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# Determining Skin Thickness with Pulsed Ultra Sound

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**A high frequency, high resolution ultrasonic echo technique is presented for determining the thickness of human skin. An experimental series is described in which the accuracy of this new technique is demonstrated by comparison with a radiological method of proven accuracy. The "ultrasonic biometric ruler" is shown to provide an accurate, simple, noninvasive method for measuring full-thickness human skin. In addition to the determination of skin thickness, it is demonstrated that the underlying subcutaneous fat and muscle can also be noninvasively "explored" with the possibility of identifying a variety of skin and underlying tissue lesions.**

During the development of a system for the measurement of the mechanical properties of human skin as described by Alexander, Cohen, and Cook [1–3] it became necessary to measure skin thickness *in vivo*. This would allow experimental results to be expressed in terms of skin stress (force/area) rather than skin tension (force/length); normalizing the data with respect to thickness differences. In addition, the measurement of thickness alone has many clinical uses including the detection of osteoporosis [4], the assessment of acromegaly [5] and the measurement of degree of dermal atrophy caused by topical corticosteroids [6,7].

The noninvasive measurement of skin thickness has been proposed and used clinically in the past with varying degrees of success. The clinical evaluation by palpation is, of course, inexact and misleading due to variations in subcutaneous fat. The most widely used and accepted technique is by the measurement of skin fold thickness with the Harpenden skinfold caliper. However, subcutaneous fat and "pinching force" variations do significantly contribute to errors in the use of this technique even though recently reported modifications [8] using a "minimal" fold of skin have demonstrated promising results. The most accurate method available to date is the radiographic technique first proposed by Black [9] in which the skin on the radial aspect of the forearm is flattened against a wood block and an x-ray beam is projected parallel to the skin onto a photographic plate. The disadvantages of high x-ray levels and shape changes occuring in a wood block have been minimized by Dykes and Marks [10] through the use of Xerography and a lucite block. However, this method still has the disadvantages of potential radiation hazards, limitation to use on the limbs and high cost per test.

This paper describes an ultrasonic echo technique for determining the thickness of human skin and presents an experimental series in which the accuracy of this new technique is demonstrated by comparison with the xerography procedure of Dykes and Marks [10]. In addition to the determination of skin thickness, it is demonstrated that the underlying subcutaneous fat and muscle can also be non-invasively "explored" using this procedure.

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## MATERIALS AND METHODS

High resolution pulsed ultrasound has been in use for a number of years in the determination of ocular geometry [11] and the diagnosis of choroidal tumors [12]. Geometry is determined by measuring the total transit time of high frequency sound pulses that are beamed into the eye and reflected off tissue interfaces where high acoustical impedence gradients are encountered. If the tissue acoustical velocity is known, the measured times can be related to distances thus transforming a transit time trace to a spatial representation of the internal structure of the eye.

A commercially available system* with a resolution in soft tissue of approximately 0.05 mm was purchased and modified for use in the measurement of skin thickness. The pulse transit time is displayed on the cathode ray tube through a reflected signal amplitude versus time display. Upon dialing in the speed of sound in human skin, 1580 m/sec. as determined by Daly and Wheeler [13], electronic pointers are used to isolate 2 signals and measure the distance between the structures that generated these reflections. The distance in millimeters is digitally displayed in the upper left hand corner of the cathode ray display as is shown in the sample traces in Fig. 1.

To obtain optimal reflections from the various skin interfaces of interest, it was found that an unfocused transducer with a resonant frequency of 15 MHz should be used, beaming the sound waves through a bath of degassed water to avoid air bubble reflections (see Fig 2). A well-defined high amplitude water/stratum corneum echo is always present. However, the dermis/subcutaneous fat echo is not always easily distinguished from the echoes from other dermal and fat structures. Applying a small vacuum to the water bath, lifting the skin away from the fat, allows observation of the relative motion of the skin and the fat. This clearly distinguishes the dermal/subcutaneous fat interface (see Fig 1). Unfortunately, resolution limitations obviate the possibility of visualizing the stratum corneum/epidermis interface or the epidermis/dermis interface.

To establish the accuracy of this technique of determining full skin thickness, measurements were made on the radial aspect of the forearm of 10 normal male and female adults ranging in age from 24 to 37 yr. A direct comparison was made at the exact same location using the radiological method of Dykes and Marks [10]. Using a Siemans x-ray unit at 50 kv-50 ma seconds exposure, soft tissue x-rays were directed at the 15 × 40 mm flattened skin of the forearm from a 1 m distance and detected by a radiation sensitive selenium coated plate. The plates were processed in a Xerox system resulting in a permanent positive image. These images were photographed and magnified to the same scale as the ultrasonic cathode ray display. The dark band due to the full thickness skin was easily distinguishable. Its thickness was measured at 7 points using a millimeter ruler encompassing the field seen by the ultrasound probe. The average of the measurements was compared to the corresponding ultrasonic determination.

## RESULTS

A typical output comparing radiological and ultrasonic determinations is shown in Fig 3. The almost one-to-one correspondence between x-ray visualized structures and ultrasonic echoes is quite dramatic. It is possible to identify the skin, the subcutaneous fat and the muscle by the location of the signals on the ultrasound display. These tissue structures are labeled in the x-ray display for the purpose of direct comparison. Minor structures within the skin and the fat provide low amplitude echoes. However, the major echoes are definitely associated with the water-skin, skin/fat and fat/muscle interfaces.

* Model 300 Biometric Ruler, Sonometrics Systems, Inc., 2067 Broadway, New York, New York 11123.

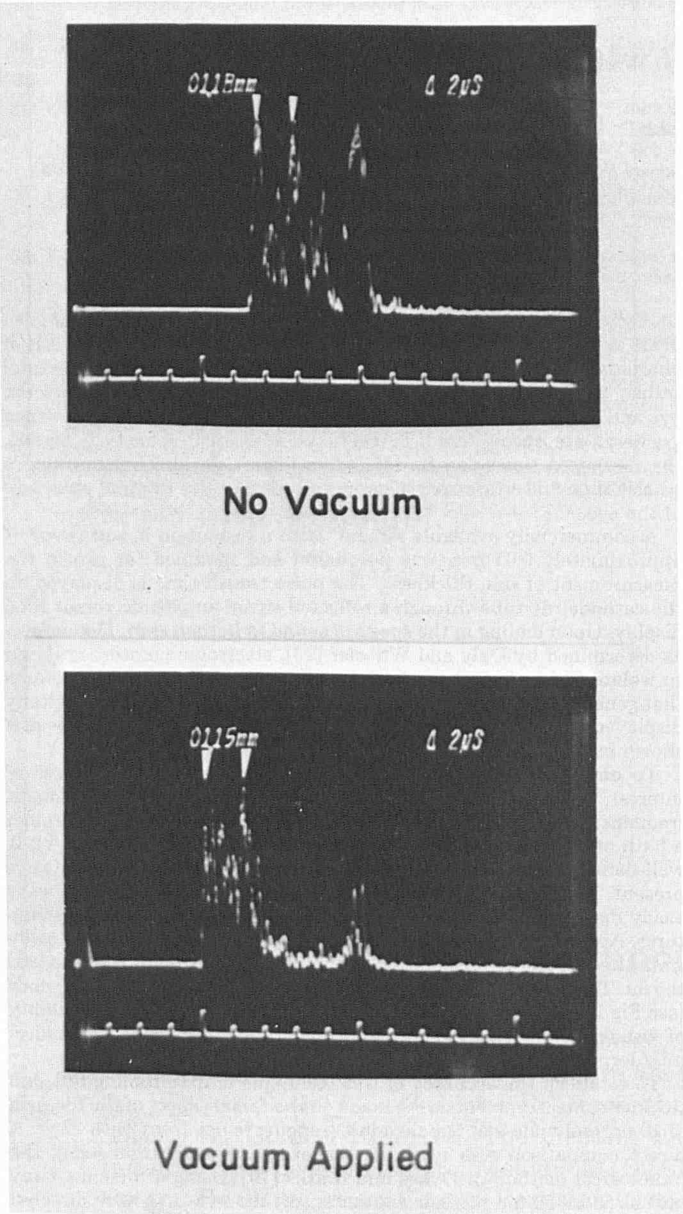


FIG 1. Cathode ray tube display of ultrasonic echos and digitally displayed skin thickness at various transducer water bath vacuum levels.

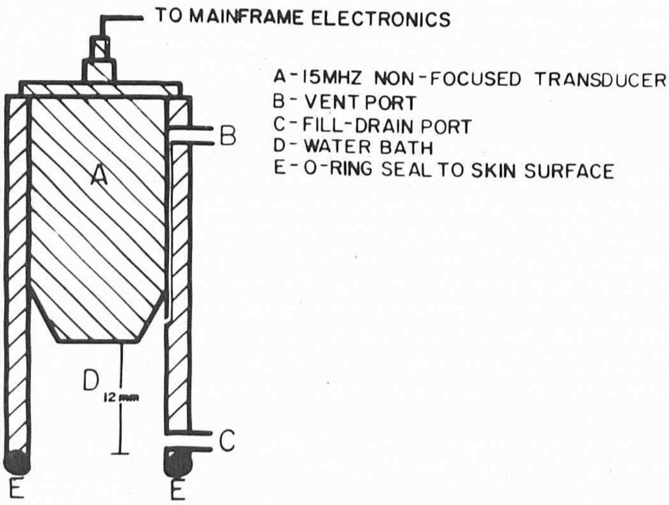


FIG 2. Ultrasonic crystal transducer assembly.

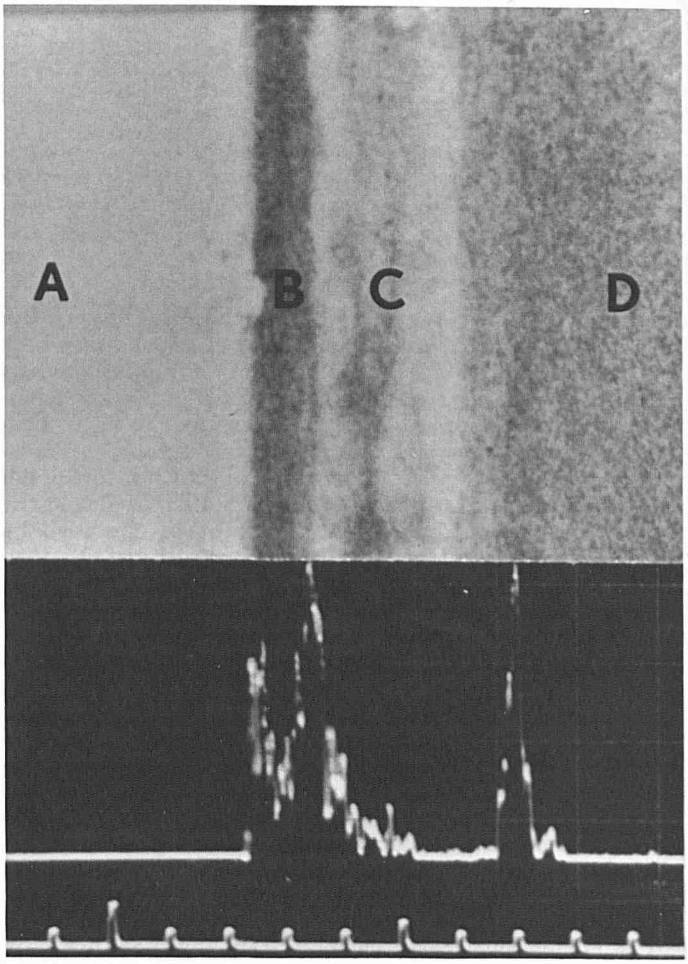


FIG 3. Comparison of X-ray and ultrasonic echo displays. *Upper display,* X-ray; *lower display,* Ultrasound. *A,* Lucite-block, *B,* skin, *C,* fat, *D,* muscle.

TABLE I. *Summary of x-ray and ultrasound data*

| Subject | Sex | Age(yr) | X-ray thickness (mm) | Ultrasonic thickness (mm) |
|---|---|---|---|---|
| TD | M | 37 | 1.19 | 1.00 |
| EP | M | 29 | 1.18 | 1.16 |
| TC | M | 24 | 1.05 | 1.16 |
| NF | M | 27 | 1.18 | 1.16 |
| EK | F | 28 | 0.84 | 0.75 |
| AB | F | 34 | 0.82 | 0.75 |
| JM | F | 37 | 0.92 | 0.92 |
| LB | F | 32 | 0.95 | 0.92 |
| DM | M | 35 | 0.90 | 1.16 |
| EA | M | 33 | 1.13 | 1.08 |

Table I contains the compilation of the results obtained from the measurements of all 10 subjects. Comparing the full skin thicknesses determined by ultrasound and x-ray, a correlation coefficient of $r=0.99$ was computed. A rank correlation coefficient of $r_s=0.91$ was obtained making the correlation significant at the 95% confidence level.

## DISCUSSION

The ultrasonic skin thickness measurement technique compares quite favorably with the x-ray method previously reported to be accurate. In addition, the subcutaneous fat layer and the outer surface of the underlying muscle belly can also be visualized. Certainly, the thickness of the fat layer can be determined as simply as was the skin thickness using the appropriate sonic velocity. This might be a very useful screening procedure in the identification and treatment of obesity. It might be possible to draw conclusions noninvasively about the internal structure of skin, fat and muscle by observing the attenuation of signal and the emission of minor echoes. It might even be feasible, as was done in the eye by Coleman et al [12], to identify tissue lesions and determine their form and possible malignancy by studying these ultrasonic echoes in detail.

## CONCLUSIONS

It has been demonstrated that readily distinguishable pulsed ultrasound echoes can be obtained from skin, subcutaneous fat and muscle and the thickness of the skin can be accurately measured with this method. Since it involves a direct visualization of a small segment of unloaded skin, the ultrasound technique is probably the most accurate technique currently available. Additionally, it has the other advantages of (1) being usable any place on the body regardless of cross-sectional depth and skin-fold availability, (2) not involving any radiation hazard, and (3) low cost per test when compared with the radiological technique. This new technique is noninvasive and simple to perform. It should prove to be of clinical value in the diagnosis and assessment of therapy for a variety of disorders that affect skin thickness and mechanical properties.

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# International Symposium on the Treatment of Psoriasis-Arthritis

This International Symposium is planned to enable dermatologists from different countries to present and discuss recent contributions in the field of different types of therapy of psoriasis and psoriatic arthritis. A partial list of speakers includes: Drs. D. Machtey, H. Maibach, A. Luger, S. Delbarre, T. Ryan, W. Avrach, and F. Sager. For those wishing to present free communications, abstracts of no more than 300 words should reach the organizer no later than December 15, 1978. The sessions will take place in Tel Aviv and at the Dead Sea Psoriasis Treatment Center, Feb. 26–March 3, 1979.

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