Application of Ultrasound Nakagami Imaging for the Diagnosis of Fatty Liver

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Recent epidemiological research has indicated that the incidence of fatty liver in the adult population has been steadily increasing. Apart from obesity and hyperlipidemia (especially an excessively high triglyceride level), alcoholism, poorly controlled diabetes, hepatitis C, and drugs (such as steroids and drugs to treat rheumatic immune disorders) are also commonly seen factors that can induce fatty liver. Although an assessment for fatty liver has become a common part of health checkups, the general public is not fully aware of its existence. Because the condition has no pronounced clinical symptoms during the early stage of the disease, most people are not aware of its presence. From a clinical perspective, fatty liver foreshadows many clinical diseases. Fatty liver is defined as the point when the liver’s fat content exceeds 5% of the weight of a normal liver. When the liver contains excessive fat, liver cells will gradually swell and eventually burst. At that time, fat will flow out of the damaged cells and infiltrate other liver cells. If the damaged liver cells cannot be promptly repaired, this will lead to fatty hepatitis, and the repair process will cause liver fibrosis, which may eventually lead to cirrhosis and liver cancer. In other words, the people of Taiwan should be aware of fatty liver, and that it is a serious threat and can eventually lead to death (Figure 1).

Clinical imaging methods used to assess fatty liver include computed tomography, magnetic resonance imaging, and ultrasound. Among these, ultrasound is currently the primary tool used to diagnose fatty liver. Ultrasound has the advantages of being noninvasive, convenient, sensitive, and highly reliable. In the hands of an experienced doctor, it can be used to quickly determine how much fat has accumulated in the liver. The vast majority of people suffering from mild and moderate fatty liver were diagnosed when an ultrasound was performed during a physical examination. There are specific clinical guidelines for the ultrasound assessment of fatty liver [1]. The definition of mild fatty liver is an echo from the hepatic parenchyma that is slightly enhanced compared with the echo from the renal parenchyma, while the blood vessels within the liver and the diaphragm can be clearly identified as usual. In the case of moderate fatty liver, the echo from some of the hepatic parenchyma is again enhanced compared with that from the renal parenchyma, but the blood vessels within the liver and the diaphragm are increasingly vague and blurry. In the case of severe fatty liver, compared with the renal parenchyma, the hepatic parenchyma has an even stronger echo, and the hepatic blood vessels, the diaphragm, and the rear part of the liver cannot be identified in images. Furthermore, measurement of the thickness of the fat in the cavities next to or around the kidneys can also be used to assess the severity of fatty liver [2].

A considerable degree of subjectivity is involved when ultrasound grayscale images are used to diagnose fatty liver, and the physician’s experience is therefore...
important. The use of advanced technology using existing ultrasound images in the diagnosis of fatty liver is currently an urgent clinical priority. From a theoretical perspective, the internal structure of different biological tissues differs, which leads to differing sound wave interference effects, which in turn result in different backscattering signals. In this context, analysis of the characteristics of ultrasound backscattering signals may improve the functional ultrasound imaging results obtained using ordinary system platforms. The progression of fatty liver inevitably causes changes in the structure of the hepatic parenchyma, which will influence the stochastic characteristics of ultrasound backscattering signals.

We have recently begun an investigation on the use of Nakagami imaging in the diagnosis of fatty liver, and developed ultrasound Nakagami parametric imaging based on generalized Rayleigh scattering (i.e., the Nakagami statistical model). In contrast with traditional ultrasound grayscale imaging, Nakagami imaging uses the statistical distribution of the raw ultrasound radiofrequency signals to create images [3,4]. According to past studies, when Nakagami parameters are \(< 1\), this indicates that the backscattering signal has a pre-Rayleigh statistical distribution, and the tissue structure may contain small quantities of scatterers or strong scatterers. Nakagami parameters equal to 1 indicate that a Rayleigh distribution exists, which means that tissue may contain periodic scatterers. The physical meaning of Nakagami parameters allows physicians to determine the arrangement of scatterers within the tissue, and their microstructure, distribution, and concentration, which is information that cannot be obtained from traditional grayscale images.

Figure 2 shows our preliminary results involving the use of Nakagami imaging to diagnose fatty liver. It can be seen that as the severity of fatty liver increases, the brightness of Nakagami images also increases. Increased brightness in Nakagami images indicates that the values of the Nakagami parameters have increased, and the statistical distribution of ultrasound backscattering has shifted from a pre-Rayleigh distribution to a Rayleigh distribution. The mechanism causing this phenomenon is an increase in the concentration of oil droplets (scatterers) in the hepatic parenchyma. One of the features of ultrasound Nakagami imaging is the provision of quantitative information concerning the concentration of scatterers. In the future, we will investigate further the applications of ultrasound Nakagami imaging in other medical conditions.

References

