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DETECTION OF LIVER AND SPLEEN PATHOLOGY AFTER VINYL CHLORIDE EXPOSURE--POTENTIAL OF GREY-SCALE ULTRASOUND AND DOPPLER TECHNIQUES

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Diagnostic ultrasound is an attractive modality for the examination of soft organs such as the liver and spleen since it is totally noninvasive, causes no discomfort and no deleterious effects have been found at diagnostic doses.

Exposure to vinyl chloride monomer used in the production of PVC can lead to widespread abnormalities, an increased incidence of cancer in many sites and particularly, is associated with characteristic liver and spleen changes. Hepatotoxicity consists of capsular fibrosis and periportal fibrosis leading to portal hypertension and splenic enlargement. Portal hypertension often results in massive fatal hemorrhage.

Diagnostic ultrasound was used in a small sample of PVC workers in whom abnormalities identified by invasive techniques were confirmed, and in several patients other abnormalities were noted which had hitherto been unrecognized.

A further development in ultrasound diagnostic techniques is the use of the Doppler principle to estimate blood velocity and flow. This technique may be applied to determine the direction and volume of blood flow in the portal vein and to quantitate thereby the degree of portal vein obstruction resulting from pathological changes in the liver.

DETECTION OF LIVER AND SPLEEN PATHOLOGY AFTER VINYL CHLORIDE EXPOSURE--POTENTIAL OF GREY-SCALE ULTRASOUND AND DOPPLER TECHNIQUES

Diagnostic ultrasound has been used for many years in obstetrics and gynecology. Recent improvements in technology have increased the resolution to approximately 2-3 mm, and this is adequate to display the liver and associated vasculature.[1,2,3] Sections through the upper abdomen using the new grey-scale ultrasound technique now reveal similar anatomical details to those which hitherto could only be observed postmortem by pathological examination. The transverse anatomy which can be demonstrated by ultrasound is shown in Figure 1. Small subdivisions of the right branch of the portal vein are seen [arrowed] and the liver consistency is well displayed. This is a prerequisite for the identification of liver and spleen changes in response to vinyl chloride exposure.

One of the major visceral complications of prolonged exposure to vinyl chloride monomer (VCM) is the development of subtle pathological changes in the liver which result in obstruction to blood flow and development of hypertension in the portal vein.[4] One sequel of such hypertension is the development of varicose veins in the lower esophagus, and 25% of patients with portal hypertension die from massive hemorrhage due to rupture of these varicose veins. In ninty percent of patients, portal hypertension is associated with cirrhosis of the liver due to alcohol abuse. Thus, techniques to image the liver substance must attempt to differentiate between alcoholic cirrhosis and VCM-related liver changes. Ultrasound is the only modality which displays normal and abnormal consistencies thereby permitting this differentiation. Since portal vein obstruction results from VCM exposure, the anatomy of this system is first considered.

Figure 2 shows a schematic diagram of the portal vein system which collects blood from the bowel. The vein draining the spleen is a large structure which is joined by the inferior mesenteric vein, receives small tributaries from the pancreas, and then joins the superior mesenteric vein to form the portal vein posterior to the neck of the pancreas. The portal vein thereby conveys blood to the liver. A transverse ultrasound section [Figures 3a & b] shows the splenic vein receiving tributaries from the spleen, receiving the inferior mesenteric vein and joining the superior mesenteric vein to form the portal vein.

The portal vein seen in Figure 2 passes from the region of the duodenum to the porta hepatis. At this point it lies anterior to the inferior vena cava. An ultrasonogram [Figure 4] in the longitudinal plane shows the portal vein [arrowed] as a rather straight structure, which is well visualized in every patient. In patients with vinyl chloride-related liver pathology, there is obstruction to the portal vein, and the pressure rises within it. At surgery, a large, tortuous portal vein is seen; and this is also seen on ultrasound examination [Figure 5]. The most common cause of portal hypertension is cirrhosis of the liver, but the appearances of a cirrhotic liver on ultrasound examination are different from the more localized periportal fibrosis one sees in the liver of these workers with vinyl chloride-related disease.[5] In VCM-exposed workers, fibrotic changes have been described on the surface of the liver,[6] and the dense echoes seen on the surface of the liver [arrowed in Figure 5] are consistent with such capsular fibrosis. The liver substance does not appear as abnormal as that seen in a cirrhotic liver from which abnormally large echoes are returned with increased attenuation.[7]

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When there is obstruction of the portal vein and portal hypertension develops, the spleen becomes passively congested since the splenic vein drains into the portal venous system. Thus, portal hypertension is suggested by the demonstration of an enlarged, congested spleen. However, the spleen is an organ which is difficult to assess clinically since it is under cover of the ribs, whereas radiography of the abdomen is also unreliable for the detection of mild to moderate splenomegaly. Spleen size can, however, be assessed by ultrasound examination, and the spleen of a vinyl chloride worker is shown in Figure 3b. The longitudinal axis is 14 cm, whereas the normal is less than 10 cm.

A preliminary survey was undertaken in 1975 of 19 workers from the British Petroleum plant, Swansea, South Wales.[8,9] Their exposures were well documented, and their medical condition fully investigated. The ultrasound examination was performed without knowledge of their exposure nor of their medical history. All ultrasound examinations were carried out by one of the authors (K.J.W.T.) and results subsequently compared with their medical and exposure history. These preliminary results have been published and are summarized here.

Four patients unequivocably normal after full investigation were found to be so on ultrasound examination. Minimal changes in two other patients were not detected by ultrasound. Nine patients with known liver disease varying from minor fatty infiltration to established portal hypertension were all confirmed to be abnormal on ultrasound examination. The four remaining patients were all definitely abnormal on ultrasound, although only two had known minimal changes consisting of elevated liver enzymes. On further investigation, three out of four of these abnormalities were confirmed. In assessing the value of ultrasound, it must be recalled that this method does not involve ionizing radiation nor any other known hazard, is totally painless to the patient and is therefore a method ideally suited for mass screening.

Since these preliminary results were reported, further technical developments have evolved which should refine the technique and increase the sensitivity. The basic pathological result of VCM liver damage appears to be the progressive obliteration of the portal vein radicles which must be accompanied by decreasing flow in the portal vein with ultimately a reversal in flow direction.[4] Ultrasound using the Doppler technique should be a sensitive and noninvasive modality to detect these changes in flow rates.

Doppler flowmeters are based on the principle that the echo reflected by a moving target is shifted in frequency. The amount of shift depends, amongst other things, on the velocity of the target in the direction of the transducer. Thus, if the portal vein can be demonstrated ultrasonically, then the velocity of blood flow through it can be estimated by frequency analyzing the Doppler shifts in the returning echo and correcting for the angle of incidence. In order to study only those signals originating from the portal vein (which is located close to other major vessels), it is necessary to use a pulse-Doppler flowmeter. This device is able to monitor the flow at any selected point on the ultrasound scan. A short burst of ultrasound is transmitted and the returning echo is sampled after a delay which allows time for the ultrasound to travel to and from the vessel of interest. This ensures that any Doppler shifts which are detected originate from blood moving at the selected range within a small region known as the sample volume. By pointing the transducer in a different direction and varying the range delay time, the sample volume can be positioned in any ultrasonically accessible region.

Reliable Doppler flow studies of the portal venous system can be performed by linking a pulse-Doppler flowmeter to a conventional ultrasound scanner. Such an interface has been achieved and described by one of the authors (P.A.).[10] A long section of the vessel is identified on the ultrasound scan and then the machine switched to the Doppler mode. The same transducer is used for both modes of operation. The sample volume is marked by a bright-up cursor on the B-scan [arrowed in Figure 4], and is maneuvered into the lumen of the portal vein. The Doppler signals from this point are monitored and frequency analyzed to determine the velocity flow components. If required, volume flow rate can be estimated by measuring the calibre of the vessel and the angle of the ultrasound beam.

During a preliminary evaluation of the technique, the volume flow in a series of five normal subjects was found to lie within the commonly accepted range of values. This study also revealed that the mean velocity through the portal vein was similar to that through the inferior vena cava, the difference in volume flows being accommodated by differences in the calibre of the two vessels. The Doppler information will be improved by including a direction-sensing facility which is currently under construction. This will allow recognition of the large reverse flow which can occur in advanced stages of portal hypertension.

In conclusion, ultrasound is a safe, noninvasive modality which permits the display of the portal vein and spleen together with the characteristic changes associated with portal hypertension. The display of the liver consistency should permit differentiation from cirrhosis. The addition of blood-velocity monitoring by Doppler should increase the sensitivity of ultrasound for the detection of VCM-related liver disease.

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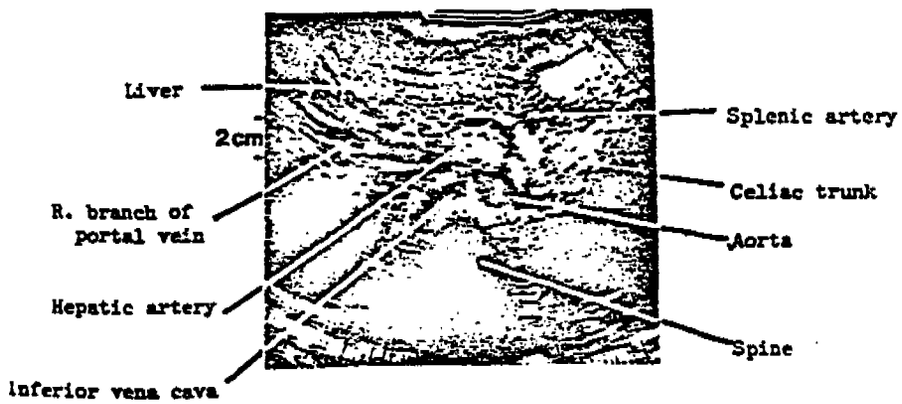

Figure 1. Transverse ultrasound scan through the abdomen showing the great vessels and their small subdivisions. Vessels with lumens less than 4 mm are very well visualized.

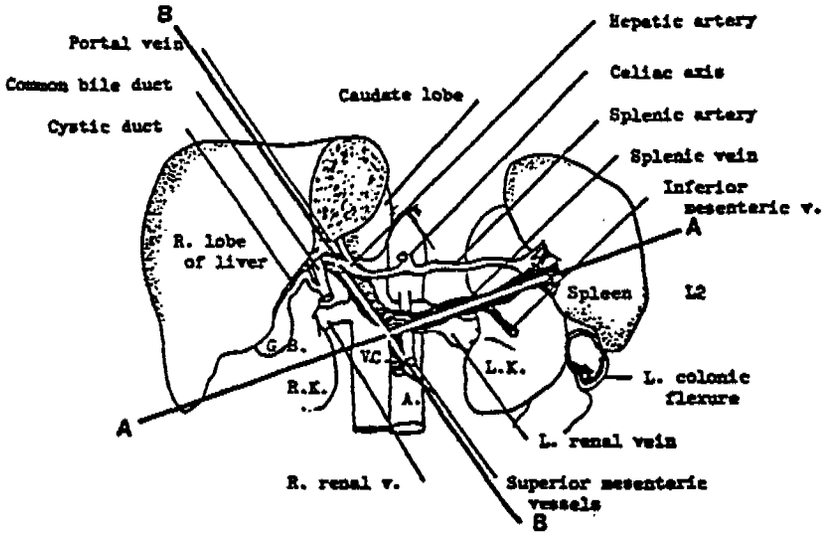

Figure 2. Schema of upper abdominal organs and vessels to show portal vein formed by junction of splenic vein and superior mesenteric vein seen in plane A-A. The portal vein so formed passes upwards in front of the inferior vena cava [VC] into the liver in the plane marked B-B. A is aorta, LK and RK are left and right kidneys and GB is gallbladder. The level of the second lumbar vertebra [L2] is marked.

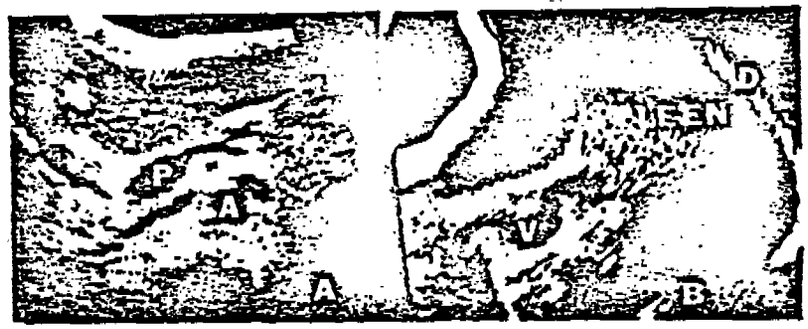

Figure 3a. Transverse ultrasound scan through liver in plane indicated by line A-A on Figure 2 showing splenic vein [arrowed] joining superior mesenteric vein to form portal vein [P]. The aorta [A] is seen posteriorly.

Figure 3b. Longitudinal section through an enlarged spleen in the plane A-A of Figure 2. The splenic vein [V] is seen leaving the hilum of the spleen. The spleen is limited above by the left side of the diaphragm [D].

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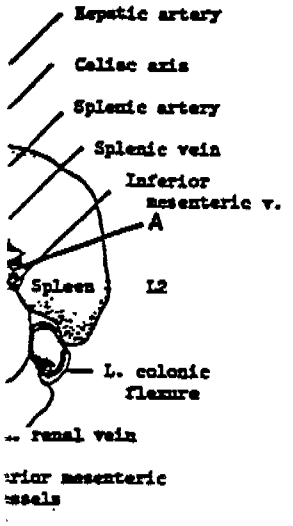

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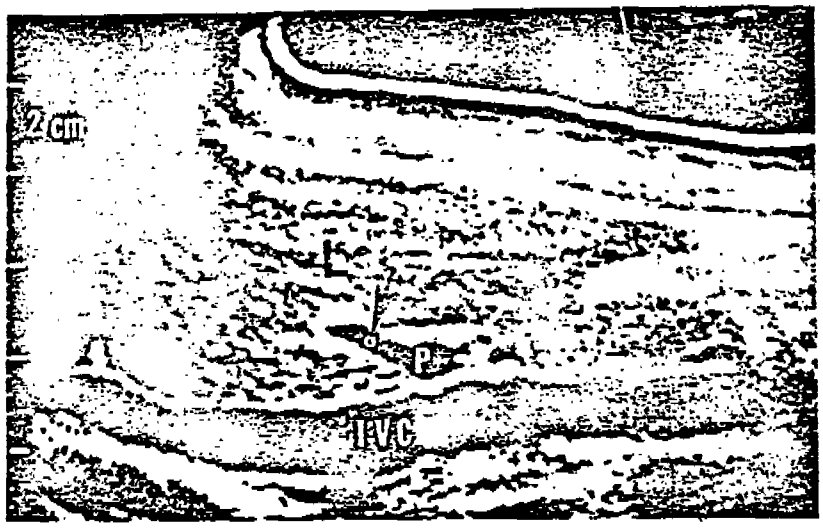

Figure 4. Longitudinal section through liver and great vessels in plane B-B in Figure 2. The inferior vena cava [VC] is seen posteriorly. The portal vein [P] extends upwards from its formation into the liver substance [L]. An electronic cursor [arrowed] can be moved into the portal vein to locate the source of Doppler flow information.

Figure 5. Longitudinal scan of portal vein [P] passing into liver substance. The portal vein is enlarged and highly tortuous consistent with portal hypertension in a patient with VCM exposure. In addition, multiple echoes appear as thick white lines on the surface of the liver [arrowed]. This is consistent with capsular fibrosis.

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