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TRANSCUTANEOUS ELECTROHEPATOGRAM IN HUMANS

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1. ABSTRACT

We could recently characterize a normal “electrohepatogram” (EHG) in a canine model. It consisted of monophasic positively deflected slow waves or pacesetter potentials (PPs). A “dysrhythmic EHG” was produced when the liver was insulted by hepatic vessel clamping or liver irradiation. The postulation that electrohepatography might act as an investigative tool in liver diseases prompted the author to develop the EHG percutaneously in humans. 23 healthy volunteers (16 men, 7 women; mean age 38.6 years) and 13 patients (8 men, 5 women; mean age 34.2 years) with huge supraumbilical ventral hernia were studied. The liver was exposed during the ventral hernia repair and 3 electrodes were sutured to the liver capsule. The optimal position for percutaneous recording was identified. The 3 electrodes were placed, 5 cm apart, on a transverse line, parallel to and 1.5-2 cm below, the costal margin. PPs were recorded from the 3 electrodes applied directly to the liver and from those applied to the skin. The wave was monophasic and positively deflected with a mean frequency of 8.3 cycle/s and amplitude of 56.5 µV. The PPs had the same frequency and amplitude from the 3 electrodes applied to the same subject. The percutaneously recorded waves were identical with those recorded directly from the liver. A percutaneous EHG could be characterized for the normal liver in humans. It might show changes in liver diseases and thus act as an investigative tool in the diagnosis of such conditions.

2. INTRODUCTION

The liver may be the site of many pathologic conditions including infections (bacterial or viral), abscesses, cysts, tumors, cirrhosis and others. The diagnostic tools for the liver are numerous and comprise sonography, CT scanning, scintiscanning, positron emission tomography, nuclear magnetic resonance, needle biopsy and others.

Electric activity could be recorded from various organs in the body including the stomach, intestine, gall bladder, sigmoid colon and rectum (1-23). It manifested as slow waves or pacesetter potentials (PPs) which may be followed by fast activity spikes or action potentials. The waves were recorded either transluminally or percutaneously (4,17,18,22). The electrogram exhibited wave abnormalities in disorders of the aforementioned organs (4,5,11,12,15,16,23,24).

Recently, we succeeded in identifying an “electrohepatogram” for the healthy liver in the canine model (25). It consisted of PPs, which were monophasic and had a positive deflection (figure 1). The waves had identical frequency and amplitude from the 3 electrodes, which were sutured to the capsule on the anterior surface of the canine liver. The mean frequency of the waves was 10.6 ± 1.8 cycles/s and the amplitude 63.7 ± 11.6 µV. The waves were reproducible when the test was repeated in the same animal. Liver insult was produced by temporary hepatic vessel clamping and by liver irradiation. Hepatic artery or portal vein clamping produced a “dysrhythmic EHG”: the waves showed irregular frequency and amplitude (25) (figure 2). Liver injury induced by irradiation effected 2 EHG patterns: dysrhythmic and silent in which no signals were recorded (25).

The findings of the aforementioned study prompted the author to study the possibility of performing electrohepatography percutaneously in humans aiming at establishing a simple and easy method of investigation, acceptable to the patients, for the diagnosis of liver disorders.

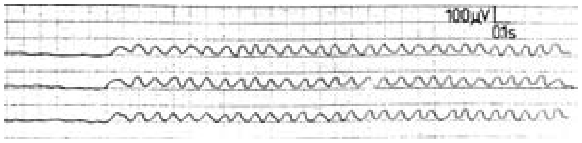

Figure 1. Electrohepatogram of a canine model showing the electric waves exhibiting the same frequency and amplitude from the 3 electrodes applied to the liver. (from ShafiK[25])

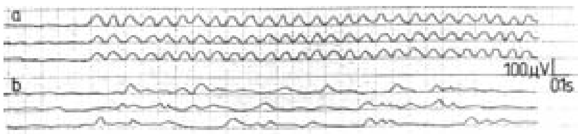

Figure 2. Electrohepatogram during hepatic artery clamping showing a "dysrhythmic pattern". The PPs had irregular frequency and amplitude. a) before clamping. b) during clamping. (from Shafik[25])

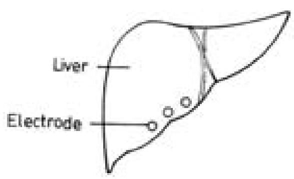

Figure 3. Site of electrode placement on the liver surface in humans.

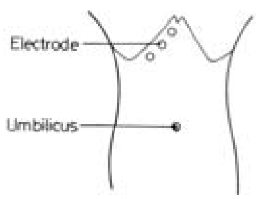

Figure 4. Site of electrode placement on the skin.

3. MATERIAL AND METHODS

3.1. Subjects

Twenty-three healthy volunteers (16 men, 7 women; mean age 38.6 ± 11.2 SD years; range 16 – 56) and 13 patients with huge supraumbilical ventral hernia (8 men, 5 women; mean age 34.2 ± 10.8; range 17 – 52) were enrolled in the study after giving an informed consent. All of the 36 subjects had normal liver functions and a normal liver on sonography. Physical examination was unremarkable in all the subjects.

We selected the patients with huge supraumbilical ventral hernia because hernia repair necessitated opening the peritoneal cavity and an access to the liver was thus easily and safely achieved. Our Faculty Review Board and the Ethical Committee approved the study.

3.2. Technique of electrohepatographic recording

The site of the percutaneous electrodes was defined at first in the patients with the ventral hernia so as to be able to compare the percutaneous signals with those obtained from the electrodes applied to the liver directly.

3.3. Direct recording

After dealing with the ventral hernia and while the peritoneal cavity was still opened, the liver was exposed. The method of direct EHG recording was already described (25) and will be mentioned in brief. Three silver-silver chloride electrodes (SmithKline-Beckman, Los Angeles, CA, USA), were fixed to the capsule of the anterior hepatic surface. They were placed as low down on the anterior surface as possible, approximately 1-1.5 cm from the lower edge of the liver, so as to be far from the lower edge of the lung and respiration artefacts. The electrodes were placed along a transverse line, 4-5 cm apart (figure 3). They were connected to a Beckman R611 recorder (Sensor Medics, Anaheim, CA) with a time constant of 10s, high-frequency cutoff of 0.08 Hz, and a paper speed of 1 mm/s.

3.4. Percutaneous recording

While the electrodes were being applied directly to the liver, the skin incision was temporarily approximated with surgical clips to allow for proper application of another set of electrodes to the abdominal skin. In order to define the optimal electrode position, several leads were used at several sites in the right hypochondreal area close to the costal margin. The most marked, regular and reproducible signals were selected for further analysis regarding contamination with a respiration component or artifacts. Respiration was registered by a strain gauge transducer which was placed around the subject's chest and connected to a separate channel of the Beckman recorder.

The optimal positions of the electrodes are shown in figure 4. The 3 electrodes were placed on a transverse line 1.5-2 cm below and parallel to the right costal margin. The first electrode was positioned 5 cm below and lateral to the xiphoid process, and the other 2 electrodes were placed 5 cm away from each other and from the firs one. The electrodes were fixed to the skin by electrode gel and were connected to a Beckman recorder as aforementioned. A reference electrode was applied to one of the lower limbs. A 20-minute recording session was performed for each patient.

3.5. Percutaneous electrohepatography in the healthy awake volunteers

After defining the optimal positions of the percutaneous electrodes, an EHG was performed for the 23 healthy volunteers. The subject was instructed to fast for 12 hours before the recording session. With the subject uncovered from above the level of the nipples to below the umbilicus, the 3 electrodes were fixed to the abdominal skin by electrode gel at the sites already mentioned (figure 4). Two recording sessions of 20 minutes each were performed for the individual subject.

The results were analyzed statistically using the Student's t-test. Differences assumed significance at

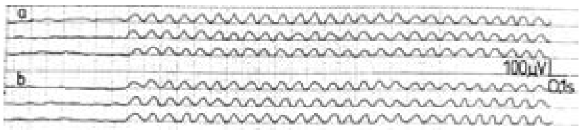

Figure 5. Normal electrohepatogram (EHG) from a patient with ventral hernia showing the electric waves exhibiting the same frequency and amplitude from the 3 electrodes applied to the liver. The percutaneous EHG (a) is identical to that recorded directly from the liver (b).

Figure 6. Percutaneous electrohepatogram from a healthy volunteer showing the PPs exhibiting the same frequency and amplitude from the 3 electrodes applied to the skin.

$p<0.05$, and values were given as mean ± standard deviation (SD).

4. RESULTS AND DISCUSSION

We did not encounter complications related to the application of the electrode whether directly to the liver or percutaneously. There was no electrode migration during the performance of the tests. The procedure was well accepted when it was performed percutaneously, and the recordings were completed in all the subjects.

The identification of the optimal location of the percutaneous electrodes for the recording of the hepatic electric waves was greatly facilitated during the ventral hernia operation. The surface electrodes were moved on the skin surface within the scope of the exposed liver. Moreover, the comparison of the obtained percutaneous signals with those received from the electrodes directly applied to the liver helped us to determine the proper location of the percutaneous electrodes, to exclude artefacts and to validate the percutaneous recordings.

Slow waves or PPs were recorded from the 3 electrodes applied directly to the liver and from those applied to the skin. Each wave consisted of a large positive deflection with a mean frequency of 8.3 ± 1.3 cycle per second (cps, range 7 – 11) and an amplitude of 56.5 ± 12.1 µV (range 42-68; figure 5). The shape of the wave was constant in all the recordings for each individual. The PPs showed the same frequency and amplitude from the 3 electrodes applied to the same subject with no significant difference ($p>0.05$; figure 5). These variables were constant when the test was repeated in the same individual ($p>0.05$). During the study we did not encounter fast activity spikes or abnormal waves recorded in the EHG.

In the individual subject, the electric waves obtained by the percutaneous route were identical with those recorded from the electrodes applied directly to his/her liver (figure 5), and they also had the same frequency and amplitude when recorded directly or when recorded percutaneously (figure 5).

Percutaneous EHG was performed in the 23 healthy awake volunteers. The recordings were successfully obtained from the electrodes located at the sites already mentioned. The PPs had a shape similar to the waves recorded from the operated patients (figure 6). The frequency and amplitude of the waves showed no significant difference ($p>0.05$) from the values recorded at the operation and already mentioned.

The aforementioned recordings were reproducible with no significant difference ($p>0.05$) when the test was repeated in the same individual.

The current study demonstrates that the liver possesses an electric activity in the form of slow waves or PPs. These waves could be recorded percutaneously in the awake subjects from sites that were similar to those defined at operation. The stable recording sites on the skin seems to be due to the fixed anatomical position of the liver.

It may be argued that the percutaneous waves are artefacts. However, these waves being synchronous and identical with those recorded from the electrodes applied directly to the liver as well as the constancy and reproducibility of the recordings appear to invalidate this argument. Furthermore, the signals registered from humans were similar to those recorded in the canine model (25). These hepatic waves could be easily differentiated from other waves in the area. Cardiac waves are identified by their characteristic shape. Respiratory artefacts are excluded by the recording of the respiratory electric activity via a transducer attached to the chest wall. Artefacts from abdominal wall musculature could also be excluded because the striated muscles have no resting electric activity. Waves from the gall bladder and common bile duct have a configuration different from that recorded from the liver (20-23). Intestinal waves are inconstant due to the peristaltic activity of the gut. Meanwhile our preceding study had demonstrated that the hepatic PPs are not derived from the hepatic artery or the portal vein (25).

The origin of these waves from the liver is not known. A recent study of the rectal electric activity was done to investigate whether the origin of these waves is neurogenic or myogenic (26), and it was suggested that these waves are not initiated by, but may be under the control of, the extrarectal autonomic innervation.

The functional significance of these waves is also not evident. In the gut and other hollow organs, the electric waves were associated with rise of the intraluminal pressure. It was suggested that these waves have a role in the motile activity of the gut. It may, likewise, be postulated that the electric waves of the liver share in its functional activity. This could be concluded from a recent study, which demonstrated that liver waves become dysrhythmic after liver insult by irradiation, or on hepatic vessels' clamping in a canine model (25).

In conclusion, an EHG could be characterized for the normal liver in humans. It is suggested that this EHG might show changes in liver diseases and thus act as an investigative tool in the diagnosis of such disorders.

5. ACKNOWLEDGMENT

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