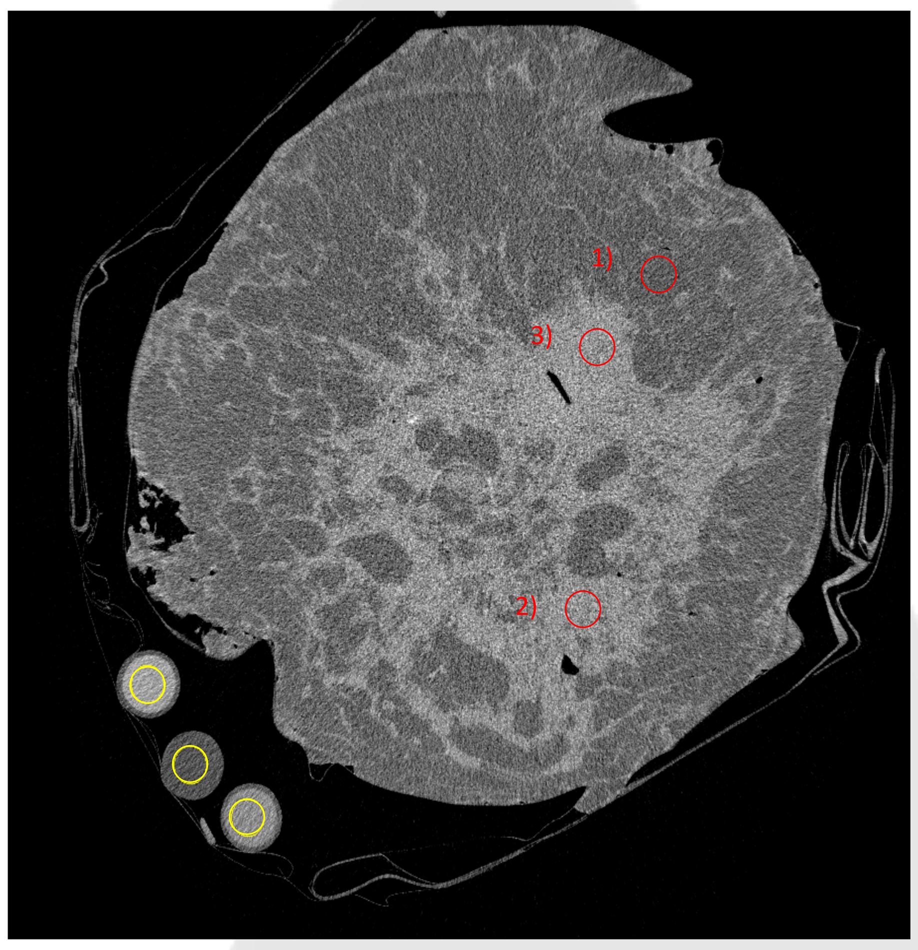

Fig 3. Phase retrieved reconstructed slice of a surgical specimen acquired at 32 keV with a MGD of 20 mGy. Yellow circles indicate the ROIs used for the calibration while red circles indicate homogeneous regions of 1) adipose tissue, 2) glandular tissue and 3) tumor.

Linear attenuation coefficients of breast tissues (cm^{-1}) are evaluated applying calibration equations to the mean value (a.u.) of homogeneous ROIs (see Fig 3). Obtained results are depicted in Fig 4 as a function of energy and they are compared with those previously published in literature [6], [7].

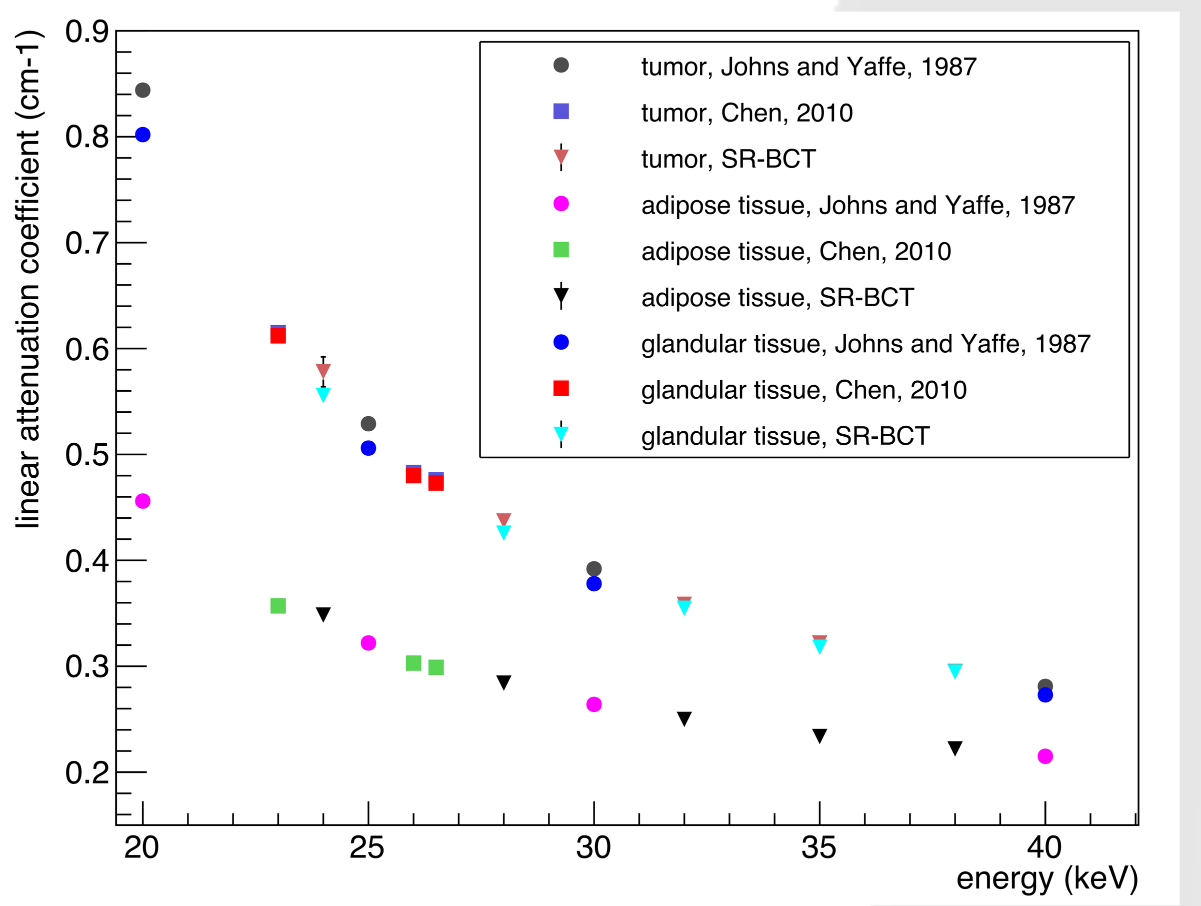

Fig 4. Comparison of the measured linear attenuation coefficients of tumor, adipose tissue and glandular tissue with data published by Johns and Yaffe (1987) and Chen et al. (2010). Standard deviations of measured values are smaller than the markers.

5. Discussion and Conclusions

- ✓ The results demonstrate that SR BreastCT allows the evaluation of linear attenuation coefficients. A good agreement with the previously published data is observed.
- ✓ No evidence of a difference in the linear attenuation coefficients between tumor and glandular tissue is found.
- ✓ Since calibration equations do not change with dose and sample an *ad hoc* calibration per each patient is not needed. Therefore, a calibration procedure based on a QC test object is under development [8].

References

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