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Dynamic measurements of total hepatic blood flow with Phase Contrast MRI

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ABSTRACT

Background/Aims: To measure total hepatic blood flow including portal and proper hepatic artery flows as well as the temporal evolution of the vessel's section during a cardiac cycle.
Methods: Twenty healthy subjects, with a mean age of 26 years, were explored. Magnetic resonance imaging blood flow measurements were carried out in the portal vein and the proper hepatic artery. MR studies were performed using a 1.5T imager (General Electric Medical Systems). Gradient-echo 2D Fast Cine Phase Contrast sequences were used with both cardiac and respiratory gatings. Data analysis was performed using a semi-automatic software built in our laboratory.
Results: The total hepatic flow rate measured was 1.35 ± 0.18 L/min or 19.7 ± 4.6 mL/(min kg). The proper hepatic artery provided 19.1% of the total hepatic blood flow entering the liver. Those measurements were in agreement with earlier studies using direct measurements.

Mean and maximum velocities were also assessed and a discrepancy between our values and the literature's Doppler data was found.

Measurements of the portal vein area have shown a mean variation, defined as a "pulsatility" index of 18% over a cardiac cycle.
Conclusions: We report here proper hepatic artery blood flow rate measurements using MRI**.** Associated with portal flow measurements, we have shown the feasibility of total hepatic flowmetry using a non-invasive and harmless technique.

1. Introduction

Anatomically, hepatic blood circulation is governed by blood flow in the portal vein and hepatic artery which rough size are respectively 12 and 4 mm in normal conditions [1]. The study of hepatic blood flow is of critical importance in several pathological conditions such as cirrhosis, responses to surgery and the development of malignancy. Few techniques can be used to assess hepatic blood flow rates values. Before Doppler ultrasonography (US) was available, portal and hepatic blood flows could only be measured by invasive techniques. Doppler US, regarded as a gold standard, provides information about red cells' velocity direction and value. Using this apparatus in B-mode echography to measure the cross-sectional area of a vessel, the mean flow rate can be assessed by multiplying this value with the mean velocity. However, the measurement of hepatic blood flow by Doppler US is significantly operator- and machine-dependent [2] and the portal vein cross-sectional area varies significantly with respiration [3,4] so that the relevance of flow rate calculation can be discussed. This fact is highlighted by discrepancies between authors' blood flow measurements results at the hepatic level.

In addition to its application in morphological examinations, magnetic resonance imaging (MRI) has also been used for quantization of blood flow in various organs. Several investigators have used phase contrast (PC) sequences to measure portal blood flow. This functional sequence uses MRI intrinsic sensitivity to tissue

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displacements. Whereas conventional MRI only represents the magnetization vector amplitude, PC-MRI also computes the phase of this vector. The phase information, given for a flow direction and coded in grayscale images, permits the calculation of displacement velocities of biological fluids [5]. The synchronization of the sequence with the heartbeats makes it possible to obtain several measurements at different moments of the cardiac cycle and allows the construction of the corresponding blood flow rates curves after segmentation and assessment of the vessel area. In absence of MRI contra-indication, the harmlessness and accuracy of MRI flowmetry made of it a useful tool for vascular dynamics exploration [6]. The main applications lie in the cerebral and cardiac fields according to the literature.

Using PC-MRI, Lycklama et al. [7] have shown that the intra-individual variability of portal flow measurements was weak and correlated with Doppler data in a population of eight healthy subjects. Debatin et al. [8] also used this imaging technique before and after trans-hepatic shunting in eighteen patients and therefore highlighted a significant portal flow increase of 134% ($p < 0.001$) after shunting. Burkart et al. [6] used this technique to differentiate patients with hyperdynamic portal flow from hypodynamic subjects in populations undergoing portal venous hypertension.

But we must notice that no hepatic arterial flows measurements were shown in these studies as it has been pointed out earlier by Annet et al. [9]. The work presented here will partially reduce this lack of knowledge.

2. Materials and methods

2.1. Patients

The study was approved by our institutional review board and subjects provided informed consent.

Twenty healthy subjects (20 males) with a mean age of 26 ± 6 years (range: 18–35 years old) were included into the study. MRI blood flow measurements were carried out, in supine position, in the portal vein and proper hepatic artery. As ingestion of food significantly influences hepatic hemodynamics [10], the subjects were in a fasting state for at least 6 h.

2.2. Methods

MR studies were performed using a 1.5T imager (Signa Horizon, General Electric Medical Systems, Milwaukee, WI) with a phased array body coil.

Fast gradient echo sequences, with breath-hold image (axial, coronal and sagittal) of the hepatic vascularization mapping were used by a radiologist to localize the appropriate orientation of the oblique section required for the flow measurements. (Fig. 1A and B).

2.3. Phase Contrast MRI (PC-MRI)

PC-MRI was performed during natural respiration using a cardiac (peripheral plethysmograph) and a respiratory (pneumatic belt) gating. Flow rates were calculated from 32 velocity images spanning the cardiac cycle.

Gradient-echo 2D Fast Cine PC sequences were used; acquisition parameters were 4 view per segment, 2 excitations, flip angle of 25°, Field of View from 14 cm × 14 cm to 28 cm × 28 cm, slice thickness of 6 mm, matrix size of 256 × 128, TR/TE minimum, band width: ±31 kHz. Encoding velocities were set to 50 cm/s for the portal vein and 100 cm/s for the proper hepatic artery. Acquisition time was 1.5–2 min for each vessel mainly depending on the subject heart rate. Each series of reconstructed data consisted in phase images associated with the corresponding magnitude images.

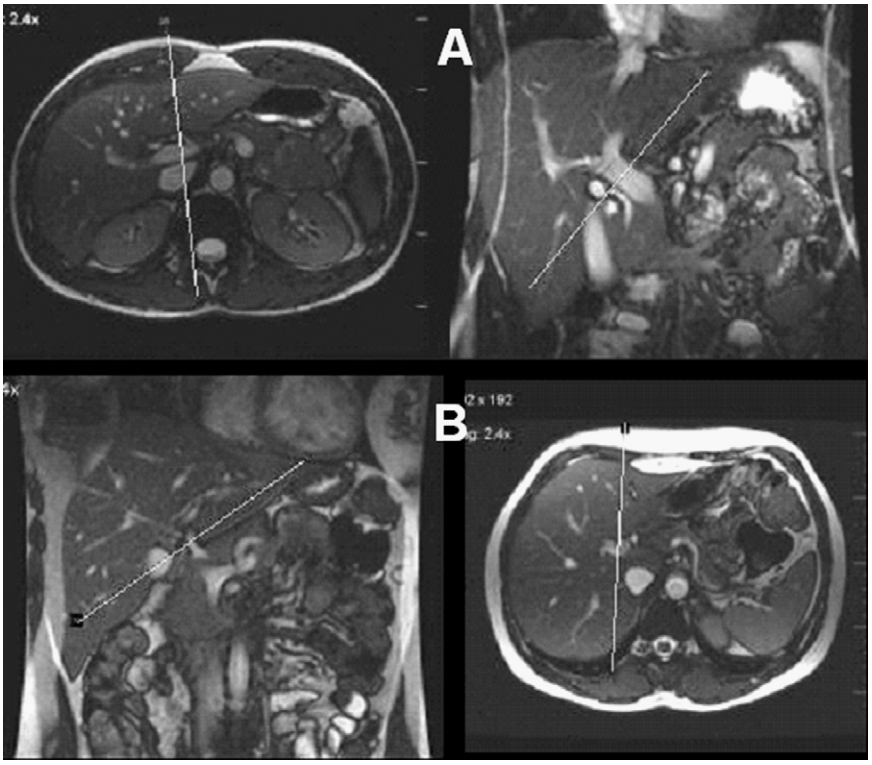

Fig. 1. Axial and coronal fast imaging employing steady-state acquisition (FIESTA; GE Medical Systems) localizer MR image of (A) portal vein and (B) proper hepatic artery; (apnea duration near 20 s). Plane sections have been set perpendicularly to the vessels' axis.