Design and Development of an Ultrasound Imaging Phantom for a New Miniature Intra-oral 20 MHz Probe

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Abstract A new 20 MHz miniature ultrasound intra-oral probe is being developed at UMIST as part of an EPSRC funded research grant. The purpose of the probe is to assess the pathology of oral cancers and to evaluate the efficacy of surgical resection. In order to test and monitor the high-resolution capabilities of the transducer, a test object (or phantom) needs to be designed and fabricated. The initial investigation will be to make a tissue mimicking material (TMM) that exhibits the specific acoustic properties [1] at this high frequency. An agar-based gel TMM is proposed and some basic imaging capabilities will be tested i.e. resolution (in 3D), contrast, dead-zone and caliper accuracy [2]. Due to the innovation of this high frequency probe, the spatial accuracy of the test features has not been previously attempted. The speed of sound and coefficients of both attenuation and backscatter are to be measured using a transducer/hydrophone set-up. All the results will be specific to operating temperature and frequency range. Both the temperature and age dependence of the TMM will be assessed. The speed and attenuation measurements will be made using substitution techniques [3], whereas the backscatter coefficient will be measures using the pulse-echo method [4].

References

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Time-Gated Fluorescence Imaging of Tetrasulfonated Phthalocyanine Dyes in a Tissue Phantom

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Phthalocyanine derivatives are currently under investigation for use in Photodynamic therapy, which is a promising treatment for cancer. These materials, which display preferential uptake in cancerous cells, also exhibit high fluorescence yields, and can be used for tumour detection. Problems with steady-state fluorescence techniques such as background autofluorescence can be eliminated by the use of time-resolved techniques. Improved contrast can be obtained with time-resolved techniques because of the differing lifetimes between autofluorescence and exogenous photosensitisers. An imaging system was constructed using a fast (200 psec) gated CCD camera and a pulsed 635 nm laser diode. A tissue phantom was assembled to test the system by drilling thirty-six wells of varying diameter and depth (10 mm to 1 mm) into a block of polymethyl methacrylate

(PMMA). The system was used to record images of chloroaluminum phthalocyanine tetrasulfonate within the wells at differing concentrations in phosphate buffer. A mixture of 1) Intralipid to mimic tissue scatter, 2) Evans blue to mimic tissue absorption, and 3) zinc phthalocyanine tetrasulfonate to mimic healthy tissue autofluorescence of varying depth was placed on top of the PMMA block. These results contribute to the precision of a time-gated imaging system to image living organisms using fluorescence lifetimes.

Quality Assurance in Thermographic Imaging Systems

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Conventional imaging systems used within the NHS (for example magnetic resonance imaging equipment, gamma cameras and diagnostic x-ray equipment) are “medical devices” and classified according to risk under the Medical Devices Directive. Thermal imaging has been used for many years but is established only in a small number of specialist centres within the NHS. Whilst thermal cameras and software are used to provide diagnostic information, generally they are sold for industrial applications and are thus not categorised as “medical devices. “

The periodic assessment of equipment after initial acceptance test is vital to ensure it continues to meet its specifications and a quantitative record of results and equipment faults should be kept. Quality assurance guidelines are already established for MRI and ionising radiation imaging modalities. The need to develop medical thermography standards is recognised and, although being addressed, will take time to be implemented clinically.

The Department of Rheumatology, Royal Free Hospital acquired a FLIR SC500 uncooled Focal Plane Array system last year. In the absence of guidelines, performance criteria were established and work was presented (1) detailing our investigations of the performance of the new system. A full risk assessment was carried out to justify the use of an industrial device in a clinical context and an initial quality assurance system devised. This has been reviewed and the performance of the system and image quality reassessed.

Reference

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Arguments for setting up an ultrasound quality assurance service in a large Hospital Trust

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IPEM, in report number 71, suggest that ultrasound scanners should be quality assured every 6 to12 months. At the Royal Free Hampstead NHS Trust there are 37 ultrasound scanners most, but not all, of which are serviced and maintained under external contracts. The amount and detail of quality assurance measures included in these contracts varies depending on the manufacturer performing them. The cost of these contracts is estimated to be between £4000 and £7000 per ultrasound scanner. Tissue mimicking phantoms to perform some basic, independent and consistent tests on these scanners would cost a similar amount.

This would be a one-off payment, covering the purchase of a multipurpose phantom, a small parts phantom and a slice thickness phantom. These should be sufficient to allow tests of scanner caliper accuracy, sensitivity, penetration, resolution and spatial uniformity for almost all scanners and transducers. For a further £2000, a calibrated precision radiation balance could be purchased allowing the testing of physiotherapy ultrasound equipment.

It is unlikely that, in providing an independent QA facility, the cost of maintenance contracts could be significantly reduced. However the protocol used could incorporate some planned preventative maintenance and monitoring of the performance of scanners would identify problems before they have a clinical impact.

Each scanner could be quality assured every six months requiring a total of one day, per scanner, per year. Considering the cost of equipment needed compared to the amount already spent on servicing contracts, our business case shows that the establishment of an ultrasound QA facility would only require a marginal increase in available resources but would provide a vital role in maintaining high standards in ultrasound imaging and reduce the Trust's exposure to risk.

Initial in vivo testing of a microwave applicator designed for the treatment of Barrett's oesophagus

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A method of treating Barrett's oesophagus using microwave radiation delivered endoscopically is proposed. The aim is to controllably heat *in situ* tissues to hyperthermic temperatures, enabling the ablation of affected tissues without damaging underlying normal tissue. A miniature microwave applicator has been developed for the uniform heating of the oesophagus. The applicator was designed to operate between 43 to 50 °C, at 915 MHz with a power of between 15 and 50W. Following successful phantom experiments, using tissue equivalent material (ε_r = 53, σ = 1.2 Sm^{-1} at 915 MHz), and *in vivo* feasibility tests a number of *in situ* tissue tests in porcines are in progress. The suitability of the applicator for treating the oesophagus is being tested. Initial experiments are aiming to determine if the oesophagus is heated uniformly, and whether the actual heating is in agreement with thermal models of the device. It should also be possible to determine the significance of blood perfusion and local vasculature, in particular whether the aorta complicates the heating pattern by acting as a heat sink. Tests are being performed with an operating temperature of 50 °C, to limit the required treatment times. Results of microwave treatment times required to achieve known radial penetrations will be presented using histology data. These results will be vital for refining the treatment and measurement protocols with a view to the development of a treatment plan.