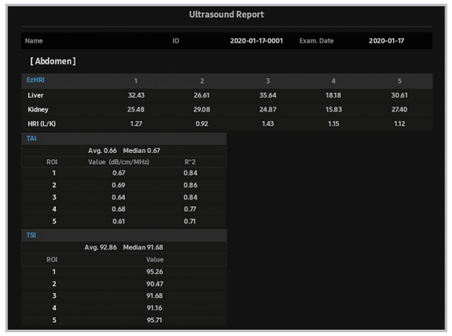
Ultrasound Report for Quantification Methods

The ultrasound report provides values obtained from measurements performed using three fatty liver quantification methods, as shown in Fig 9. EzHRI™ shows the average brightness levels of ROIs within the liver and kidney, as well as the HRI value. TAI™ and TSI™ provide users with the measured values, and assist with comparative analysis by providing the average and median values. It can be performed up to five measurements and saved the data for the methods respectively.



Ultrasound Report

Name		ID	2020-01-17-0001	Exam. Date	2020-01-17
[Abdomen]					
EzHRI	1	2	3	4	5
Liver	32.43	26.61	35.64	18.18	30.61
Kidney	25.48	29.08	24.87	15.83	27.40
HRI (L/K)	1.27	0.92	1.43	1.15	1.12

TAI — Avg. 0.66 Median 0.67

ROI	Value (dB/cm/MHz)	R^2
1	0.67	0.84
2	0.69	0.86
3	0.64	0.84
4	0.68	0.77
5	0.61	0.71

TSI — Avg. 92.86 Median 91.68

ROI	Value
1	95.26
2	90.47
3	91.68
4	91.16
5	95.71

Fig 9. Report for quantification methods

Conclusion

Samsung provides measurement methods for the three properties presented in ultrasound signals (echogenicity, attenuation, and backscatter) that can be used to track the progress of fatty liver. These are significant improvements from conventional qualitative and inconvenient measurement methods, helping users diagnose fatty liver disease and measure fatty liver through a simpler quantified index. Samsung's unparalleled non-invasive quantification tools are expected to help users provide their patients with more convenient and improved fatty liver diagnosis solutions.

References

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2. V. Borges, et al., Sonographic Hepatorenal Ratio: A Noninvasive Method to Diagnose Nonalcoholic Steatosis. Journal of Clinical Ultrasound, 2013, 41.1, 18-25.
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5. Hyungsuk Kim, Tomy Varghese. Attenuation estimation using spectral cross-correlation. IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control. 2007, 54.3, 510-519
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7. P. Mohana Shankar. A general statistical model for ultrasonic scattering from tissues. IEEE Transactions on Ultrasonics Ferroelectrics and Frequency Control 2000. 47.3, 727-36
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* This document is provided to help you understand the feature of EzHRI™, TAI™, TSI™. The objectivity is not guaranteed.

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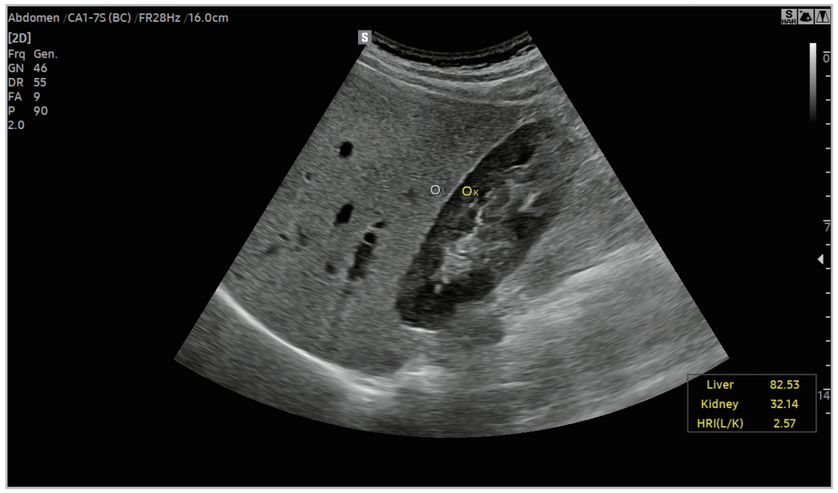
TL-EzHRI_TAI_TSI-JWP-200228-EN

SAMSUNG

EzHRI™, TAI™ & TSI™

Non-invasive Quantification Methods of Fatty Liver



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Quantification Tools for Fatty Liver

Non-Alcoholic Fatty Liver Disease

Non-Alcoholic Fatty Liver Disease (NAFLD) is an umbrella term that encompasses a spectrum of disorders, such as fat deposits in the liver, steatohepatitis, liver fibrosis, and cirrhosis, which can be found during an ultrasound and liver biopsy and are neither caused by alcohol consumption nor accompanied by other disorders. Recent figures show that the prevalence of NAFLD in Asia and the USA is approximately 30%, while its global prevalence is approximately 25% [1]. Fat deposits in the liver can increase the chances of triggering inflammatory responses and also lead to liver fibrosis. Hence, it is important to continuously monitor the liver once the patient is diagnosed with fatty liver disease. Ultrasound in patients with fatty liver typically shows increased echogenicity of the liver parenchyma relative to the right kidney cortex due to accumulation of neutral lipids in hepatocytes. Moreover, technologies that quantify attenuation of ultrasound signals generated from inside the liver, as well as changes in the scattering properties, which may occur depending on the severity of fatty liver, have been introduced and are currently being studied.

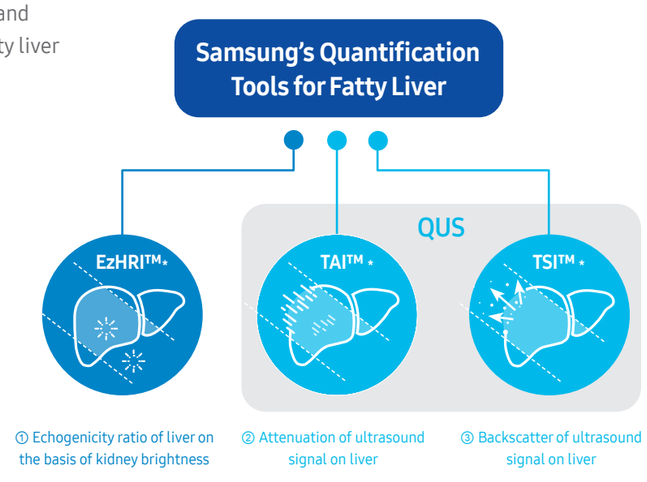
Ultrasound Signal Changes by Fatty Liver

Ultrasound signals are changed by the tissue characteristics of the human body. As the signals pass through a fatty liver, such changes can be measured in terms of three properties which are altered based on the degree of fat deposits: the amplitude, the variation of the frequency component, and the degree of signal scattering. These properties have generally been combined and displayed as brightness information on ultrasound images. Recently, several different methods have been introduced to quantify these properties and aid in the diagnosis of fatty liver.

Fig1. Ultrasound signal changes by fatty liver

Samsung's Quantification Tools for Fatty Liver

In order to feature the different measurement principles and ensure ease of use, Samsung's quantification tools for fatty liver provide measurement methods for three properties: ① Echogenicity, ② Attenuation, and ③ Backscatter. The characteristics shown by each of these ultrasound measurement principles change as hepatic steatosis progresses.



* HRI : HepatoRenal Index

* TAI™ : Tissue Attenuation Imaging

* TSI™ : Tissue Scatter distribution Imaging

EzHRI™

Hepato-Renal Index with Automated ROI Recommendation

Technical Principle of HRI

Studies have shown that the hepatorenal index (HRI) or hepatorenal ratio (HRR) is a sensitive and non-invasive test [2,3,4]. It is a simple calculation of the B-mode ratio, or the brightness ratio of the liver parenchyma over the renal cortex in each user-selected ROI. The equation used to calculate the value is shown to the right [2,3,4].

$$HRI = \frac{Brightness\ of\ liver}{Brightness\ of\ kidney}$$

Eq 1. Hepatorenal index equation

EzHRI™

EzHRI™ functions in much the same way as the conventional HRI, but offers greater convenience and an improved workflow by suggesting initial ROI positions. The calculation involved in determining initial ROI positions requires three steps: Liver and kidney segmentation, ROI extraction from both the liver and the kidney on a user-selected image, and calculation of the HRI. EzHRI™ segments the input image (Fig 2) into the kidney and liver (Fig 3), based on deep learning technology. It then uses the stochastic analysis method, which extracts three brightness classes from each segmented organ (Fig 4), to extract only the cortex while excluding other anatomical structures and image artifacts.

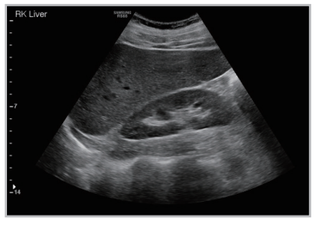


Fig 2. Input image

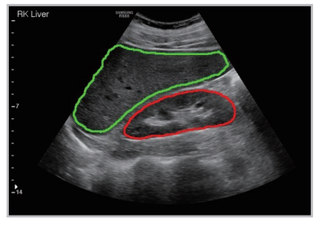


Fig 3. Segmentation of liver and kidney

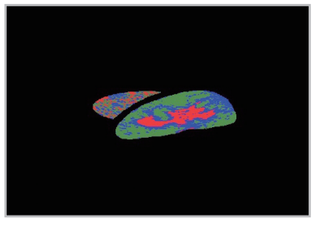


Fig 4. Three brightness classes

Lastly, it finds the ROIs in the liver and kidney exhibiting the lowest brightness variance, calculates the average brightness ratio for each ROI, and then measures the HRI value (Fig 5). Users may also position the ROIs based on individual preferences and measure the HRI value. EzHRI™ provides users quantified HRI, with the comfort that Samsung's cutting-edge technologies brings to enable them to diagnose quicker and trace the analysis conveniently.

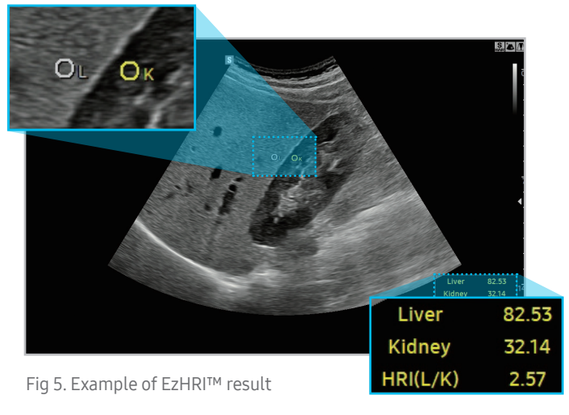


Fig 5. Example of EzHRI™ result

QUS for liver
Quantitative Ultrasound Methods in Diagnosis

TAI™ (Tissue Attenuation Imaging)

TAI™ is a tool that quantitatively measures attenuation of ultrasound signals received from the liver. Attenuation of ultrasound signals is a gradual loss of signal strength due to absorption, reflection, refraction, scattering, etc. TAI™ quantifies attenuation based on changes in the center frequency under the optimal transmission and reception conditions. Attenuation is greater in higher frequency components, resulting in changes in the center frequency of the signal. The figure below (Fig 6) shows that attenuation causes a change in the center frequency at a deeper depth, while a more severe fatty liver is associated with a greater attenuation [5,6].

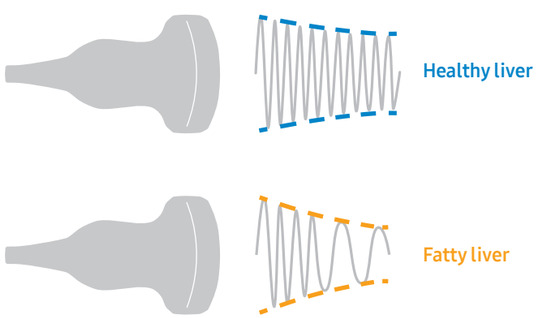


Fig 6. Ultrasound attenuation between healthy liver and fatty liver

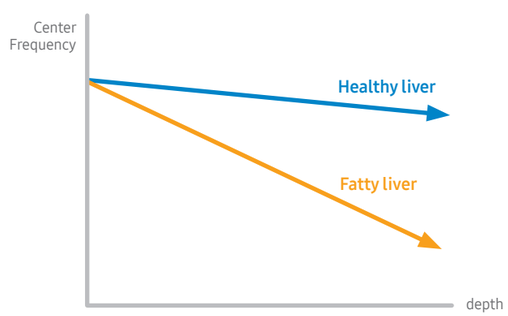
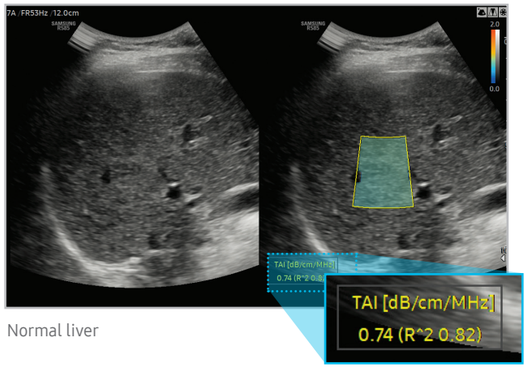
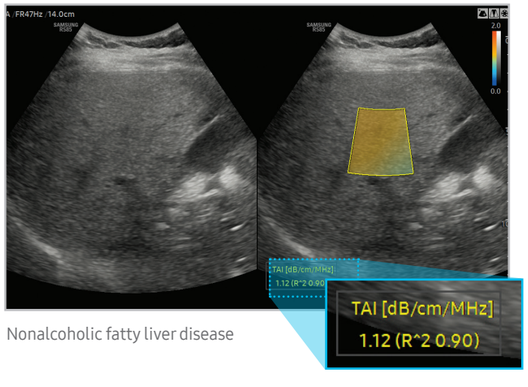


Fig 7. Center frequency shift along the depth



Normal liver



Nonalcoholic fatty liver disease

Precaution

To ensure accurate measurement, it is recommended that the user should select an ROI in the liver parenchyma window, excluding the major veins, at least 3 cm from the liver capsule, while the patient is holding their breath. Note that the reliability of the measurement is expressed as an R^2 value. It is recommended that the user performs a measurement in a region with an R^2 value of 0.6 or above. An R^2 value below 0.6 is displayed in red, and measurement in such a region is not recommended.

TSI™ (Tissue Scatter distribution Imaging)

TSI™ is a tool that quantifies the scattered signal distribution based on backscattered signals. Scattering, the reflection of ultrasonic waves in multiple directions not affected by their entry angle, produces speckle patterns in ultrasound images. This changes the distribution of backscattered ultrasound signals, based on the scattering intensity. The distribution can be modeled by applying a statistical distribution. The Rayleigh distribution is used to represent the case of a high density of random scatterers without coherent signal components. Based on this model, TSI™ represents scattering by quantifying the correlation between the backscattered signals and the Rayleigh distribution [6,7,8].

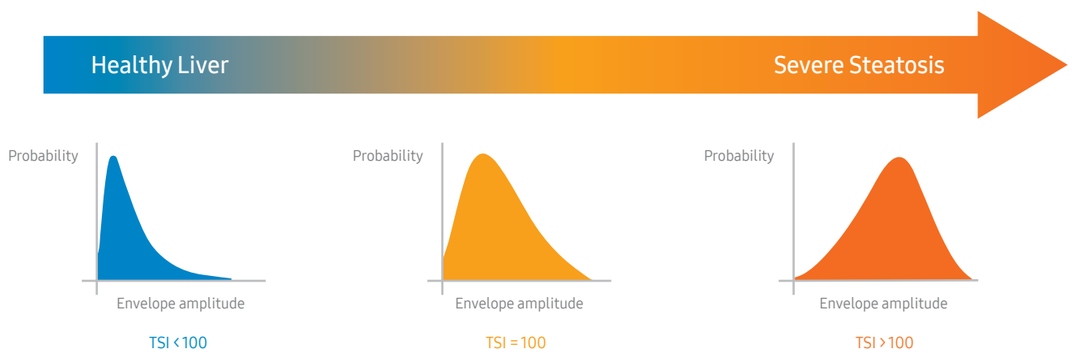
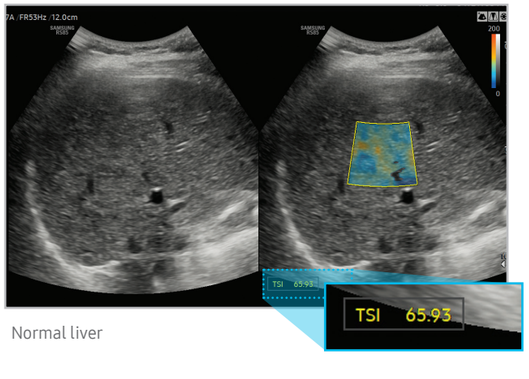
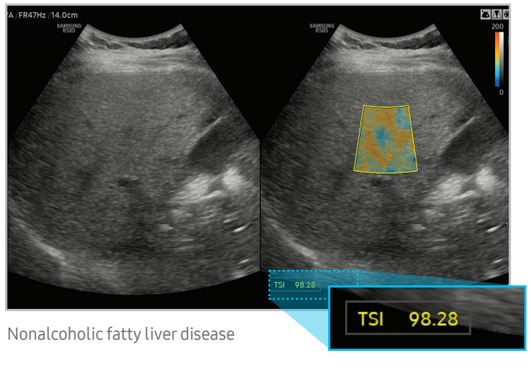


Fig 8. Backscattered distribution depending on the severity of fatty liver



Normal liver



Nonalcoholic fatty liver disease

The left image shows a healthy liver with a TSI value corresponding to a Pre-Rayleigh distribution, while the right image shows a severe fatty liver with a TSI value corresponding to a Post-Rayleigh distribution.

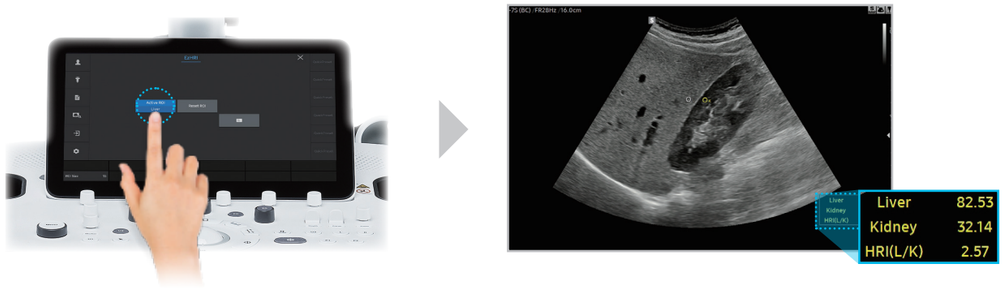
How to Use

Workflow of Quantification Tools for Fatty Liver

EzHRI™

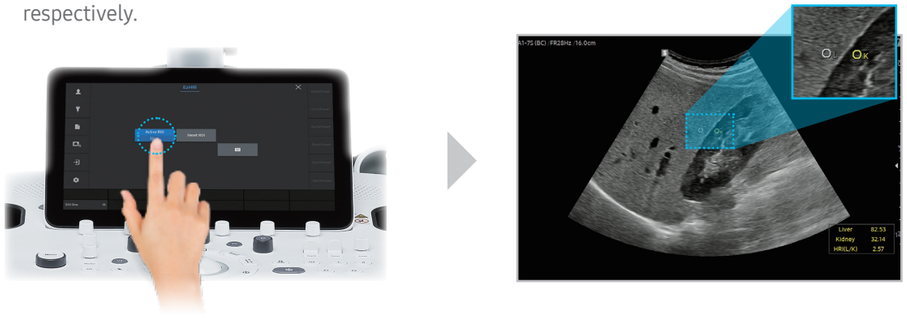
Press the “EzHRI” button after scanning

Press the “EzHRI” button on the touch screen after freezing a clear view of the right liver lobe and right kidney. Initial liver and kidney ROIs are proposed automatically and the HRI value is displayed on the screen.



[Optional] ### Press the “Activate ROI” if ROIs need to be modified

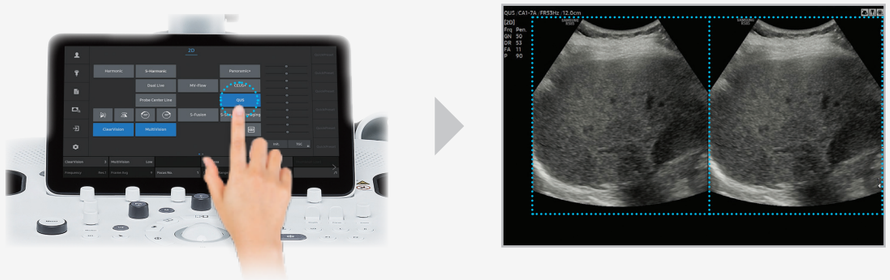
Press the “Activate ROI” button if the proposed initial positions of the liver and kidney ROIs need to be modified. The ‘L’ and ‘K’ labeled ROIs should be placed in the liver parenchyma and renal cortex respectively.



QUS

Press the “QUS” button after scanning

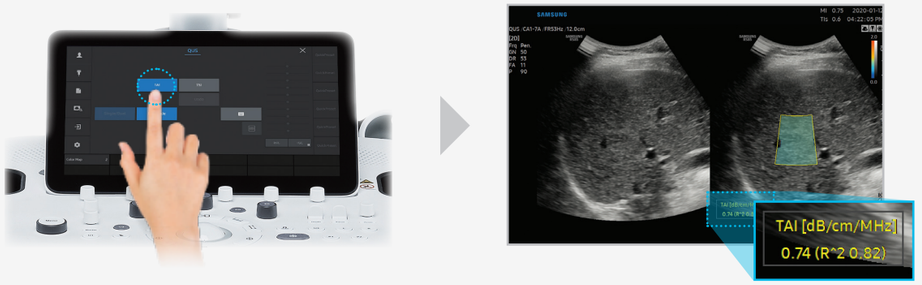
Enter the QUS mode by pressing the “QUS” button on the touch screen. A dual view will be displayed on the screen.



TAI™

Press the “TAI” button

Press the “TAI” button on the touch screen to display an ROI on the screen. Position the ROI that meets the recommendation in the precaution. The TAI and R^2 values will then be displayed at the bottom of the screen.



TSI™

Press the “TSI” button

Press the “TSI” button on the touch screen to display an ROI on the screen. Position the ROI that meets the recommendation in the precaution. The TSI value will then be displayed at the bottom of the screen.