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Philips Auto ElastQ

Improving the quality and workflow of liver stiffness assessment

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Overview

Auto ElastQ software, introduced on the Philips EPIQ Elite and Affiniti ultrasound platforms, is designed to improve the quality and consistency of liver stiffness measurements and streamline the process of performing those measurements as part of an overall abdominal ultrasound examination.

Background

Auto ElastQ is a new automated measurement capability for use with Philips Ultrasound 2D Shear Wave Imaging – (ElastQ). ElastQ provides visualization of liver stiffness over a 2D region. With ElastQ, an acoustic pulse is used to “push” tissue in the axial direction, perpendicular to the face of the transducer. This push pulse generates a transverse (or shear) wave that moves parallel to the face of the transducer. The shear wave moves more quickly in stiff tissue and more slowly in soft tissue. Therefore, the shear wave speed can be used to estimate the stiffness of the underlying tissue. Auto ElastQ is an automated way to make stiffness measurements within the ElastQ image.

Shear wave elastography in ultrasound has become a well-accepted method for measuring the stiffness of the liver. Consensus panels such as the Society for Radiologists in Ultrasound (SRU) have put forth clinical management guidelines for patients based on these measured values.[1]

One advantage of ElastQ as compared to prior point quantification methods (such as Philips Ultrasound Point Shear Wave Imaging – ElastPQ) is the fact that with ElastQ, artifacts in the 2D shear wave image can be visualized and avoided when taking the measurement. Some common artifacts include reverberation from the abdominal wall, as well as vessels within the ElastQ region. To obtain an accurate measurement of the stiffness of the liver, shear wave speed must be estimated in homogeneous tissue where shear wave propagation is consistent.

Current challenges with elastography measurements

While 2D shear wave elastography has been available for several years, performing high-quality measurements with low interoperator variability remains a challenge. Some of the variability can be reduced by standardizing the acquisition protocol, including guidance on patient positioning and management of respiration. Despite this, the actual measurement of liver stiffness, even after a high-quality acquisition, can still be highly variable among users.

This can be attributed to several factors:

1. **Lack of temporal consistency –** Obtaining a high-quality consistent shear wave image in the liver requires allowing enough time for the shear waves to generate, propagate and reach steady state. It has been observed that some users do not wait long enough for a stable shear wave image to form. If the patient is still freely breathing, some of the shear wave image may be showing transient artifacts from respiratory motion. Measurements made on these transient artifacts will not reflect the actual stiffness of the liver.
2. **Subjectivity –** Users are trained to place their measurements in a region of the liver where the stiffness value is representative of what is shown in the ElastQ box. This selection is relatively straightforward for normal, soft livers where the shear wave image is uniform **(see Figure 1)**. It becomes increasingly challenging and subjective with diseased, cirrhotic livers **(see Figure 2)**. In these livers, the shear wave image tends to be rather heterogeneous, and finding a representative region is often a subjective judgment on the part of the user.
3. **Presence of artifacts –** While more experienced users can recognize and avoid artifacts in the image when performing a measurement, less experienced users may have a difficult time recognizing artifacts such as reverberation.

Beyond the issue of interoperator variability, taking multiple stiffness measurements required in an elastography protocol is time-consuming. It typically involves multiple acquisitions in which the patient must do repeated breath holds, followed by the user scrolling back through each acquisition to pick the desired frame for measurements, and finally placing the measurement region of interest (ROI) in the proper location in the frame. This increases exam time, slows patient throughput and adds to the repetitive motion injury concerns of clinicians performing the exam.

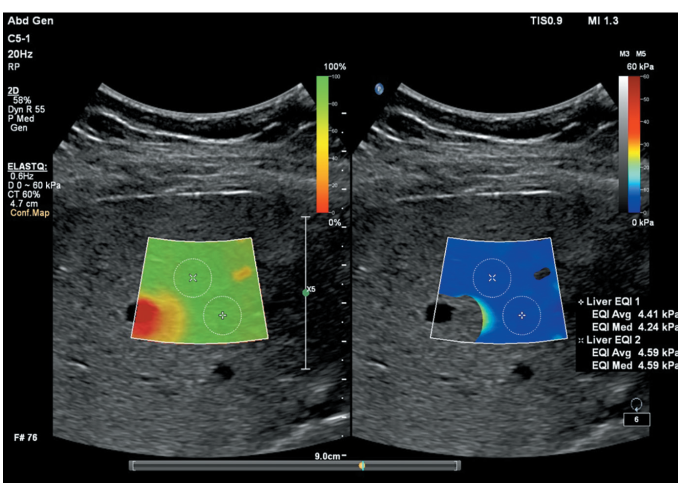

Figure 1
ElastQ image of a normal liver with low stiffness values.

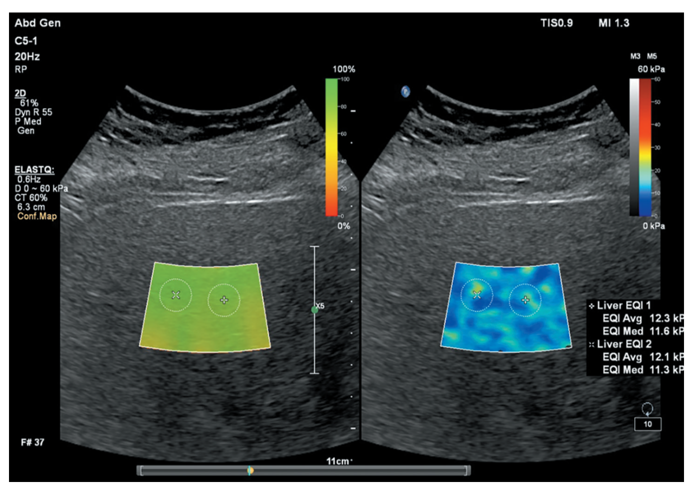

Figure 2
ElastQ image of a stiff liver of a patient with known cirrhosis.

Auto ElastQ operating principles

Auto ElastQ is a capability on the Philips EPIQ Elite and Affiniti platforms that works to improve the quality of liver stiffness measurement by streamlining the process of obtaining stiffness measurements. It does so by automatically selecting frames within a cineloop of the liver to use for measurements. Within these selected frames, Auto ElastQ analyzes the ElastQ image and automatically places the measurement ROI in an appropriate location within the image based on various image analysis metrics.

Automatic frame selection

During an elastography exam, the user finds the appropriate acoustic window, holds the transducer steady and has the patient do a breath hold. During this time, the user watches the series of ElastQ images onscreen and hits "Freeze" when several frames have been acquired. With manual ElastQ workflow, the user would then have to scroll back through the cineloop buffer, inspecting each ElastQ frame and determining if it is acceptable for measurements.

With Auto ElastQ, the software automatically analyzes the series of ElastQ frames and selects up to three frames for measurements based on the temporal stability of the frames **(Figure 3)**.

The frame selection is done by comparing each unique ElastQ frame with its adjacent neighbors. Some of the metrics used in ranking the stability of each frame include:

- Frame-to-frame difference between a frame and frames that are just before and just after that frame.
- Percent filling within the ElastQ box. This is a measure of how many pixels within the box exceed the selected confidence threshold.

Frames having a combination of low frame-to-frame difference and high filling are selected by the Auto ElastQ algorithm and presented to the user.

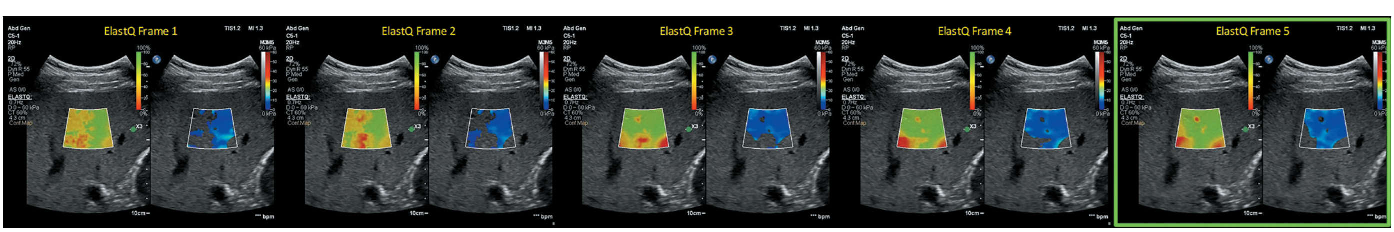

Figure 3
Series of elastography frames captured during a 6-second acquisition. The shear wave propagation becomes increasingly stable over time, resulting in increasing fill in the ElastQ box. The final frame (highlighted in green) is selected as the most stable frame for measurement based on its similarity with the prior frame and the high degree of fill.

Automatic ROI placement

For each selected frame, Auto ElastQ determines where to place the measurement ROI based on several characteristics of the ElastQ image.

Prevalence of the stiffness value

Proper manual placement of the ROI requires that the user positions the ROI in an area of the elastography image that is representative of the overall stiffness across the entire image. For example, an ElastQ image acquired of a soft liver will look predominantly blue in the default color map. In that case, the ROI should be placed in a representative blue region. In comparison, a stiff liver would look mostly green, and therefore the ROI should be placed in a representative green region, even if there are also small areas of blue in the image.

To find the region that is most representative of the stiffness values in the ElastQ box, Auto ElastQ looks at the stiffness value at each pixel location and determines what percentage of pixels in the box have similar values to that pixel. Locations where the stiffness values are seen throughout the image are assigned high prevalence values. Locations with values that are not seen elsewhere are assigned low prevalence values **(Figure 4)**.

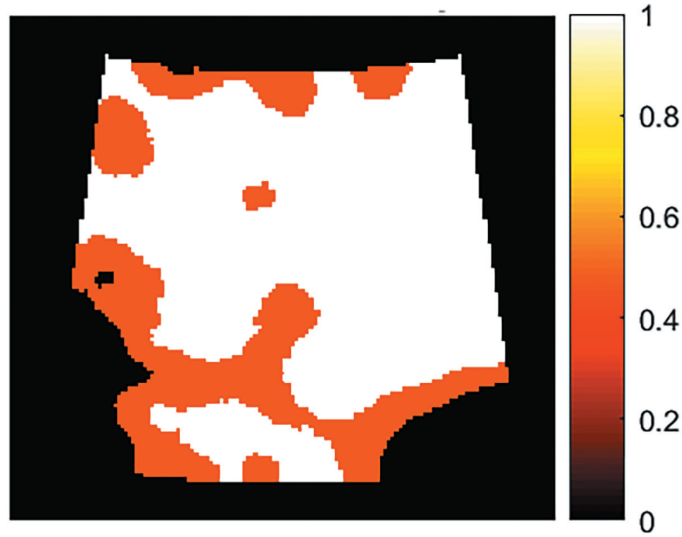

Figure 4
Prevalence map showing prevalence of a particular stiffness value relative to the rest of the ElastQ image. Pixel locations colored white (higher end of the scale) have stiffness values that occur in many other locations in the box, while pixel locations colored red (lower end of the scale) have stiffness values that are not present elsewhere.

Smoothness

Shear wave speed estimation relies on assuming that the shear waves are propagating in a homogeneous medium. One possible way to characterize the homogeneity of the medium and the consistency of the shear waves generated is by looking at the local standard deviation within subregions in the shear wave image **(Figure 5)**. The local standard deviation will be lower where the tissue is homogeneous and higher in regions where there are underlying vessels, reverberation or transient artifacts. Auto ElastQ will preferentially place the ROI in regions with the lowest local standard deviation values.

The importance of placing the ROI in low standard deviation regions has been reported in publications such as Brattain, et al.[2] The most recent guidelines on liver elastography from the World Federation for Ultrasound in Medicine and Biology (WFUMB)[3] recommend taking the local standard deviation over the mean stiffness for each measurement ROI and minimizing this ratio to improve the quality of each measurement.

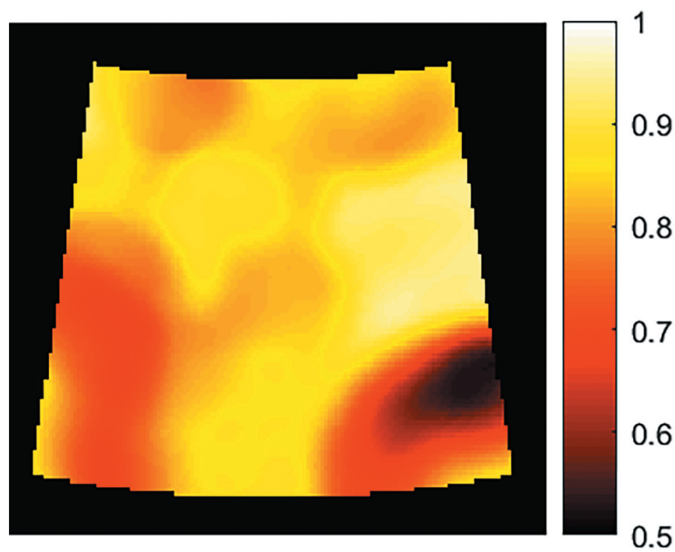

Figure 5
Smoothness map showing the local standard deviation within sub-regions in the ElastQ image.

Temporal stability

Finally, Auto ElastQ estimates the temporal stability of each subregion in the image relative to the neighboring frames. Artifacts due to motion tend to be transient and appear in only one frame and not in adjacent frames. Subregions with artifacts will show low temporal stability, while subregions with consistent shear waves will exhibit a high degree of temporal stability **(Figure 6)**. Auto ElastQ will preferentially select subregions with high temporal stability.

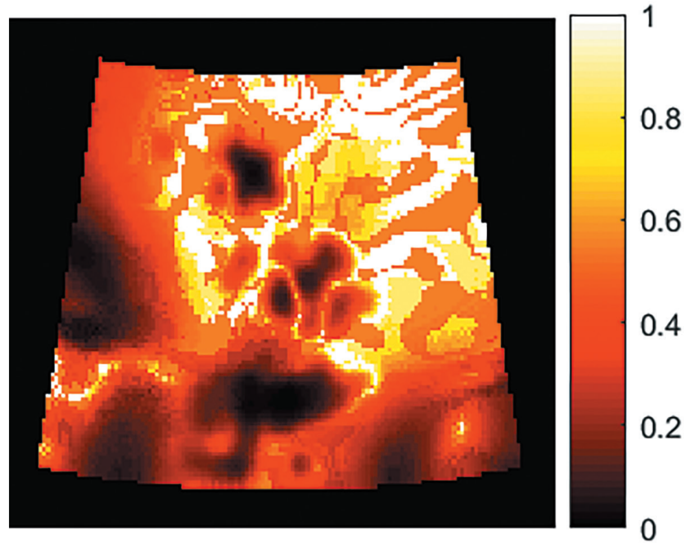

Figure 6
Temporal stability map showing how similar or different each subregion is compared to the adjacent ElastQ frames.

Final heat map

The prevalence, smoothness and temporal stability maps across the ElastQ imaging box are combined to form a composite heat map. The measurement ROI is then placed at the peak of the composite heat map **(Figure 7)**.

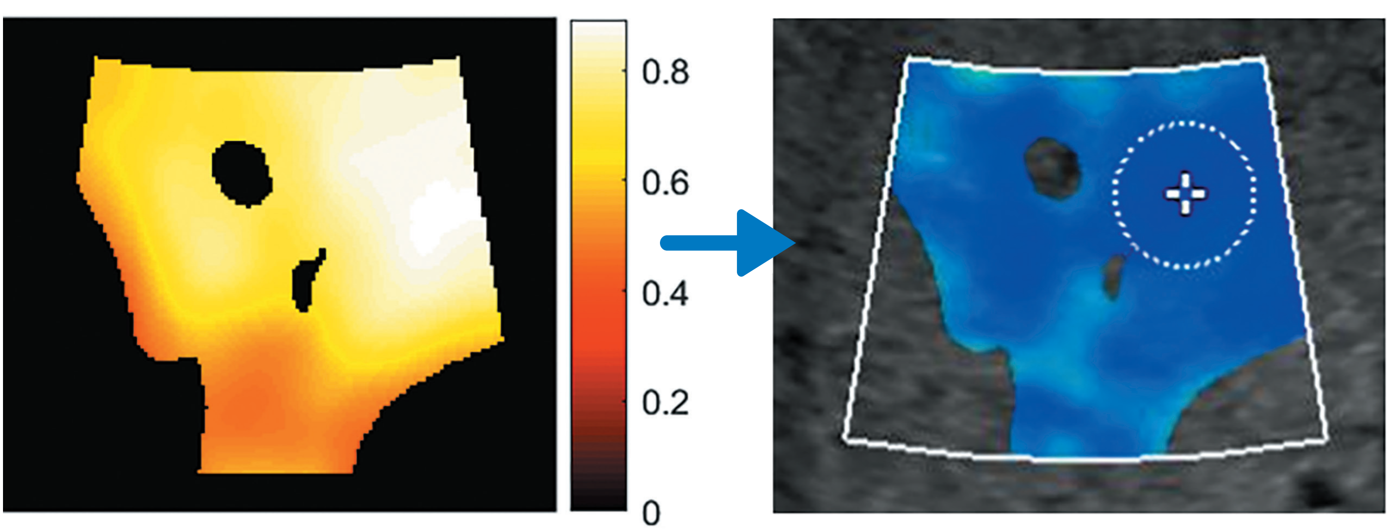

Figure 7
Final heat map based on a composite of the other heat maps. The measurement circle is placed at the peak of the final heat map.

User interface

When the Auto ElastQ button on the Elasto touchscreen is enabled **(Figure 8)**, pressing the "Freeze" button causes the system to automatically determine which three frames to use for measurements and display the first of the three frames. The ROI is launched and placed in the desired location based on the composite heat map described.

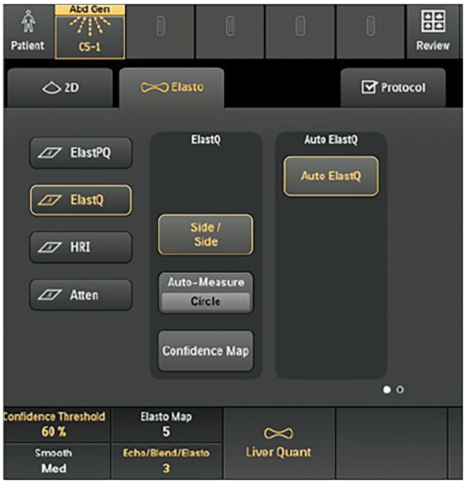

Figure 8

ElastQ touchscreen showing the Auto ElastQ button. Enabling this button causes the system to automatically select the frames and locations for measuring liver stiffness.

If the user agrees with the frame selected and the ROI position, pressing the "Acquire" button will record the image and assign the measured values to the first "Liver EQI" label. Doing so brings up the "Next Frame" control in the middle trackball button **(Figure 9)**. Pressing the "Next Frame" button will cause the system to jump to the second frame of the three selected and place the ROI on the second frame according to the composite heat map for that frame.

This sequence can be repeated one more time to get the third measurement.

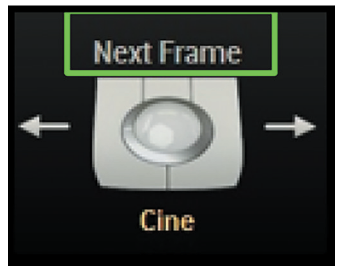

Figure 9

"Next Frame" control allows the user to jump to the next ideal frame for performing ElastQ measurements.

When Auto ElastQ performs the ElastQ measurements, the image information display area will show the additional information highlighted by the green box in **Figure 10**.

Auto EQ Fr 1/3: Indicates that this is the first of the three frames selected by Auto ElastQ for measurements. The user is free to select a different frame other than that chosen by Auto ElastQ, but doing so will cause the "Auto EQ Fr 1/3" label to disappear.

Auto EQ ROI: Indicates that the ROI shown in the image has been placed by Auto ElastQ. The user can move that ROI position manually using the trackball. Doing so will cause the "Auto EQ ROI" label to disappear.

Note: The recommended cineloop capture duration is about six seconds after the patient suspends breathing. If the loop duration is shorter, the Auto ElastQ feature may provide fewer than three frames for the user to perform measurements. In instances where all frames show minimal fill (< 50%) inside the box, Auto ElastQ will place the measurement ROI in the middle of the ElastQ box, colored in red, to indicate that the algorithm was unable to find a suitable frame or location for measurement. **(Figure 11)** It is up to the user to decide if the ROI should be manually placed or if an ElastQ reacquisition is needed.

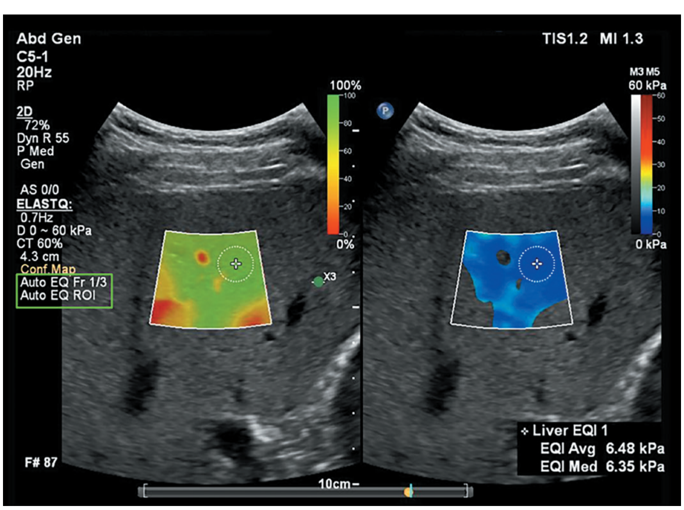

Figure 10

ElastQ image with the first measurement ROI selected by Auto ElastQ.

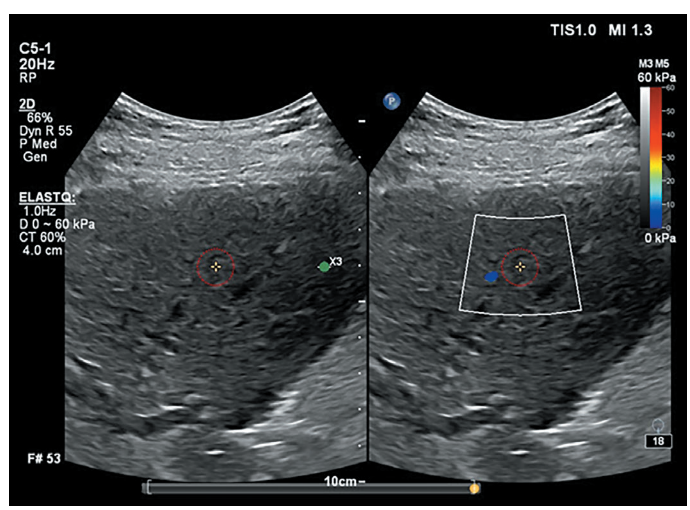

Figure 11

ElastQ image where the lack of ElastQ data in the box results in a red ROI circle being placed in the middle of the box, indicating that Auto ElastQ was unable to find an appropriate location for measurement.

Summary of clinical study data

A retrospective study was conducted using data from 107 patients, across three sites, who were suspected of, or diagnosed with, non-alcoholic fatty liver disease (NAFLD), non-alcoholic steatohepatitis (NASH) or liver cirrhosis from August 2020 to August 2024. The demographics of the patient population are shown in **Table 1**. Each subject was scanned with the C5-1 transducer on the Philips EPIQ Elite ultrasound system, and a total of three elastography loops were acquired for each patient. Three measurements per loop were done on the three loops from each patient by each individual expert reader, for a total of nine measurements per patient. The median value of the nine measurements was the elastography result for that patient by each expert reader. The results from the expert readers were averaged and used as the manually measured liver stiffness value for each patient. For the Auto ElastQ result, the three loops were analyzed in "Review" on a Philips EPIQ Elite system with the Elevate software release. The median of the nine Auto ElastQ measurements from the three loops was taken to be the Auto ElastQ-measured liver stiffness for each patient.

	Datasets (N=107) Mean ± SD (N) (Min, Max) or % (n/N)
Age (years)	54.6 ± 12.8 (102*) (24,86)
Gender	
Male	38.3% (41/107)
Female	61.7% (66/107)
Ethnicity	
Asian	3.7% (4/107)
Black or African American	4.7% (5/107)
White	89.7% (96/107)
Hispanic/Latino	1.9% (2/107)
Height (cm)	168.6 ± 10.0 (107) (144.0, 198.1)
Weight (kg)	90.2 ± 21.2 (107) (53.5, 149.2)
BMI (kg/m²)	31.6 ± 6.4 (107) (20.2, 50.0)

*Age information was not available for five of the subjects.

Table 1
Demographics of the clinical study population.

Figure 12 shows the distribution of liver stiffness values of the patients in the study using the vendor-neutral "rule of four" from the SRU consensus guidelines. **Figure 13** shows the plot of the stiffness measurements done by Auto ElastQ as compared to the average results from human expert readers. Excellent agreement between Auto ElastQ and human experts is demonstrated with a Lin's concordance correlation coefficient of 0.97 with a 95% confidence interval of (0.96, 0.98).

Distribution of patients

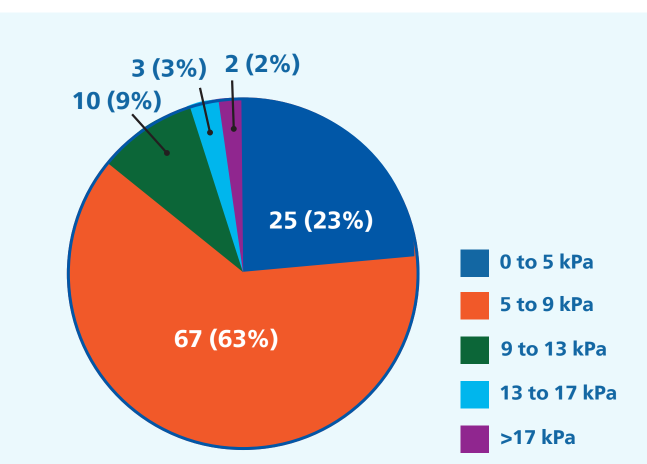

Figure 12
Distribution of patient liver stiffness values based on the categories outlined in the "rule of four" used in the SRU consensus guidelines.

Auto ElastQ vs human experts

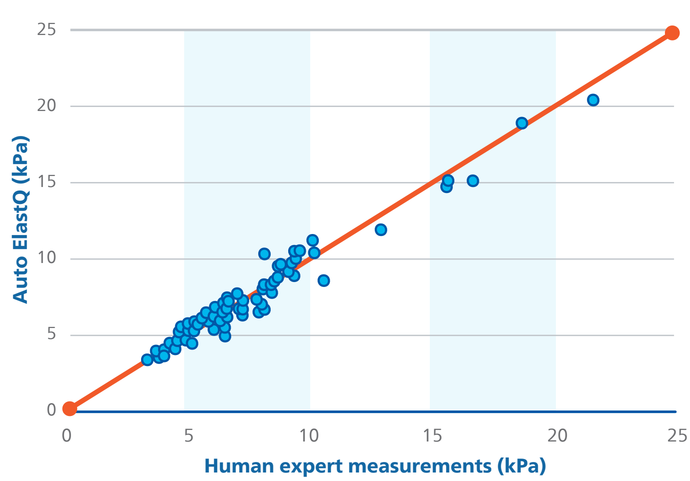

Figure 13
Auto ElastQ measurements as compared to measurements on the same datasets by human experts.

Time reduction in liver elastography measurements

As part of the retrospective study, the time taken to perform the nine elastography measurements for each subject was also collected. The measurement time per subject was estimated by comparing the time of the first measurement and the last measurement. Twenty subjects were randomly selected, and the average time duration for manual measurements by the three human expert readers was compared against the result when three other human readers performed the measurements aided by Auto ElastQ.

Average time taken for manual measurements was 175 seconds (standard deviation ± 61 seconds) as compared to 70 seconds (standard deviation ± 36 seconds) for elastography measurements aided by Auto ElastQ. Analysis done on the time taken for both groups shows a statistically significant ($p < 0.0001$) reduction of measurement time, with Auto ElastQ-aided measurements taking 60% less time than manual measurements **(Figure 13)**.

Average time taken for measurements

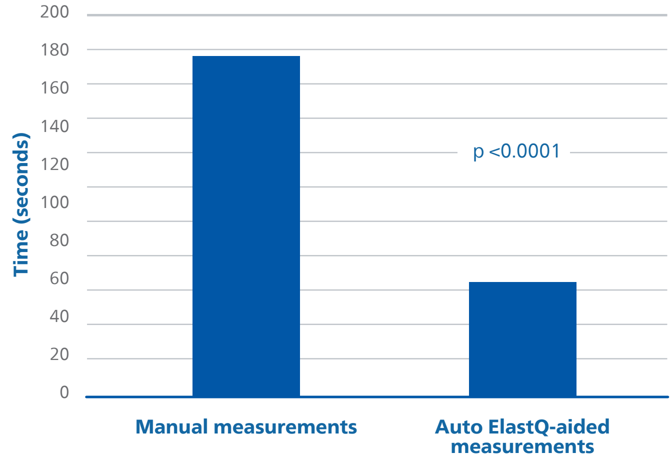

Figure 12

Difference in average time taken for the two groups: manual elastography measurements and elastography measurements aided by Auto ElastQ. Time taken was averaged across three readers in each group and also across the 20 datasets.

Conclusion

Auto ElastQ is an important new tool to reduce the subjectivity present when making liver stiffness measurements using ElastQ. This tool looks at the differences between frames in a cineloop to select appropriate frames for liver stiffness measurements. Within the selected frames, the ElastQ image is analyzed by Auto ElastQ to decide where the measurement ROI should be placed. This is a tool that incorporates many of the best practices for liver elastography measurements. In doing so, it not only improves the consistency of ElastQ measurements, but it also streamlines the workflow and reduces the time needed for measuring liver stiffness as part of an overall abdominal ultrasound examination.

References

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3. Ferraioli G, Barr RG, Berzigotti A, et al. WFUMB Guideline/Guidance on Liver Multiparametric Ultrasound: Part 1. Update to 2018 Guidelines on Liver Ultrasound Elastography. Ultrasound in Med. & Biol., Vol. 50, pp. 1071–1087, 2024.

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