



Research Center for Frontier Medical Engineering

Ultrasonics & Medical Imaging Lab.

第2回 バイオ超音波顕微鏡研究会

2013.07.13

びまん性肝疾患の定量評価へ向けた試み

千葉大学

フロンティアメディカル工学研究開発センター

Ultrasonics and Medical Imaging Laboratory

山口 匡



国立大学法人 千葉大学

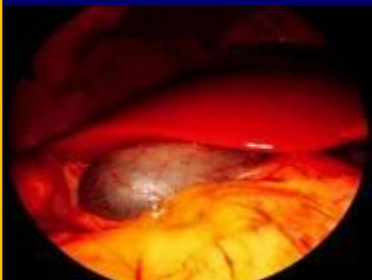
National University Corporation
Chiba University

肝線維症のエコー信号の特徴

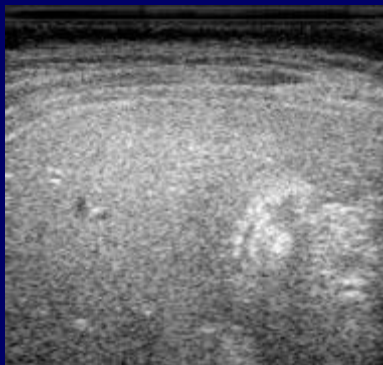


[UMI]

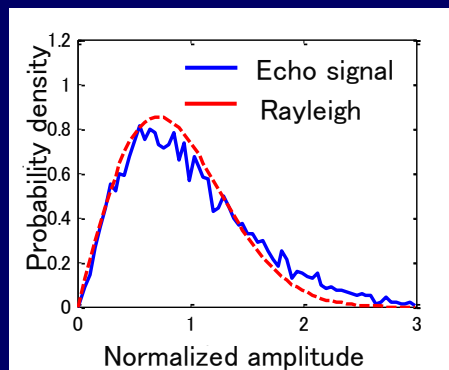
Normal liver



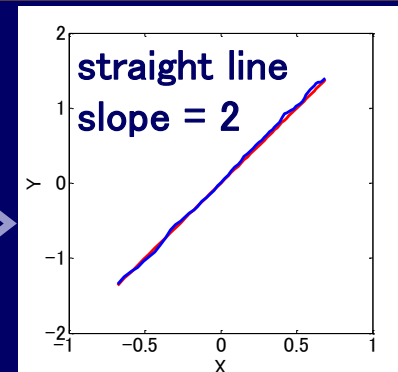
Homogenous



US image



probability density

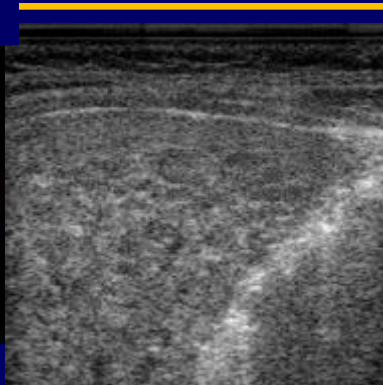


Q-Q probability plot

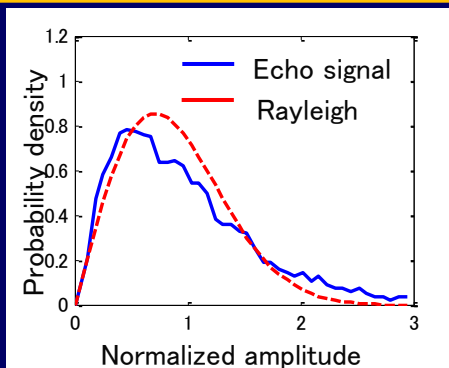
Liver fibrosis



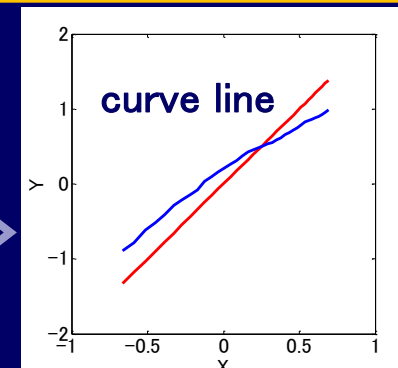
Fiber tissue



US image



probability density



Q-Q probability plot

Rayleigh distribution

$$p(x) = \frac{2x}{\sigma^2} \exp\left[-\left(\frac{x}{\sigma}\right)^2\right]$$

x : amplitude

σ^2 : variance

Q-Q probability plot

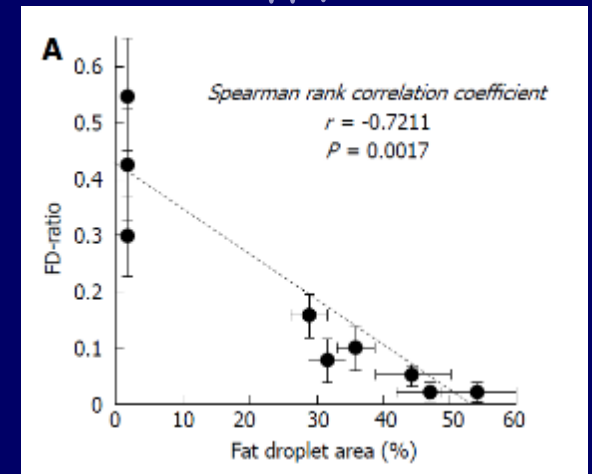
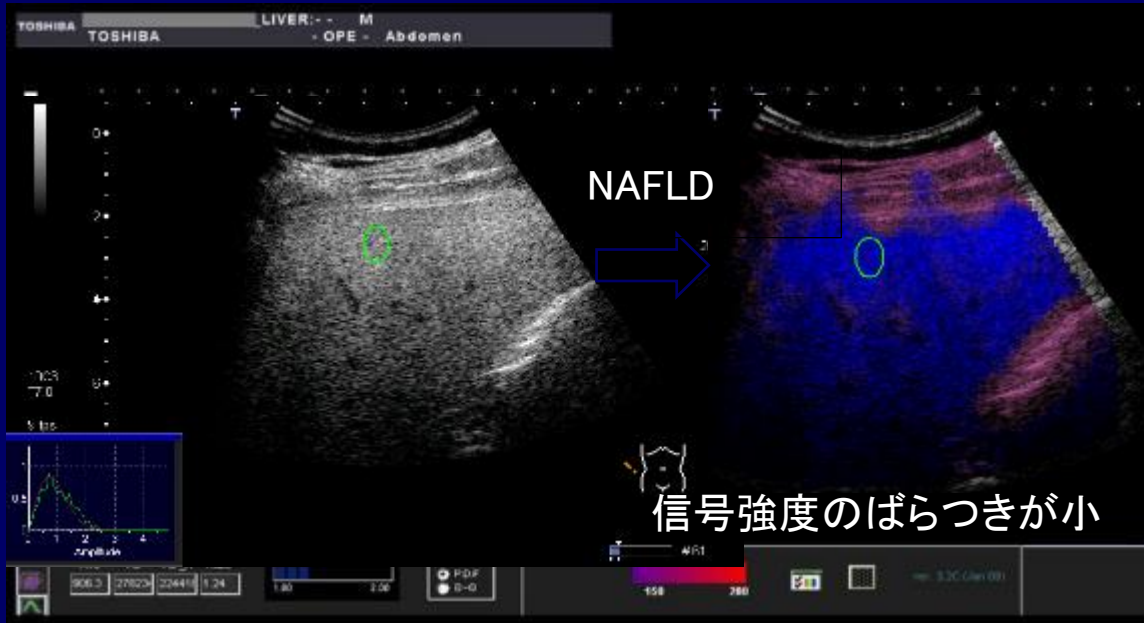
$$P(X) = \int_0^X p(x) dx$$

$$X = \ln(x)$$

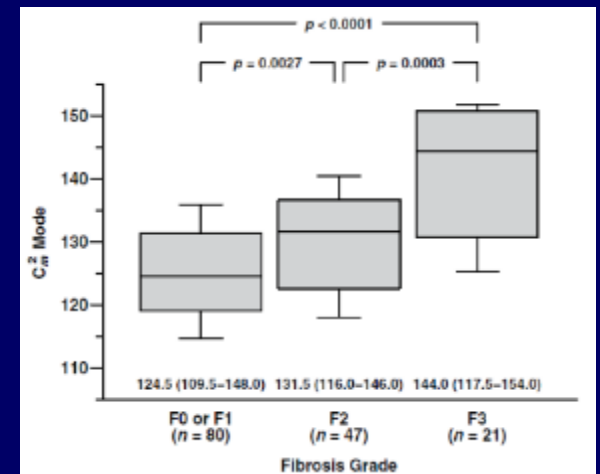
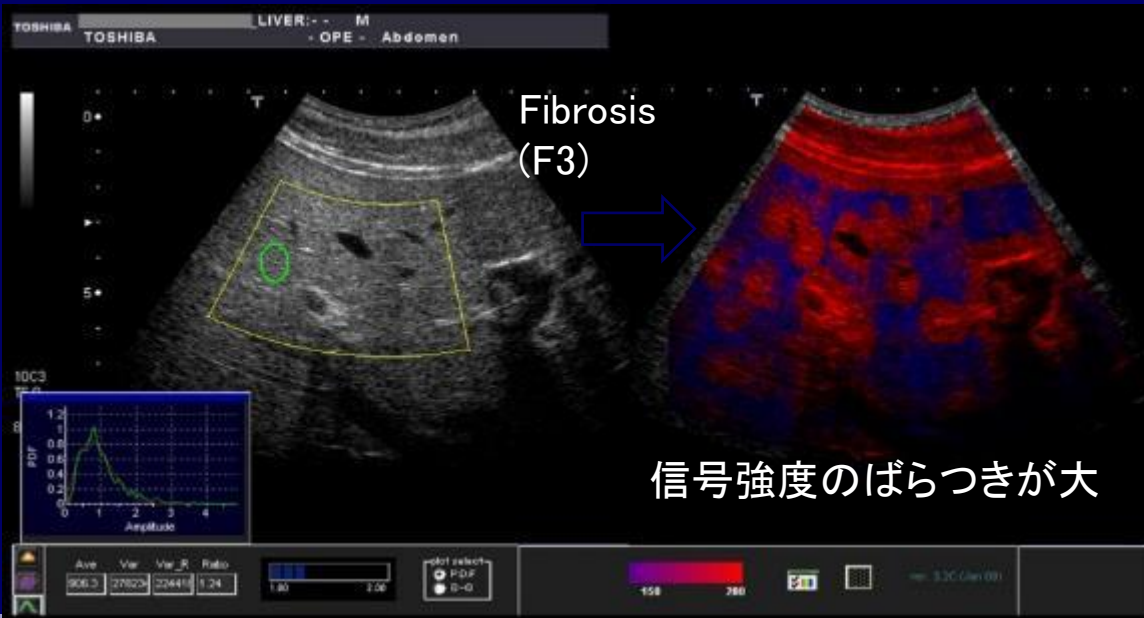
$$Y = \ln[-\ln(1 - P(X))]$$

組織構造の不均質性(散乱体密度)の評価

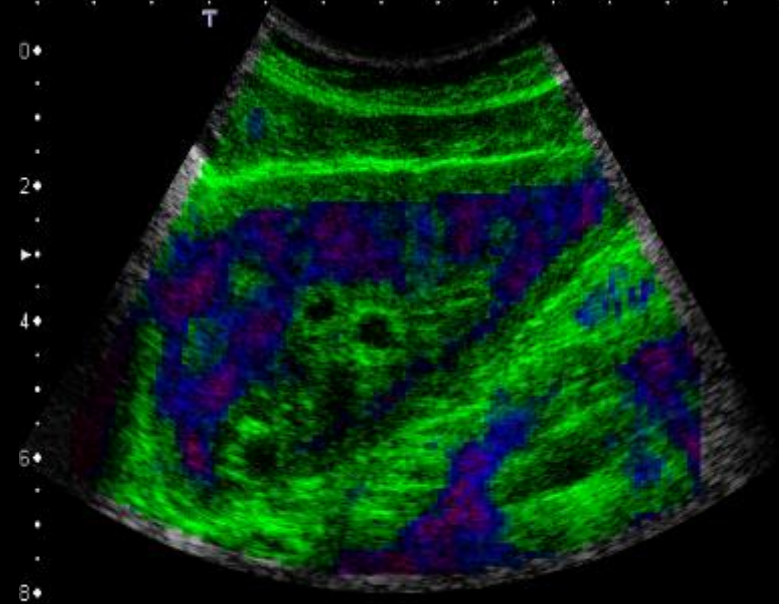
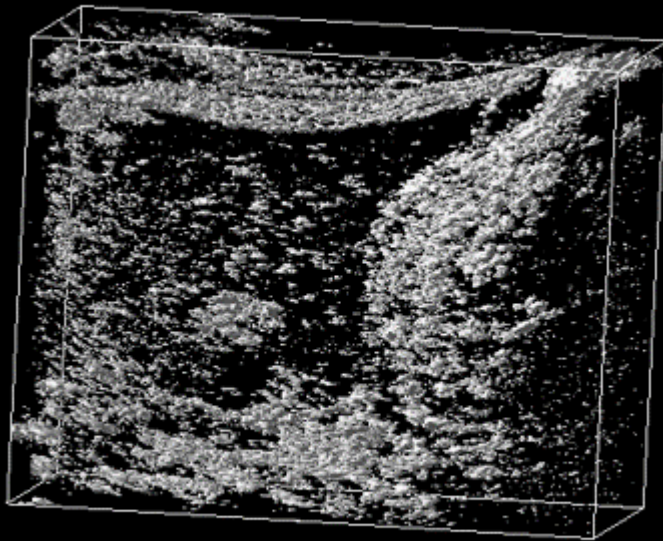
[UMI]



脂肪沈着の判定結果例



線維化の判定結果例



肝臓中の散乱体構造の不均質性を評価

- 線維の検出
- 脂肪可の評価

実用化されているび慢性肝疾患の定量診断法



[UMI]

SIEMENS VTTQ (Virtual Touch Tissue Quantification)

Measure the speed of sound of shear wave for elasticity estimation (push pulse)



<http://www.medical.siemens.com/>

TOSHIBA ASQ (Acoustic Structure Quantification)

Estimate the scatterer structure by statistical echo analysis



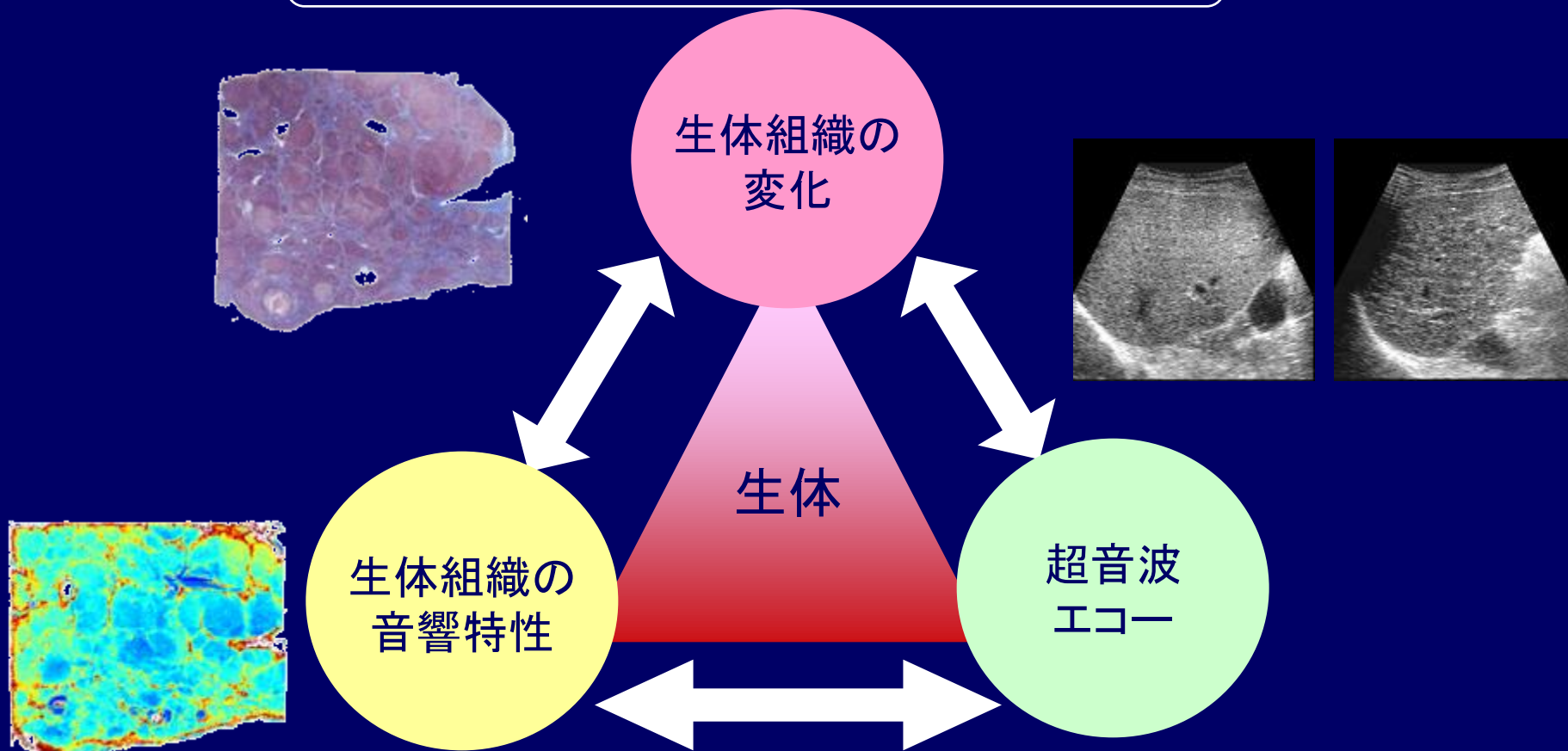
Measure the stiffness by phase tracking of shear wave (mechanical vibration)



<http://www.echosens.com>



① 生体組織の物理的・化学的な変化



② 組織中を音が伝搬する様子の変化

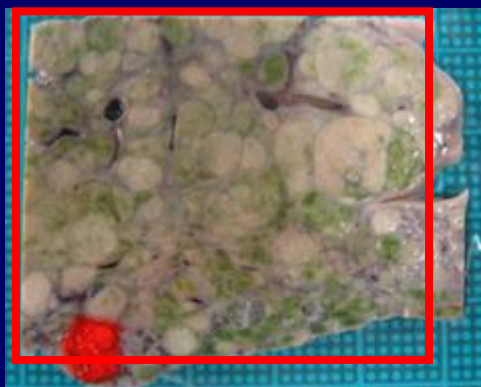
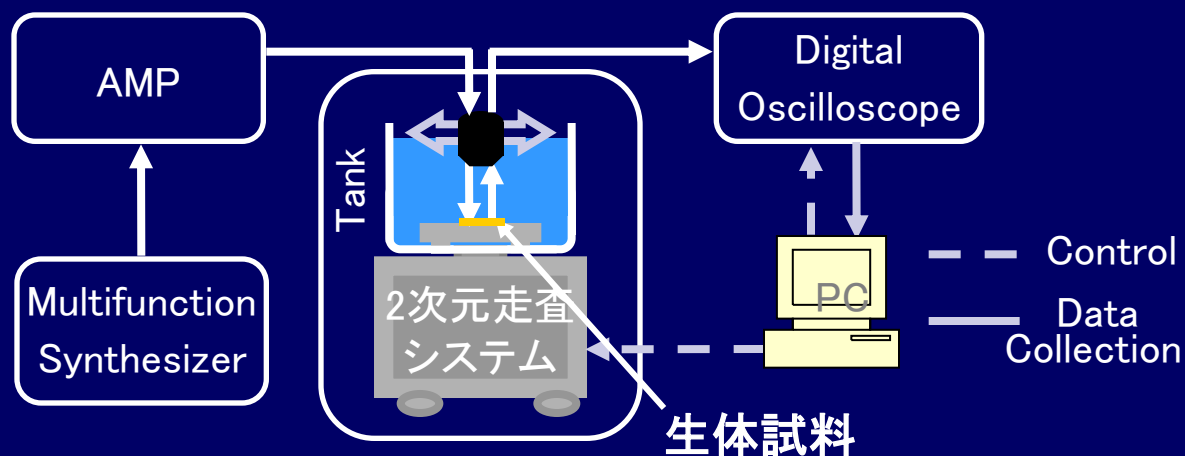
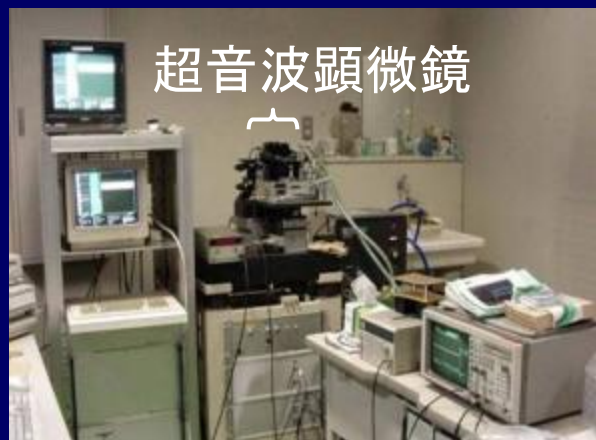
③ エコー信号の変化

生体組織の音響特性計測（～2009）

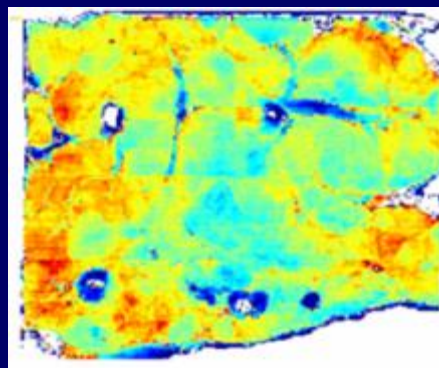


[UMI]

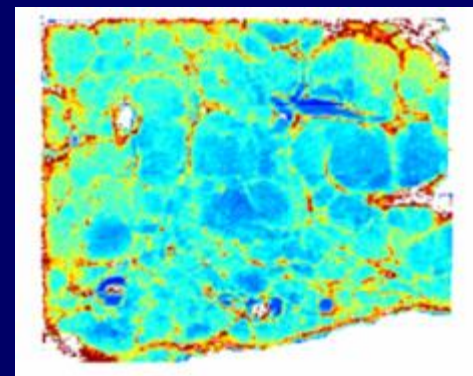
25MHzの超音波を用いて生体組織の音響特性（音速，減衰）を計測 ⇒ 二次元分布として可視化



組織切片

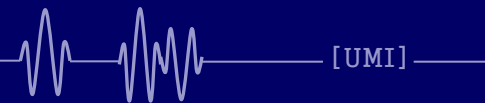


音速分布



減衰分布

生体組織の音響特性計測（～2009）

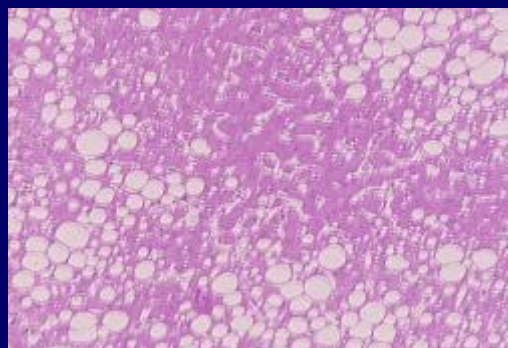


病理標本

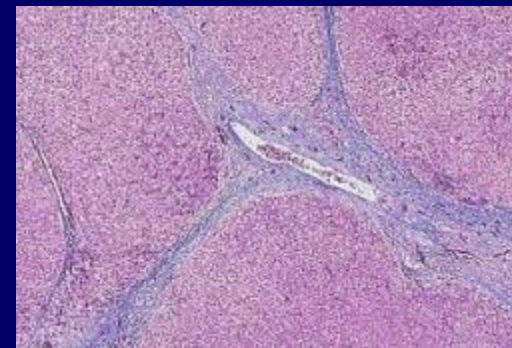
ラット正常肝



ラット脂肪肝



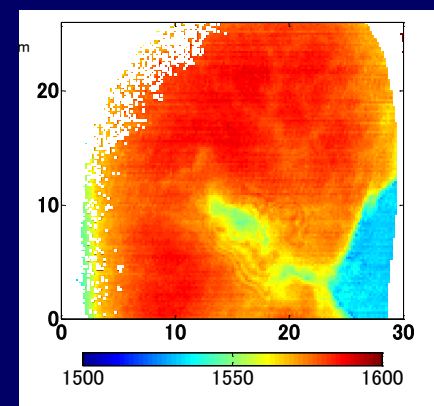
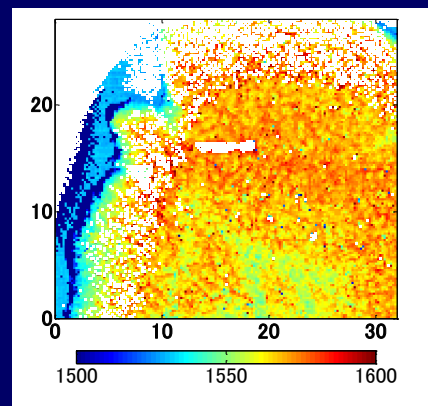
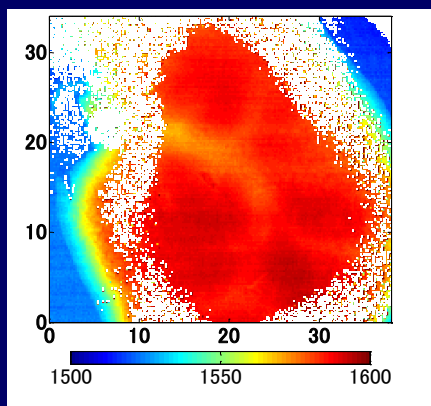
ラット硬変肝

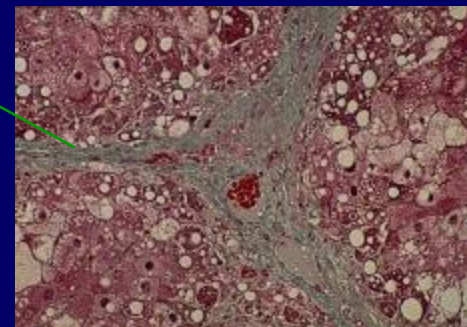
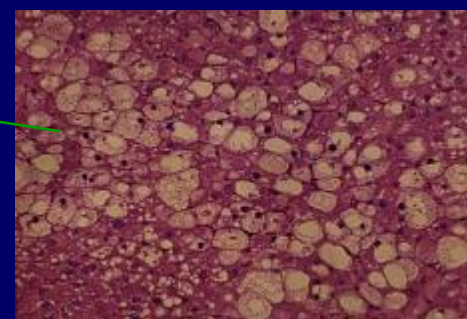
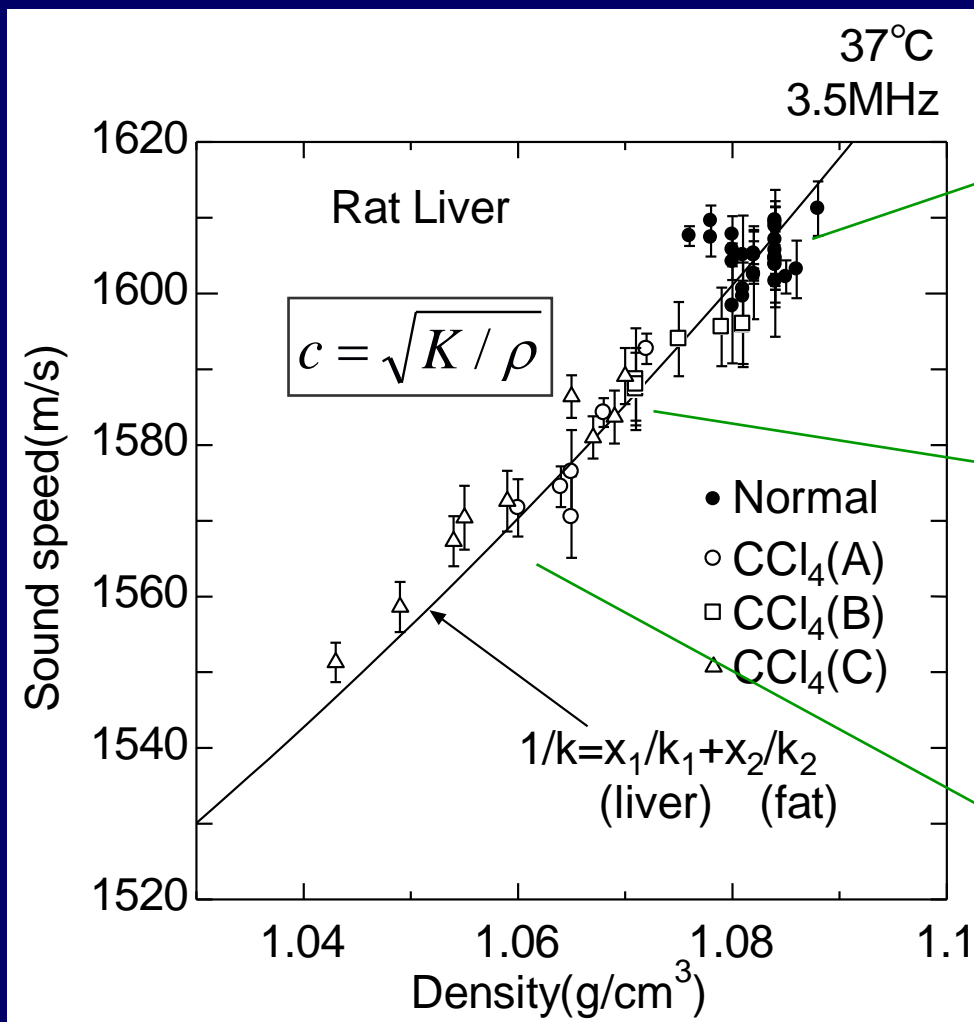


生体試料



音速分布



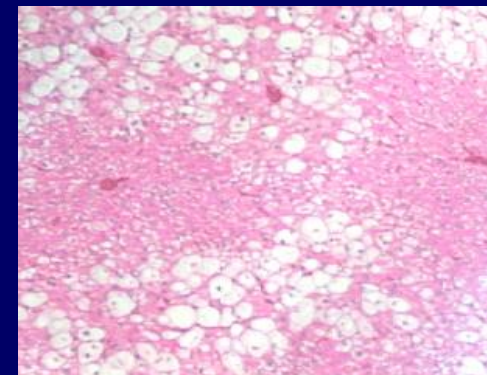
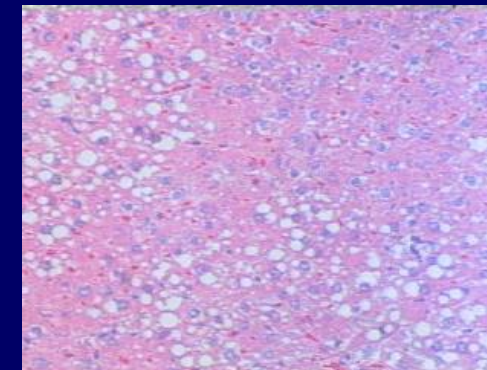
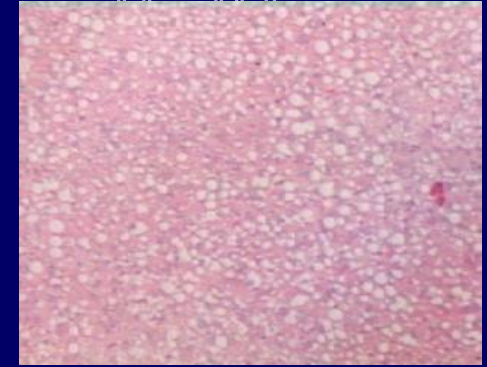
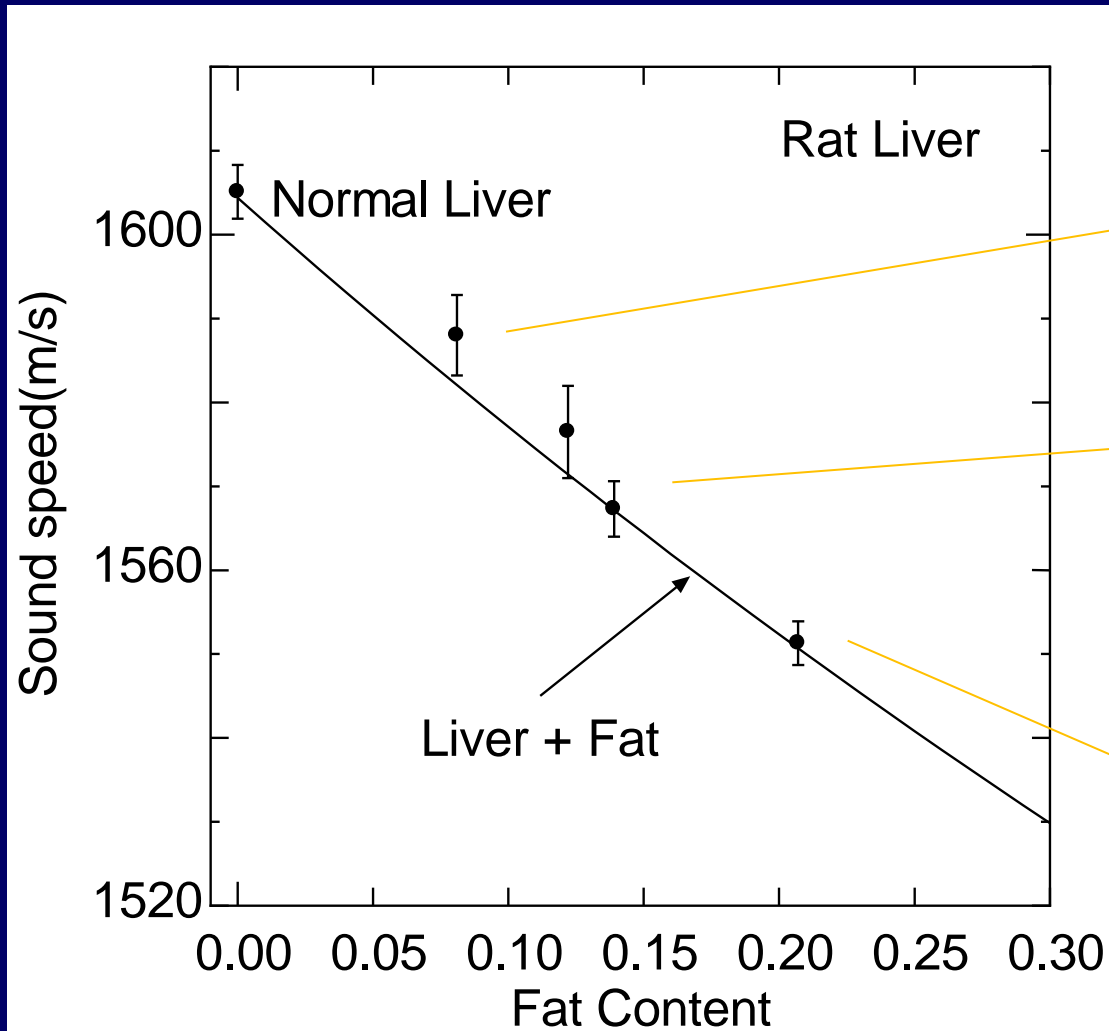


組織密度と音速の関係
(Hachiya, Tanaka, et al)

生体組織の音響特性計測 (～2009)



[UMI]



(Hachiya, Tanaka, et al.)

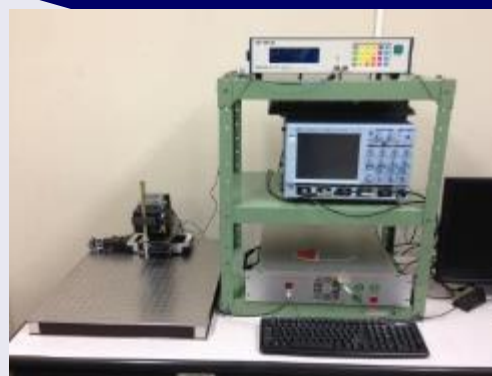
生体組織音響特性の総合的理解のために

[UMI]

- Comparison between from 1-MHz to 250-MHz is doing as in vivo, in vitro and ex vivo works



Clinical scanner
1-MHz to 15-MHz



3-D scanner
10-MHz to 50-MHz



Bio-US microscopy
60-MHz to 250-MHz

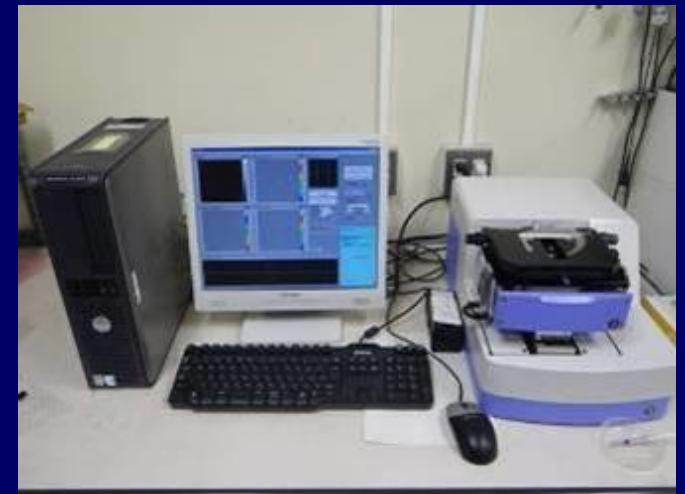
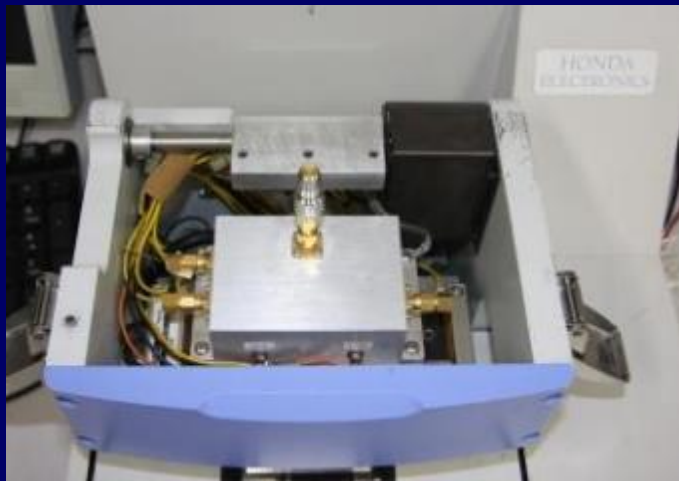


バイオ超音波顕微鏡による生体音響特性計測 (2011~)

[UMI]

Scanning system:

- Customized AMS-50SI (Honda Electronics)
- 2- μm step size in 2D (sample moves)
- “Upside-down” configuration
- RF signals digitized at 2 GHz (8-bit A/D)
- 300 by 300 RF lines per acquisition
- RF signals averaged 4 times
- 2 min total scan time
- 30 dB SNR



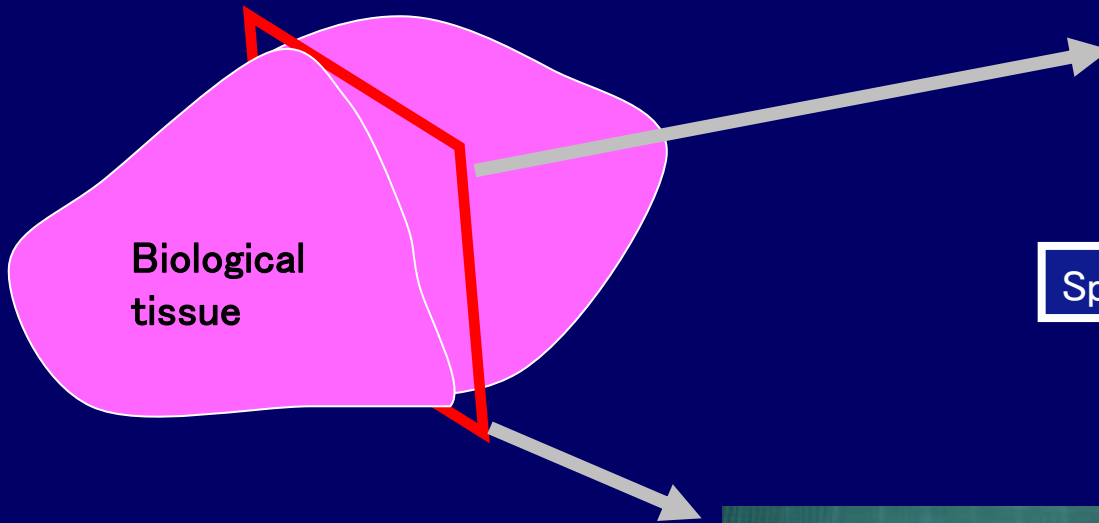
ラット肝臓の音響特性計測



[UMI]

- Rat is anesthetized and sacrificed
- Fresh liver is harvested
- Fixed and embedded in paraffin

Acoustic microscopy:
• 10- μ m thick



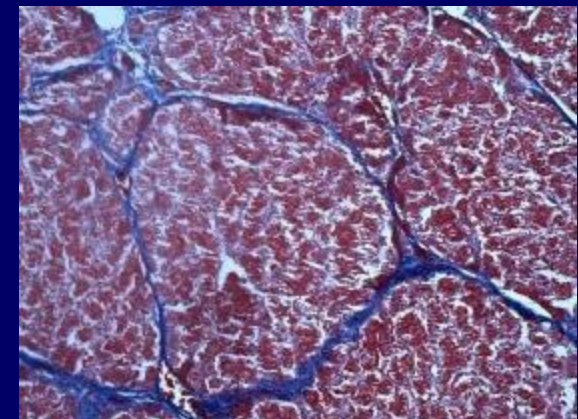
Biological
tissue



Speed of sound and attenuation

Histology:

- 4- μ m thick (adjacent section)
- H&E stain (fatty and normal)
- Azan stain (fibrotic)

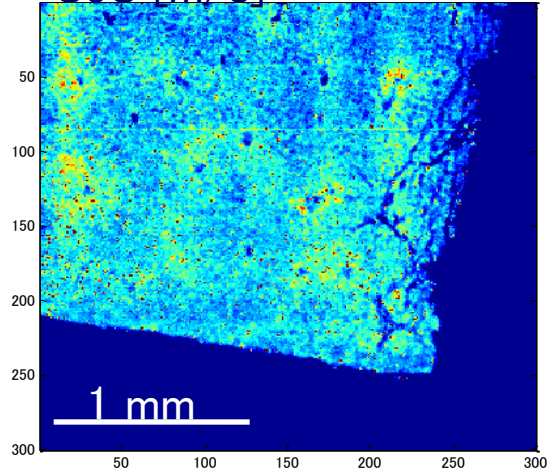


Results: Illustrative C-mode Images < Normal >

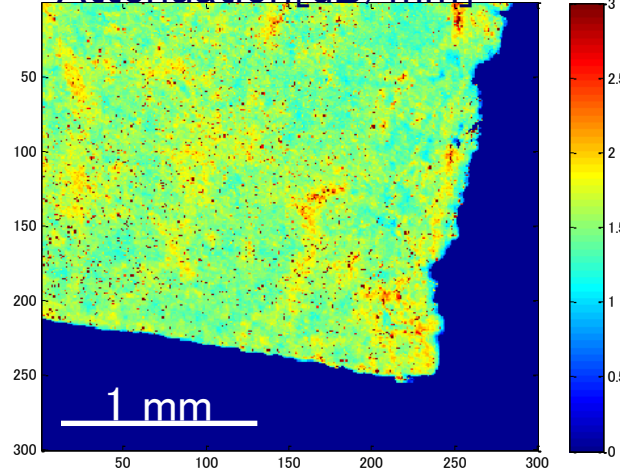
[UMI]

120-MHz (2.4 mm * 2.4 mm)

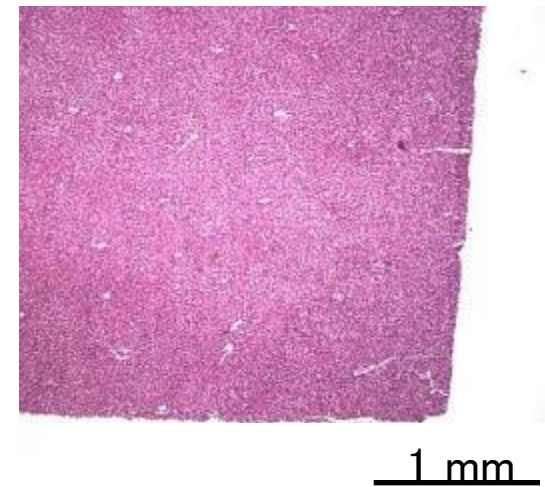
SoS [m/s]



Attenuation [dB/mm]

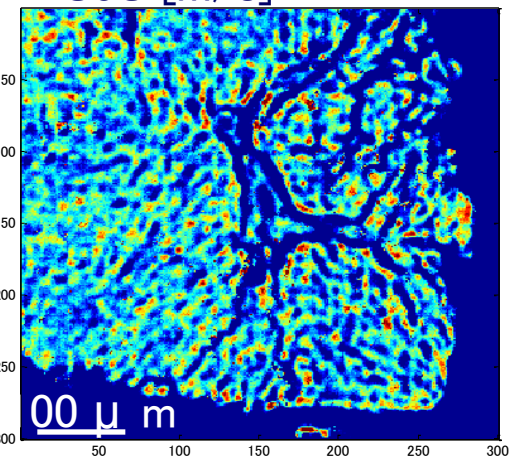


Histology [H-E Stain]

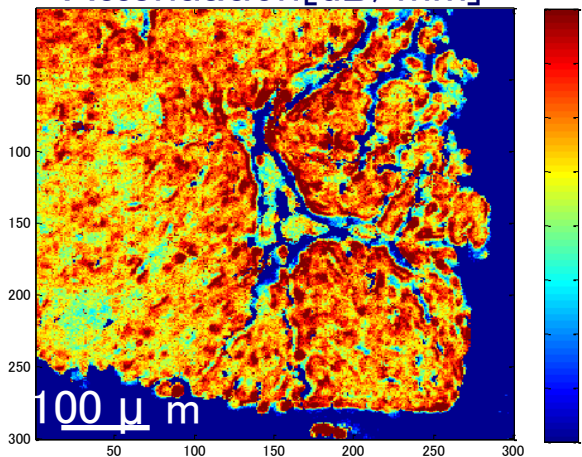


250-MHz (600 μ m * 600 μ m)

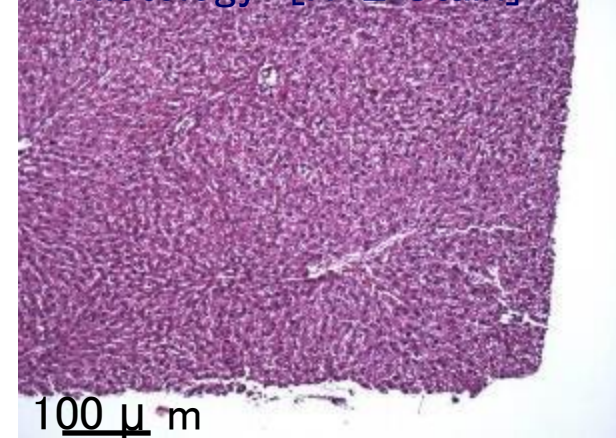
SoS [m/s]



Attenuation [dB/mm]



Histology [H-E Stain]

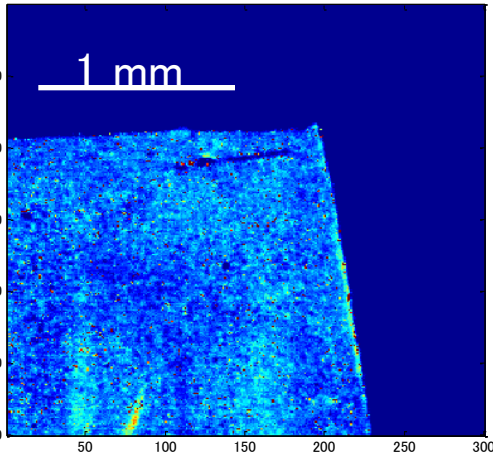


Results: Illustrative C-mode Images < Fatty >

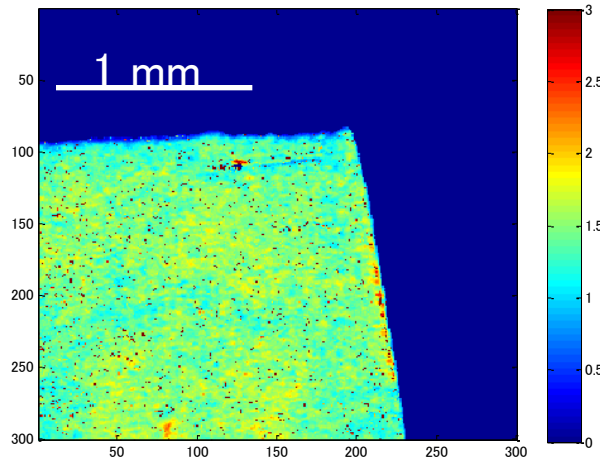
[UMI]

120-MHz (2.4 mm * 2.4 mm)

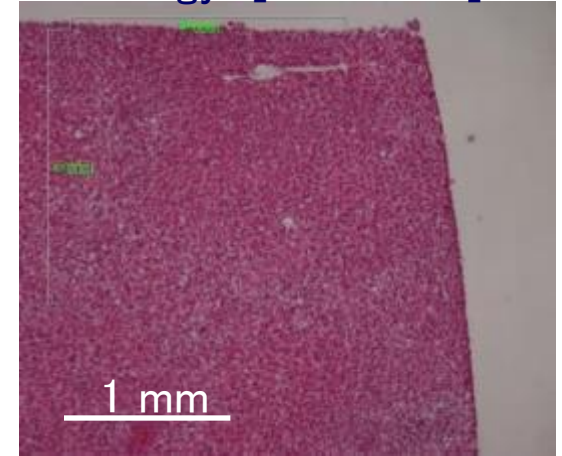
SoS [m/s]



Attenuation [dB/mm]

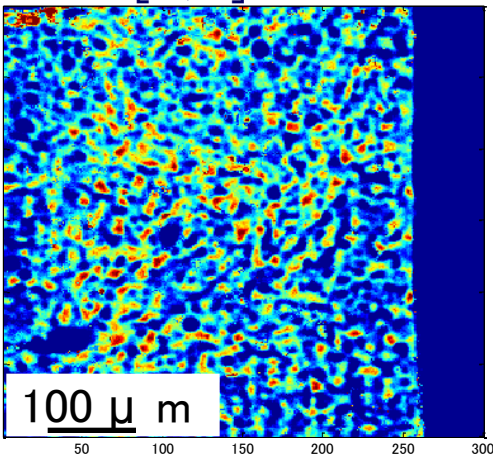


Histology [H-E Stain]

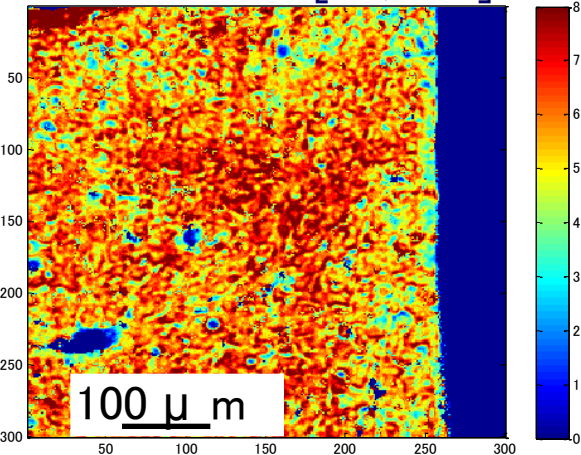


250-MHz (600 μ m * 600 μ m)

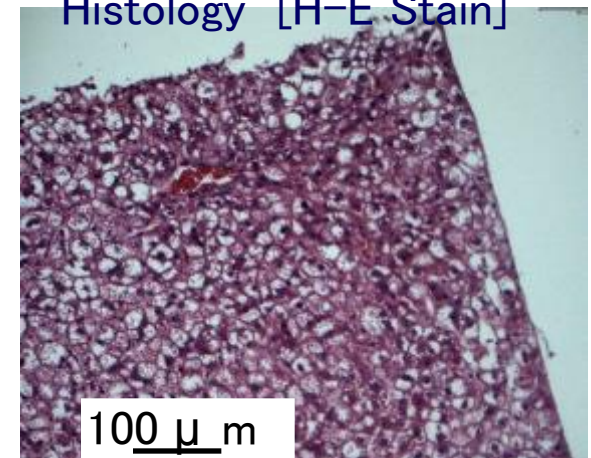
SoS [m/s]



Attenuation [dB/mm]



Histology [H-E Stain]



Results: Illustrative C-mode Images < Fibrosis >

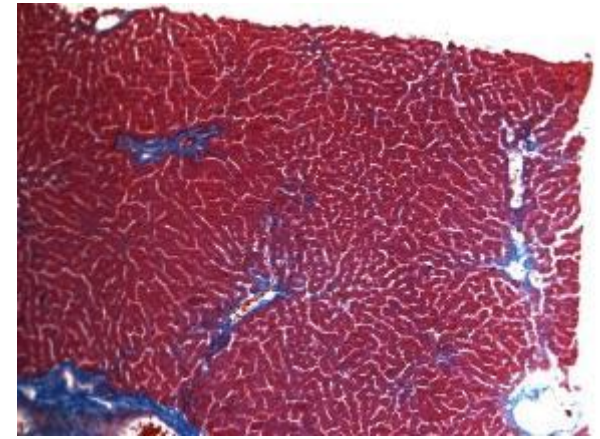
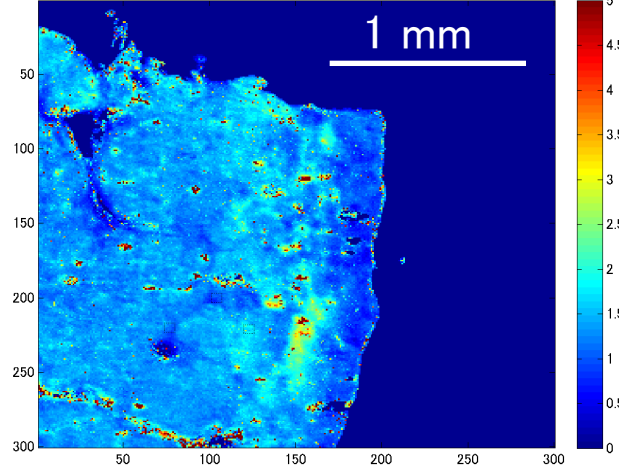
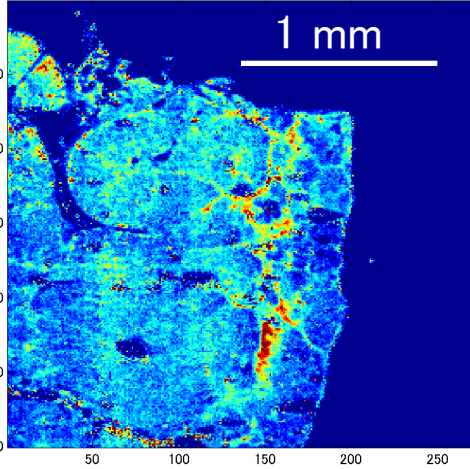
[UMI]

120-MHz (2.4 mm * 2.4 mm)

SoS [m/s]

Attenuation[dB/mm]

1 mm



250-MHz (600 μ m * 600 μ m)

SoS [m/s]

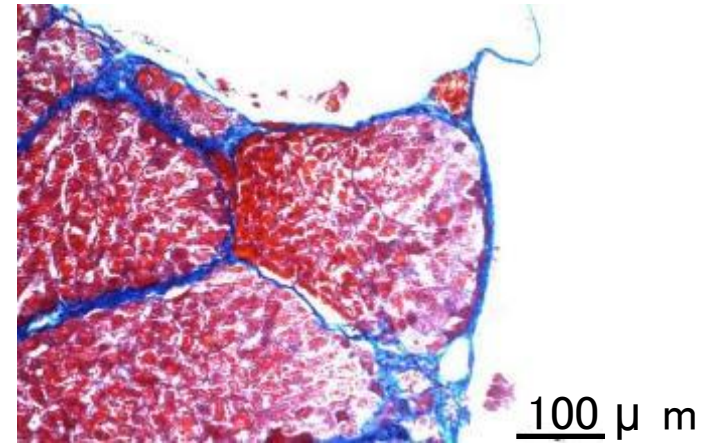
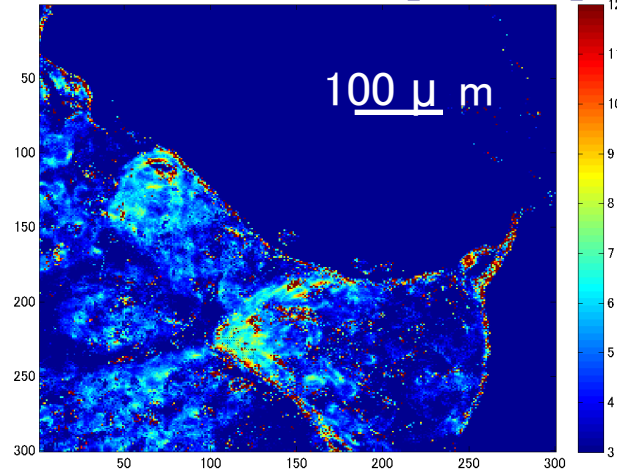
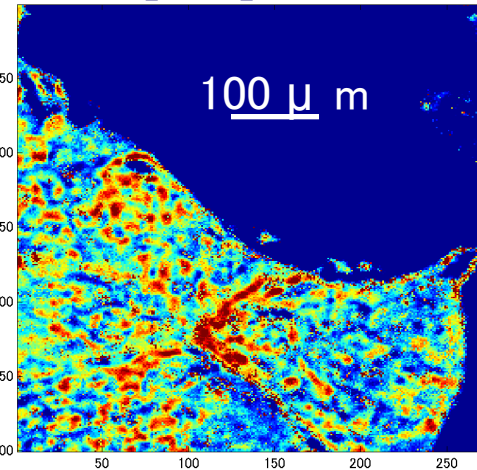
Attenuation[dB/mm]

Histology [Azan Stain]

100 μ m

100 μ m

100 μ m

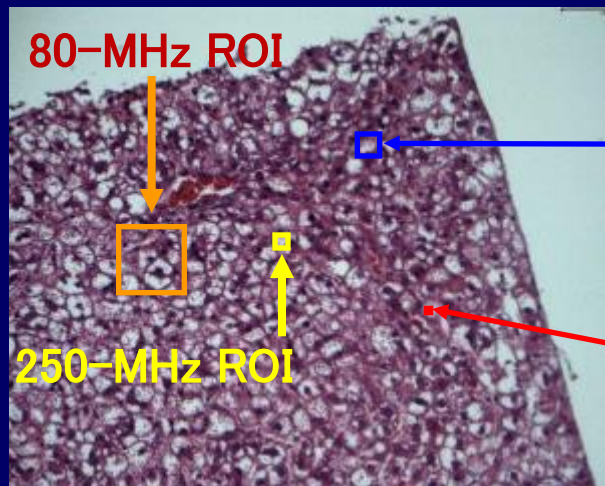


減衰—音速と周波数の関係



[UMI]

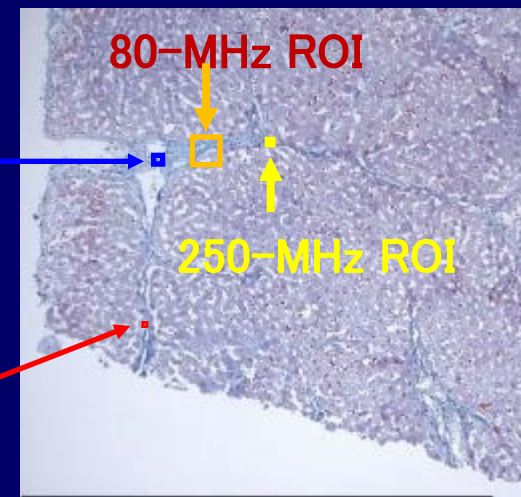
- Three ROIs chosen for each liver image
one by one matching with histology
- 7 by 7 pixels ; three times from lateral beamwidth
(i.e., 60 μm by 60 μm in 80-MHz image
12 μm by 12 μm in 250-MHz image
- Normal tissue (no vessels) for normal livers
- Fatty deposits for fatty livers
- Fibrous regions for fibrotic liver



Histology of Fatty Liver

80-MHz
lateral
beamwidth

250-MHz
lateral
beamwidth



Histology of Fibrosis Liver

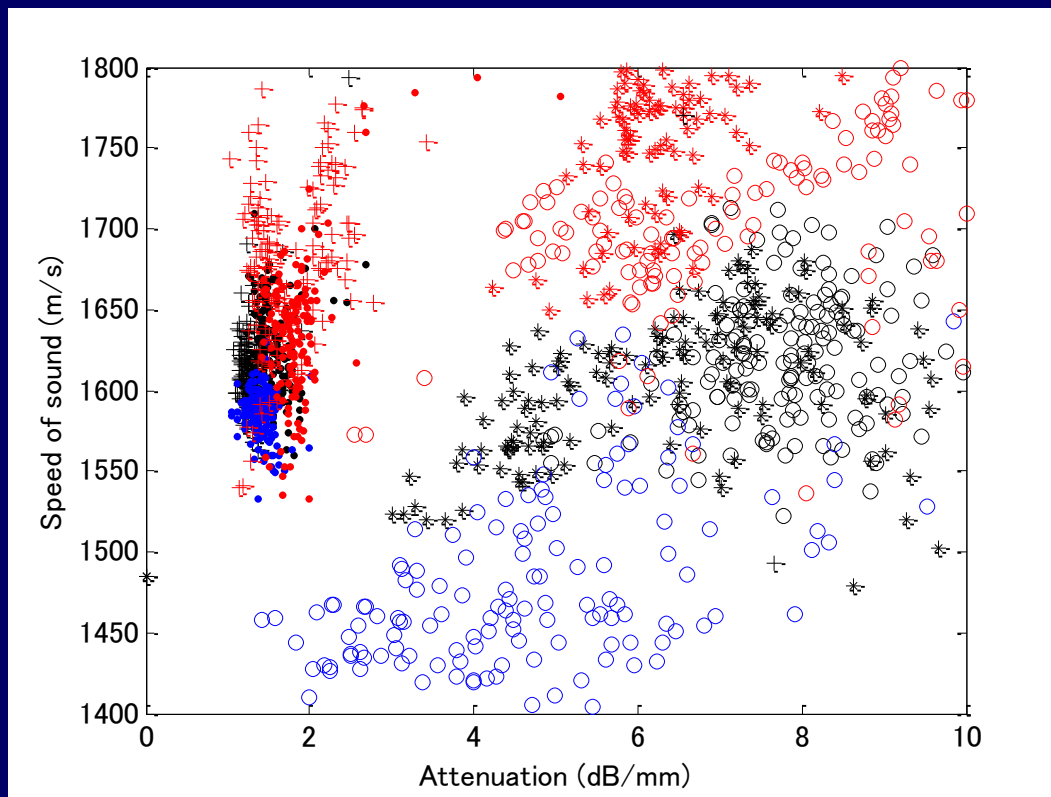
減衰－音速と周波数の関係



[UMI]

120-MHz

- Normal 1
- + Normal 2
- Fatty
- Fibrosis 1
- + Fibrosis 2



250-MHz

- Normal 1
- * Normal 2
- Fatty
- Fibrosis 1
- * Fibrosis 2