TISSUE CHARACTERISATION AT WFUMB '85

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Abstract—A workshop was held immediately after the WFUMB '85 conference in Sydney to review the papers on the subject of Tissue Characterisation presented at the Conference, and to discuss their implications on the future of the subject. The Workshop took the form of a panel discussion with each panellist presenting a different aspect of Tissue Characterisation. This paper reports the general thrust of the discussion of the papers, and of the techniques covered.

Key Words: Attenuation, Attenuation slope, Diffraction, Dynamics, Scattering, Sound speed, Texture analysis, Tissue characterisation, Ultrasound.

Following the WFUMB '85 conference in Sydney, a Workshop was held to discuss the papers presented on Tissue Characterisation at the conference. The meeting was attended by the ten panellists (who are the co-authors of this paper) and 20 other participants. The Proceedings of WFUMB '85 have been published (1) in the form of 1, 2, or 4 page abstracts and the reader is referred to these for details of the individual papers presented. The relevant papers are referred to by Proceedings page number within the text of this paper. The discussion was divided into sections covering different aspects of tissue characterisation.

SOUND SPEED

This topic attracted ten papers, the greatest number on any individual subject, with contributions from Japan, U.K., and Australia. By contrast only one paper was presented on measurement of sound speed from pulse-echo data at WFUMB '82 in Brighton.

By way of introduction it was pointed out that since the determination of sound speed required knowledge of distance within the tissue, the general case of sound speed imaging was ill-posed. The papers presented all made considerable simplifying assumptions including assuming a single sound speed within the tissue. The techniques used varied considerably. One approach, first presented at WFUMB '82, was to use two overlapping sector scans with the mis-registration of two images of the same structure being used in a ray tracing computation to determine the apparent sound speed (Robinson, p. 36; Chen and Robinson, p. 518). The scans are obtained from a multi-transducer water-delay echoscope, or a compound real time twin-sector scanner. In a variation of this method a linear array was used with refracting prisms on its face to provide two images of the same structure (Bamber and Abbott, p. 517). Only a minor modification to a commercial scanner was required to implement the technique. Again the amount of displacement between the two images was used to calculate an average sound speed.

Another approach particularly useful in determining the sound speed within an encapsulated isolated region, was the use of a linear array to determine the transverse diameter of the region. An A-mode transducer or sector scanner with its line of sight at right angles to the array lines of sight is used to determine the transit time across the diameter measured by the linear array (Ohtsuki et al., p. 521). Yet another approach was to use a dynamically focussed phased array
and to change the focus parameters to optimise the resolution of the image of the diaphragm behind the liver (Katakura et al., p. 516). The optimal focussing implied a particular sound speed within the tissue. Another method used a focussed crossed beam system with a pulse being transmitted on one beam and the echo received from the overlapping area on the other beam (Akamatsu et al., p. 522). The sound speed is obtained by dividing the path length, as measured from the transducer positions and orientations, by the travel time of the pulse. In a development of this technique, the two crossed beams are provided by the two ends of a linear array, with the beams being formed by phased array techniques (Iinuma et al., p. 515).

Most of the papers were preliminary in nature and quoted measurement errors ranging from .5 to 3%. The precision needed for clinical use is at least 1% to separate the range of values in normal and abnormal conditions. There were some clinical results available from the more precise systems. Two Japanese reports of sound speed in the liver indicated that the sound speed was increased above the normal value in cirrhosis (Hayashi et al., p. 520; Akamatsu et al., p. 522). However, results from Australia showed sound speed decreased in cirrhosis (Doult et al., p. 80). It was thought that the difference was due to the different nature of the cirrhosis, with the patients examined in Australia suffering from alcohol-related cirrhosis while those from Japan suffered from post-necrotic cirrhosis. This hypothesis has not yet been tested. One finding which has already found clinical application, is the relationship between sound speed and the degree of myelofibrosis in the spleen. Serial studies on patients under chemotherapy have shown that the variation in sound speed closely followed biopsy results in the degree of fibrosis (Manoharan et al., p.113).

ATTENUATION

This was the second most popular subject with six papers. Two papers discussed attenuation measurement techniques. One was based on a quadrature detector, which allowed computation of the phase of the echo signal (Miwa et al., p. 523). From this phase, the spectral centroid was computed and used in a spectral shift method of attenuation slope determination. The other discussed the accuracy of the zero-crossing technique in conditions of non-Gaussian spectrum (Ophir et al., p. 529). Two papers presented clinical results using grey levels read from scan-converter values on B-scan images with standardised TGC. One of these papers reported an increase in attenuation for chronic liver disease such as alcoholic liver disease, chronic hepatitis, and haemochromatosis (Singcharoen et al., p. 525). The other found increased attenuation in fibrocystic disease and neoplasm, but not in chronic hepatitis (Ciatti et al., p. 526). A paper using the spectral difference method of attenuation slope estimation reported an increase for cirrhotic and fatty livers and iron excess, with observed ranges which overlapped between conditions (Doust et al., p. 80), and an increase with increasing myelofibrosis in splenomegaly (Manoharan et al., p. 113). The frequency shift method was used to differentiate between cirrhotic, fatty and normal liver (Tanaka et al., p. 573) and to differentiate focal tumours from normal tissues (Thijssen et al., p. 501). The popular assumption that attenuation is proportional to frequency was questioned by one paper using in vitro measurements (Thijssen et al., p. 501).

The questions raised by the papers were as follows:

- Is attenuation measurement alone, good enough?
- What tissue parameters correlate with attenuation?
- What is the frequency dependence of attenuation?
- Are tissue scattering and attenuation sufficiently homogeneous for accurate attenuation measurements?
- Is it possible to correctly account for beam effects?

It was pointed out in discussion that with all of the tissue characterisation techniques so far suggested, attenuation is the method most readily applied in the clinical environment. It requires the least critical scan placement and reduces the problems of overlying tissue. Prototype commercial scanners incorporating time domain attenuation measurement techniques are already undergoing clinical trials. However, at this stage the ranges of values assigned to normal and various classifications of abnormality overlap to such an extent that the predictive value of individual measurements is severely reduced. It is also restricted to relatively large, homogeneously scattering organs. There was no agreement on which of the five issues listed above, or some other factor was responsible for this overlap. It may be that identification of more appropriate classification parameters to which the attenuation measurement is related will offer some improvement in the clinical usefulness of attenuation measurements.

SCATTERING

There were a small number of papers on scattering, with no agreement on the method of measurement or the results to be expected. In some papers absolute backscattered power was measured (Thijssen et al., p. 501; Fujiwara et al., p. 511; Shung, et al., p. 509; Nishio, et al., p. 510). The results on tissue can be summarised as follows. In liver the amount of backscatter increases from abscess to normal to tumour to fatty, and in the heart from lymphosarcoma to normal to
in a function of frequency is measured. One paper (Shung et al., p. 509) presented results from in vitro experiments to confirm that the scattering function with frequency was a power law, i.e. \( s = a \times f^n \) over a frequency range of 2–7 MHz, while another (Thijssen et al., p. 501) that the value of \( n \) was 2, over a frequency range of 4.5–9 MHz in liver. Another paper addressed scattering theory from velocity and density variations (Ueda et al., p. 538).

In the discussion there was no unanimity as to whether the scattering in tissue is simple or multiple. For scattering measurements to be useful clinically, appropriate correction for overlying tissue attenuation must be made, and the diffraction effect compensated.

**DIFFRACTION CORRECTIONS**

Diffraction correction becomes of considerable importance when investigating ultrasonic scattering or attenuation methods in vivo. The ultrasonic beam varies as a function of range and also as a function of frequency and bandwidth, thus directly influencing scattering or attenuation estimations. Methods suggested for coping with this problem include experimental design to hold the effect constant, calculation or measurement of the field and experimentally derived calculations of the parameter of interest. Papers were presented on the effect of tissue propagation (Thijssen et al., p. 532) and experimentally derived beam corrections using scattering reflectors (Miwa et al., p. 524; Okijima et al., p. 528), or alternatively by employing the data from a C-scan over a single small reflector (Thijssen et al., p. 532).

The difference in results obtained using different test targets for calibration was discussed. Targets used were plane reflectors, spherical reflectors matched to the beam wave-front, and various scattering structures. No agreement was reached as to the most appropriate physical target to be used as the target should match the scattering properties of the tissue. A piece of the tissue itself provides a suitable target, but is not generally possible to achieve.

The global estimation of attenuation slope using the zero-crossing method was found to be independent of beam position, implying that in this case no beam correction was required (Ophir et al., p. 529).

**TEXTURE ANALYSIS**

The approach to image texture or speckle seems to be divided into two camps. In one camp the texture is regarded as containing useful information useful to the clinician, or worthy of statistical evaluation to extract useful tissue characterisation information (Thijssen et al., p. 507). The other camp views the texture in ultrasonic echograms as simply an interference phenomenon influenced more by the properties of the ultrasonic beam than by the tissue itself. The consensus of the discussion was that both approaches have their place. In fact if the words texture and speckle are given very specific meanings there are not in fact two "camps." Texture is a general term used for any pattern of grey levels in the echogram which will usually, though not necessarily, include speckle, which is the interference pattern produced when structure finer than the system is capable of resolving is interrogated with coherent sound. The aims of speckle reduction schemes should be to leave the component of image texture due to resolved object texture unaltered and available for texture analysis (Bamber et al., p. 545). Reduction of the amount of speckle may well lead to improvement in grey scale contrast resolution to reveal small local differences in echo properties while the characteristics of the textural pattern become more important in the analysis of diffuse diseases where the properties of the image texture may be the only parameter available for the evaluation of the condition.

**IMAGING**

The philosophy behind tissue characterisation imaging is that the spatial distribution of the tissue characterisation parameter is at least as important as its absolute value. If a reasonable quality image of the distribution of the parameter can be provided to the clinician, he can then use the same interpretative powers which he already uses on the images obtained from ultrasound, X-ray, nuclear medicine, CT and MRI. The parameters for imaging presented at the conference included instantaneous frequency (FM imaging), attenuation, spectral slope and the non-linearity parameter.

A system for imaging the instantaneous frequency was described (Ranalli, p. 495) and clinical results presented (Rifkin et al., p. 88; Aufrichtig et al., p. 82). Claimed advantages of this system included clearer delineation of regions of macronodular liver cirrhosis and hepatic portal fibrosis. As the techniques necessary to generate the frequency modulation images have not been disclosed it was difficult to assess the relevance of the technique. It appears, however, that the system was not pure FM but contained considerable amplitude information as well. It was suggested that perhaps the system was actually displaying the intercept on the zero frequency axis of the spectral slope as has been previously described by Lizzi et al. Although the images presented were interesting, insufficient data were avail-
able to make a proper technical and clinical evaluation of the technique.

An attractive method for superimposing tissue characterisation parameters on good quality conventional grey scale images by the use of colour coding was demonstrated. One paper (Lizzi et al., p. 497) showed encouraging examples as a means for differential diagnoses of intraocular tumours. In this work, images of scatterer size, cepstrum, and discriminant functions based on a number of spectral features were displayed for ocular and abdominal tumours. The response to treatment in ocular tumours could be followed. Other parameters suggested include local attenuation, spectral slope (Wilson, p. 527) and non-linearity parameter (Akiyama et al., p. 503; F. Dunn et al., p. 502).

It was concluded that imaging of tissue characterisation parameters is a useful technique which should be explored more fully.

**SIGNAL PROCESSING AND TISSUE DYNAMICS**

A number of signal processing systems were presented, which had application to tissue characterisation. The determination of acoustic impedance was suggested by one paper (Schibuya et al., p. 504) while another applied a sophisticated deconvolution technique to the eye to determine reflector geometry, attenuation and acoustic impedance (Herment et al., p. 514). Analysis of the echo reflected from lung surface was shown to be useful in the detection of pulmonary edema (Rhyne et al., p. 530). Cepstral analysis was used to differentiate between normal myocardium which had a single peak in the response, and infarction which had a double peak (Matsumoto et al., p. 512).

Two papers described the use of tissue motion induced by cardiac or aortic pulsation as a diagnostic parameter. In one (Dadd and Wilson, p. 506), the phase of backscatter was tracked in a radio frequency M-mode recording to measure displacements and compressions. Another approach (Tristam et al., p. 505) was to use the correlation between adjacent M-mode lines of sight to detect motion. Both papers reported variations between normal and abnormal liver.

**CONCLUSION**

It was agreed that, using the definition that a technique is clinically accepted when it is used away from the laboratory where it was developed, ultrasonic tissue characterisation has to date had a disappointingly low acceptance. The ways to improve this situation seem to lie in a number of areas.

The entity which is related or correlated with the value of the tissue characterisation parameter should be well chosen, so that the specificity of the technique is increased. Increased application should be made of superimposing the distribution of local values of the parameter on a high quality grey scale image either by colour or overlay. In this way the pattern- recognition properties of the eye and brain can come into play more readily. If suitable techniques were made available in commercial equipment, it would allow a greatly expanded effort of clinical investigation of tissue characterisation to be carried out in diverse clinical fields.

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**REFERENCE**