

Elastografie

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¹http://www.uth.tmc.edu/schools/med/rad/elasto/slides/mainslideshow/main_slide_show.pps

Elastography: Imaging of Tissue Elastic Properties *In-Vitro* and *In-Vivo*

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Definition

Elastography:

An imaging technique whereby local axial tissue strains are estimated from differential ultrasonic speckle displacements. These displacements are generated by a weak, quasi-static stress field.

The resultant strain image is called an **Elastogram.**

Motivation

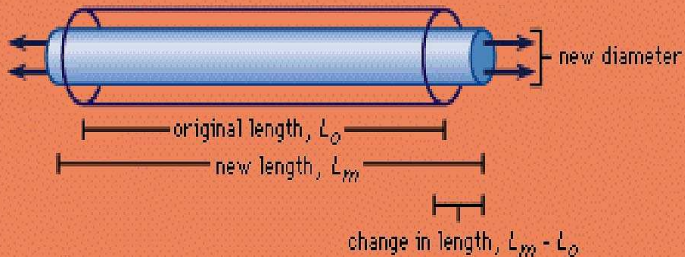
- *Most pathological changes are associated with changes in tissue stiffness.
- *Palpation is an effective method for lesion detection and evaluation.
- *Many cancers (breast, prostate) are iso-echoic, and hence difficult to detect by ultrasound.



Basic data on breast tissues

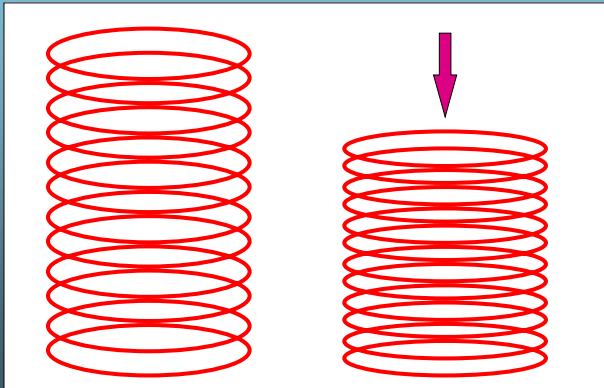
Tissue Type	Tissue Stiffness (kPa)					
	5% precompression			20% precompression		
	Strain rate			Strain rate		
	1%/dsec	10%/dsec	40%/dsec	2%/dsec	20%/dsec	80%/dsec
Normal fat (n=40)	18 ± 7	19 ± 7	22 ± 9	20 ± 8	20 ± 6	23 ± 5
Normal glandular (n=31)	28 ± 14	33 ± 11	35 ± 14	48 ± 15	57 ± 19	66 ± 17
Fibrous (n=21)	97 ± 33	107 ± 32	118 ± 83	220 ± 88	233 ± 59	245 ± 83
Ductal tumor (n=23)	22 ± 8	25 ± 4	26 ± 5	291 ± 67	301 ± 58	307 ± 78
Infilt. ductal tumor (n=32)	106 ± 32	93 ± 33	112 ± 43	558 ± 180	490 ± 112	460 ± 178

Basic Principles: Normal strain

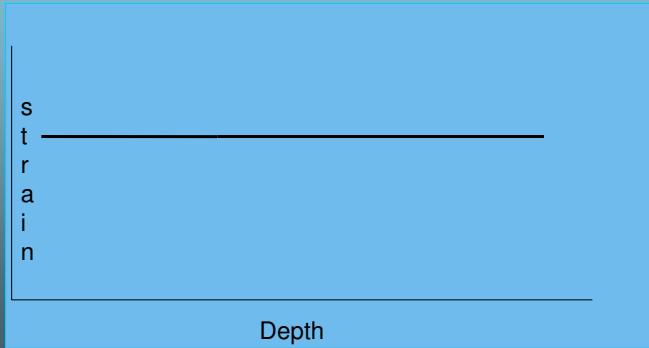


$$\text{normal strain} = \frac{\text{change in length}}{\text{original length}} = \frac{L_m - L_0}{L_0}$$

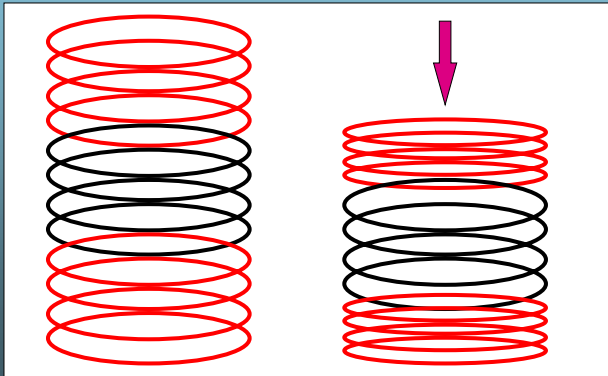
One Dimensional Uniform Spring System



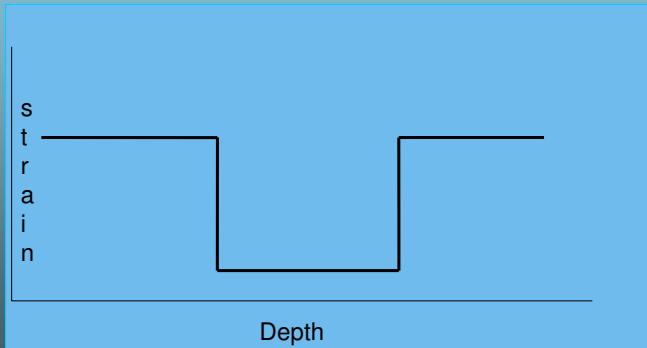
Strain Profile in Uniform Spring



One Dimensional Non-Uniform Spring System

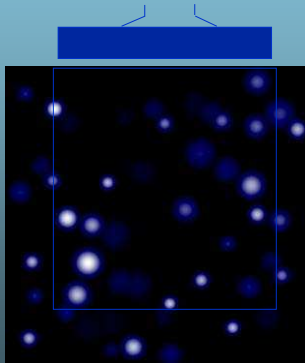


Strain Profile in Non-uniform Spring

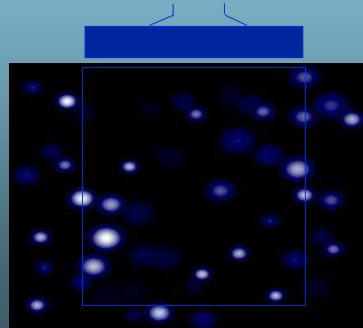


Basic Principles: Tissue Compression Model

Two-dimensional representation/ perfect-slip conditions

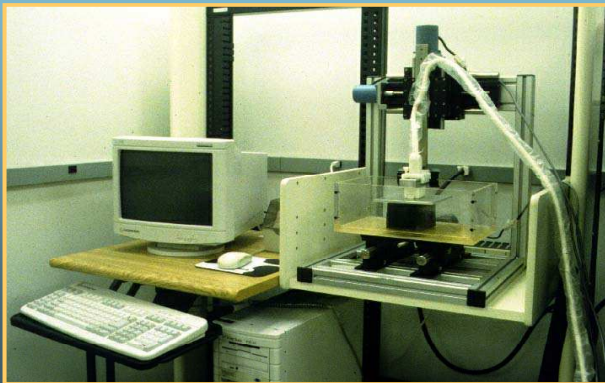


5/98 *Before compression*



After compression

Elastography data acquisition system



Basic Principles: The Elastography Process

ESTIMATION OF STRAIN

Post-compression
RF A-lines

Pre-compression
RF A-lines

Local Cross Correlation
Analysis

ESTIMATION OF STRESS

Applied
Stress

Theoretical Stress
Distribution

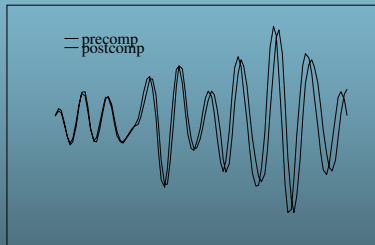
Absolute Axial Stress
Estimation

$$Y_{local} = \left(\frac{\text{Stress}}{\text{Strain}} \right)_{local}$$

ELASTOGRAM



RF signal compression: 2% applied strain

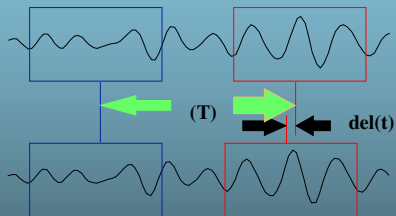


Notice that a small compression (strain) of the tissue results in a small compression of the signal (similar to frequency modulation)



Basic Principles: Estimation of Strain

Pre-compression RF line



Post-compression RF line

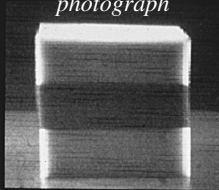
$$\text{Strain} = \frac{\text{del}(t)}{(T)}$$

Elastography

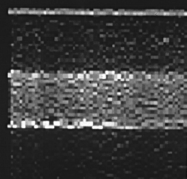
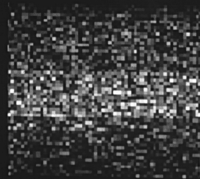
- Definition
- Motivation
- Basic principles
- Early experiments and images 
- Contemporary results
- Future directions

Layered foam phantom (*ca.1991*)

photograph



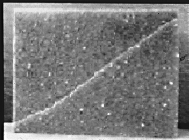
sonogram



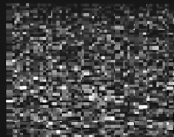
elastogram

Sponge w/ diagonal cut (ca. 1991)

photograph



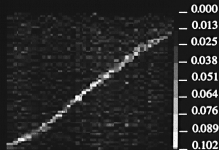
sonogram



elastogram I



elastogram II

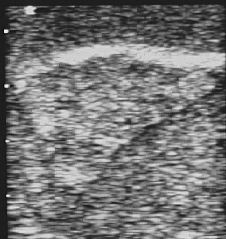


Breast carcinoma *in vitro* (ca. 1992)

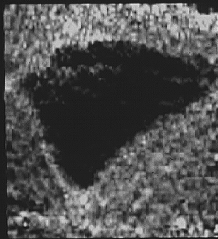
sonogram

elastogram

1 cm



(S)




(E)

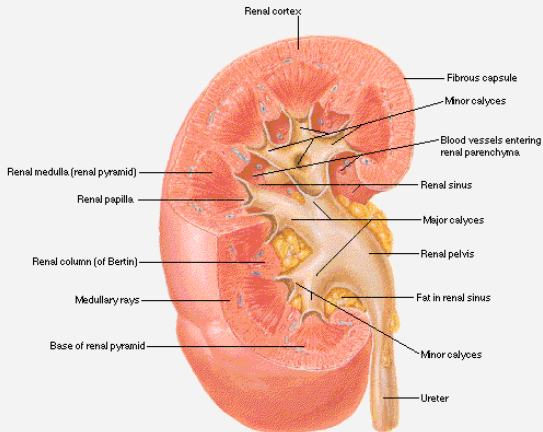
Breast Carcinoma *in-vivo* (ca. 1993)



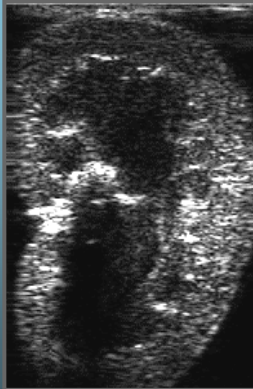
Elastography

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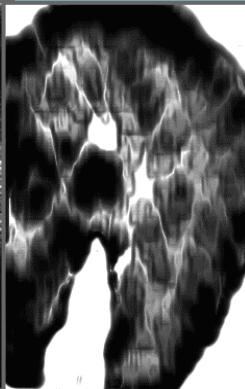
Right Kidney Sectioned in Several Planes



Elastogram from an ovine kidney



Sonogram



Elastogram

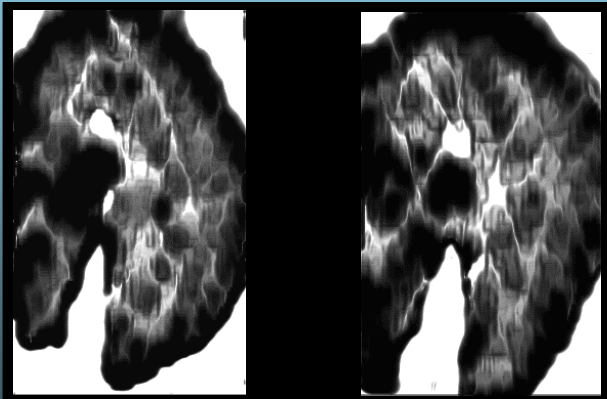


Photograph



Ovine Kidneys *in-vitro* (1997)

Two longitudinal elastographic views at 5 MHz

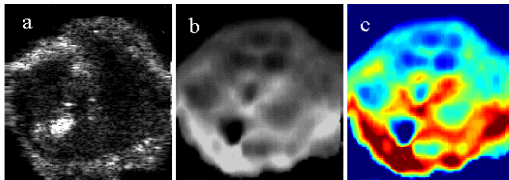




IEEE TRANSACTIONS ON



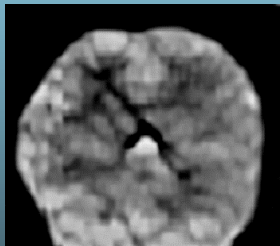
ULTRASONICS, FERROELECTRICS, AND FREQUENCY CONTROL



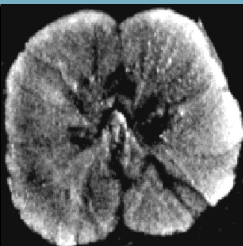
July 1998 Volume 45 Number 4 ITUCER (ISSN 0885-3010)

Canine prostate *in-vitro* (1998)

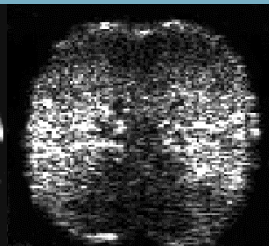
Transverse slice



Elastogram

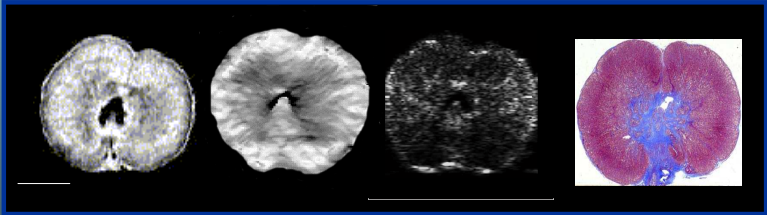


Photograph

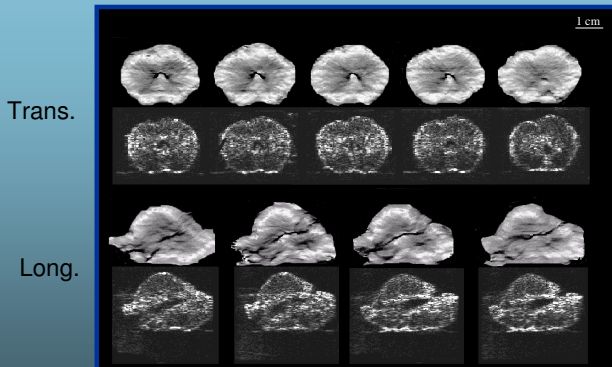


Sonogram

MRI, Elastogram, Sonogram and Pathology
Images from a Canine Prostate at 5 MHz
(1999)



Canine Prostate *in vitro* @ 5 MHz

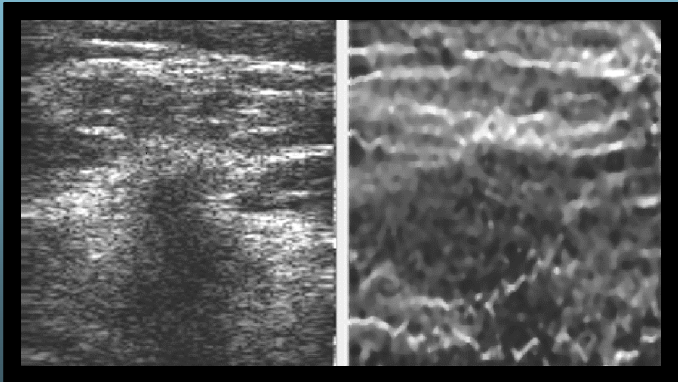


Infiltrating Ductal Carcinoma of the Breast

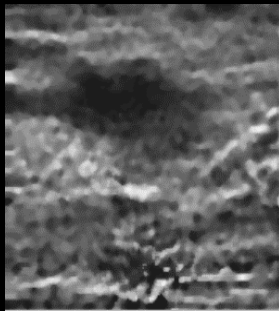
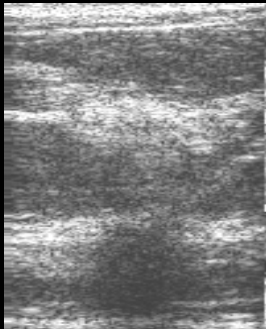
sonogram

(1996)

elastogram



Invasive Ductal Carcinoma (*1996*)

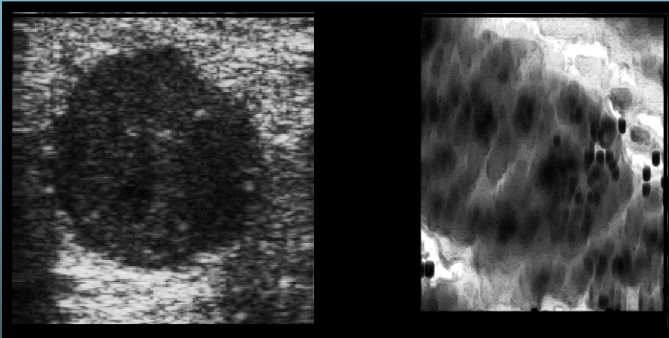


1996

Sonogram

Elastogram

Multifocal Breast Cancer *in-vivo* (1998)

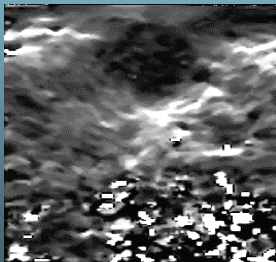
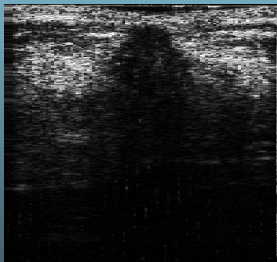


2/98

Sonogram

Elastogram

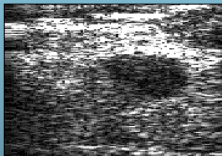
Infiltrating Ductal Carcinoma of the Breast
In Vivo at 5 MHz (1999)



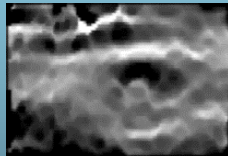
1

Breast tumors *in-vivo* (1999)

Fibroadenoma

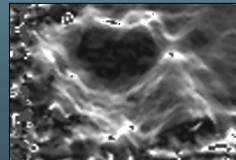
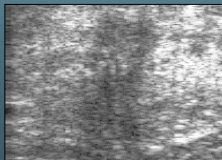


Sonograms

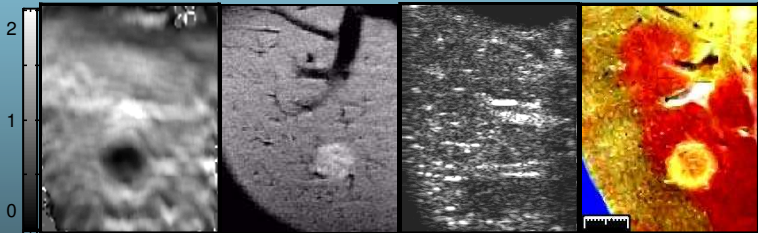


Elastograms

Infil. Duct. Carcinoma



HIFU lesion in Canine Liver




elastogram

T2 MRI

Sonogram

Pathology

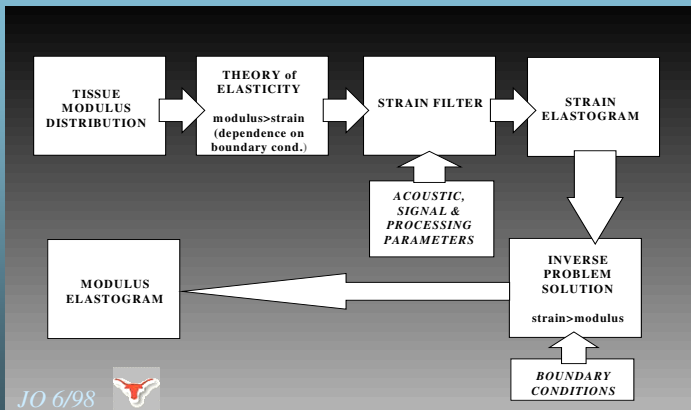
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- **Future directions** 

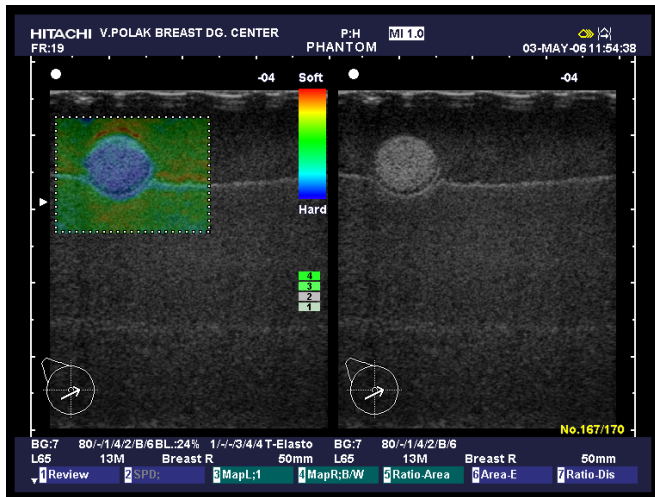
Conclusions and Future Directions

- Elastography conveys *new and probably clinically important tissue information*;
- The tradeoffs among engineering/elastographic image parameters are now reasonably well understood;
- Elastography can operate in hypoechoic areas (ex. shadows);
- Reliable *small elastic contrast exists among normal soft-tissue* components; good CNR allows its visualization;
- Pathology generally exhibits *large elastic contrast*;
- Promising areas include breast, prostate, vasculature, small parts and treatment monitoring.

Elastography: Block Diagram



Sonoelastogram — Hitachi



Alternativní elastografické techniky

Buzení

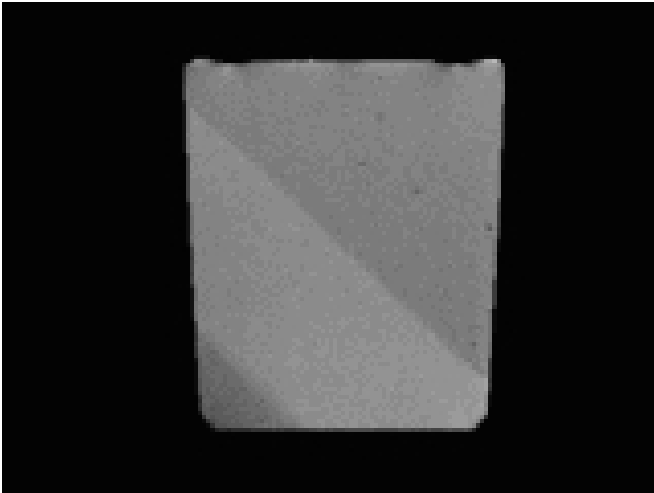
Excitace

- Kvazistatické (pomalé), tlakem sondy
- Impulsní
- Harmonické
 - Mechanicky
 - Interferencí ultrazvukových paprsků

Snímání

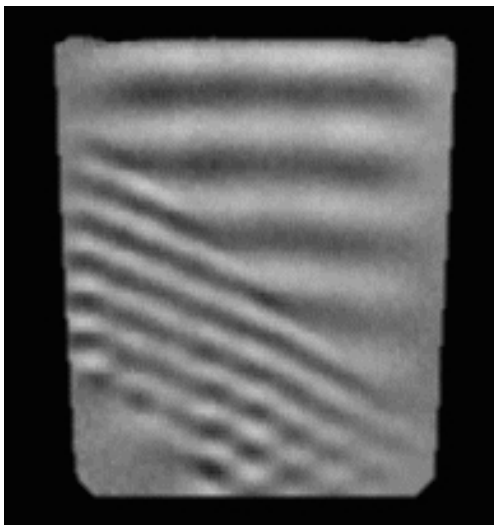
- Ultrazvuk
- Laserový vibrometr (interferometr)
- MRI
 - + 3D data

Fantom



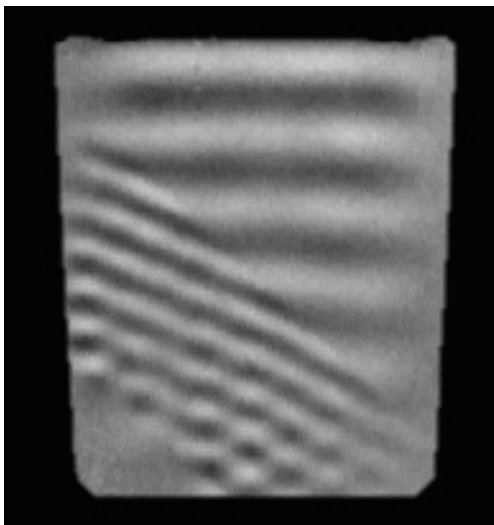
Materiály s různou tuhostí.

Harmonické buzení



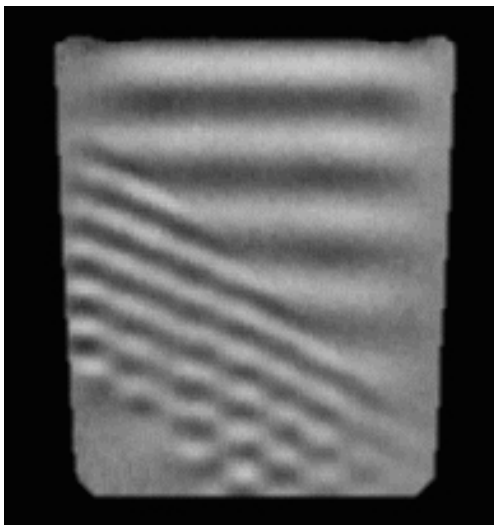
- MRI snímání
- Tužší hmota → rychlejší vlnění

Harmonické buzení



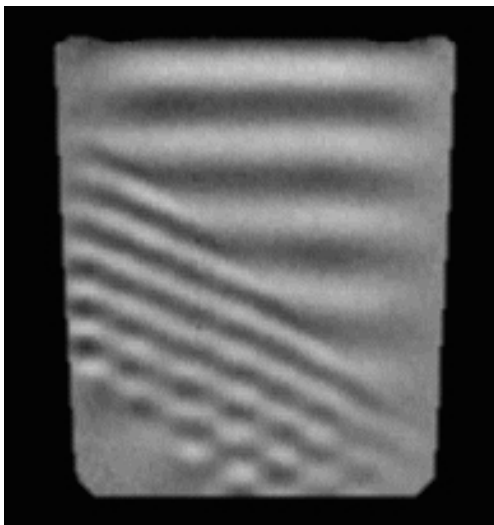
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Harmonické buzení



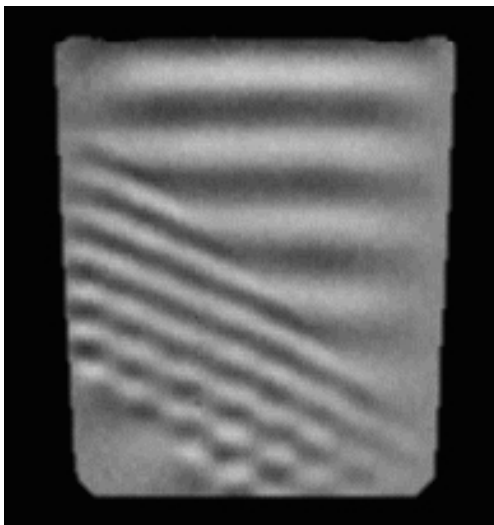
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Harmonické buzení



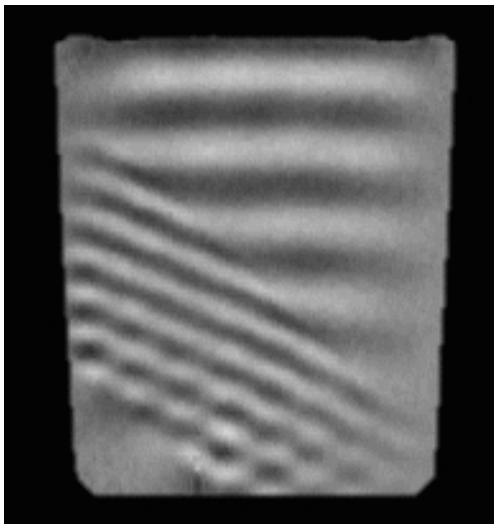
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Harmonické buzení



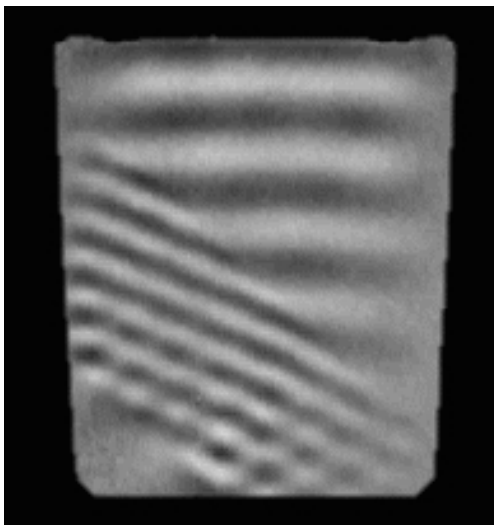
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Harmonické buzení



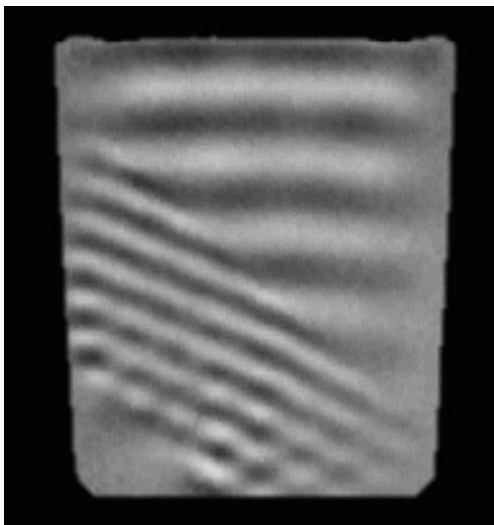
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Harmonické buzení



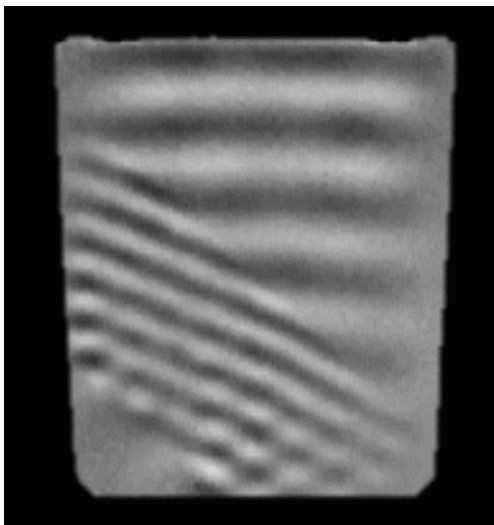
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Harmonické buzení



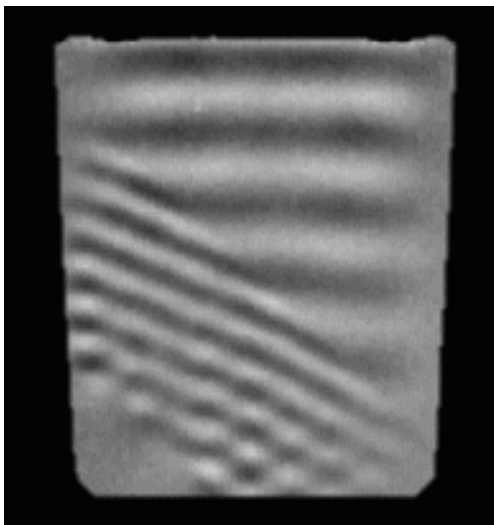
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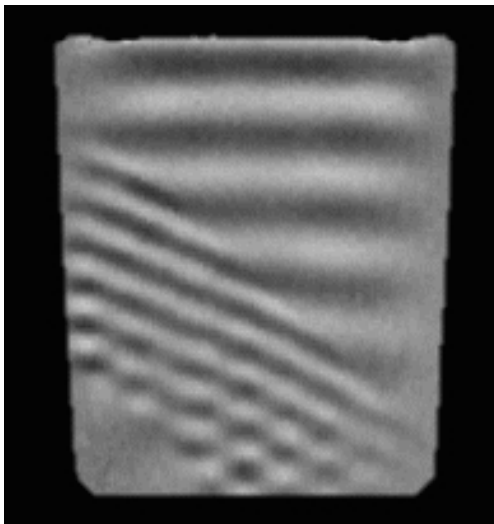
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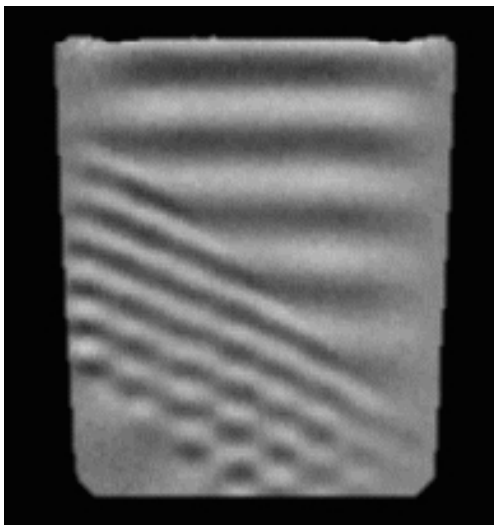
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Harmonické buzení



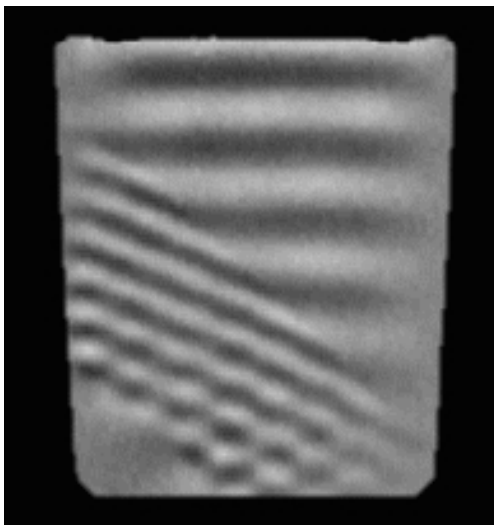
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Harmonické buzení



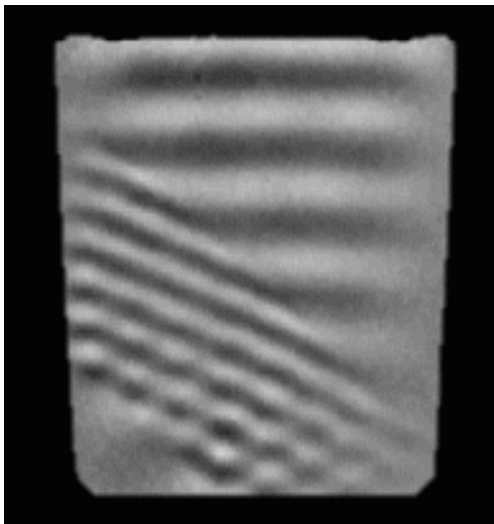
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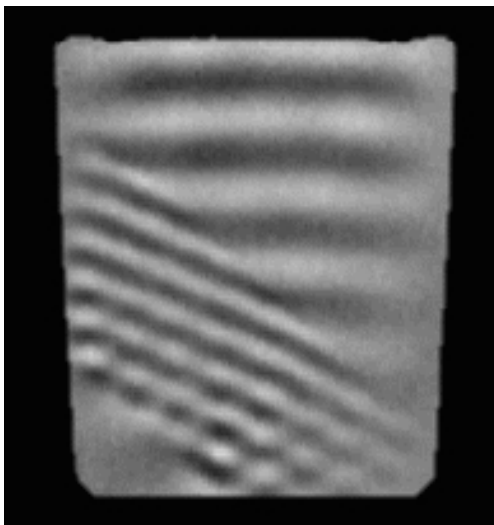
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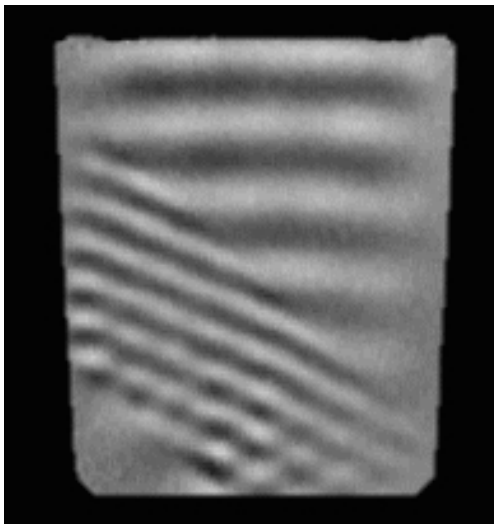
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Harmonické buzení



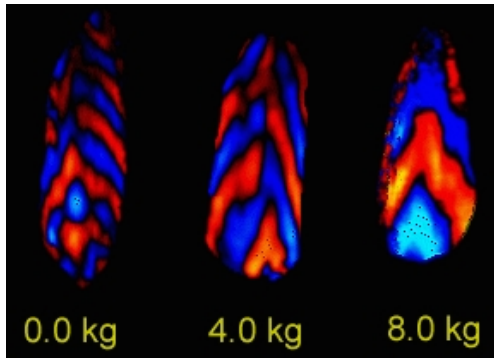
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Harmonické buzení

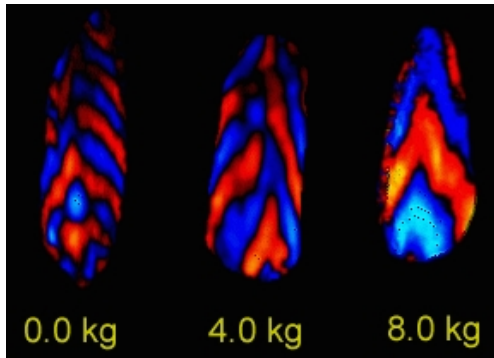


- MRI snímání
- Tužší hmota → rychlejší vlnění

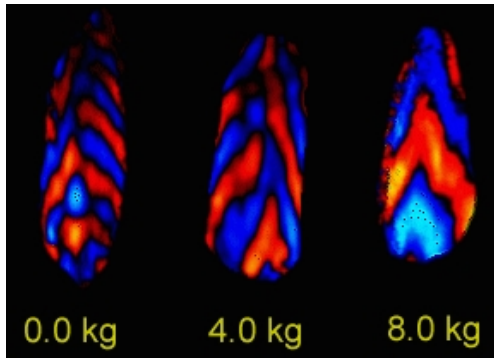
Sval při zatížení



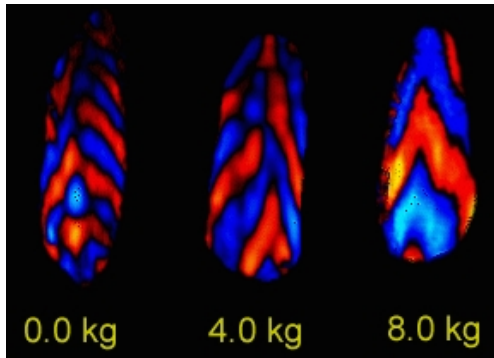
Sval při zatížení



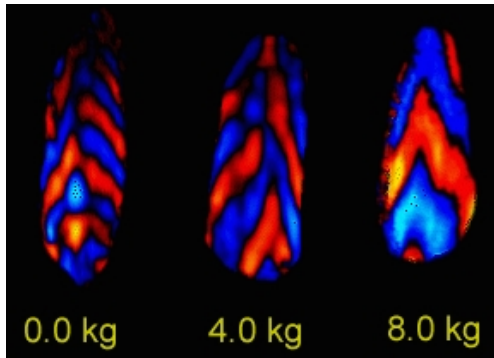
Sval při zatížení



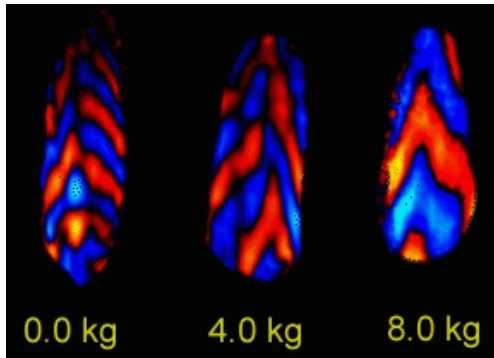
Sval při zatížení



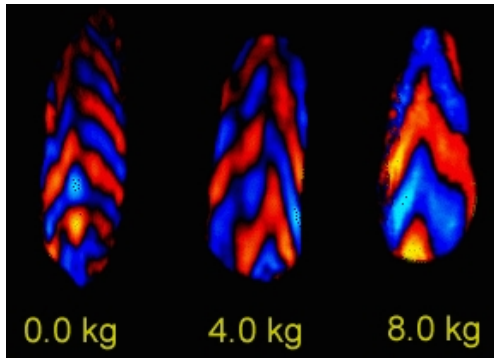
Sval při zatížení



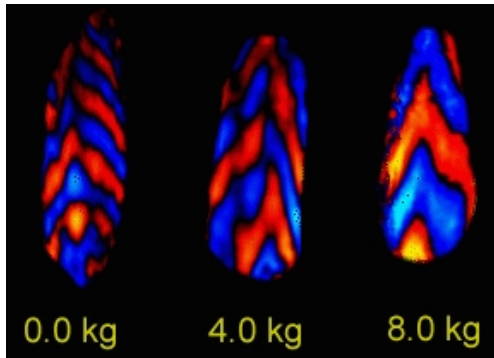
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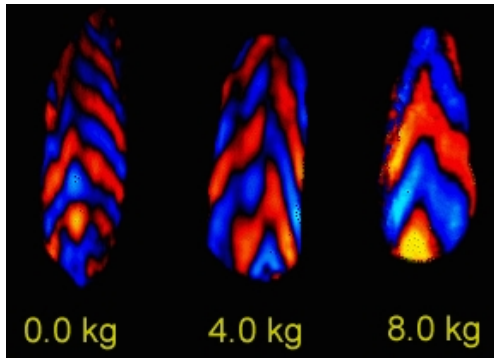
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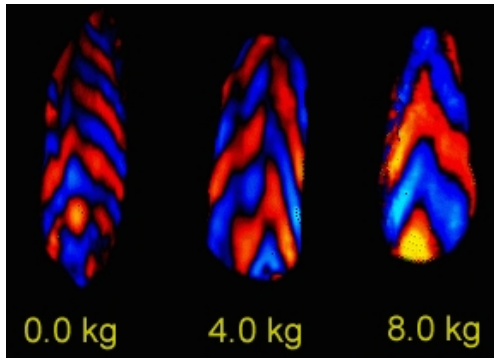
Sval při zatížení



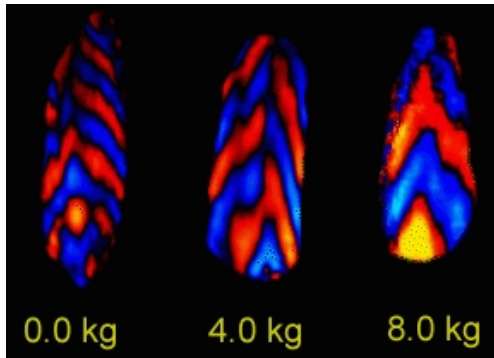
Sval při zatížení



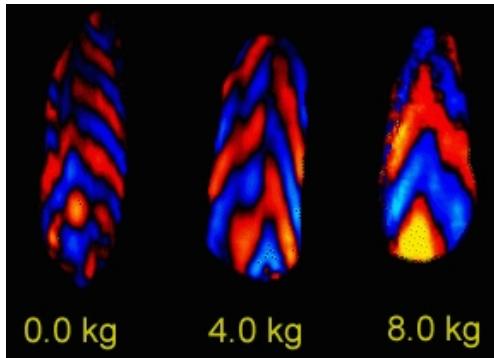
Sval při zatížení



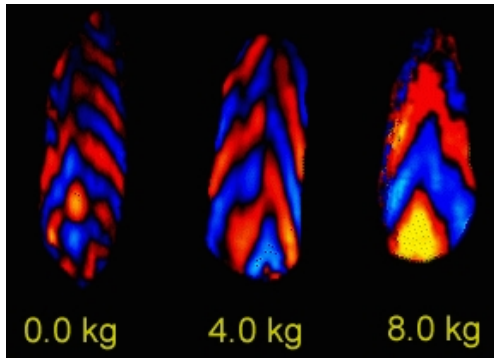
Sval při zatížení



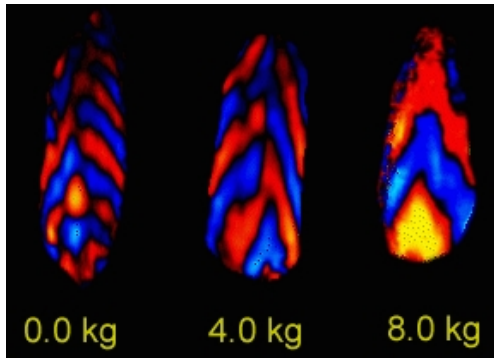
Sval při zatížení



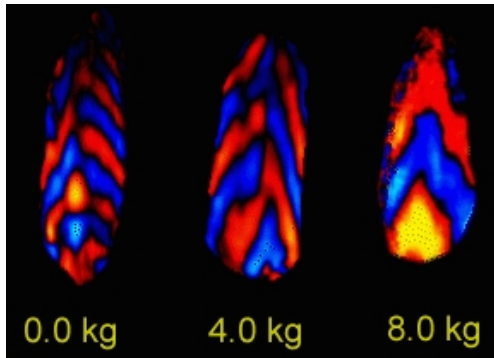
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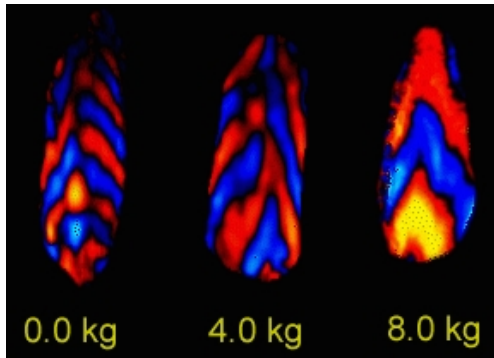
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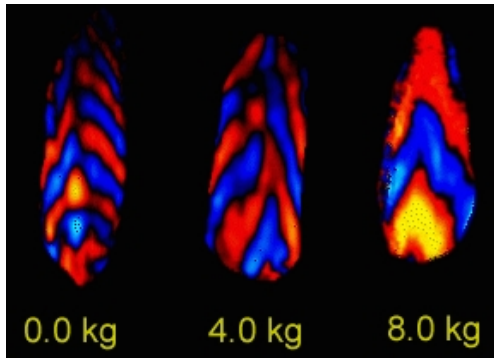
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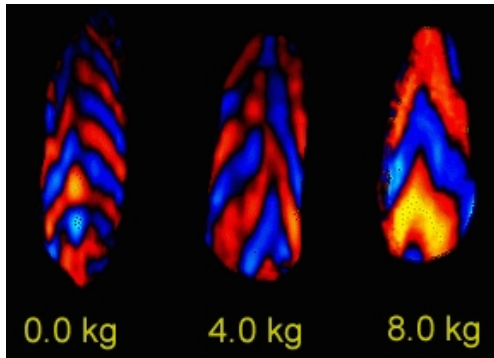
Sval při zatížení



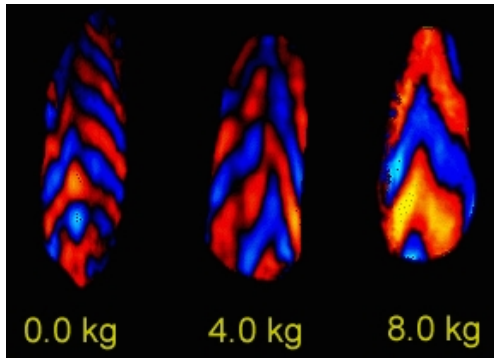
Sval při zatížení



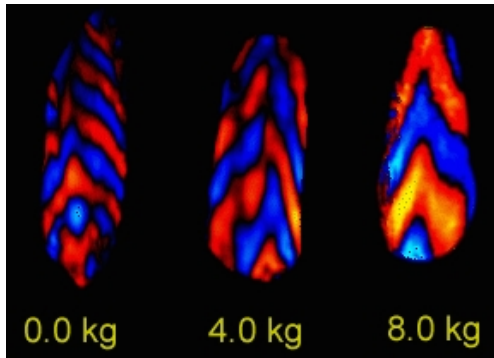
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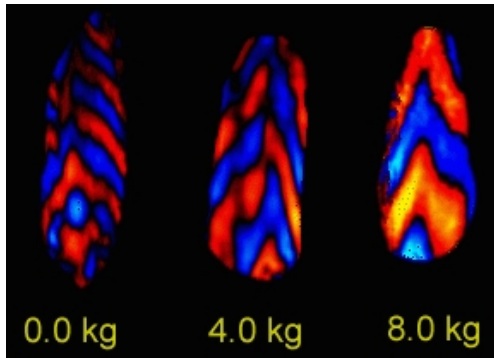
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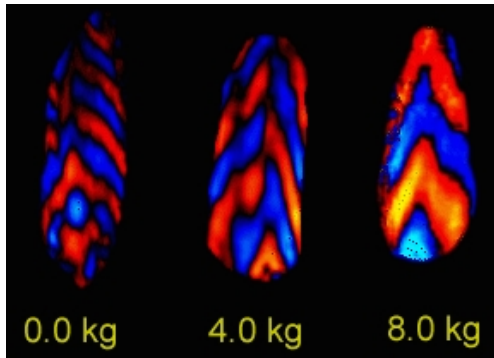
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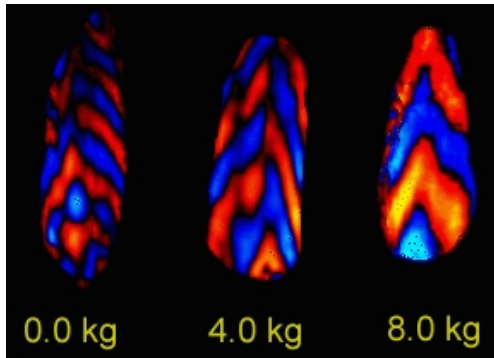
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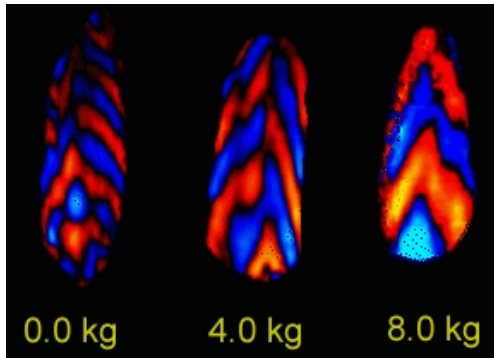
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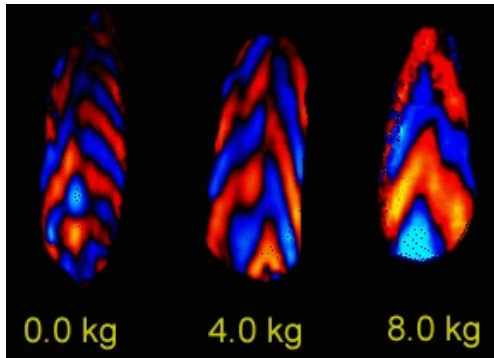
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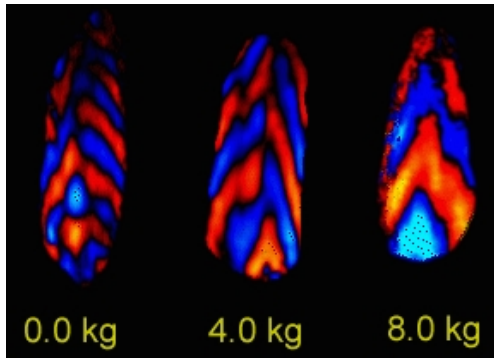
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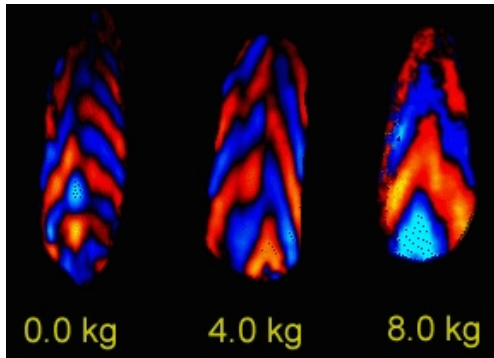
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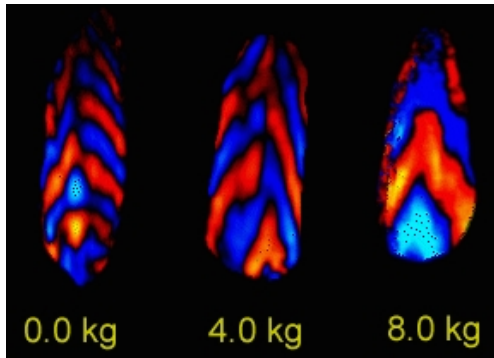
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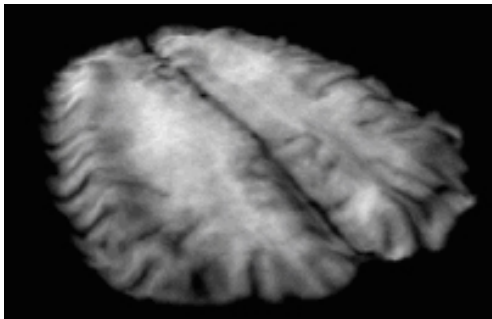
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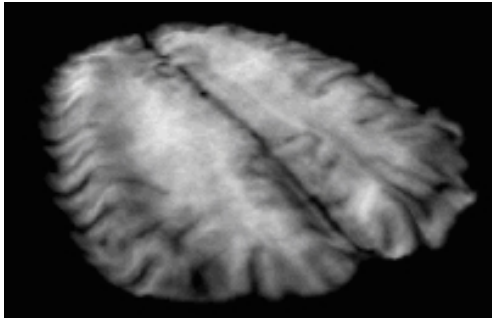
Sval při zatížení



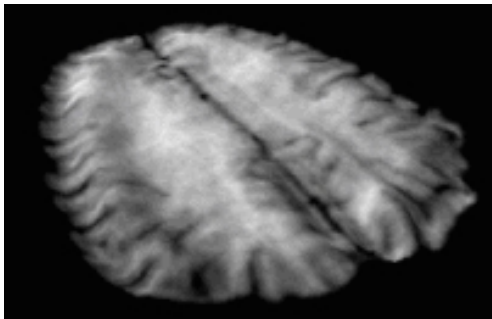
Vlnění v mozku



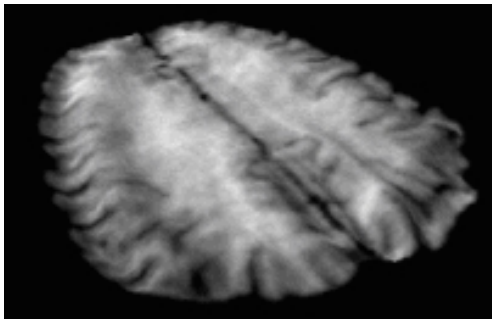
Vlnění v mozku



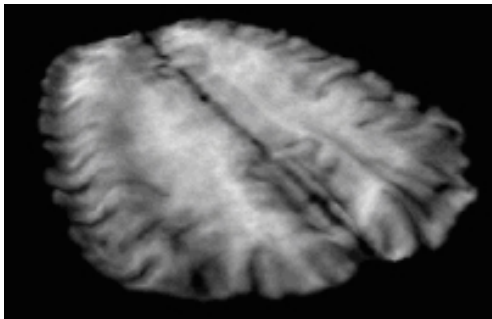
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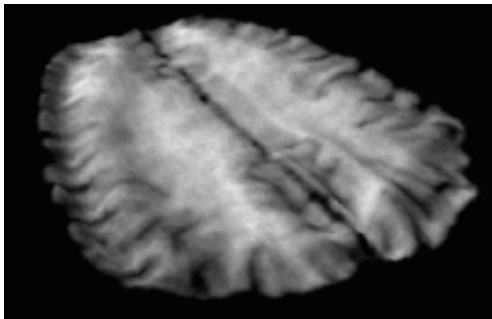
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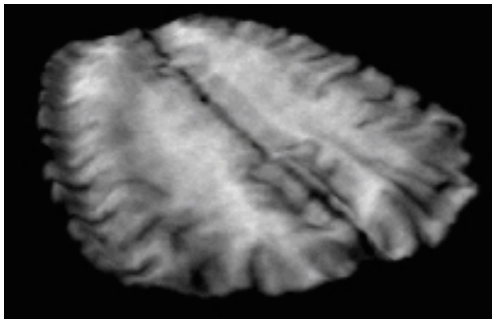
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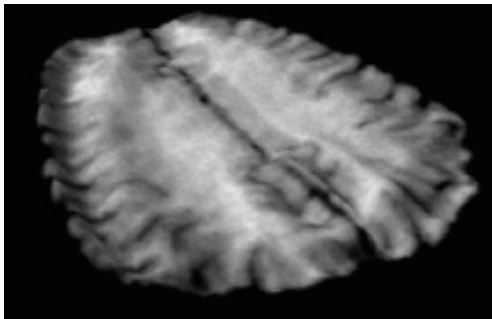
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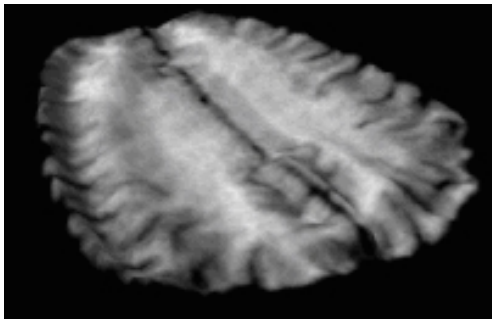
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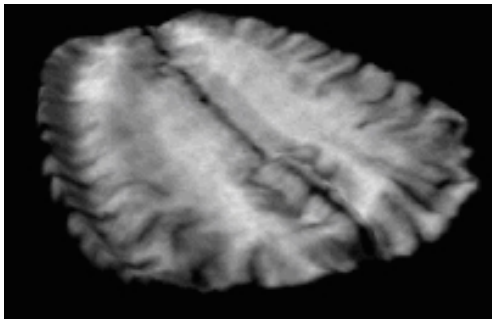
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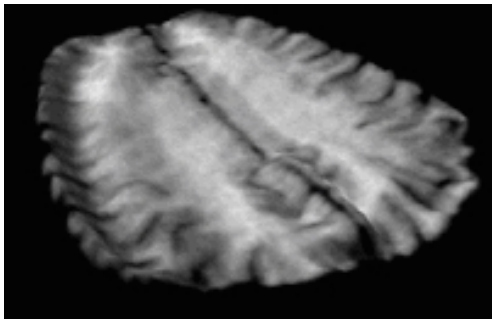
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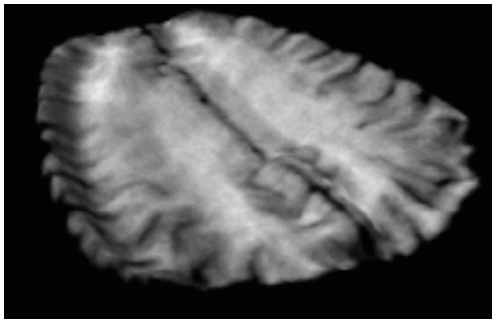
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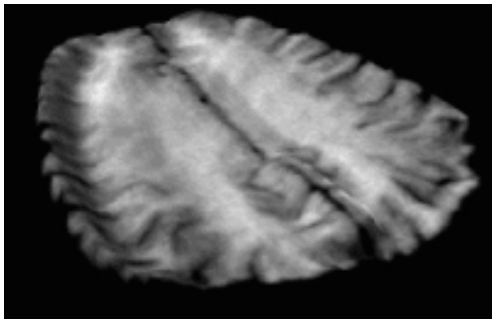
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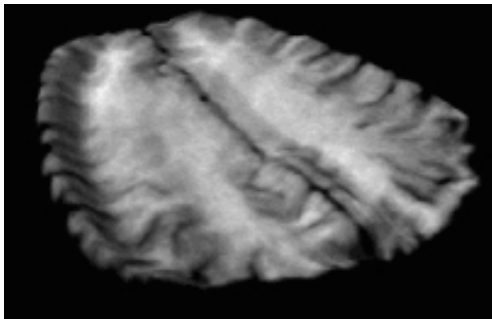
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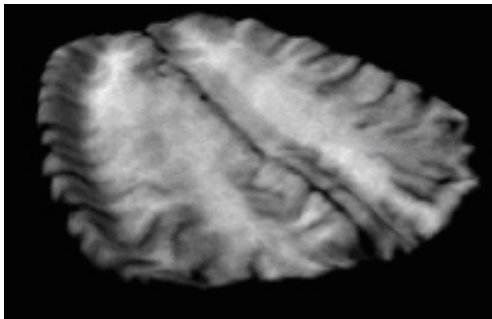
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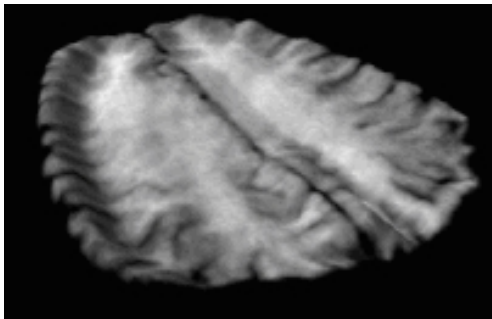
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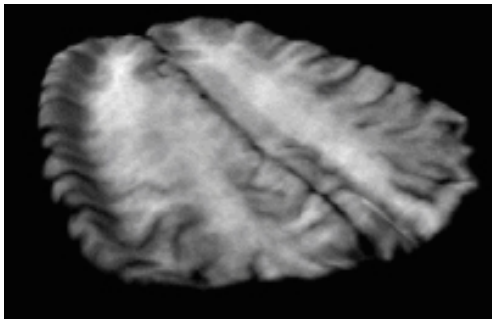
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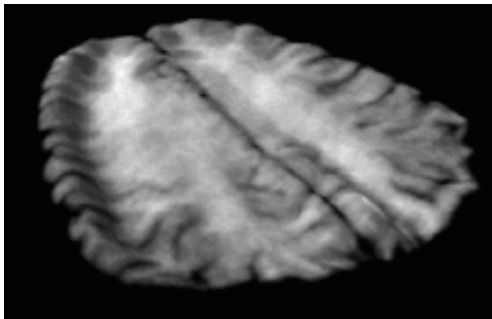
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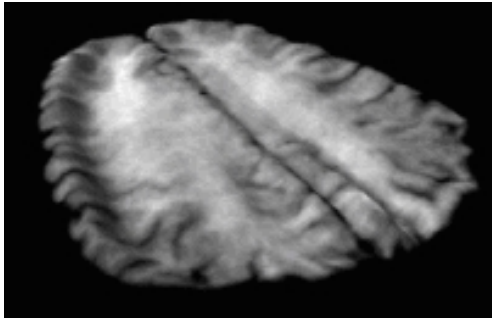
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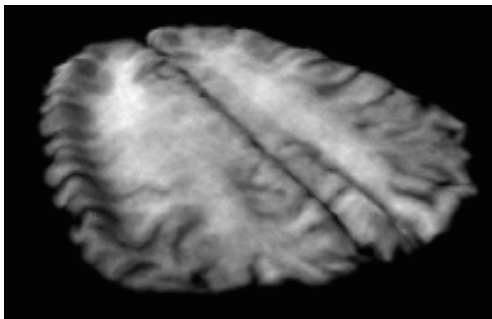
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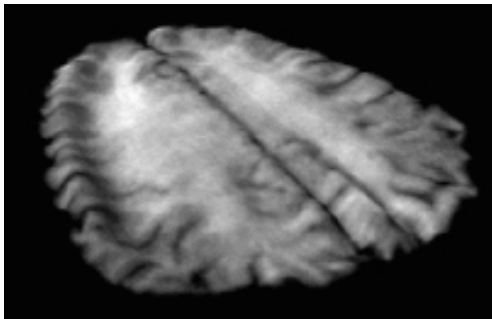
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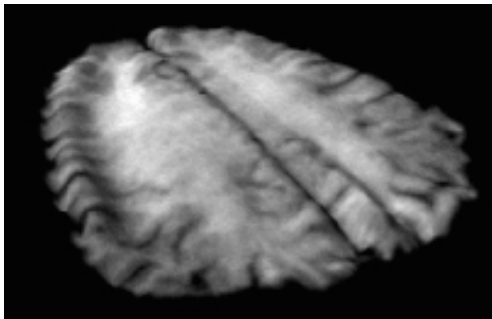
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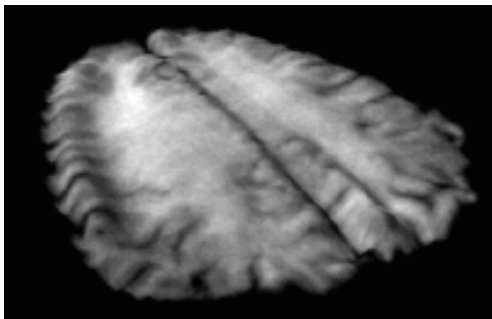
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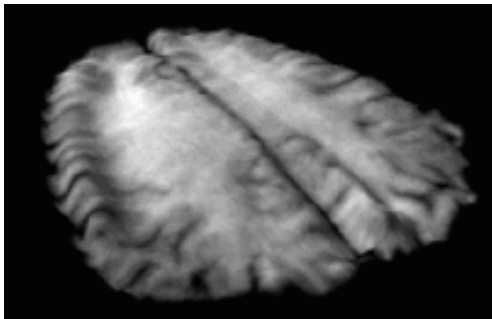
Vlnění v mozku



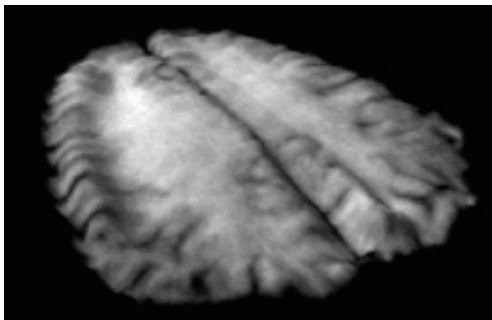
Vlnění v mozku



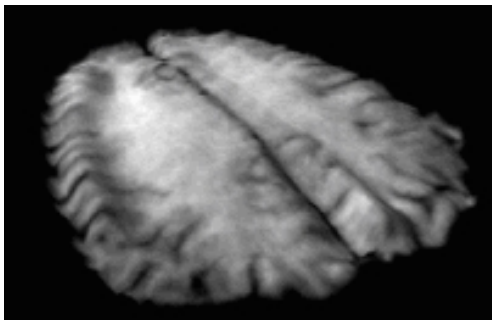
Vlnění v mozku



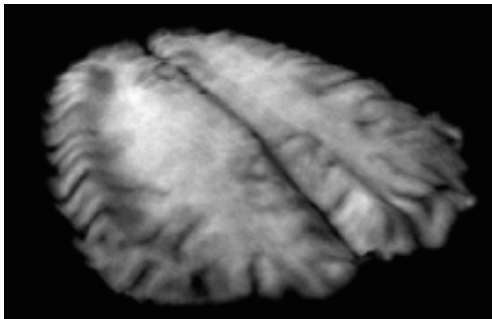
Vlnění v mozku



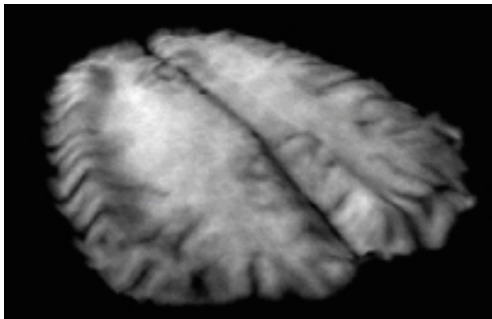
Vlnění v mozku



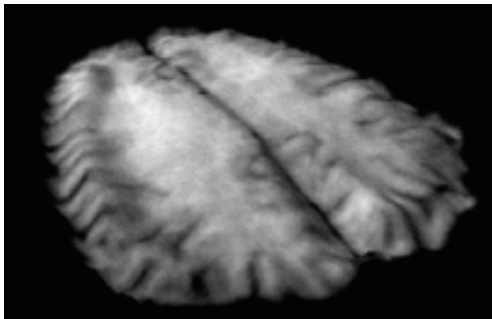
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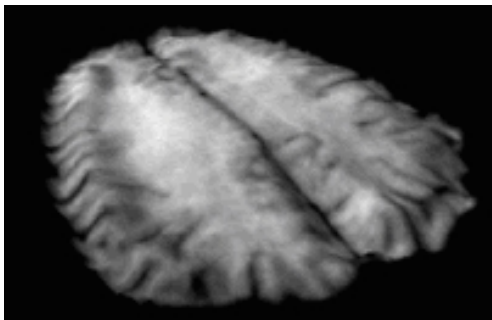
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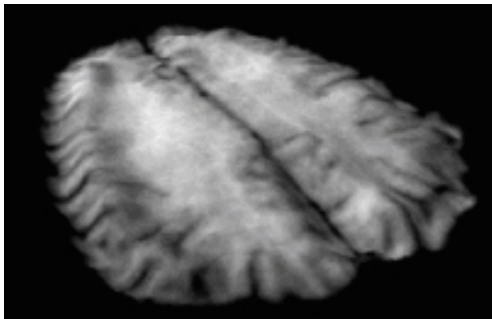
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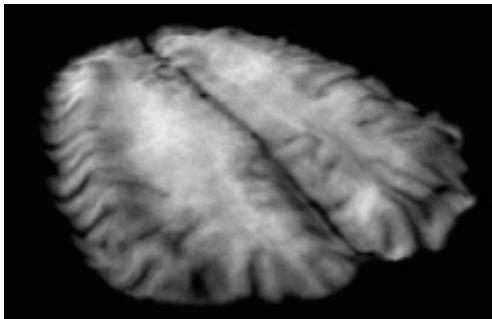
Vlnění v mozku



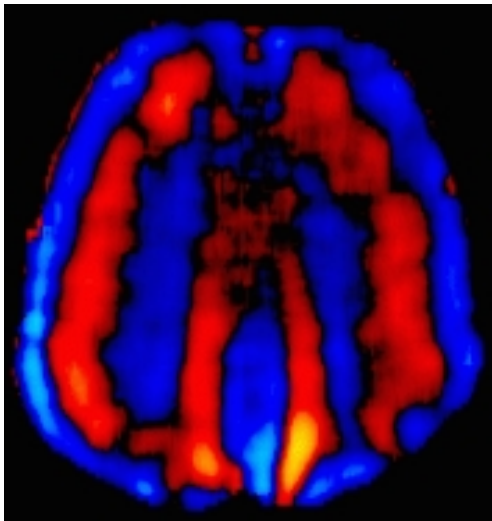
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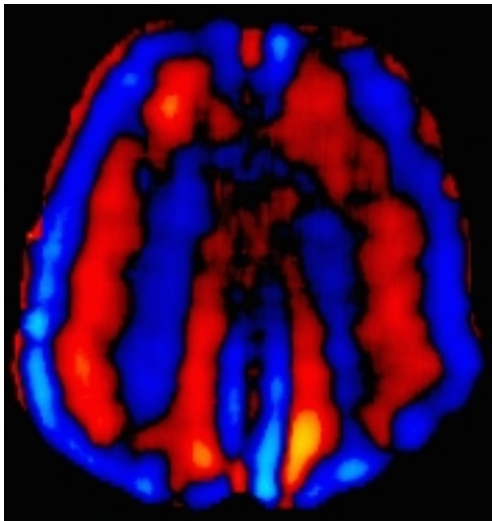
Vlnění v mozku



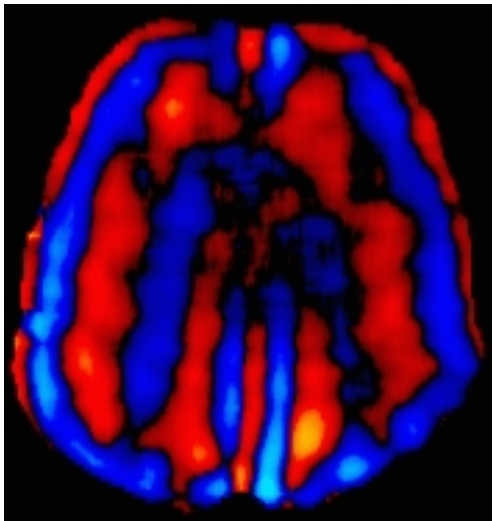
Vlnění v mozku (2)



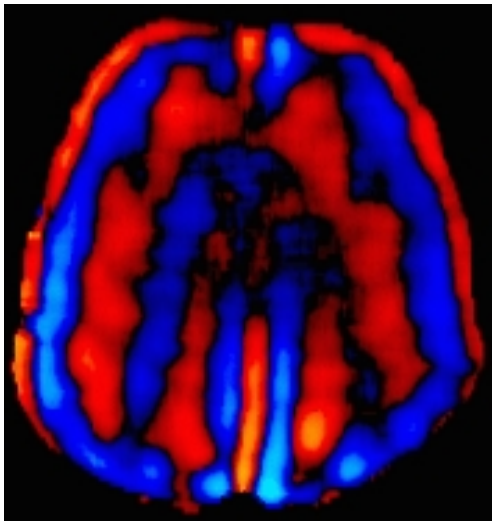
Vlnění v mozku (2)



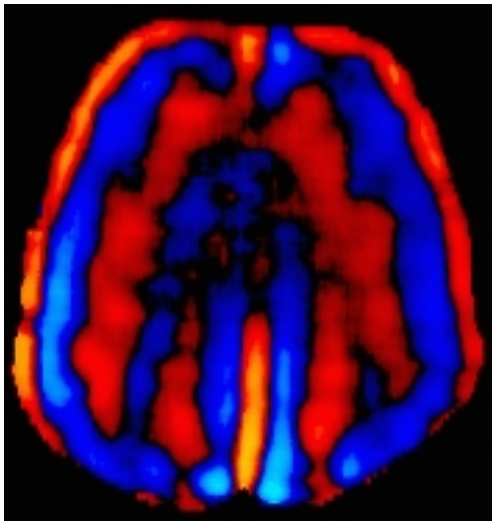
Vlnění v mozku (2)



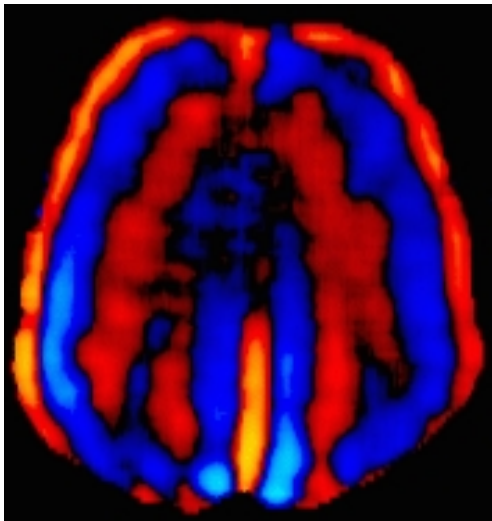
Vlnění v mozku (2)



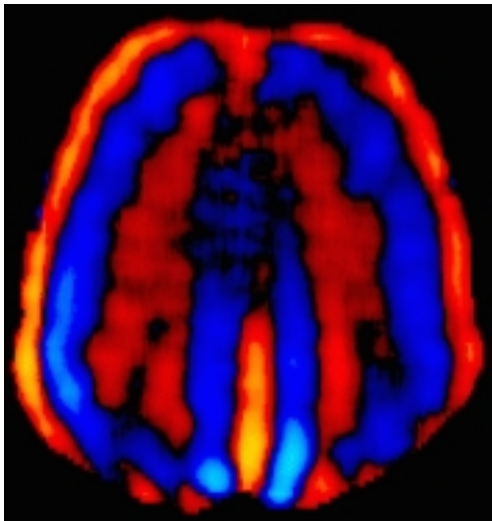
Vlnění v mozku (2)



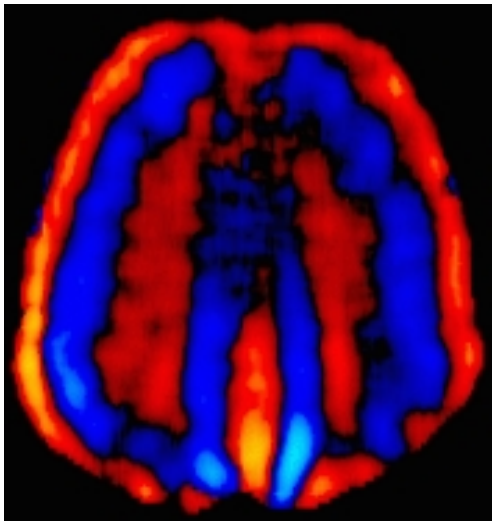
Vlnění v mozku (2)



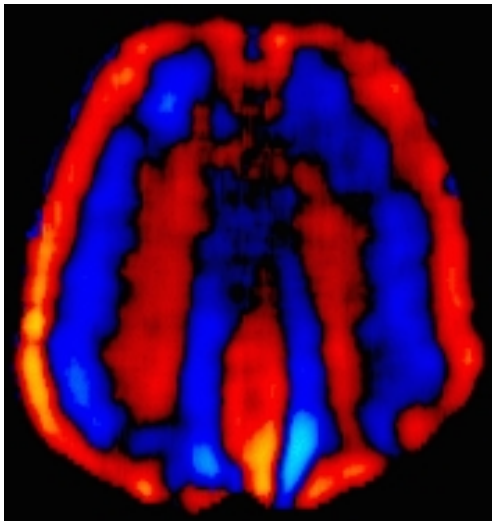
Vlnění v mozku (2)



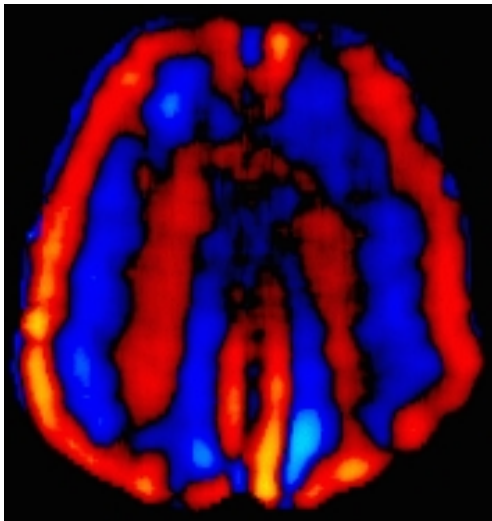
Vlnění v mozku (2)



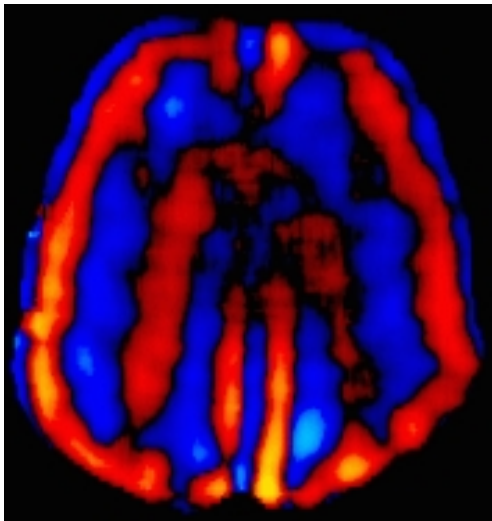
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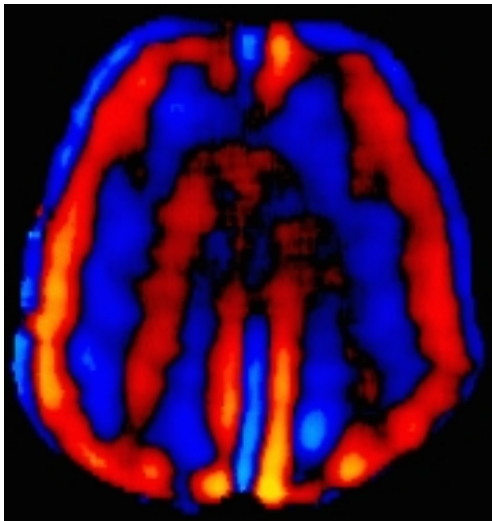
Vlnění v mozku (2)



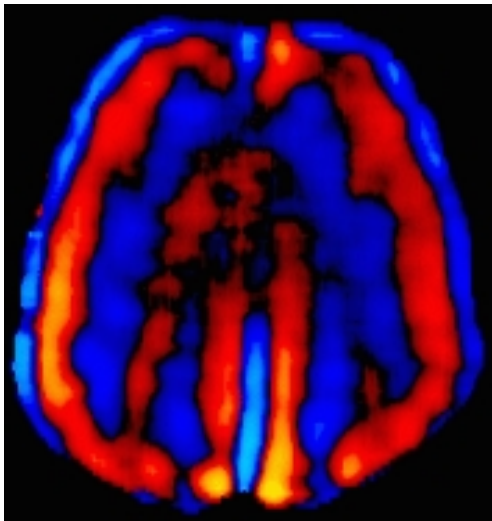
Vlnění v mozku (2)



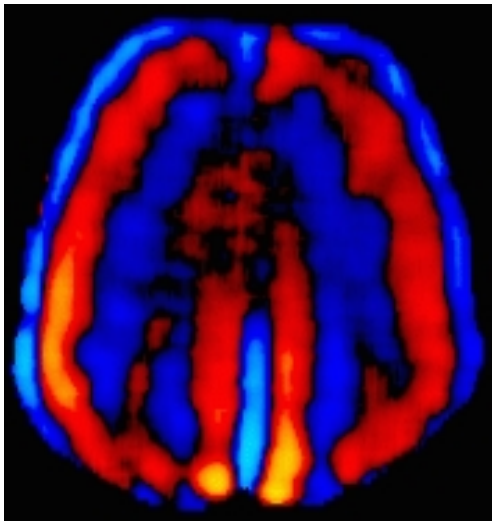
Vlnění v mozku (2)



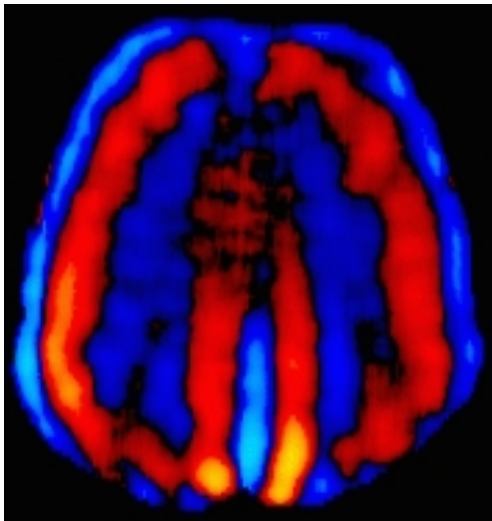
Vlnění v mozku (2)



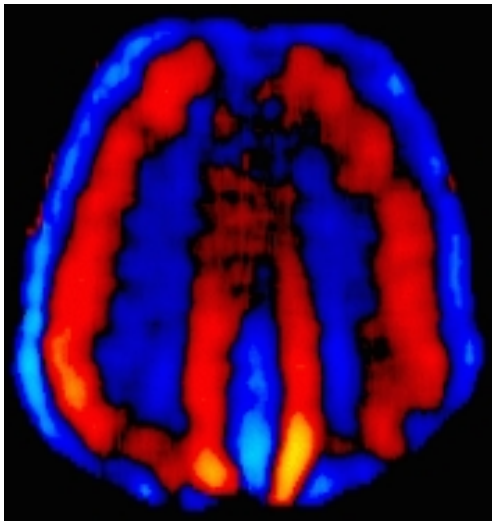
Vlnění v mozku (2)



Vlnění v mozku (2)



Vlnění v mozku (2)



Elastografie – závěr

- Neinvazivní metody měření elastických parametrů *in vivo*
- Tuhost často koreluje s diagnózou; klinické využití v blízké budoucnosti
- Technicky náročná řešení, specializovaný hardware
- Jednodušší snímání → složitý inverzní problém