Elastosonography in Veterinary Medicine

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• Diagnostic imaging medicine has evolved faster than other fields because it is closely linked to technology. In some countries, this decreased the equipment costs and improved its access.
• Many new technological features have been added to the modern diagnostic ultrasound system

• Most of them are the result of the efforts towards a better spatial resolution (digital beam, spatial compound, tissue harmonic imaging, matrix array transducers)
Palpation is well known in medicine practice. It involves the squeezing of a lump, for example, in order to establish whether it is hard or soft in comparison to the surrounding tissue.
- Soft tissues mechanical attributes are determined by their molecular constitution (fat, collagen, elastin), macro and microscopic structural organization.

- One of soft tissue important characteristics is its inherent elasticity that may be altered by pathophysiological processes such as aging, inflammation, and malignant tumors.
- Echogenicity and mechanical properties are not always related;
- Elastography provides images that are related to the tissue stiffness.
- Elastic tissues
  - soft
  - slower sound speed
  - Easily compressed and tensioned, even with less pressure or strain
  - benign

- Less elastic tissues
  - fibrotics and hard
  - higher sound speed
  - stronger resistance deformation
  - malignant
- Elastosonography is the ultrasound imaging of tissue stiffness compared to the surround tissue.
- The analyzed area is submitted to a load and the system measures its response.
- The load applied to the tissue can be considered static;
- The data acquisition time is so short that the pressure may be considered to be constant;
- The answer to the applied load is modified (Hookean’s mathematic expression) demonstrating viscoelasticity and dynamics properties of the interest region (qualitative and quantitative).
Commercially available types are divided into:

- Quasi-Static or Static Elastography
- *Transient Elastography* (Fibroscan)
- *Supersonic Shear Imaging*
- Acoustic Radiation Force Impulse (ARFI)
Quasi static elastography

- commercially available in several equipments
- manual
- operator dependent
- longer learning curve
- low reproductibility (intra and inter observer)
Transient elastography - Fibroscan®

• Advantages
  – first technology to assess liver parenchyma
  – most of the studies in humans

• Disadvantages
  – High cost
  – Can’t be used in obese and ascitic patients
  – No B-mode image
  – Small sample
Definition

Physical principles

Types of elastography

History and perspectives

Clinical indications
Acoustic Radiation Force Impulse (ARFI) & SuperSonic Shear wave imaging

Focal waves of ultrasound to generate marginal and orthogonal waves (shear waves) inside the organ

- Better penetration,
- Can be used in obese and ascitic patients
- Can be used during routine scanning (at the same time as B-mode scanning).
- Focal lesions detections

Shear wave - ARFI

Advantages:
- faster
- accurate
- quantitative assessment

Disadvantages:
- High cost
- Small sample
Shear wave - SuperSonic

Advantages:
- faster
- reliable
- elasticity calculations better precision

Disadvantages
- High cost
- No correlation with cut-off values between different equipments
Elastography

History and Perspectives

- 460 b.C. (Hipócrates)

... 1997 - 2012
MEASUREMENT OF SOFT TISSUE MOTION USING CORRELATION BETWEEN A-SCANS

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(Received 12 January 1981; in final form 12 September 1981)

Abstract—The advent of real-time B-scanning has led to interest in the diagnostic value of the dynamic properties of soft tissue. Present ultrasonic techniques for investigating motion cannot measure the motion of homogeneous tissues. A technique has been developed which uses the correlation coefficient between A-scans to measure the amplitude and frequency of their motion, both in water tank experiments and in vivo. The success of the technique, which is digitally implemented, supports the validity of stochastic models for the acoustic structure of soft tissues. The motion pattern observed in vivo can be correlated with the arterial pressure pulse.

Key words: Acoustics, Ultrasonics, Tissue motion, A-Scans, Correlation coefficients, Liver scans.
Elastography
History and Perspectives

• 1991:
  – Terminology “elastogram” and “elastography”

ULTRASONIC IMAGING 13, 111-134 (1991)

ELASTOGRAPHY: A QUANTITATIVE METHOD FOR IMAGING THE ELASTICITY OF BIOLOGICAL TISSUES

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Elastography

History and Perspectives

- 1997:
  - First studies in humans
  - Mastology (free hand elastography)

**Elastography of breast lesions: initial clinical results.**

Garra BS, Cespedes EI, Ophir J, Spratt SR, Zuurbier RA, Magnant CM, Pennanen MF.

Department of Radiology, Georgetown University Medical Center, Washington, DC 20007-2197, USA.

**Abstract**

**PURPOSE:** To determine the appearance of various breast lesions on elastograms and to explore the potential of elastography in the diagnosis of breast lesions.

**MATERIALS AND METHODS:** A total of 46 breast lesions were examined with elastography. Patients underwent biopsy or aspiration of all lesions, revealing 15 fibroadenomas, 12 carcinomas, six fibrocystic nodules, and 13 other lesions. The elastogram was generated from radio-frequency data collected with use of a 5-MHz linear-array transducer. The elastogram and corresponding sonogram were evaluated by a single observer for lesion visualization, relative brightness, and margin definition and regularity. The sizes of the lesions at each imaging examination and at biopsy were recorded and compared.

**RESULTS:** Softer tissues such as fat appear as bright areas on elastograms. Firm tissues, including parenchyma, cancers, and other masses, appear darker. The cancers were statistically significantly darker than fibroadenomas (P < .005) and substantially larger on the elastogram than on the sonogram. Seventy-three percent of fibroadenomas and 56% of solid benign lesions could be distinguished from cancers by using lesion brightness and size difference. Some cancers that appeared as areas of shadowing on sonograms appeared as discrete masses on elastograms.

**CONCLUSION:** Elastography has the potential to be useful in the evaluation of areas of shadowing on the sonogram. It also may be helpful in the distinction of benign from malignant masses.
Elastography
History and Perspectives

• 1999:
  – Urology

A New System for the Acquisition of Ultrasonic Multicompression Strain Images of the Human Prostate In Vivo

Andreas Lorenz, H.-J. Sommerfeld, Miguel Garcia-Schürmann, Stathis Philippou, Theodor Senge, and Helmut Ermert, Senior Member, IEEE
Elastography

History and Perspectives

• 2000:
  – Cardiology

Characterization of Plaque Components With Intravascular Ultrasound Elastography in Human Femoral and Coronary Arteries In Vitro

Chris L. de Korte, Gerard Pasterkamp, Anton F. W. van der Steen, Hein A. Woutman and Nicolaas Bom

Circulation. 2000;102:617-623
doi: 10.1161/01.CIR.102.6.617

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539
Elastography
History and Perspectives

- 2003: Hepatology (Transient elastography)

**Abstract**

Chronic hepatitis is accompanied by progressive deposit of hepatic fibrosis, which may lead to cirrhosis. Evaluation of liver fibrosis is, thus, of great clinical interest and, up to now, has been assessed with liver biopsy. This work aims to evaluate a new noninvasive device to quantify liver fibrosis: the shear elasticity probe or fibroscan. This device is based on one-dimensional (1-D) transient elastography, a technique that uses both ultrasound (US) (5 MHz) and low-frequency (50 Hz) elastic waves, whose propagation velocity is directly related to elasticity. The intra- and interoperator reproducibility of the technique, as well as its ability to quantify liver fibrosis, were evaluated in 106 patients with chronic hepatitis C. Liver elasticity measurements were reproducible (standardized coefficient of variation: 3%), operator-independent and well correlated (partial correlation coefficient = 0.71, p < 0.0001) to fibrosis grade (METAVIR). The areas under the receiver operating characteristic (ROC) curves were 0.88 and 0.99 for the diagnosis of patients with significant fibrosis ($\geq F2$) and with cirrhosis ($= F4$), respectively. The Fibroscan is a noninvasive, painless, rapid and objective method to quantify liver fibrosis.
Elastography
History and Perspectives

• 2007:
  – Orthopedy

**Real-time ultrasound elastography of the normal Achilles tendon: reproducibility and pattern description.**

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**Abstract**

AIM: To investigate the feasibility and reproducibility of real-time freehand ultrasound elastography (RTE) of the normal Achilles tendon and to describe its elastographic appearances.

MATERIALS AND METHODS: Fifty normal Achilles tendons were prospectively examined using RTE performed by tissue compression using the hand-held transducer. The information was colour-coded (red=soft, green=medium, blue=hard) and superimposed on the B-mode image. Each tendon was examined three times transversely and longitudinally by two radiologists and the ratio between tendon and retro-Achilles fat strain (strain index) was calculated. The reproducibility of the elastograms was assessed qualitatively and quantitatively using the strain index inter and intra observer variation coefficient (intra/inter-CV and intra/inter-CC, respectively).

RESULTS: All tendons were clearly visualized on the elastograms. Nineteen tendons (19/50, 38%) appeared homogeneously green/blue (type 1). Thirty-one tendons (31/50, 62%) appeared green with longitudinal red stripes (type 2). The intra- and inter-CC values of the strain index were lower for the transverse plane than for the longitudinal plane (0.43, 0.45, 0.41 and 0.78, 0.66, 0.51, respectively). The intra-CV and inter-CV values were higher for the transverse than for the longitudinal plane measurements (39%, 37%, 30% and 30.50%, 30.10%, 29.60%, respectively).

CONCLUSION: RTE of the normal Achilles tendon is a feasible method. The reproducibility of the strain index is good and higher for longitudinal elastograms. Qualitative assessment enables the discrimination of two distinct elastographic patterns. Further studies are required to assess the clinical value of this method.
2007:

- Oncology/Head and Neck (Sonoelastography)

_Cervical Lymph Node Metastases: Diagnosis at_ (Radiology: Volume 243: Number 1—April 2007)

**Purpose:** To prospectively estimate the accuracy of sonoelastography in the differentiation of benign and metastatic cervical lymph nodes (LN) in patients suspected of having thyroid or hypopharyngeal cancer, with histologic nodal findings as the reference standard.

**Materials and Methods:** The study protocol was approved by the hospital review board; each patient gave written informed consent. One hundred forty-one peripheral neck LN (60 metastatic, 81 metastasis, 21 women; mean age, 58 years ± 13 [standard deviation]) were examined. Patients referred for surgical treatment of suspected thyroid or hypopharyngeal cancer were exam-
Elastography History and Perspectives

• 2008:
  – ARFI

Published in final edited form as:

**Quantifying Hepatic Shear Modulus In Vivo Using Acoustic Radiation Force**

Mark L. Palmeria,*, Michael H. Wanga, Jeremy J. Dahlia, Kristin D. Frinkleya, and Kathryn R. Nightingalea

a Department of Biomedical Engineering, Duke University, Durham, NC 27708-0281, USA
The value of strain ratio in differential diagnosis of thyroid solid nodules

ACOUSTIC RADIATION FORCE IMAGING (ARFI) AS A NEW METHOD OF ULTRASONOGRAPHIC ELASTOGRAPHY ALLOWS ACCURATE AND FLEXIBLE ASSESSMENT OF LIVER STIFFNESS


Available online 14 January 2011.

Publication Year: 2010
Elastography and Contrast-enhanced Ultrasonography in the Early Detection of Hepatocellular Carcinoma in an Experimental Model of Nonalcoholic Steatohepatitis

Cibele F. Carvalho, Maria C. Channah, Claudia P. M. Souza de Oliveira, Bruno Coletti, Flair J. Carrilho, Giovanni G. Cerri

Received 25 October 2012, accepted 25 April 2013, published online 03 May 2013.

Background/objective
The early detection of focal hepatic lesions using ultrasound scanning is challenging, and this challenge becomes even greater in the presence of diffuse parenchymal disease. This study aimed to evaluate the diagnostic performance of elastography and contrast-enhanced ultrasonography (CEUS) in the early detection of hepatocellular lesions in an experimental rat model of nonalcoholic steatohepatitis (NASH).

Methods
B-mode and Doppler ultrasonography was performed weekly in 30 rats divided into a NASH group (n = 20) and a group without liver disease (n = 10). The animals underwent elastography and CEUS and were then euthanized. Liver nodules were assessed by histopathology.

Results
Doppler mapping results of lesions with vascularization were considered indicative of malignancy, with a sensitivity of 29% before and 71% after contrast injection. The specificity was 71% before and 96% after CEUS. Elastograms of positive lesions showed areas of high stiffness, which were indicative of malignancy. This malignancy was confirmed by the histologic evaluation, with a sensitivity of 90% and a specificity of 60%. After CEUS analysis, 4 nodules were identified that were not observed on B-mode ultrasonography. Early wash-in was significantly associated with malignancy (sensitivity of 88% and specificity of 67%).
ULTRASOUND ELASTOGRAPHY OF THE LIVER, SPLEEN, AND KIDNEYS IN CLINICALLY NORMAL CATS

JENNIFER WHITE, JOHN GAY, RAELLYNN FARNSWORTH, MATT MICKAS, KWANGGI KIM, JOHN MATTOON

A large amount of overlap exists in the B-mode ultrasound appearance of normal and abnormal liver, spleen, and kidney tissues in cats. Therefore, invasive tissue sampling procedures remain the standard method for diagnosing diseases in these organs. The purpose of our study was to assess the feasibility of ultrasound elastography as a technique for improving noninvasive characterization of the feline liver, spleen, and kidneys. Elastography was performed on 10 unsedated, clinically healthy cats. Numeric (strain) values (0 = softest to 255 = firmest) assigned to color pixels within regions of interest resulted in median scores (interquartile ranges) of body wall, 207.50 (189.75–224.00); liver, 119.00 (105.00–138.25); spleen, 127.50 (121–142.00); right renal cortex, 83.50 (64.00–130.00); right renal near field, 125.50 (110.75–139.75); left renal cortex, 77.50 (52.00–116.25); and left renal near field, 126.00 (114.00–145.25). Strain values were not different between organs. Body wall median was the only significantly different value (P < 0.05). Strain ratio values of body wall organ were as follows: liver, 1.76 (1.38–2.00); spleen, 1.68 (1.47–1.83); right renal cortex, 2.31 (1.61–3.15); right renal near field, 1.62 (1.41–2.01); left renal cortex, 2.66 (1.45–4.13); and left renal near field, 1.51 (1.29–1.89). Subjectively, hepatic and splenic parenchymal tissues were homogeneous in compressibility and similar in elasticity to one another. Renal cortical tissue was softer compared to medullary tissue. Findings indicated that ultrasound elastography is a feasible technique for objectively and subjectively characterizing the feline liver, spleen, and kidneys. Further research is needed in cats with confirmed diseases of these organs, to compare the diagnostic sensitivity of ultrasound elastography vs. B-mode ultrasonography. © 2013 American College of Veterinary Radiology.

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Funded by Washington State University Veterinary Clinical Sciences Intramural Grants.
Presented at the ACVR Annual Conference 2012, Las Vegas, NV.
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Received April 23, 2013; accepted for publication October 3, 2013. doi: 10.1111/j.2044-3862.2013.00170.x
ELASTOGRAPHY OF THE NORMAL CANINE LIVER,
SPLEEN AND KIDNEYS

ANDREW HOLDSWORTH, KATE BRADLEY, SALLY BIRCH, WILLIAM J. BROWNE, VIRGINIE BARBERET

Elastography is a simple, expedient and noninvasive technique that may be used to assess the elasticity or stiffness of a tissue, in conjunction with traditional B-mode ultrasonography. Quantitative assessment of tissue stiffness can be made which involves measurement of the shear wave velocity within the tissue of interest. The goal of this study was to assess the feasibility of elastography for clinical use in the abdomen of conscious small animals and to investigate factors that affect shear wave velocity measurement. Elastography was performed on the liver, spleen, and kidneys of 15 dogs at predefined depths within the parenchyma. Breed, age, gender, neuter status, and weight were documented for each animal. Depth at which measurements were taken had a significant negative relationship with the shear wave velocity value obtained. Individual dog effects, such as weight and gender, also appeared to have a significant effect on the shear wave velocity measurement for specific organs; weight had a significant positive effect on the shear wave velocity for each of the organs examined, whereas the effect of gender was inconsistent between organs (having a positive effect for the liver and a negative effect for the spleen). It is hoped that these results may act as a baseline to guide further work into the field of elastography in companion animals. © 2014 American College of Veterinary Radiology.

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Received October 10, 2013; accepted for publication February 2, 2014.
doi: 10.1111/vru.12169
Main clinical indications
- focal lesions malignancy detection in breast, prostate, thyroid, pancreas, testicles;
- fibrosis quantification (human medicine);
- a few researches with animals in order to focal lesions malignancy detection in prostate and liver (experimental models)

Righetti et al., 1999; Bilgen et al., 2003; Konig et al., 2005; Carvalho et al., 2013;
Definition
Physical principles
Types of elastography
History and perspectives
Clinical indications

Carvalho et al., 2012
Carvalho et al., 2012

Definition
Physical principles
Types of elastography
History and perspectives
Clinical indications
Hepatic Fibrosis quantification

ARFI – Acoustic Radiation Force Impulse

Friedrich-Rust et al. Radiology 2009 (252):595-604

Definition
Physical principles
Types of elastography
History and perspectives
Clinical indications
Clinical and current applications

• Elastrography softwares are currently available on several machine systems and their capability to evidence and improve focal parenchymal lesions characterization that supports the application.
• Our studies:
  - hepatic elastography (ARFI) in dogs
  - hepatic elastography (ARFI) in cats
  - elastography (ARFI) of testicles and prostate in dogs

Near Future...

• Additional applications await results of research efforts...
• Ultrasonography is a dynamic imaging diagnostic tool with technological advances and constantly changes to our concepts and perception... so we have step up!
References

References

Thank you for your attention!