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EVALUATION OF DYSFUNCTIONS OF THE LOWER URINARY TRACT USING FREQUENCY DOMAIN TOOLS

AIMS OF STUDY

Non-invasive diagnostic methods of voiding dysfunctions, to date, are primarily based on the examination of a single value derived from the flow rate diagram (e.g. MFR, AFR, TMF, etc.). This single value, however, represents only part of the inherent information contained in a flow rate diagram; furthermore, in certain cases (for example, when the flow rate presents many irregular fluctuations), the diagnostic value is inhibited.
The method presented herein is based on the investigation of the flow rate in the frequency domain. This is achieved using the Discrete Fourier Transform (DFT), and by examining the value of certain parameters of the DFT coefficients. The motivation for investigating the spectral characteristics is the intuitive argument that for a normal person voiding evolves smoothly, and thus has a low frequency content. The outlined process takes into account all the flow rate values during the entire voiding process to form its spectrum, and therefore, exploits, significantly more information than present methods.

PATIENTS AND METHODS

The present method has examined a population of 60 people. These people have been classified as having normal (31 samples) or abnormal (29 samples) voiding behavior, based upon medical diagnosis. For each of these people, the flow rate has been recorded (at a sampling rate of 10Hz) and digitally filtered to reduce noise. Then, the spectral content of the flow rate has been obtained, by applying DFT. The DFT provides a sequence of coefficients for frequencies between 0 and 5Hz (with a 0.01Hz step), where higher frequencies correspond to abrupt temporal changes in the flow rate.
Typically, the flow rate of a normal person presents smooth changes in time and is similar to a bell-shaped function. The flow rate of a person with a voiding disjunction, on the other hand, may present significant fluctuations and may deviate from the bell shape, depending on the cause of disjunction. In the frequency domain, this behavior is reflected to a mainly low frequency content for normal people and a significant high frequency

content for abnormal people.
The DFT coefficients represent the contribution of each frequency in the shape of the flow rate. The coefficients sequence is then processed to derive their maximum value, as well as, statistical properties, namely, the mean, standard deviation (std.) and variance (var.). The maximum value for all samples coincides with the coefficient at the 0th frequency, that is, it represents the DC component of the spectrum, and is equivalent to the AFR. The extracted values are then used to create the plots of mean *vs.* max., std. *vs.* max., and var. *vs.* max., for each sample. The different spectral content between normal and abnormal people is expected to be apparent in some (or all) of these diagrams, should the underlying principle be valid. The outlined process has been implemented in software.

RESULTS

The following plots depict the obtained results. In these plots, normal people values are denoted by '*', and abnormal people values are denoted by 'o'.

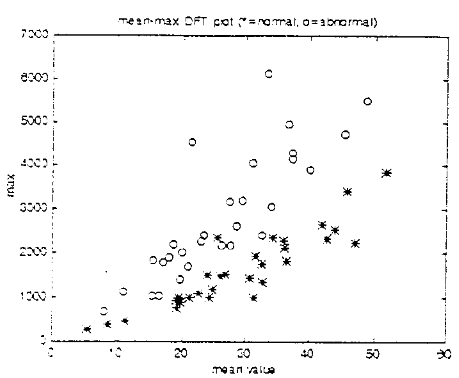

Figure 1

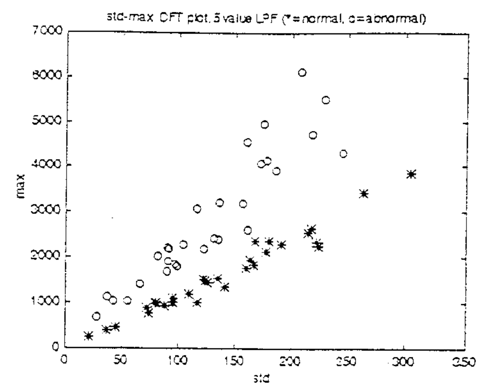

Figure 2

In Figure 1, the mean value of the DFT coefficients is plotted vs. the maximum value of the coefficients. This plot clearly indicates the existence of two clusters. For the same value of the maximum coefficient (that is, for the same AFR), normal people present a higher mean value of the DFT coefficients. Most samples in this plot agree to their initial classification.
In Figure 2, the value of the standard deviation for the DFT coefficients is plotted vs. the maximum value of the coefficients. This plot also indicates clearly the existence of two distinct clusters for normal and abnormal people. For the same value of the AFR, normal people present a larger value for the standard deviation of the DFT coefficients, than abnormal people do. A large standard deviation means that the dispersion of the values for normal people is bigger, and consequently, that the values of the remaining coefficients are very small compared to the maximum one. This, in turn, means that the frequency content is concentrated to lower frequencies, unlike in cases where a smaller standard deviation is observed. The agreement of the diagnostic results in this plot to the initial diagnosis is complete.

CONCLUSIONS

The above results enforce the argument that a normal person's flow rate contains lower frequencies, and thus, the voiding function can be performed smoothly. The std. vs. max. plot exhibits a more distinct separation of the clusters and is strongly suggested for diagnostic purposes. The agreement of the frequency domain results to those obtained with time-domain methods is almost complete. Future research will be directed (i) on the development of additional criteria in the frequency domain, (ii) on the establishment of clear boundaries between clusters, and (iii) on the examination of a larger and more dispersed group of people.

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