Available online at www.sciencedirect.com
SCIENCE DIRECT®

Digestive and Liver Disease 37 (2005) 786–792

Digestive and Liver Disease

www.elsevier.com/locate/dld

Liver, Pancreas and Biliary Tract

Transthoracic electrical bioimpedance: A non-invasive technique for the evaluation of the haemodynamic alterations in patients with liver cirrhosis

F. Dazzani, M. Micati, P. Caraceni, G.M. Drago, M. Domenicali, P. Pacilli, V. Tomassetti, E. Gelonesi, F. Trevisani, M. Bernardi *

Department of Internal Medicine and Hepatology, Alma Mater Studiorum University of Bologna, 40138 Bologna, Italy

Received 20 January 2005; accepted 24 May 2005
Available online 18 July 2005

Abstract

Background/aim. Transthoracic electrical bioimpedance is a non-invasive technique for the evaluation of systemic haemodynamics. Compared to Doppler ultrasound, it has the advantage of being operator-independent, providing continuous monitoring and being less influenced by postural changes. Until now, transthoracic electrical bioimpedance has been applied to a very limited extent in liver cirrhosis. We, therefore, aimed to compare transthoracic electrical bioimpedance and echocardiography in the assessment of haemodynamic status in cirrhotic patients.

Patients/methods. Thirteen patients with compensated cirrhosis, 10 patients with cirrhosis and ascites and 12 controls were enrolled. Haemodynamic parameters (stroke volume, cardiac output, heart rate, mean arterial pressure and vascular peripheral resistance) were assessed simultaneously by transthoracic electrical bioimpedance monitoring with BioZ.com™ for at least 10 min and Doppler ultrasound.

Results. The absolute mean values of haemodynamic parameters obtained by the two techniques were quite similar in all groups; furthermore, a good agreement between transthoracic electrical bioimpedance and echocardiography measurements was found for all the parameters. Finally, transthoracic electrical bioimpedance proved easy to employ and provided continuous real-time monitoring of cardio-circulatory variations.

Conclusions. The present study showed a significant correlation between transthoracic electrical bioimpedance and echocardiography in the assessment of systemic haemodynamics in patients with cirrhosis, supporting the employment of transthoracic electrical bioimpedance in pathophysiological studies requiring real-time continuous monitoring of haemodynamic parameters.

Keywords: Echocardiography; Liver cirrhosis; Systemic haemodynamic; Transthoracic electrical bioimpedance

Patients with advanced cirrhosis develop systemic haemodynamic alterations, termed 'hyperdynamic circulatory syndrome', which are due to a reduction in peripheral vascular resistance (PVR) and a compensatory increase of cardiac output (CO) [1]. These alterations, which correlate to the severity of the liver disease [2], contribute to the appearance of severe complications of cirrhosis, such as renal sodium retention and ascites, hepatorenal and hepatopulmonary syndromes, and increased susceptibility to shock [3].

Conversely, the haemodynamic status in patients with a compensated disease is less defined, as many patients with pre-ascitic cirrhosis do not present hyperdynamic circulation when studied in the upright posture. Indeed, we have shown that increased CO and reduced PVR only appear when they are evaluated in the supine posture for at least 1 h [4,5]. Thus, further studies are warranted in order to define more clearly the haemodynamic status of patients with pre-ascitic cirrhosis.

Although the most reliable method of evaluating the haemodynamic status of cirrhotic patients is angiography with dye- or thermodilution, its invasiveness has led several

* Corresponding author. Tel.: +39 051 6362939; fax: +39 051 6362930.
E-mail address: mauro.bernardi@unibo.it (M. Bernardi).

1590-8658/$30
doi:10.1016/j.dld.2005.05.008

investigators to employ Doppler echocardiography [4–8]. Such a technique, however, also has potentially important limitations, especially when repeated measurements are needed in a short time interval and in different postures [9]. Therefore, the availability of alternative and more efficient non-invasive techniques can be particularly useful in the study of the haemodynamic status in cirrhosis.

Transthoracic electrical bioimpedance (TEB) was proposed by Kubicek et al. in 1966 as a non-invasive and operator-independent method able to provide continuous monitoring of many haemodynamic variables [10]. The TEB technique depends on detection of changes in the electrical impedance across the thorax due to the movement of blood during each cardiac cycle: stroke volume (SV) is calculated by a complex impedance waveform, which represents the variation of thoracic impedance [11]. So far, this technique has been mostly employed in intensive and acute heart care units. According to two meta-analyses, TEB seems particularly useful for trend analysis of different groups of patients, and an acceptable correlation between TEB and invasive methods, including thermodilution, has been demonstrated [12,13]. At present, the use of TEB for the evaluation of the haemodynamic parameters has not been validated in cirrhotic patients.

Therefore, the aim of this study was to determine whether the assessment of systemic haemodynamic parameters with TEB correlates with that obtained by Doppler echocardiography, which currently represents the most used non-invasive technique in studies dealing with haemodynamic abnormalities in cirrhosis.

1. Patients and methods

1.1. Subjects

Three groups of subjects were enrolled in the study: (1) 13 patients with compensated cirrhosis; past or current ascites were excluded by clinical questioning and ultrasonography; (2) 10 patients with cirrhosis and ascites; (3) 12 healthy individuals of comparable sex and age serving as controls.

The diagnosis of cirrhosis was based on histological findings and/or the evidence of portal hypertension by oesophageal varices at endoscopy and/or enlarged portal vein and splenomegaly at ultrasonography. Height, weight, body surface area, aetiology of hepatic disease and Child–Pugh score were also evaluated.

Exclusion criteria were the use of β-blockers, ongoing acute infections, recent variceal bleeding and spontaneous bacterial peritonitis (within 1 month), and the presence of hepatocellular carcinoma outside the Milan criteria [14]. Furthermore, the exclusion criteria related to TEB technical limitations were: height under 120 cm or above 230 cm, body weight under 30 kg or above 155 kg, severe arterial hypertension (mean arterial pressure (MAP) > 130 mmHg), sustained cardiac arrhythmia, moderate to severe disease of heart valves and massive pleural effusion, as indicated in the operator's manual of the device.

Informed consent was obtained from each patient and control, and the senior staff of our institution approved the study protocol.

1.2. Instruments

Cardiac ultrasound examination was performed by means of AU 3 Partner (Esaote, Genoa, Italy) with a 2.5 mechanical sector transducer by the same operator, as described elsewhere [4,5]. Intra-observer coefficient of variation, tested in twenty subjects, was approximately 10%. The operator performing echocardiography was blinded to the TEB readings.

TEB monitoring was performed by means of BioZ.com™ (CardioDynamics International Corporation, San Diego, CA, USA). The BioZ.com™ measures the change in impedance by injecting a high frequency (70 kHz) and low amplitude (2.5 mA) alternating electrical current through the thorax between a pair of sensors placed on the neck and another pair placed on the mid-axillary line at the xiphoid process level (each sensor of a pair is placed 5 cm from the other). BioZ.com™ is also provided with a cuff for automatic blood pressure measurement.

1.3. Haemodynamic parameter assessment

Haemodynamics were assessed in supine position kept for about 15 min. Haemodynamic parameters were collected simultaneously by TEB monitoring for at least 10 min and Doppler echocardiography.

1.3.1. SV

SV was measured by TEB according to the formula [30]: $SV = VEPT \times LVET \times [(dZ/dt_{max})/BTI]$, where VEPT is the volume of electrically participating tissue; LVET, the left ventricular ejection time; dZ/dt_{max}, the rate of change of impedance during systole and BTI, the basal thoracic impedance.

In order to ensure accuracy and stability of parameters, the data displayed by TEB was the average of the values collected over a 30-heartbeat interval. This value is automatically and continuously recalculated every 10 heartbeats; thus, the displayed values are based on data from the 10 most recent beats plus the last 20 beats of the previous data update.

Doppler ultrasound evaluation of SV was assessed in a parasternal long axis view in order to obtain a good US Doppler scan through aortic annulus during ventricular systole. SV was calculated as follows [15]: SV (ml) = area LVOT $(cm^2) \times 0.785 \times TVI = (D/2)^2 \times \pi \times 0.785 \times TVI$, where LVOT is the left ventricular outflow tract; D, diameter of the aortic valve annulus under ventricular systole; TVI, time–velocity integral of aortic annulus inflow during ventricular systole.