



The future of MRI: way beyond the image

Dafna Ben Bashat, PhD

Deputy Director Sagol Brain Institute
Director of Advanced Imaging Lab



מכון סגול
לתפקודי המוח
תל-אביב



Sagol Brain
Institute
Tel-Aviv

✉ dafnab@tlvmc.gov.il



The future of MRI: way beyond the image

1977 - The first live human subject was imaged

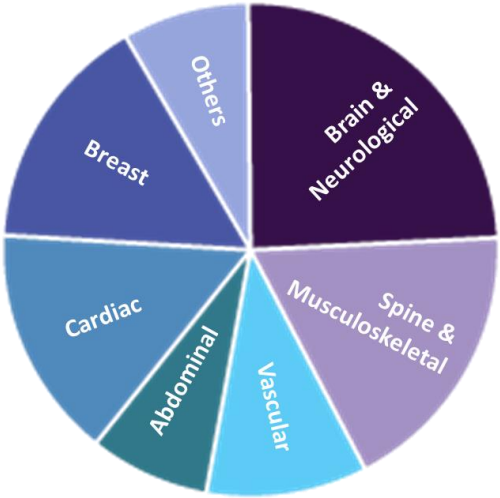
1980 - MRI machines became commercially available

42 years passed



What is MRI?

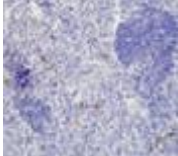
Medical Imaging: CT, US, X-Ray, MRI
40M MRI scans Year/USA - 7% expected growth rate
\$ 5.6B global MRI market (2021)



Global MRI market share, by application, 2020 (%)

➤ Multi-contrast

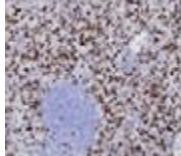
SMA vascular maturation



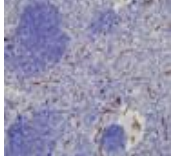
Cell size Medulloblastoma



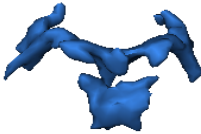
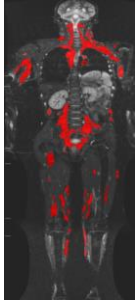
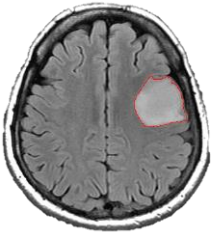
Ki67 Cell proliferation



CD31 vascularity



➤ True 3D



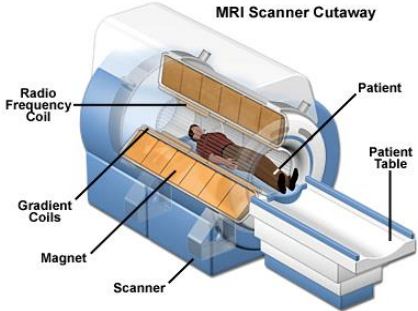
➤ Non-ionization – Radio Frequency (meters)

What is MRI?



r.f. Radiation

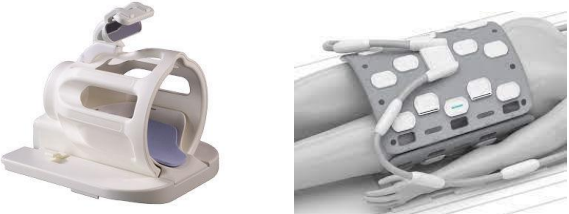
Magnet



Magnetic Field Gradients



Receive Signal



Images



The future of MRI: way beyond the image

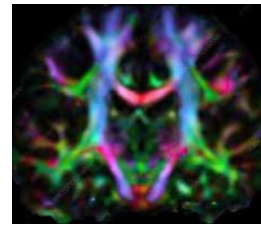
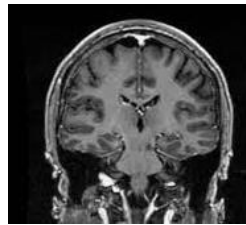
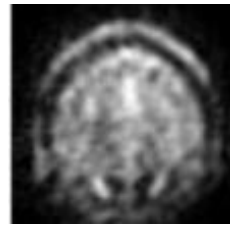
➤ Technology – Hardware

Magnets & Coils



➤ Software- contrasts

Image acquisition & reconstruction

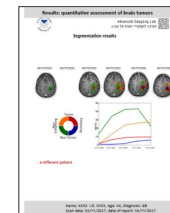


➤ Image analysis – workflow

Computer vision

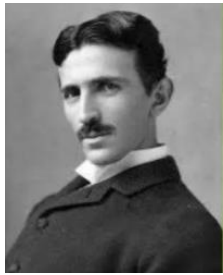


➤ MRI – way beyond the image



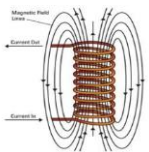
MRI: Technology Hardware

1882



Nikola Tesla

Discovered the rotating Magnetic Field



1937

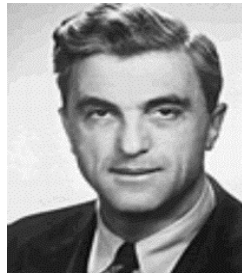


Isidor Rabi

Discovery of Nuclear Magnetic Resonance



1946

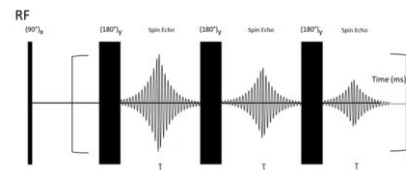


Felix Bloch

new methods for nuclear magnetic



Edward Purcell

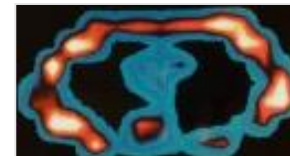


1971

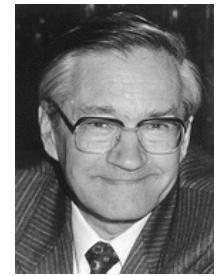


Raymond Damadian

Tumor detection by NMR

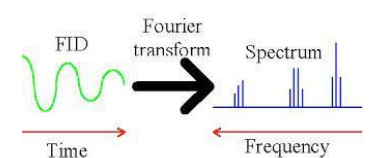


1980

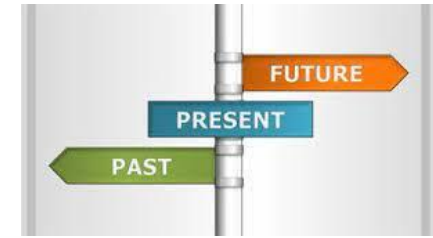


Richard Ernst

Fourier transform nuclear magnetic



MRI: Technology Hardware



Increased magnetic field strength



0.5 Tesla \rightleftarrows **1.5 / 3.0 Tesla** \rightleftarrows **7 Tesla** \rightleftarrows **10.5 Tesla**

FDA approved

FDA approved

FDA approved

PRESENT

TASMC - Sagol Brain Institute



Prisma 3T



Skyra 3T



Avanto Fit 1.5T



Ingenia 1.5T



PET/MRI



MRI-ocology

FUTURE

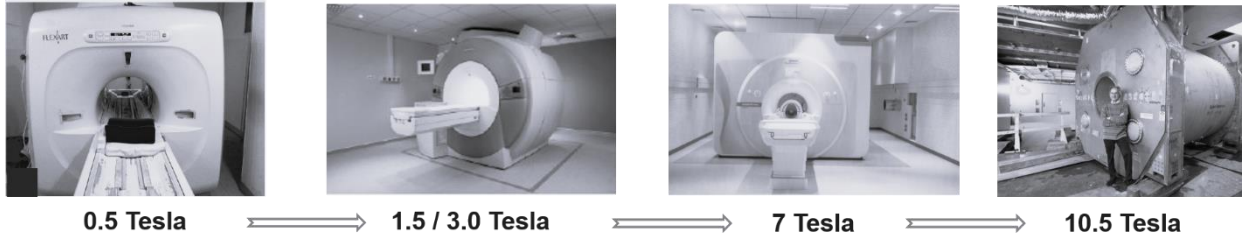


5T United?



MRI guided proton beam therapy

MRI: Technology Hardware



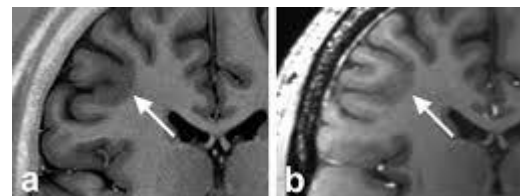
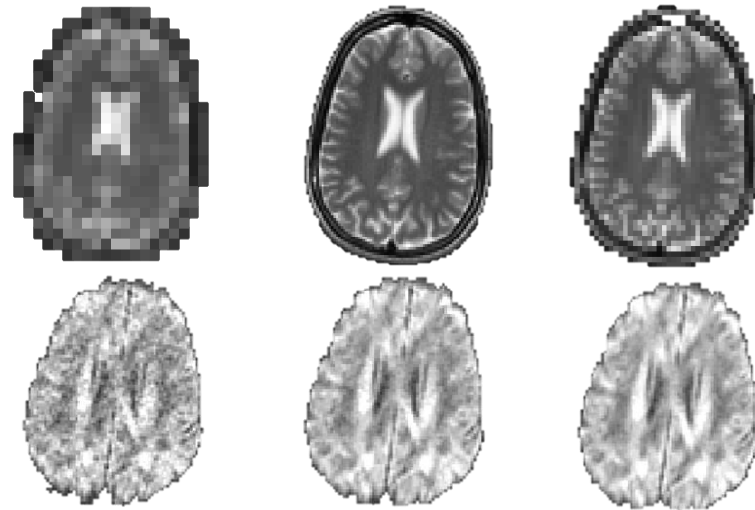
Resolution



Signal to Noise Ratio



Improve diagnosis



MRI: Hybrid Technology

Research at the Advanced Imaging Lab (AIL)

PET - MRI



Research: PET/MRI, SPECT - MRI

Parkinson disease
Alzheimer's disease
Lewy Body Dementia

Brain tumors

EEG - fMRI



Research:

Epilepsy
Emotion
Chronic pain

MRI for radiation planning



Research:

Brain tumor
Radiation field- NAWM

MRI: Technology Hardware

FUTURE

New portable MRI has the potential to change the future of healthcare



Pictured from L-R: Laura Barlow, Dr. Anthony Traboulsee, Adam Dvorak and Dr. Shannon Kolind.



Dr. Kolind tests out the Hyperfine scanner in the atrium of the DMCBH.



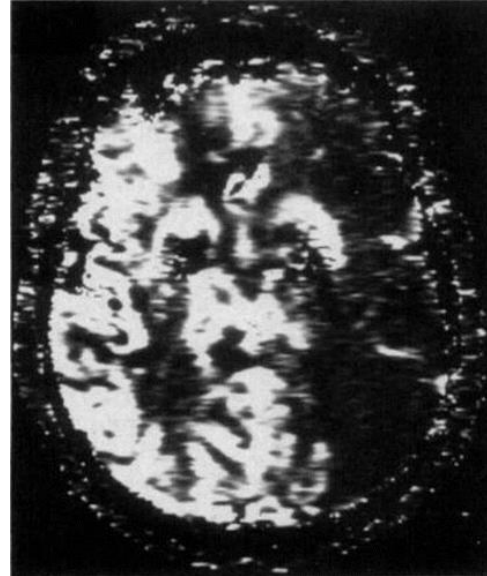
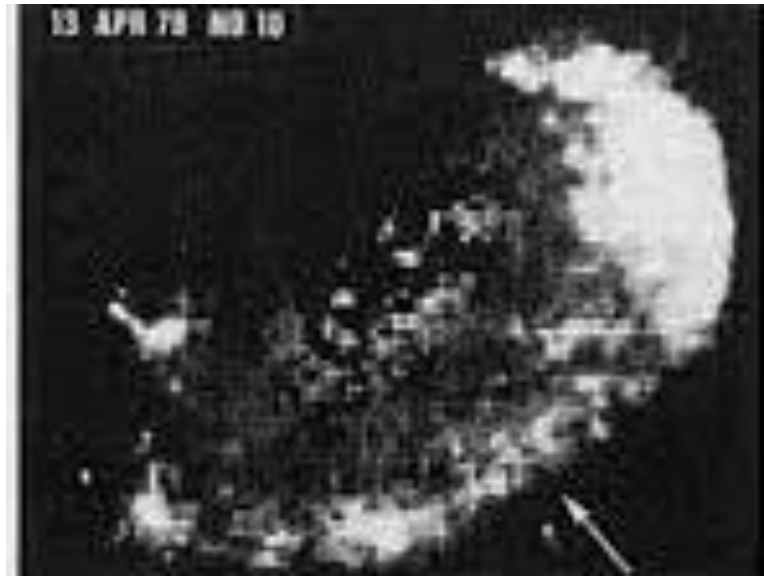
<https://www.centreforbrainhealth.ca/news/new-portable-mri-has-the-potential-to-change-the-future-of-healthcare/>

<https://hyperfine.io/specialties/neurocritical-care>

PAST

MRI: Technology Software

The first Abdomen & Brain MR images



MRI: Technology Software

1977



Peter Mansfield

Echo-planar imaging

1987



Charles Dumoulin

MR angiography

1992

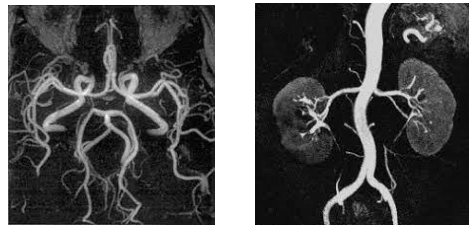
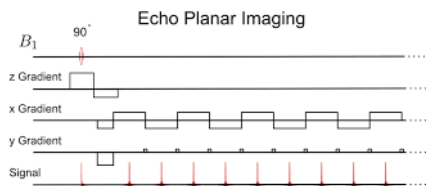


John (Jack) Belliveau

BOLD MRI - fMRI



Seiji Ogawa



PRESENT

MRI: Technology Software

FUTURE

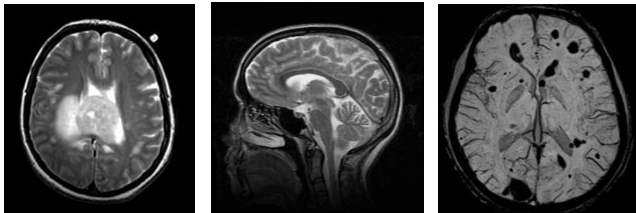
Multi-parametric approach

3D information

Microstructural properties of the tissue

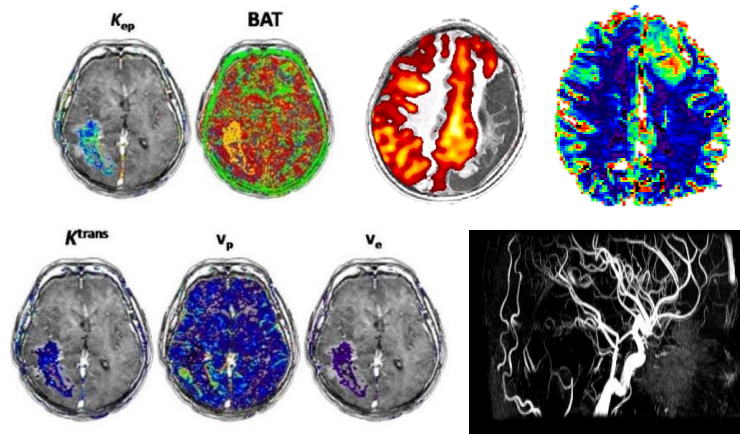
Structural information

Conventional methods



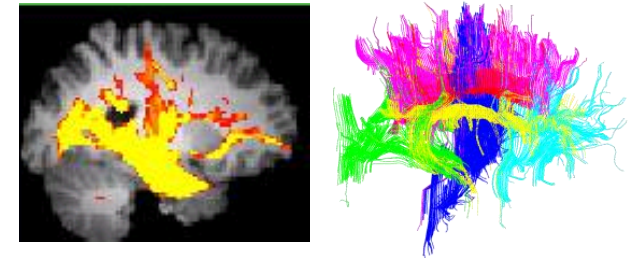
Vascular imaging

DSC / DCE / ASL MRA / MRV



Structural and connectivity

Diffusion Tensor Imaging (DTI)



PRESENT

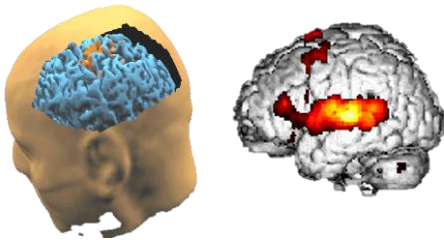
MRI: Technology Software

FUTURE

Functional MRI

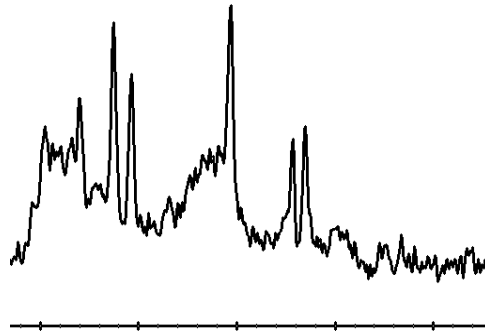
1990 – BOLD

Functional
Imaging (fMRI)

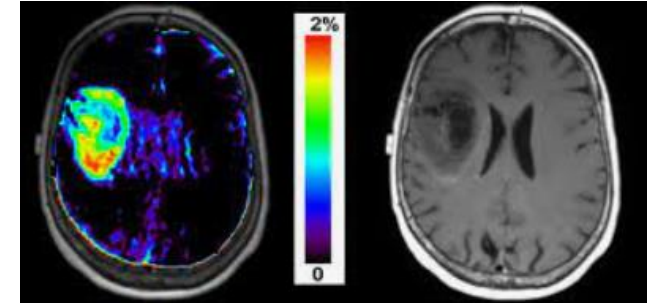


Metabolic information

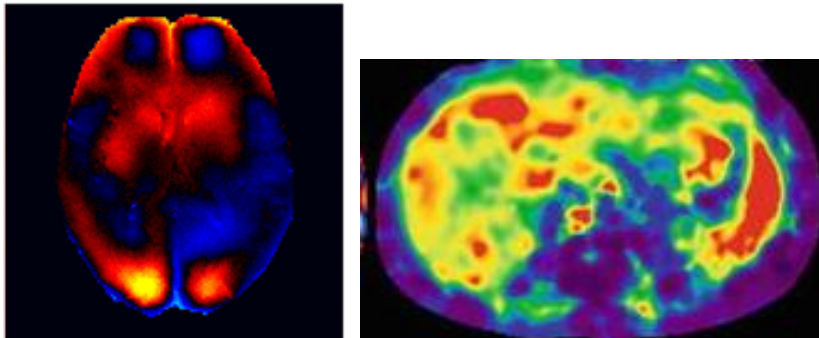
Spectroscopy - MRS



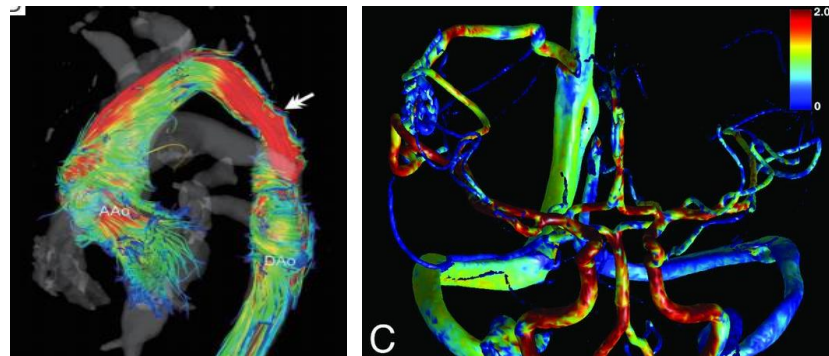
CEST



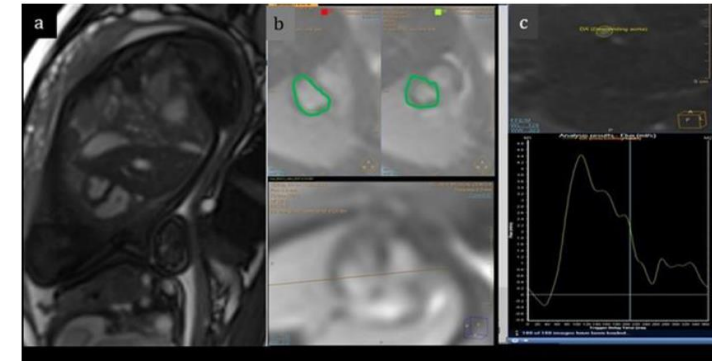
MR Elastography



4D flow



Cardiac MRI & fetal cardiac



PRESENT

MRI: Technology Software

FUTURE

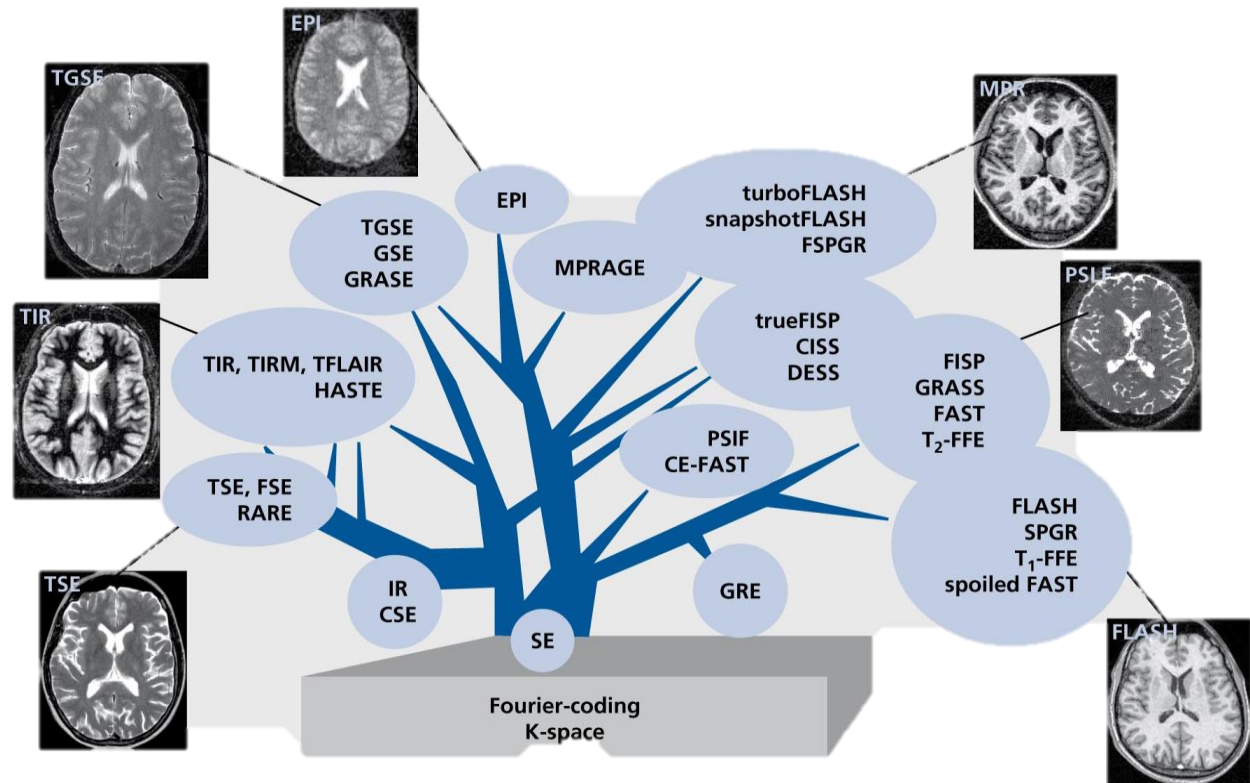
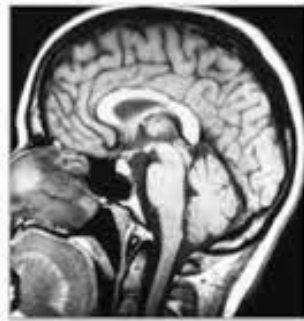
Scanning time:

One slice acquisition: 6 min.....2 min.....200 μ sec

Whole organ scan: 40 min..... 3 min..... 40 sec....6 sec



FT
↔

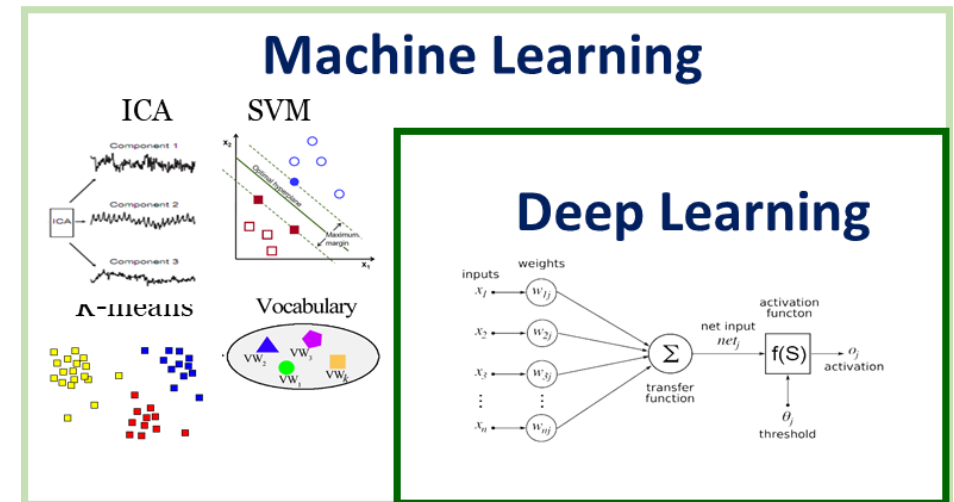
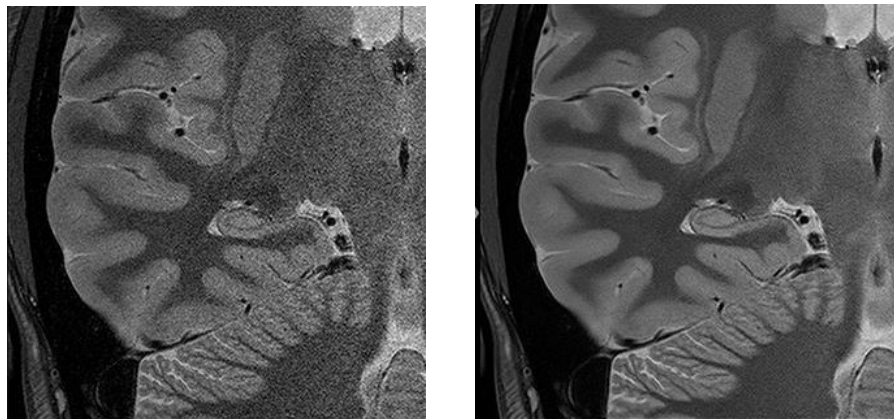
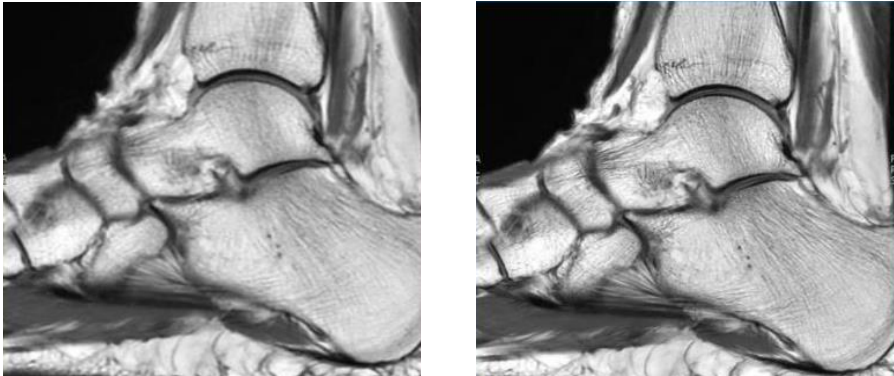


PRESENT

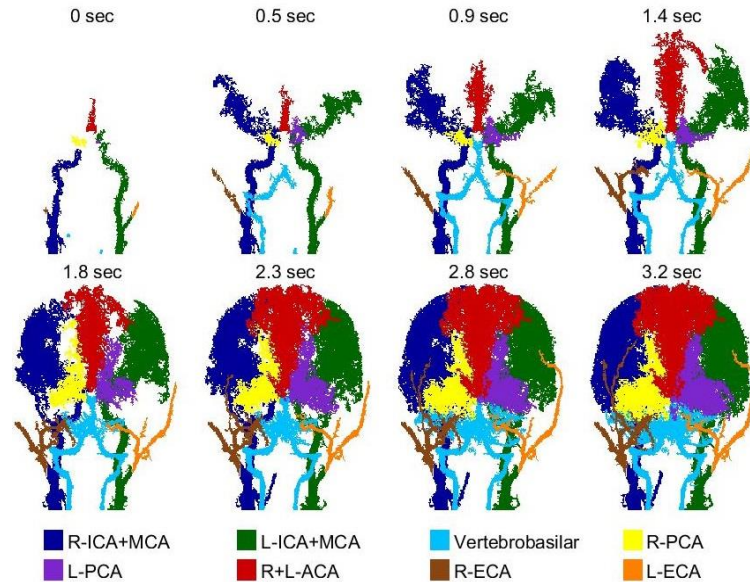
MRI: Technology Software

FUTURE

Deep Learning and image reconstruction:
Reduces scanning time & Improves image quality



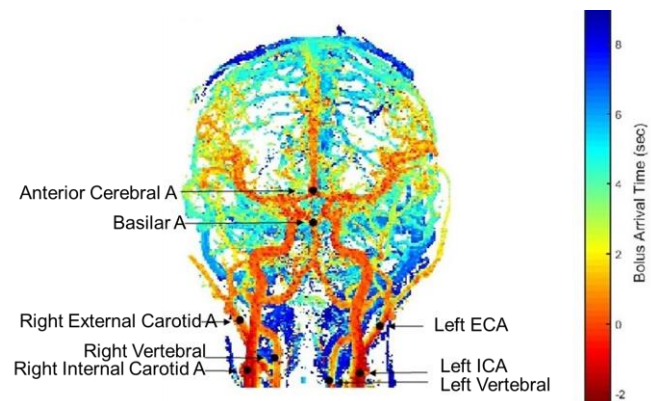
MRI: TWIST analysis



**Before
Surgery**



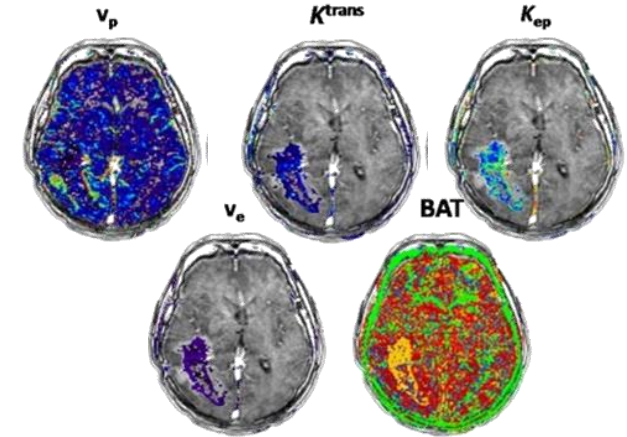
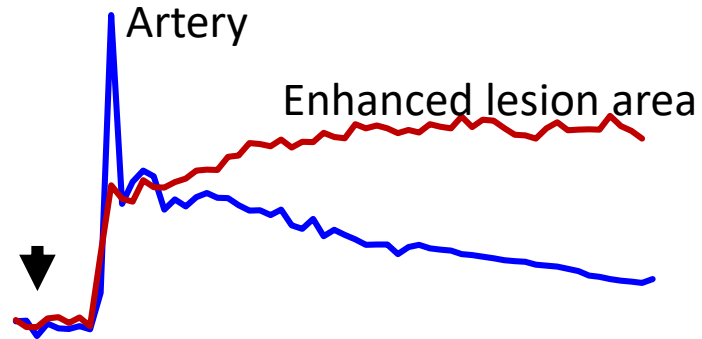
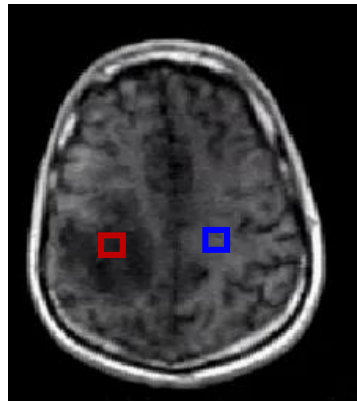
**After
Surgery**



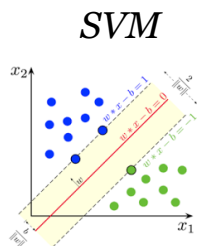
Gerl O... Ben Bashat D, 2017
Soroush Heidari et al., 2020
Daphna Link... Ben Bashat, 2020

Multi-parametric classification - DCE

- DCE analysis using DUSTER



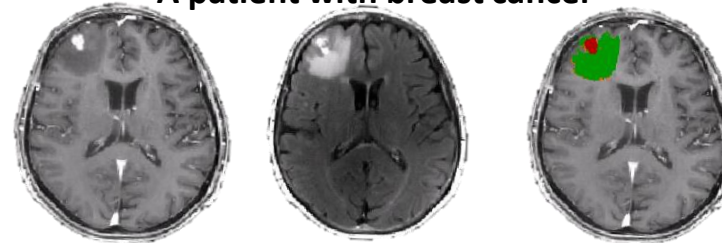
- Multi-parametric automatic classification



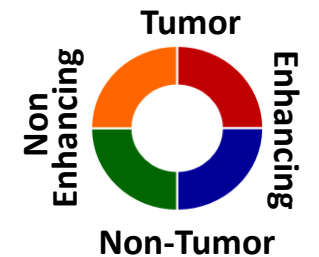
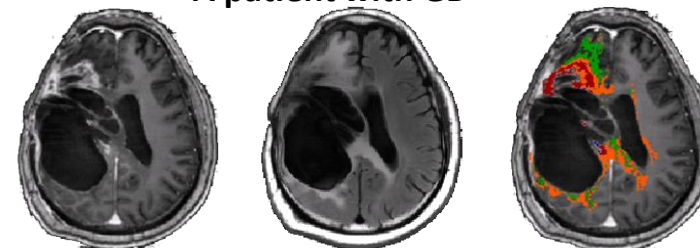
V_p, K^{tras}, K_{ep}
 V_e, BAT, T_1, T_1+C

nT₁WI+Gd nFLAIR Classification

A patient with breast cancer results



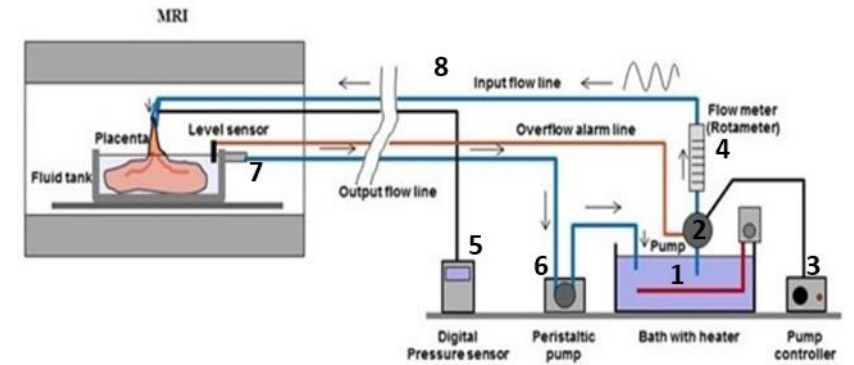
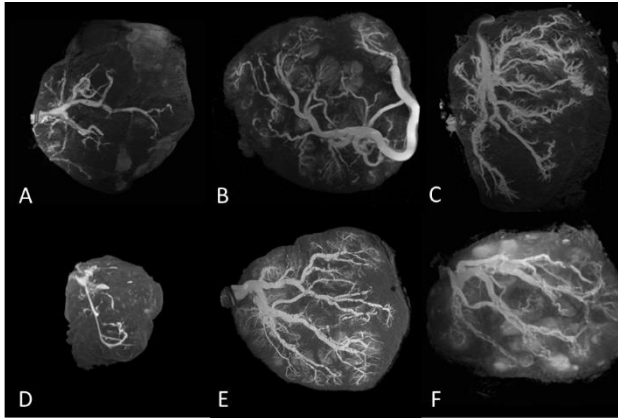
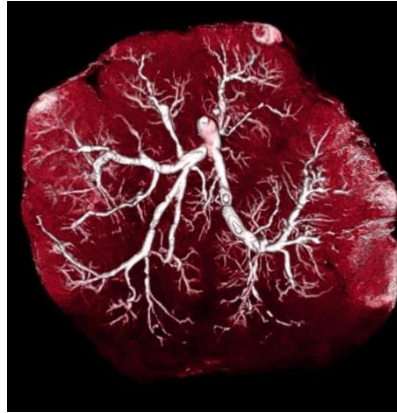
A patient with GB



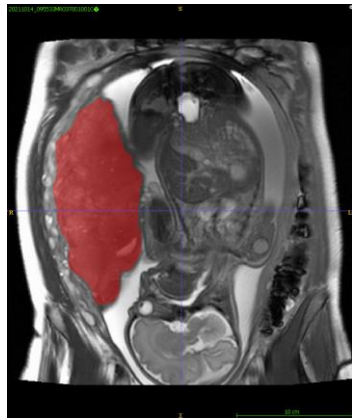
G. Liberman et al., Eur J Radiol. Feb, 2013; 82(2):e87-94; M. Artzi et al., Eur J Radiol, Jul, 2014; 83(7):1250-6; M. Artzi et al., 2015,121(2); M. Artzi et al. J. Neurooncol, 2016; 127(3):515-524; M. Artzi et al., Magn Reson Imaging. 2016

MRI: placental imaging

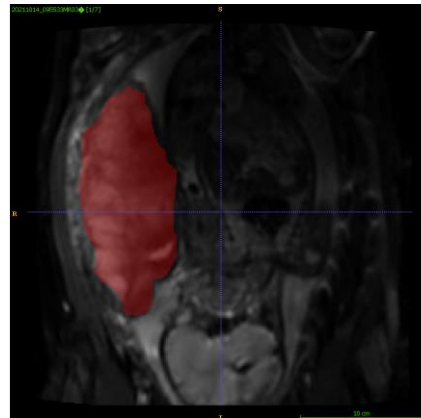
Ex-vivo studies:
structural-functional
interplay



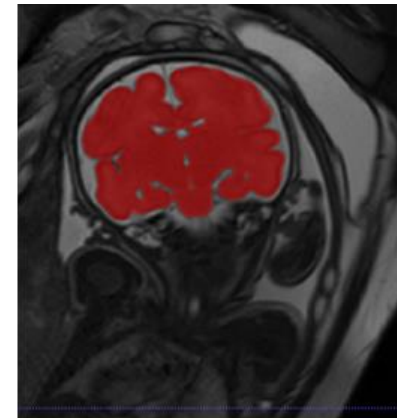
In-vivo studies:
structural-functional
interplay



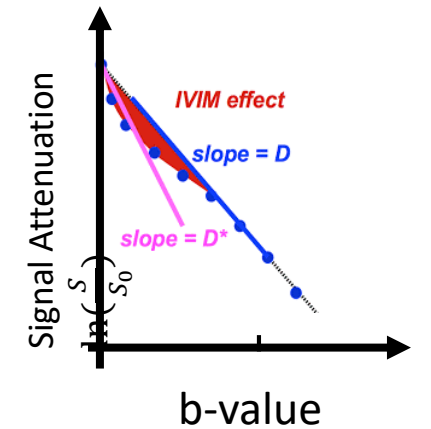
T2 with placenta
segmentation



IVIM images



Brain volume
extraction

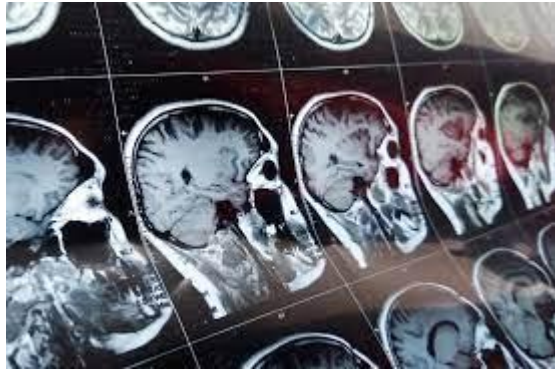


IVIM analysis

PRESENT

MRI: Workflow

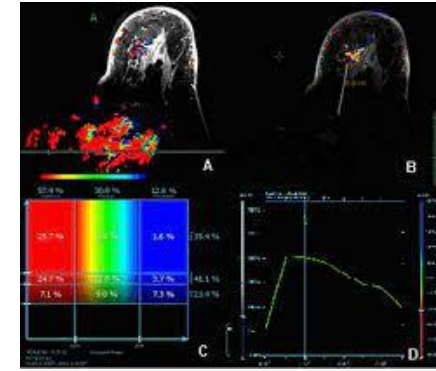
FUTURE



Films



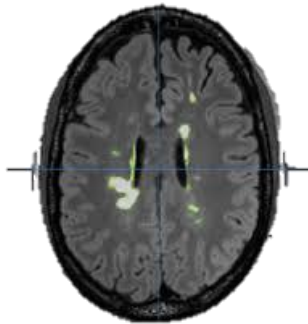
Computers



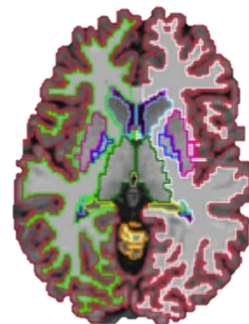
Use of CAD

(computer aided diagnostic tools)

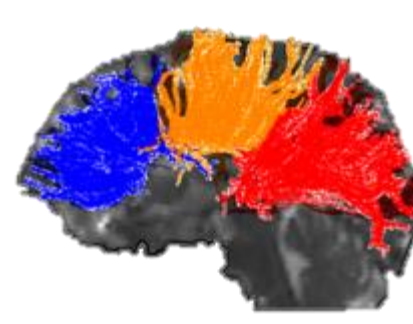
Semi – automatic tools



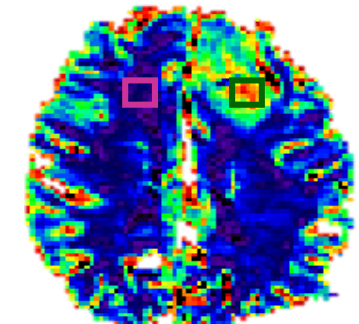
Lesion segmentation



Brain segmentation

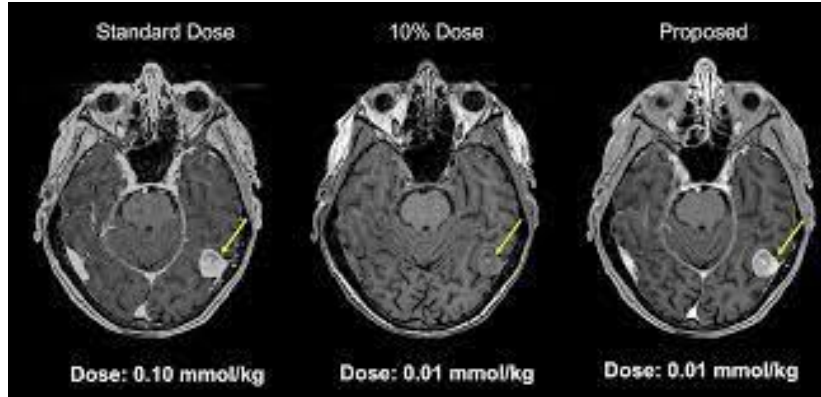


Streamline Tractography

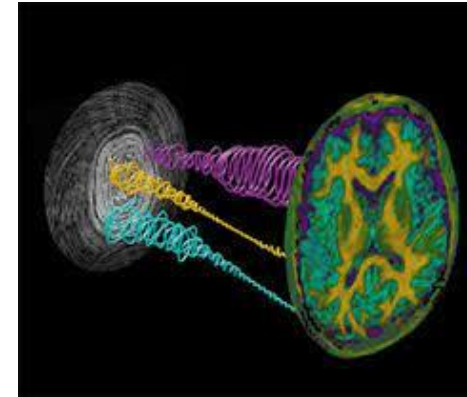


Perfusion analysis

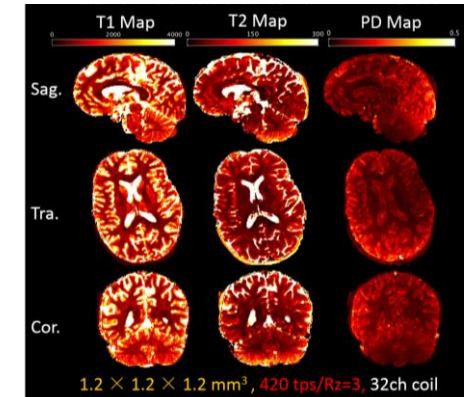
DL & Image analysis



DL - Reduce the dose of contrast agent



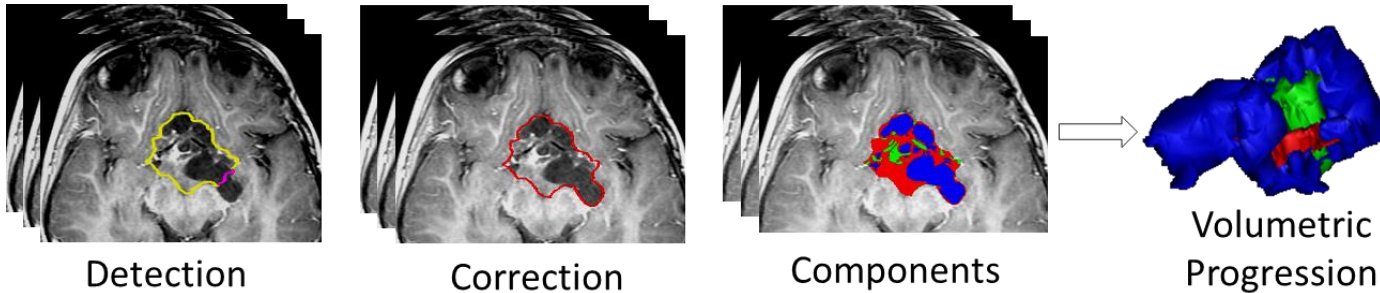
Reduce scanning time and increase image quality
1.2 mm iso whole brain 3D MF in 7 min 27 sec – Harvard University



Improves entire workflow

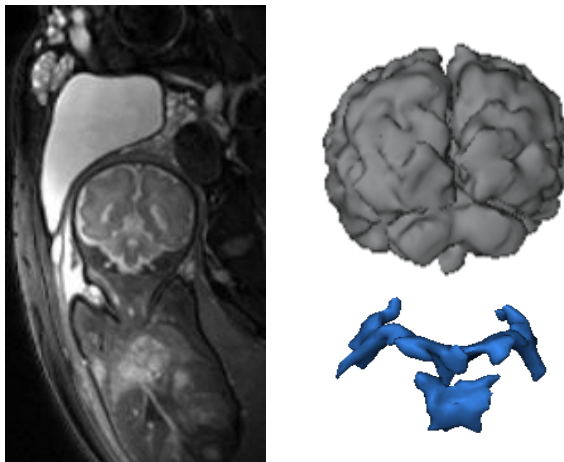
DL & Image analysis

Tumors segmentation & classification



Weizman L...Ben Bashat D., 2010
Weizman L...Ben Bashat D., 2011
Weizman L...Ben Bashat D., 2014

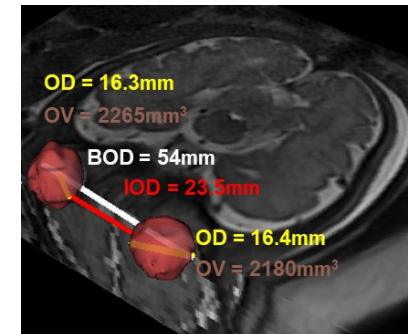
Fetal Brain and organs segmentation



Spector B, et al, 2021
Spector B...Ben Bashat D, 2022, Submitted
Ben Zvi O...Ben Bashat D, 2021 & Submitted

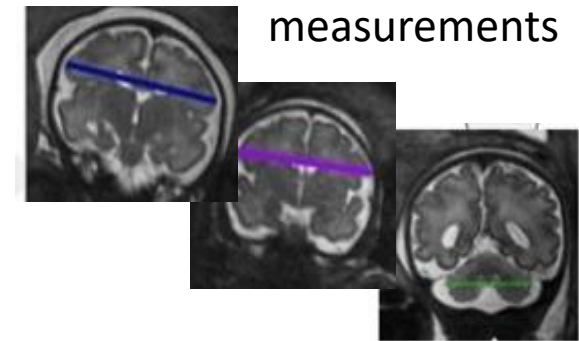
Automatic Linear Measurements

Ocular measurements



Avisdris, B. ... D. Ben Bashat... 2021
B. Spector-Fadida, .. Ben-Bashat,. 2021
N. Avisdris / D. Link-Sourani,... D. Ben-Bashat. ISMRM, 2021
Ben0Zvi O...D. Ben Bashat, ISMRM, 2021

Fetal Cerebrum - measurements



MRI: way beyond the image

FUTURE



- Easily implemented protocol
- Short acquisition time
- Imaging markers: repeatability, reproducibility, accuracy, sensitivity, specificity
- Diagnosis at the subject level (n=1)

-
- **Comprehensive assessment**
 - **Easy interpretation of the results – provide solution to unmet clinical need**
 - **Provides guidelines, solution, prediction....**

PRESENT

MRI: way beyond the image

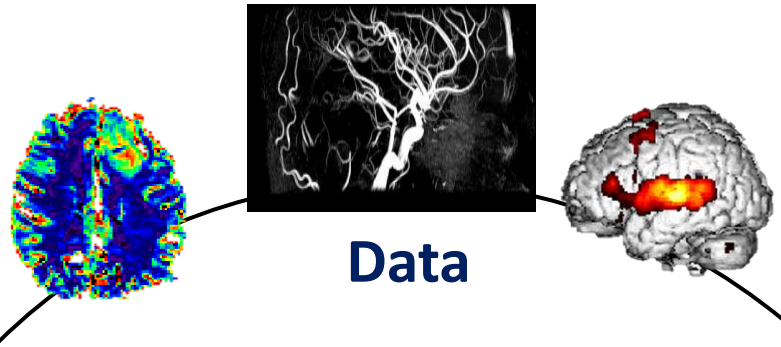
FUTURE

Multi-contrast MRI protocol

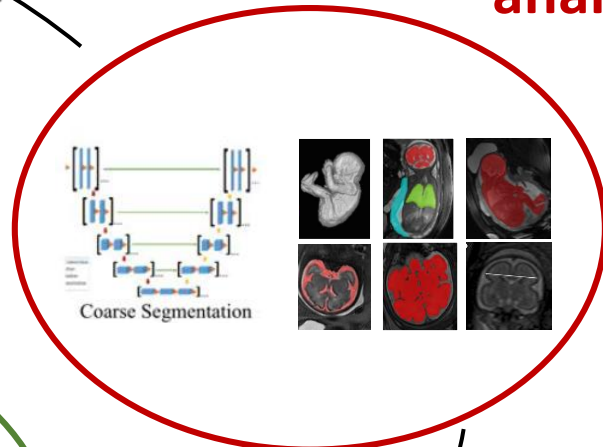


Fetus Brain

- localizer
- haste_localizer
- tra_12_tra
- cor_12_null
- hag_12_null
- tra_11_824
- cor_11_824
- tra_824_01w
- cor_824_01w
- tra_12_824_brhemo
- cor_12_824
- tra_12_824
- hag_12_824
- hag_12_824_3mm
- hag_12_824_3mm
- hag_12_824_3mm
- Cor_VOL_BODY_12_824_8M_2breathing
- Cor_VOL_BODY_12_824_8M_2breathing
- tra_824_30
- LMP_824_30_30
- Cor_12_haste_mother
- Cor_12_haste_placenta
- PLACENT_12_1026

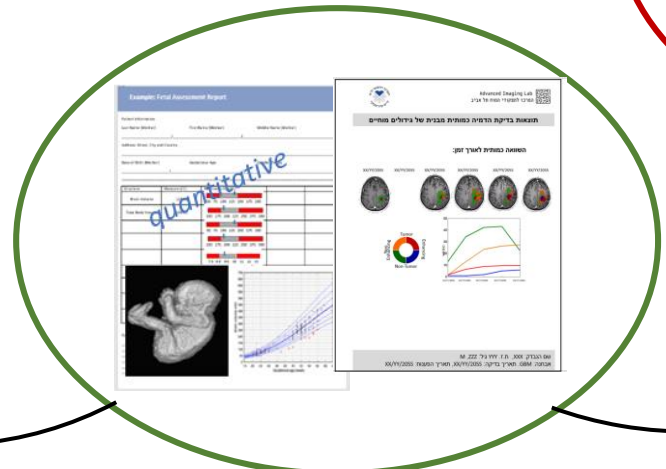


Signal & Image analysis



Coarse Segmentation

Clinicians approval
Quantitative report



quantitative

Automatic 3D quantitative measures using DL and AI methods

PRESENT

MRI: way beyond the image

FUTURE

Baseline Scan

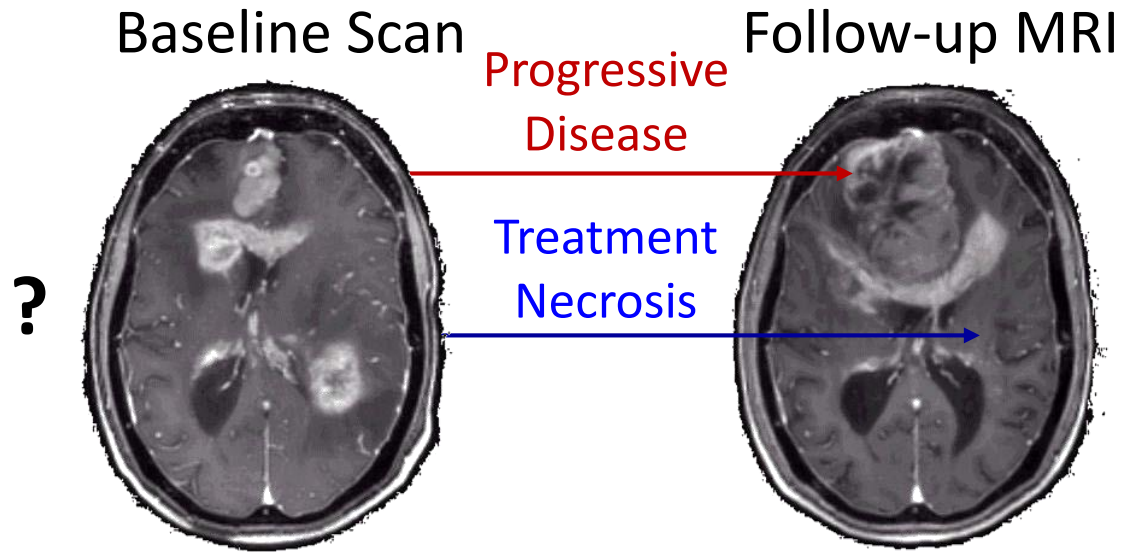


G. Liberman ... D Ben Bashat., Eur J Radiol. Feb, 2013; 82(2)
M. Artzi ... D Ben Bashat., Eur J Radiol, Jul, 2014; 83(7):1250-6;
M. Artzi ... D Ben Bashat., J. Neurooncol ,2016; 127(3):515–524;
M. Artzi ... D Ben Bashat., Magn Reson Imaging. 2016

PRESENT

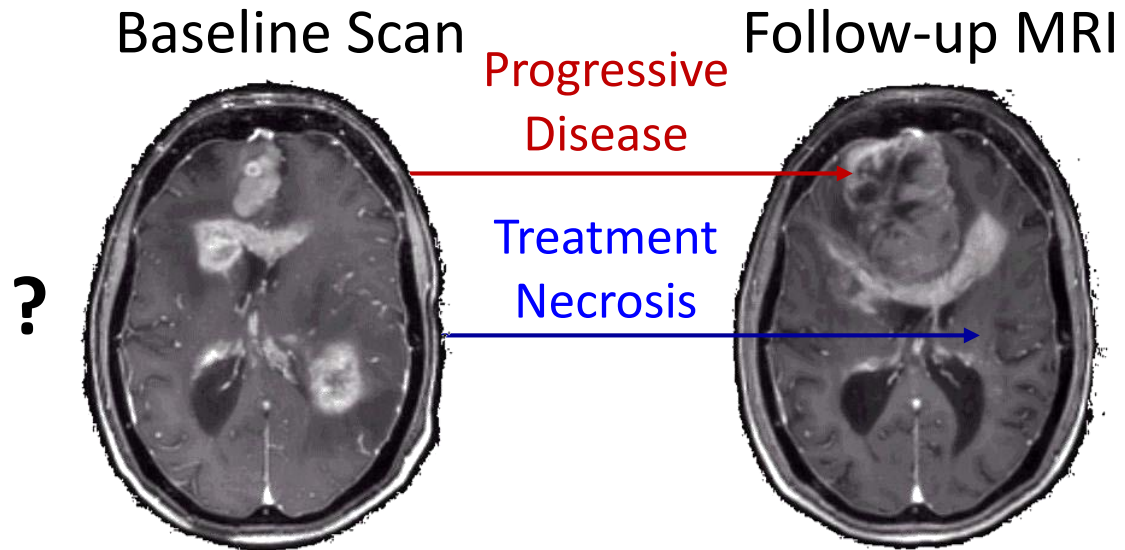
MRI: way beyond the image

FUTURE

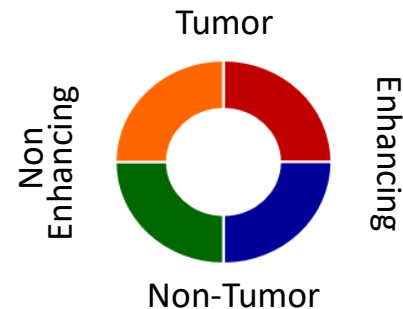
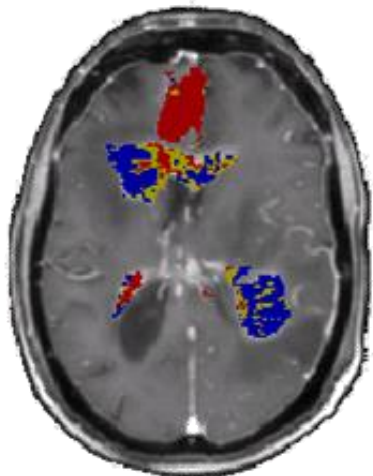


G. Liberman ... D Ben Bashat., Eur J Radiol. Feb, 2013; 82(2)
M. Artzi ... D Ben Bashat., Eur J Radiol, Jul, 2014; 83(7):1250-6;
M. Artzi ... D Ben Bashat., J. Neurooncol, 2016; 127(3):515-524;
M. Artzi ... D Ben Bashat., Magn Reson Imaging. 2016

MRI: way beyond the image



Classification results at baseline



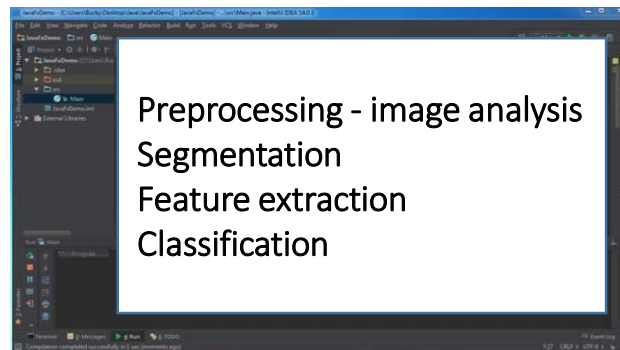
G. Liberman ... D Ben Bashat., Eur J Radiol. Feb, 2013; 82(2)
 M. Artzi ... D Ben Bashat., Eur J Radiol, Jul, 2014; 83(7):1250-6;
 M. Artzi ... D Ben Bashat., J. Neurooncol, 2016; 127(3):515-524;
 M. Artzi ... D Ben Bashat., Magn Reson Imaging. 2016

Mode of use - interpretation/report

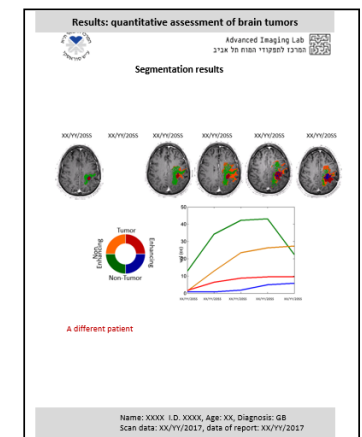
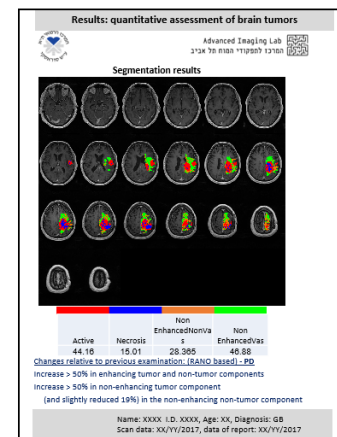
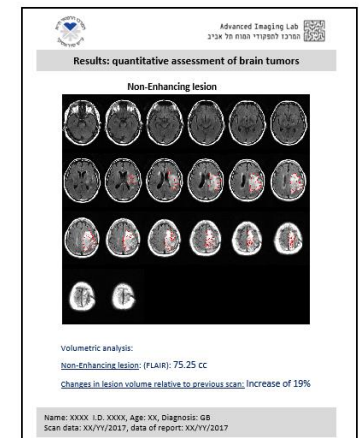
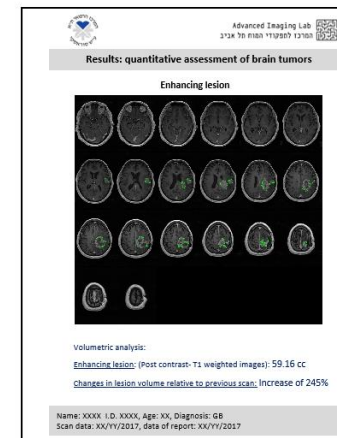
Custom MRI acquisition

20-Brain Tumors

```
AAHHead_Scout_64ch-head-coil
AAHHead_Scout
t1_t2d_sag
t1_mprage_tra_p2_iso
DCE_FA_20
DCE_FA_30
DCE_FA_15
DCE_FA_10
DCE_FA_5
DCE_FA_3
DCE_MAIN
tra_t2_tirm_dark-fluid
DCE_X_4_rep
tra_t2_isc_
tra_t2_sw3d_
DCE_X_4_rep
DTI_ep2d_diff_mddw_20_isov
ASL_3D_tra_iso
DCE_X_4_rep
ep2d_perfusion Inj Delay 15 sec
t1_mprage_tra_p2_iso
svs_se_30
svs_se_135
```



Quantitative report



Recently the Israeli Ministry of Health approved this scan

Adding genetic, clinical, history and behavioral information

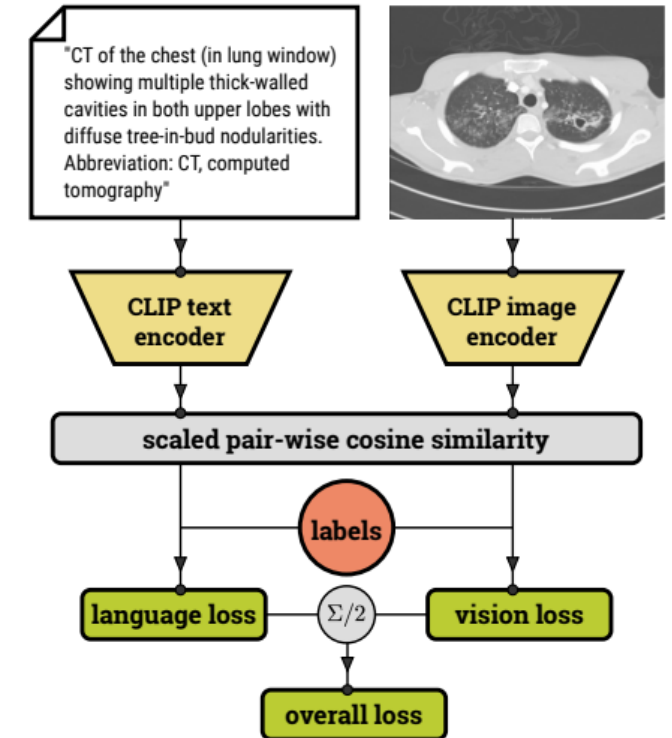
MRI – way beyond the image



Does CLIP Benefit Visual Question Answering in the Medical Domain as Much as it Does in the General Domain?

Sedigheh Eslami et al, 2021

CLIP (Contrastive Language-Image Pre-Training):
Connecting Text and Images



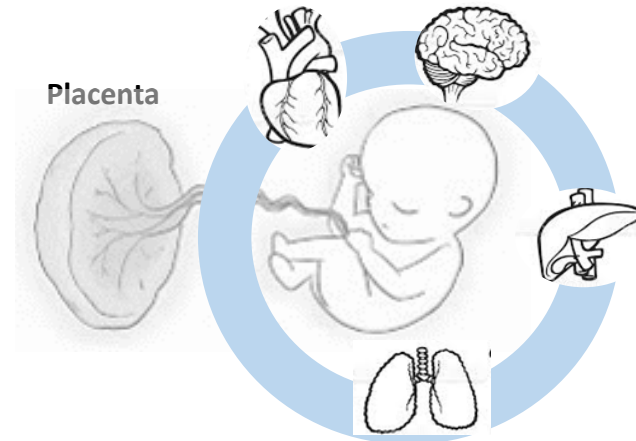
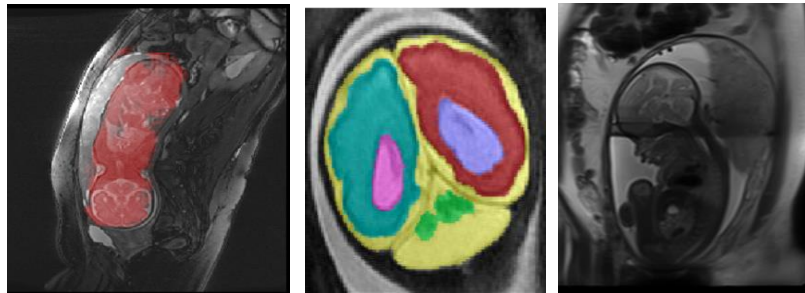
Imaging, Genetic, Clinical, History, Blood tests, Pathology, Behavior

MRI – way beyond the image



Advanced Fetal Imaging

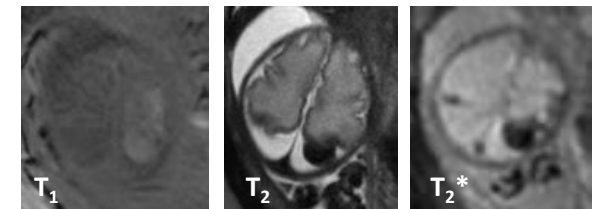
Volumetric assessment



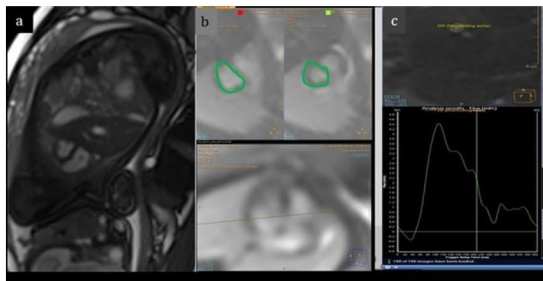
Fetal Brain Development



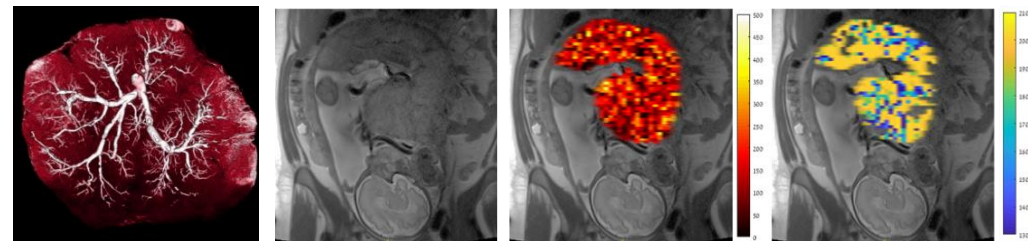
Extra axial hemorrhage



Fetal Cardia



Placental structure and function



T2

PBF

ATT

PRESENT

MRI: way beyond the image

FUTURE

Custom MRI acquisition

```

20-Brain Tumors
AAHead_Scout_64ch-head-coil
AAHead_Scout
t1_f12d_sag
t1_mprage_tra_p2_iso
DCE_FA_20
DCE_FA_30
DCE_FA_15
DCE_FA_10
DCE_FA_5
DCE_FA_3
DCE_MAIN
tra_i2_tirm_dark-fluid
DCE_X_4_rep
tra_i2_lse_
tra_i2_swi3d_
DCE_X_4_rep
DTI_ep2d_diff_mddw_20_isov
ASL_3D_tra_iso
DCE_X_4_rep
ep2d_perfusion Inj Delay 15 sec
t1_mprage_tra_p2_iso
svs_se_30
svs_se_135

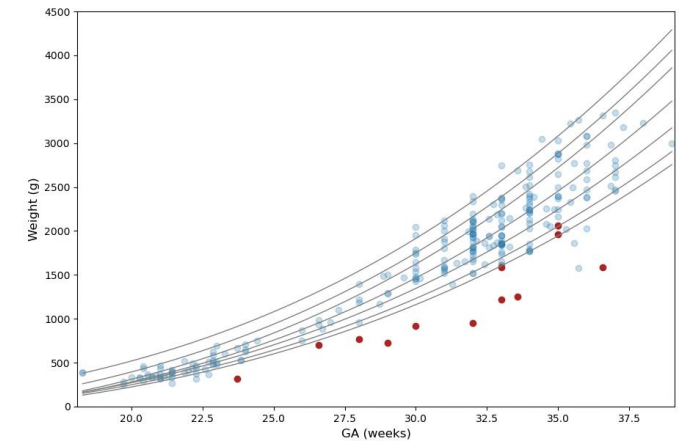
```



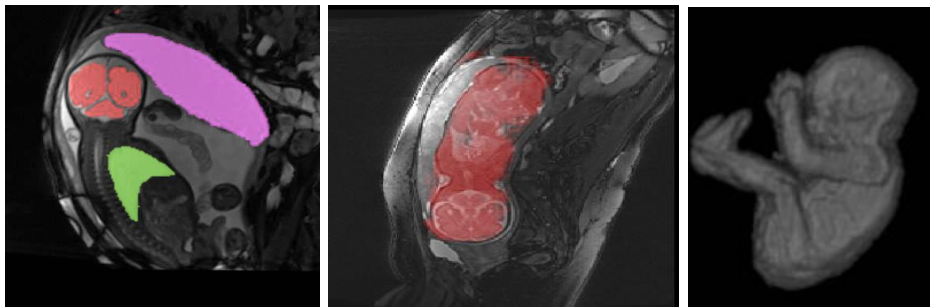
Preprocessing - image analysis
 Segmentation
 Feature extraction
 Classification



Quantitative results Multi-organs Multi-contrast



Spektor Fadida ... D Ben Bashat., Submitted



Imaging, Genetic, Clinical, History, Maternal information

MRI – way beyond the image



➤ Technology – Hardware

Magnets & Coils

High field magnet &
Portable low-field with
metamaterial



➤ Software- contrasts

Images/ reconstruction

High number of contrasts – short acquisition time

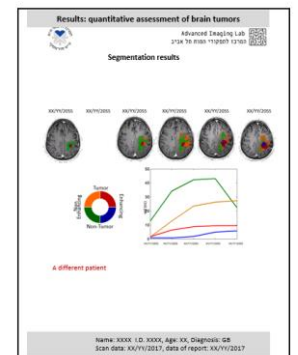
➤ Image analysis - Computer vision

Use of DL methods for image
reconstruction and analysis

➤ MRI – way beyond the Image

Full report for the physician

Way beyond the image





Thank You!

Dafna Ben Bashat., PhD



מכון סגול
לתפקודי המוח
תל-אביב



Sagol Brain
Institute
Tel-Aviv



dafnab@tlvmc.gov.il



