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Ultrasonic Differentiation of Normal Liver Structure As a Function Of Age and Species

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Introduction

Echograms of normal human liver obtained by previous investigators using ultrasonic visualization techniques show acoustic reflections from the outer surface but little or no reflections from the interior. However, when pathological conditions are present in the liver such as abscesses, carcinoma or cirrhosis then strong acoustic echoes can be obtained from the regions of such abnormal conditions. Although sufficient progress has been made to allow clinical application of the ultrasonic visualization techniques to detect liver pathologies, a number of problems remain which, unless solved, would hinder a widespread use of the method. In addition, since the echo pattern obtained for normal liver does not show reflections from internal structures, it is apparent that, at the present stage of development, this technique is not likely to be successful as a detector of the early development of an abnormal condition. The approach taken, in the present study, to the problem of detecting the structure of normal mammalian liver by ultrasonic techniques is to use the cat as an experimental subject since its liver is morphologically similar to that of the human. Consideration was also given to the study of the livers of other species with anatomic features which might form good reflecting targets for the ultrasonic energy. The most widely accepted structural unit for mammalian liver is the so-called hepatic lobule of the pig. Viewed in cross section the pig lobule can be generally described as a polygonal shaped unit approximately 1.2 mm in diameter

with borders heavily outlined by connective tissue and with the approximate center occupied by the central vein opening; radiating from the borders of the lobule to the edge of the central vein are numerous sinusoids (capillaries) which are embedded in a continuous framework of hepatic cells laid down in the form of plates or sheets. This general description of the hepatic lobule is also acceptable for the liver of man and the cat with the exception that in both of these mammals the connective tissue between the lobules is poorly developed. The liver of the adult pig, therefore, makes a most interesting subject for acoustic study: its basic architecture is similar to that of other mammals (including man and cat) with the exception of the presence of connective tissue surrounding each lobule; this connective tissue structure is dense and completely distributed throughout the liver in a regular repeated pattern.

Materials and Methods

The acoustic system consists essentially of a one inch diameter, PZT, focusing examining transducer of 1.00 MHz frequency, an elliptically shaped reflector designed to receive pulses reflected from the biological sample and re-reflect them to a second reflector (hyperboloid in form) which directs the signals into a 1/8 inch diameter lithium sulfate receiving transducer. (Olofsson, S., Acustica, 13, 361, 1963) The good azimuthal resolving power of this system is one of its primary advantages. The signals from the receiving transducer are transmitted through a linear amplifier system, and displayed finally on a cathode ray tube. The unit containing the two transducers and the two reflectors is under automatic control and can scan all the major aspects of the intact liver of the experimental animal by movement in three mutually perpendicular directions and wobbulation in a vertical direction at an angle of $\pm$ 20°. For in vivo experiments the anesthetized experimental animal mounted in a chair type device is immersed to the top of its chest in a sound tank containing 38°C degassed distilled water.

Experiments

A series of acoustic visualization experiments were carried out on sections of freshly excised liver of adult pigs and adult cats. The general result found was that at cathode ray intensity and amplifier gain settings at which essentially no

reflections could be detected from the excised liver of the cat, dense reflections were recorded throughout the tissue of the pig. In view of these results, efforts were concentrated on the problem of detecting the structure of cat liver with particular emphasis on using a linear amplifier system that would give greater sensitivity or gain than that previously applied. Using this more sensitive instrumentation the next series of ultrasonic visualization experiments was carried out with a unique biological preparation in which part of a liver lobe of a live cat was extruded outside the abdominal wall with circulation completely intact. This preparation had all the advantages of an in vivo sample with intact circulation with the added advantage that the liver tissue was directly exposed to the sound energy without any interference of overlying tissue. It was found that with sufficient amplifier sensitivity it was possible to detect the internal structure of the cat liver not only for the extruded liver lobe but also for the intact and excised livers. The individual reflections obtained from the internal structure of the cat liver were of smaller dimensions than those obtained from adult pig liver. It is of interest to compare echograms of the livers of the cat and the pig obtained under in vivo conditions. Since it was not feasible, because of their weight and size, to carry out an in vivo study with adult pigs, a purebred strain (Poland China) of young female pigs, ranging in age from three to eight weeks, was used. Histological studies were carried out on the livers of young and adult pigs and adult cats. In the case of the young pigs, these studies definitely showed the presence of the polygonal shaped lobular pattern formed by light connective tissue. The histological results for the adult pig and adult cat agree with the results described in the literature which are outlined above.

Using the techniques previously described, for each experimental pig ultrasonic scans were made of the intact liver, the exteriorized liver and the excised liver. For each of these scans four sensitivity settings of the linear amplifier system were used with a factor of ten from minimum to maximum. At the completion of the excised liver scan, the tissue was prepared for histological study. Precisely the same series of experiments, with the exact conditions of instrumentation settings was carried out on the liver of adult cats. Therefore, the results of the ultrasonic

scans could be precisely compared for the two species. The complete details of the results of this study can not be presented here, but the primary finding was that with sufficient amplifier sensitivity the liver structure of both species can be detected with approximately equal clarity and, under the same conditions of sensitivity of the instrumentation, the ultrasonic echograms of the livers of the young pig and of the adult cat are very similar. Since cat liver tissue has little connective tissue in comparison with the regular pattern of connective tissue of the young pig and since it is morphologically similar to human liver, the result is important in studying the role of ultrasonic energy in detecting the structure of normal human liver.

The echogram of the liver of the adult pig can be easily distinguished from that of the liver of the young pig (or adult cat) since the reflection pattern is made up of larger structural units with considerably greater intensity for the same sensitivity setting. It is of interest to know whether this acoustic reflection pattern of the liver of the adult pig is specifically associated with the most predominant feature noted in the histological studies - namely a continuously repeated pattern made up of polygonal lobules with diameters more than double that of the young pig and bordered by very heavy connective tissue. An initial investigation of this was carried out by studying freshly excised beef liver from an adult Hereford steer both by means of ultrasonic scans and by histological sections. The echograms obtained from this beef liver were almost indistinguishable from those obtained from adult pig liver. The histological studies showed the presence of a relatively large amount of heavy connective tissue but this was randomly distributed and definitely did not show any repeated pattern such as that of the liver of the adult pig.

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Note: The authors regret that references to other investigators' work on the ultrasonic visualization of liver tissue can not be given here because of space restrictions.