

Brain core temperature of patients before and after orthotopic liver transplantation assessed by diffusion weighted imaging thermometry

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Aims and objectives

Neurological complications are common in patients with end-stage liver disease or cirrhosis, and they can occur at any time before and after the liver transplantation. Extrapyrarnidal sign and hepatic encephalopathy could affect patients with poorly compensated cirrhosis or appear after transjugular intrahepatic portosystemic shunt positioning [1].

During liver transplantation, the cerebral blood flow (CBF) may be affected by hemodynamic changes associated with transplantation, especially after the reperfusion of the donor liver [2,3].

The restoration of the normal liver function after liver transplantation can also determinate changes in the cerebral metabolism [3].

Cerebral metabolism is responsible for the production of brain heat. The generated heat is removed mainly through the circulation of blood in the intracranial vessels and the circulation of the cerebrospinal fluid (CSF) in the ventricular system.

The balance between heat production and heat removal allows maintaining a stable temperature in the brain parenchyma. Due to the neuronal metabolism, the brain temperature is usually approximately 1°C higher than the body core temperature.

Magnetic resonance (MR) with diffusion-weighted imaging (DWI) is a new, easy and non-invasive method to assess the brain temperature. This method is based on the measured diffusion coefficient of the CSF in lateral ventricles to calculate the temperature of the cerebrospinal fluid [4].

The purpose of our study was to assess the brain core temperature of adult patients with end-stage liver disease before and after orthotopic liver transplantation (OLT) using the DWI thermometry as a noninvasive temperature measurement technique based on the diffusion coefficient of the cerebrospinal fluid in the lateral ventricles.

Methods and materials

Patient population

Our retrospective cohort study was reviewed and approved by the Institutional Research Review Board (IRRB) of our institution, and informed consent form was waived; however, informed written consent to the MR was obtained in all patients.

The data were collected analyzing retrospectively the MR exams performed from January 2014 to January 2017. The study group comprised 19 patients (16 men, 3 women; age range 42-70 years, mean age 57.9 ± 7.4 years). The mean score of the model for end-stage liver disease (MELD) [5] was 23.7.

All of the patients underwent brain MR imaging within 30 days before OLT and within 30 days after OLT. The etiology of end-stage liver disease was determined as follow: n. 1 drug-related fulminant hepatic failure; n. 3 nonalcoholic steatohepatitis, n. 8 hepatocellular carcinomas, n. 3 HCV/HBV/HDV infection related, n. 1 primary biliary cholangitis, n. 1 acute liver failure on chronic sclerosing cholangitis, n. 1 cryptogenic cirrhosis, and n. 1 liver cirrhosis.

MR examination

The MR exams were performed on a 1.5T MR scanner (Signa Excite, General Electric Medical Systems, Milwaukee, USA).

The DWI images were acquired with the following parameters: repetition time (TR), 6000 ms; echo time (TE), 88 ms; b value, 1000 s/mm^2 ; image averaging, two times; field of view (FOV), 230 mm; motion-sensitizing gradients applied in 15 directions; and 42 3-mm-thick sections obtained without intersection gaps. The duration of gradient pulse and the interval between the gradient pulses (##) were 64.1/40.9 ms. Diffusion time was 50.5 ms. Acquisition time was 3 minutes.

Other conventional MR imaging protocol included axial and sagittal fast-spin echo (FSE) T2W (5100/110 [TR/TE]) images, axial fluid-attenuated inversion-recovery (FLAIR) (8000/140/2400 [TR/TE/TI]) images, along with axial, sagittal, and coronal non-enhanced and contrast-enhanced (0.1 mmol/Kg gadobutrol - Gadovist, Bayer, Germany) FSE T1W (650/15 [TR/TE]) images with a field of view (FOV) of 22 cm, matrix 320x320, slice thickness 5 mm, intersection gap 1 mm, number of excitations 2.

Image analysis and temperature estimation

The kinetic theory states that a direct relationship exists between the absolute temperature (T) and the diffusion coefficient (D).

MR can be adopted to measure the diffusion coefficient of non-restricted water molecules [6]. Studies performed by Mills [7] and Kozak et al. [8] demonstrated that the temperature of the CSF can be estimated using this diffusion coefficient detected by MR. We calculated the diffusion constant in the lateral ventricle using the following previous reported equation [9,10]:

$$D = \ln(S_0/S) / b$$

in which D is the diffusion coefficient (square millimeters per second), b is the applied diffusion weighting (seconds per square millimeter), and S_0 is the voxel signal intensities of the reference and S is the voxel signal intensity in DWI images.

The brain core temperature (T in degree Celsius) was calculated using the following equation, applying the founded D value:

$$\text{CSF: } T = 2256.74/\ln(4.39221/D) - 273.15$$

The temperature estimation of CSF is calculated within the lateral ventricles because this method is only applicable to non-restricted water and the diffusion of the CSF is almost equal to the free diffusion of pure water (Figure 1).

The estimated temperature of the lateral ventricle was compared in patients before and after the liver transplantation.

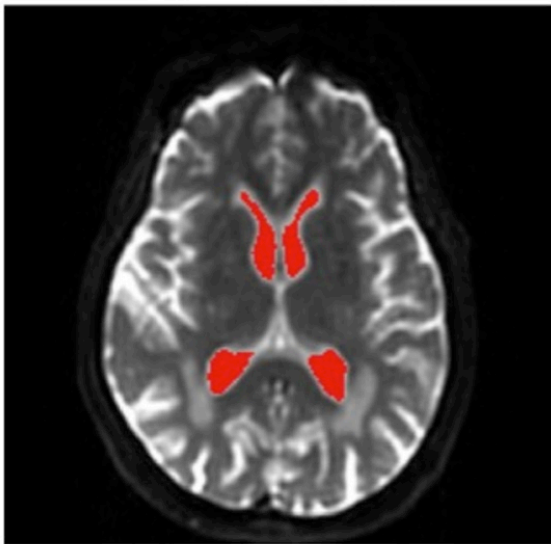
Statistical analysis

Statistical analysis was performed using a nonparametric Mann-Whitney U test to compare the patient's brain core temperature before and after liver transplantation.

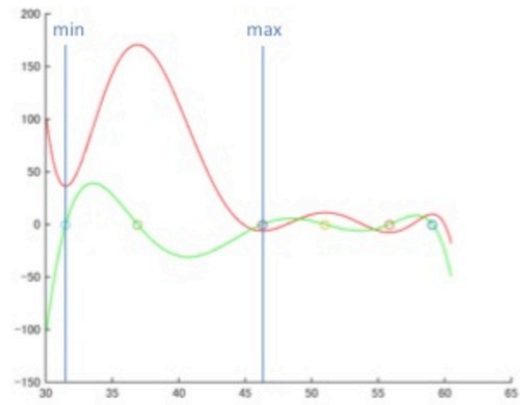
A $p < 0.05$ was considered as statistically significant for the correlation.

The statistical analysis was performed using SPSS Statistics software (SPSS, Chicago, IL, USA). As the sample size for this study was small, we assessed the power of the Wilcoxon rank-sum test with the analysis software G*Power (Heinrich-Heine-University Düsseldorf, Germany) to ensure that statistical power of 0.90 for the result was achieved comparing the brain core temperature of 19 patients before and after OLT.

Images for this section:



Red colored area: selected LV for temperature calculation



Curve-fit histogram

Representative temperature of LV was calculated as an average between min. and max. threshold.

Fig. 1: To measure DWI thermometry the region of interest (ROI) was placed by manually tracing the peripheral margin of the lateral ventricle

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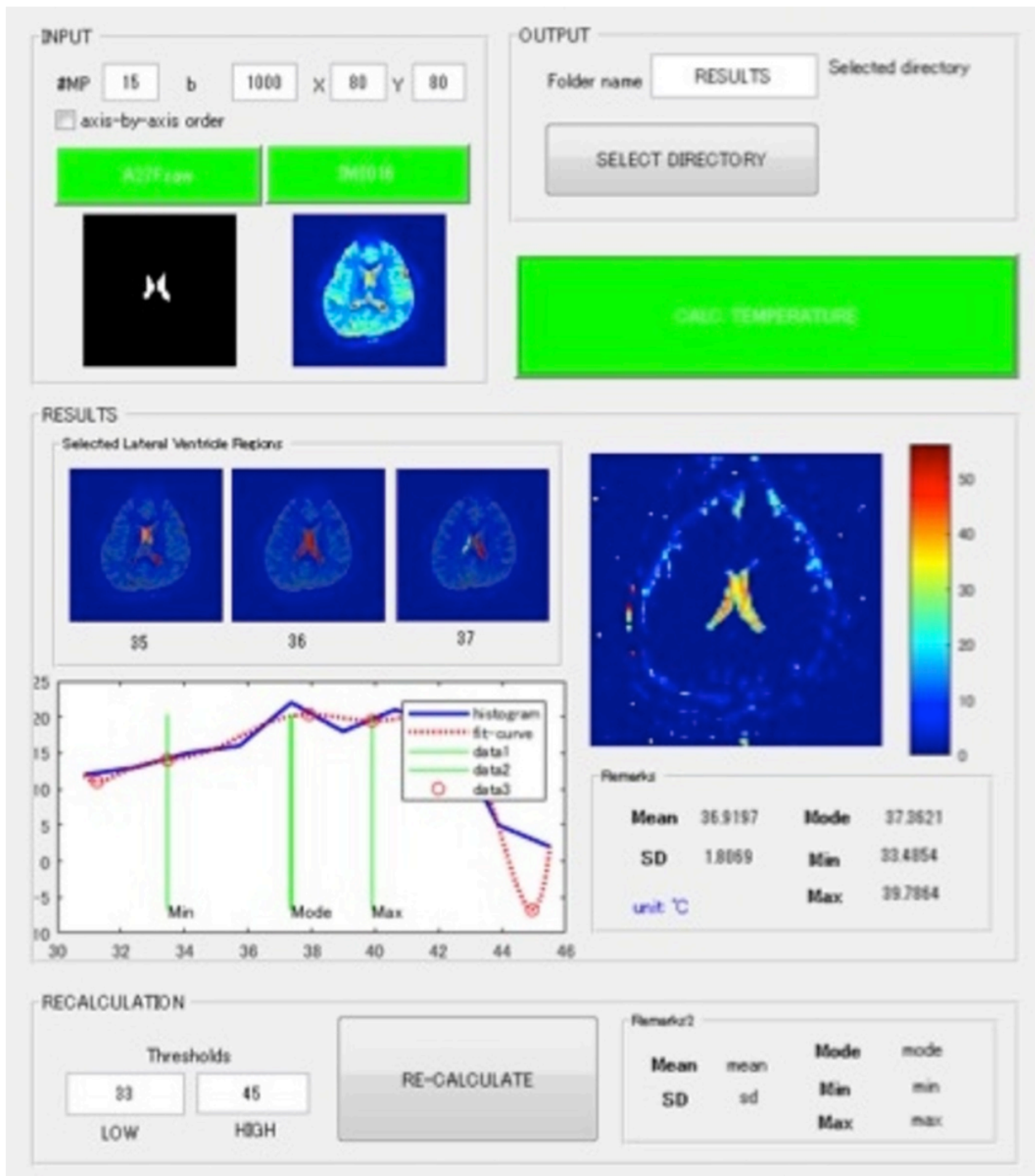


Fig. 2: To measure DWI thermometry the region of interest (ROI) was placed by manually tracing the peripheral margin of the lateral ventricle.

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Results

The brain core temperature was successfully measured noninvasively in all patients before and after OLT using magnetic MR diffusion-weighted imaging thermometry technique.

The mean \pm standard deviation of the brain core temperature measured before and after OLT was respectively 38.67 ± 1.76 °C and 38.60 ± 0.99 °C (figure 2 and 3).

There was no statistically significant difference between the estimated temperature before and after liver transplantation ($P = 0.643$, risk of beta-error = 0.90). No neurological complications were clinically found in all patients following the surgical procedure.

Images for this section:

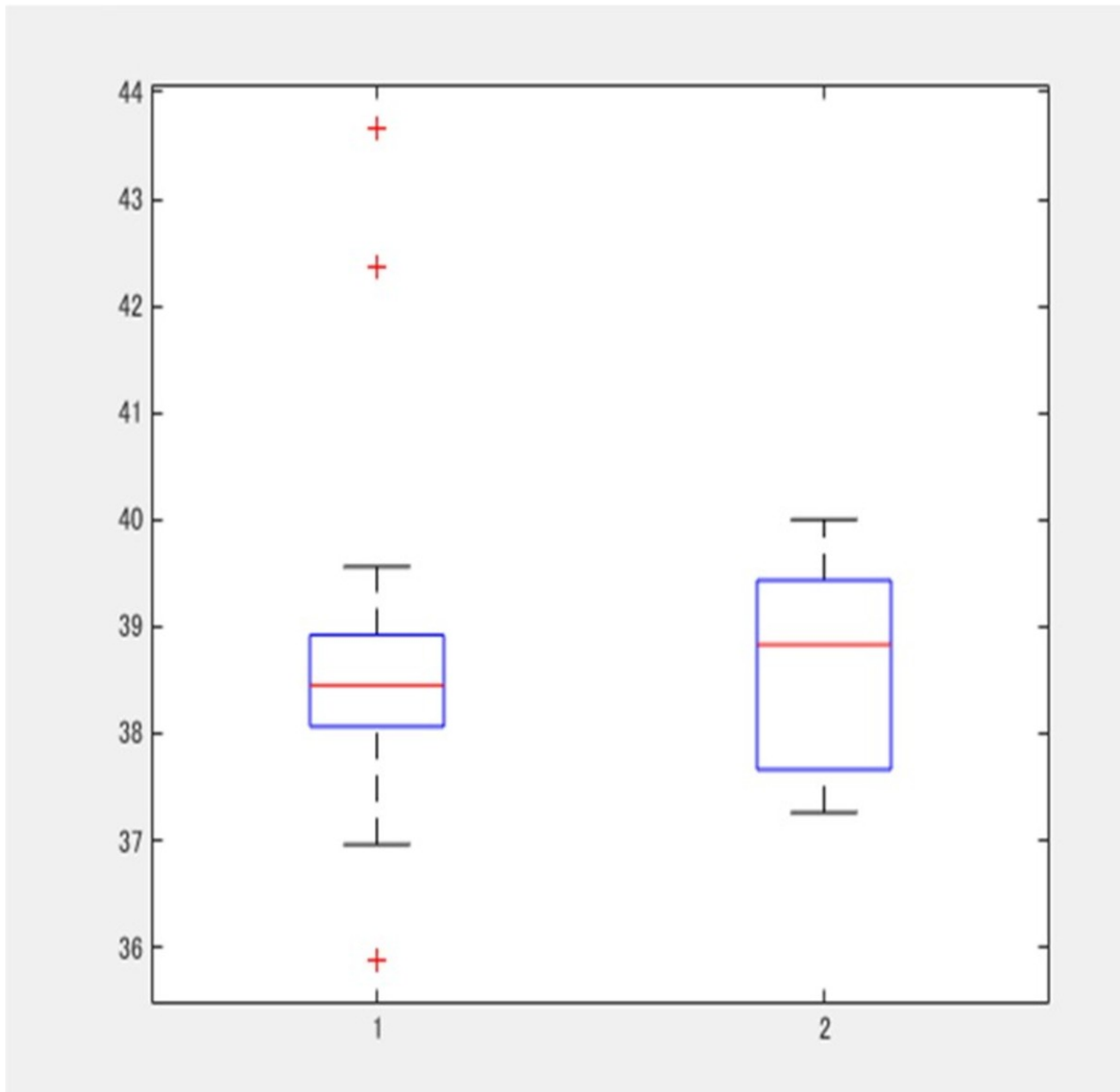


Fig. 3: Graph representing mean \pm standard deviation of the ventricular cerebrospinal fluid temperature (LV Temp) expressed in $^{\circ}\text{C}$ in patients before (1) and (2) after orthotopic liver transplantation measured using DWI-based MRI thermometry. No significant difference was observed (38.67 ± 1.76 $^{\circ}\text{C}$ vs 38.60 ± 0.99 $^{\circ}\text{C}$, Mann-Whitney U test: $P = 0.6403$, risk of beta-error = 0.90).

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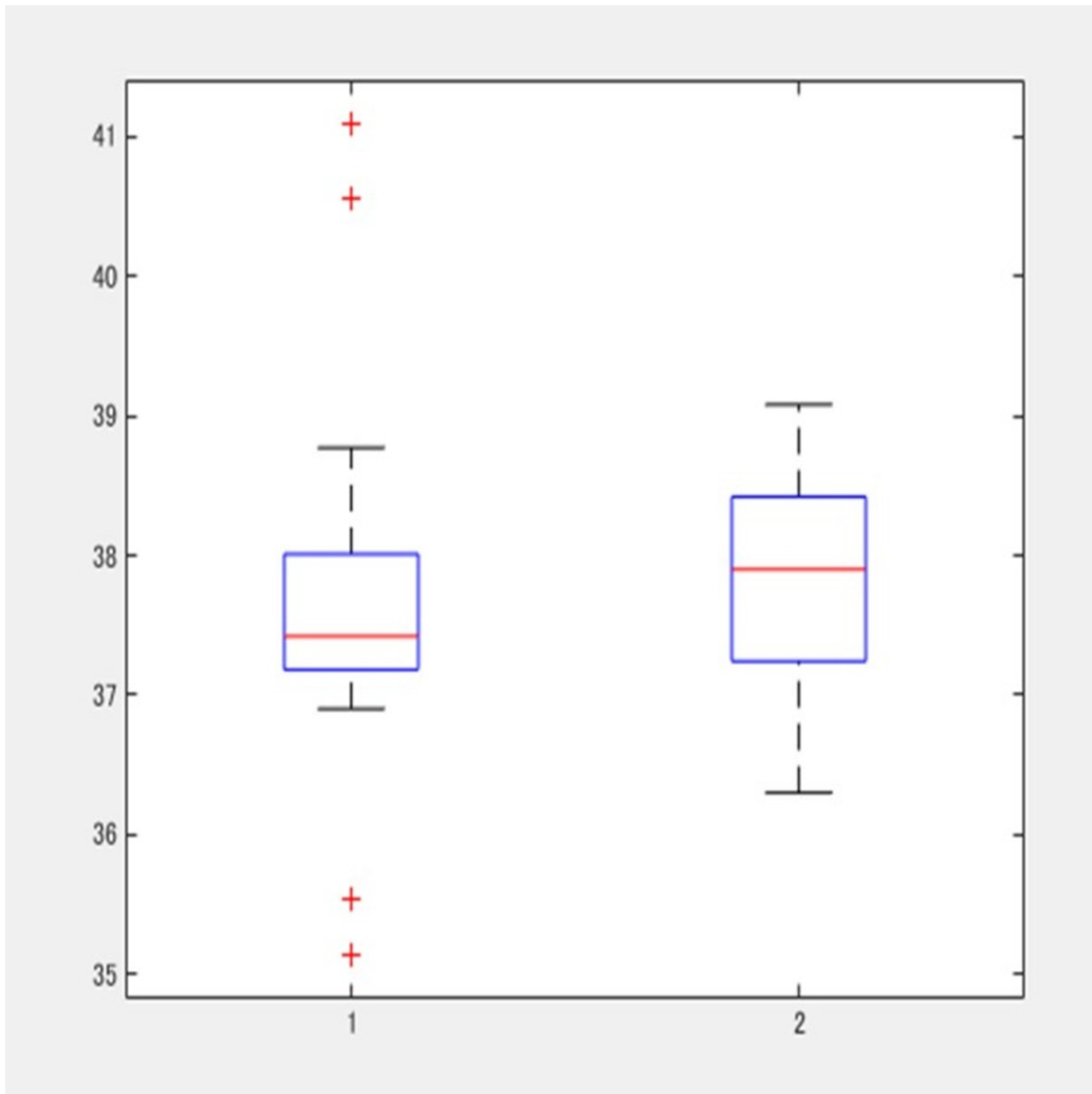


Fig. 4: Graph representing LV cerebrospinal fluid mode temperature (LV Temp) expressed in °C before (1) and after (2) the orthotopic liver transplantation. No significant difference was observed between two groups (Mann-Whitney U test: $P = 0.3809$).

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Conclusion

The results of this study demonstrated that no significant difference in brain core temperature was found in patients before and after liver transplantation by using DWI thermometry.

To the best of our knowledge, no other study has previously investigated the brain core temperature using DWI thermometry in patients who underwent liver transplantation.

Neurologic complications are relatively common after solid organ transplantation and are affecting up to 30% of liver transplant recipients [11,12]. Neurological complications can develop any time after transplantation, they can increase the morbidity and complicate the post-transplant management. The etiology is commonly related to immunosuppressant neurotoxicity and opportunistic infections rather than cerebrovascular blood abnormality.

Cerebrovascular complications, including ischemic strokes and intracranial hemorrhage, are rare after liver transplantation and most studies report a prevalence of 4-7% in transplant recipients [3].

Moreover, pre-transplant liver failure may be associated with various neurologic complications directly related to liver dysfunction such as hepatic encephalopathy increasing the risk of post-transplant neurological complications [13].

The autoregulation of cerebral blood flow could be impaired in patients with end-stage liver disease and encephalopathy [14]. These patients are vulnerable to the sudden decrease of cerebral perfusion and oxygenation during orthotopic liver transplantation [3].

In our patient population brain temperature was stable after liver transplantation suggesting that no changes in the brain metabolism and cerebral blood flow occurred during surgery.

In conclusion, our study demonstrates a stable brain core temperature in patients undergoing OLT. Brain core thermometry using DWI-based MR imaging may provide a useful supplementary brain biomarker to confirm that cerebral blood flow and cerebral metabolism are stable in patients undergoing OLT.

Personal information

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