Secondary Sound Classification for the Assessment of Focus Positioning in Shock-Wave Lithrotripsy

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In Proceedings of Nordic Meetings in Medical and Biological Engineering, p. 64, Lund, Sweden, June 1993.
SECONDARY SOUND CLASSIFICATION FOR THE ASSESSMENT OF FOCUS
POSITIONING IN SHOCK-WAVE LITHOTRIPSY

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A problem encountered when using acoustic shock-waves for kidney stone disintegration is that the positioning of the focus relative to a stone, for the best possible fragmenting effect, is critical. The standard methods for focus positioning are ultrasound or x-ray imaging. These methods are, however, not always sufficient and a better indication of a well positioned focus would be valuable. The secondary sound emitted as a result of each shock-wave has been found to contain useful information. A skilled operator is able to hear from the timbre of these sound pulses when the positioning of the focus is adequate. A method for the automatic evaluation of secondary sounds, using a computer, is developed in this work.

Since the sounds are transient, time-domain features, such as the envelope, could contain relevant information. Due to the variable multipath propagation from the sound source to the microphone, however, the envelope is not reliable for this application. The frequency content is, therefore, used as a basis. Previously, a method using an autoregressive signal model has been developed and the findings published. The frequency magnitude function of such a model coincides well with the main characteristic of the signal spectrum. The classification was made using a projection of a multi-dimensional model parameter space onto a two-dimensional surface, where the separate clusters showed the different classes.

A new method, based on logarithmic power spectra of the sounds, has been developed. The spectra are parameterized using the coefficients of an expansion in a set of orthonormal base functions. These problem oriented base functions are calculated using a set of logarithmic spectra of sounds representing all the different classes. Singular value decomposition (SVD) of a matrix of these logarithmic spectra results in three matrices. One of the resulting matrices contains the base functions. Another matrix contains the corresponding coefficients for each spectrum. These coefficients represent points in a multi-dimensional space and the different classes collect as clusters in this space. Discriminating surfaces can be defined in this space and used to classify each new sound as it is recorded.

Secondary sounds have been recorded both clinically and using phantoms. These recordings have been used to develop and evaluate the algorithms. In both cases the results of the analyses show that it is possible to discriminate between efficient and non-efficient treatment. A severe problem, however, is that the classification criterion depends on the specific measurement arrangement and a new calibration would be necessary each time.