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A study on acoustical parameters for the characterization of artificially removed adult renal stones

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ABSTRACT

In the present investigation, Ultrasonic characterization on artificially removed (in and around Chidambaram town) human renal stones are studied to determine further the design parameters such as sonic velocity, specific acoustic impedance and modulus of elasticity etc., to develop a kidney stone disintegrator. Due to the variation in the chemical composition of the stones, a large variation in the value of ultrasonic parameters is found. The results give the necessary information about the ultrasonic propagation in different type of renal stones.

Keywords: Ultrasonic velocity, Kidney stone, acoustic impedance, attenuation.

INTRODUCTION

Now days, ultrasonic wave velocity has been used in conventional medical diagnostics therapy and surgical tools in different sensitive parts of the human body such as glands, heart, urinary tracts, reproductive organs etc.[1,2]. Especially in human physiological system, kidney is a major organ, which separates extra minerals, water, wastes, etc., from the blood after digestion. In the pathological condition let the kidney failure, inhibitor disorder and increase in mineral values in the blood or urine continuously, one can get the renal stones anywhere in the urinary tracts. The presence of such stones causes discomfort to patients and disruption of these stones is, generally, by surgical means. Several other techniques like laser, extra corporeal shock wave lithotripsy, explosives[3,4] have been used for the removal of the stones non-invasively and have created large disadvantages such as tissue damage, pain etc., It can be overcome by ultrasonic method of treatment[5,6]. In the present study, ultrasonic parameters of kidney stones like ultrasonic velocity, acoustic impedance, attenuation and dynamic modulus of elasticity are determined. A large variation in the ultrasonic properties of kidney stones has been observed due to their complex structures and variable compositions. It will provide valuable information for the development of disintegrators.

MATERIALS AND METHODS

The kidney stone samples, named as KS_1 to KS_{10} , used in the present study were procured from Rajah Muthiah Medical College and Hospital, Annamalai University. The chemical nature of the different kidney stone samples of both the sexes of patients, aged from 40 to 70, living in and around Chidambaram town were analyzed by FT-IR technique and confirmed by using X-ray diffraction study [7]. The chemical compositions of all the kidney stone samples studied by X-RD are given in Table 1.

Table 1.Chemical Nature of the Sample from X-RD Analysis

Sample	Chemical nature of the sample	Name of the chemical
KS_1, KS_2, KS_6 and KS_7	$C_5H_4O_3.2H_2O$	Uric acid
KS_3, KS_5, KS_8 and KS_9	$CaC_2O_4.H_2O$	Calcium Oxalate monohydrate
KS_4 and KS_{10}	$Ca_{10}CO_3$ $(PO_4)_5OH$	Carbonate hydroxy apatite

In the present investigation, the ultrasonic velocity on adult kidney stones was measured using a Pulse echo overlap technique at a fixed frequency of 10 MHz with good accuracy. A double probe contact (between the kidney stones) through transmission technique was used for the measurement of parameters. The sample faces were shaped to have better flat surfaces. The ultrasound medical gel was used for proper acoustic coupling between the transducer and kidney stone samples.

The measurement of pulse transit time 't' for a known propagation distance 'd' gives a direct measurement of velocity as,

$U = d/t$ …(1)

Acoustic impedance

$Z=U\rho$ …(2)

The dynamic modulus of elasticity

$E_d= U^2 \rho$ …(3)

The attenuation coefficient

$\alpha = 20 \log [A_1/A_2] d^{-1}$ …(4)

Where A_1 and A_2 are the amplitudes (in V) of the reference signals wit and without the kidney stone respectively.

RESULTS AND DISCUSSION

The average values of velocity and other related parameters in various kidney stone samples (ten in this case) were measured and calculated using the equations 1-4 and are given in the Table 2.

Table 2. Average values of ultrasonic parameters on kidney stones at 10MHz

Sample	U	ρ	Z X10^{-6}	E_dX10^{-9}	α
	ms^{-1}	kgm^{-3}	Kg $m^{-2}s^{-1}$	Nm^{-2}	dB/cm
KS_1	2301	898.3	2.066	4.756	4.761
KS_2	2221	933.3	2.072	4.603	5.676
KS_3	3010	1568.1	4.719	14.207	3.185
KS_4	1836	1018.5	1.869	3.433	11.541
KS_5	2963	1576.1	4.669	13.837	3.768
KS_6	2234	1101.1	2.459	5.495	5.271
KS_7	1972	1790.0	3.529	6.961	5.869
KS_8	2986	1580.7	4.719	14.093	3.535
KS_9	2780	1582.6	4.399	12.231	3.727
KS_{10}	1816	1866.7	3.389	6.156	12.166

The large variation in the ultrasonic parameters viz., propagation velocity, acoustic impedance, dynamic modulus of elasticity and attenuation was found. The ultrasonic propagation velocity of the kidney stones has been found to vary from 1816 to 3010 m/s. It was observed that as the velocity increases, the absorption decreases. The attenuation (α) varies from 3.185 to 12.166 dB/cm in the present work. Acoustic impedance and dynamic modulus of elasticity are found to vary from 1.869 to 4.719 and from 3.433 to 14.231 respectively.

The variation in the values of the samples was mainly due to the complex chemical composition of stones (i.e.,) due to the presence of calcium, magnesium, and ammonium phosphate as well as due to the geographical reasons. Thus, it has been found that the kidney stone samples having a greater percentage of oxalates have a greater ultrasonic velocity and the samples having phosphate and other constituents were found to have low ultrasonic velocity.

The determined values of ultrasonic data will help the design of ultrasonic disintegrators for the disruption of kidney stones. The similar observations were made by Agarwal et al.,[8] and Singh et al.,[9].

CONCLUSION

A comparative study of ultrasonic properties and chemical constituents of kidney stones have been made. Kidney stones having a greater percentage of calcium oxalate monohydrate and a higher ultrasonic propagation velocity were found to be more difficult to disrupt, in comparison to the other types of stones. Thus, the determined values of ultrasonic data will help the design of ultrasonic disintegrators for the disruption of kidney stones.

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