Introduction

The growing imbalance between the need and the availability of liver donors has resulted in an increasing use of extended liver criteria donors, which are more likely to have hepatic steatosis (HS) with a risk of early graft dysfunction in case of severe (≥67%) macrovesicular steatosis. While accurate evaluation of HS is crucial for optimal donor selection, the diagnostic performance of noninvasive criteria for liver steatosis using clinical, biological, and morphological criteria remains limited and prevents a reliable assessment in daily practice. On the opposite, frozen section analysis of liver biopsy remains the gold standard to evaluate HS but its systematic use is not realistic in the very specific organizational setting of organ procurement. Altogether, the assessment of the degree of HS currently relies on visual inspection of the liver by an often junior surgeon, and may lead to inappropriate liver grafts selection.

In this context the development of an easy-to-use, handy and accurate device for noninvasive quantification of HS would obviously be most desirable. As smartphones have become ubiquitous in modern culture and their systematic use is not realistic in the very specific organizational setting of organ procurement.

Methods

In the present pilot study, all grafts procured by the Beaujon Hospital Liver procurement team between January 2017 and February 2017 were included. These grafts all underwent biopsy and pictures. First, HS was estimated on triangular frozen section biopsies harvested on the left lobe during liver procurement (in case of suspected severe HS) or after reperfusion during LT as a routine procedure at our institution. Steatosis was assessed on the basis of the percentage of hepatocytes with macrovesicular steatosis using a quantitative scale up to 100%. According to the widely used scoring approach, HS was categorized as: Normal (grade 0) macrovesicular steatosis from 0% to 5%; Mild (grade 1) macrovesicular steatosis from 6% to 33%; Moderate (grade 2) macrovesicular steatosis from 34% to 66%; Severe (grade 3) macrovesicular steatosis >67%.

Second, digital pictures of the livers were taken during liver procurement using the same commercially available smartphone (iPhone 6S- Apple Inc, Cupertino, CA, USA). Exposure, white-balancing and focus area selection modes were commonly non-adjustable. Pictures of the livers were taken in situ before aortic cross-clamp with the highest resolution. The graft was photographed from a distance of approximately 30 cm with automatic flash light; the operating lights were turned away from the graft and maximal externalization of the liver from the abdominal cavity was applied. A set of images was created by manually cropping the original photos so the target organ occupies 85-100% of the frame. A team of dedicated engineers then processed the images using the CaptureProof software (ComputerVision Technology). The cropped frames were converted from Red Green Blue (RGB) to Hue Saturation and Value (HSV). The Hue (one of the main properties of a color, defined technically as ‘the degree to which a stimulus can be described as similar to different from stimuli that are described as red, green, blue, and yellow) channel of the image was isolated and used to create a frequency histogram of all Hues in the image. The dominant Hue of the image was the red. The peaks of the reds Hues histograms were characterized as an asymmetric Gaussian (Figure 1) and the results values were characterized as follows: µ: Peak location of the most frequent colour; σ: Width of the peak; and r: Asymmetry of the peak. Finally, histogram characteristics µ, σ and r were correlated to HS percentage of liver grafts using the Spearman and Pearson correlation coefficients as appropriate.

Results

Overall, 12 consecutive livers from deceased donors procured with the intention to be transplanted were included. A total of 34 photos of liver grafts taken intraoperatively were aortic crossclamping were analyzed. The grafts were anonymously linked to their respective French Network for Organ Sharing number (numcrystal), to ensure patients privacy and blinding for CaptureProof Engineers. Liver biopsy was performed every hour in all cases. The median weight of biopsies was 20 mm (range: 18-22mm). Five liver biopsies were performed during donor surgery because of gross appearance of severe HS and were discarded while the remaining seven were considered suitable for transplantation and underwent reperfusion biopsy. The characteristics of the donors of discarded and transplanted grafts are described in Table 1 and Table 2. Image analysis of manually selected areas of both liver lobes (avoiding specular reflection) was assessed in less than 60 seconds. Redness Hue histogram distribution showed a significant correlation between Hue histogram distribution and HCS: (C = 0.86, p=0.001; Pearson correlation coefficient: 0.83, p=0.001 for C and C = 0.87, p=0.001; Pearson correlation coefficient: 0.84, p = 0.001 for D) (Figure 2). Examples of liver frame, histogram and Hue spectral image for each of the 4 classifications of hepatic steatosis are reported in Figure 4. Up to now, while several alternatives to histopathology for the assessment of HS have been proposed (MRI, Spectroscopy, Biologic impedance analysis), none of them has to date shown practical in the very specific setting of organ procurement. To the best of our knowledge, this is the first report evaluating the performance of a smartphone camera to assess macrovesicular steatosis at procurement site with liver biopsy as the reference. This result could only be achieved using a standardized protocol in photo-shooting, which supports previous findings regarding how to optimize intraoperative photography. Currently, there are over 90,000 mobile apps directed towards healthcare and there is tremendous enthusiasm for the potential of these apps demonstrated by the neworns mobile health, or m-Health, technologies. Hence, the next logical step will be the development of a dedicated mobile app, allowing for real time assessment of HS in an organ procurement setting. In this context, the adjunction of clinical, biological and imaging pre-procurement data such as age, BMI, GGT and Housefeld Index may also allow for the optimization of the algorithm in order to improve both detection and quantification of HS.

Conclusions

There are several limitations to this small size preliminary report. Importantly, the software is currently unable to differentiate macro- and microsteatosis, whereas only macrosteatosis is predictive of liver graft dysfunction. Yet, our image analysis is not a substitute of liver biopsy as it does not predict other pathologies (biliary degeneration, centrilobular necrosis, and also adversely affect graft outcome. In conclusion, our study proves for the first time, the feasibility of analysis of smartphone image parameters and allows for future steatosis assessment in liver graft, but as using a single image capture is performed rigorously. Future larger studies will have to aim at simplifying this analysis in a dedicated smartphone application in order to make it clinically relevant in a setting of organ procurement.

References


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