How using DCE-MRI and registration to measure the concentration of the contrast agent ([CA]) inside the human and guinea-pigs (GP) cochlea?

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- Physiology department mostly oriented to Audiology and Cochlear Physiology.
- University of Auckland
- Auckland, New Zealand
- I have been there for 7 months

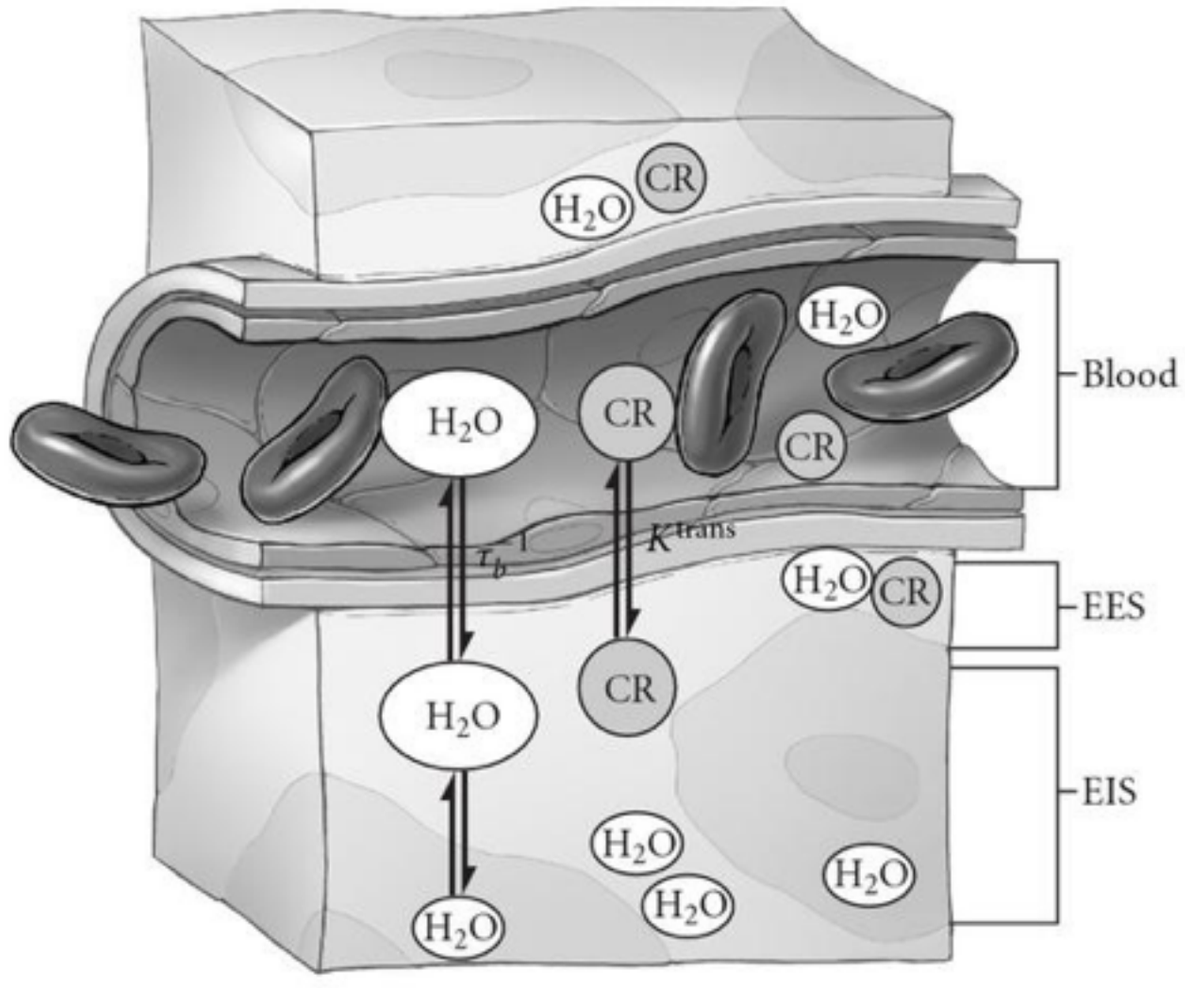
Table of contents

Context: Ménière desease

- Desease - syndroms:
  - Mostly old people,
  - Attacks of rotational vertigo, hydrops and hearing loss, …
  - Reasons are mostly unknown.
- UoA has contacts with hospital and patients with MD.
- Animal (Guinea Pigs, GP) with preliminary results.

Barrier and CA

- Our hypothesis:
    - The cochlea is filled with liquids. They have a very precise concentrations of ions (K, Ca, …). Ions are necessary to the neuronal activations.
    - **The Blood Labyrinth Barrier (BLB) leaks some molecules resulting hearing losses and vertigo.**
- Using MRI to validate the hypothesis.
- What is the amount of CA that goes cross the BLB

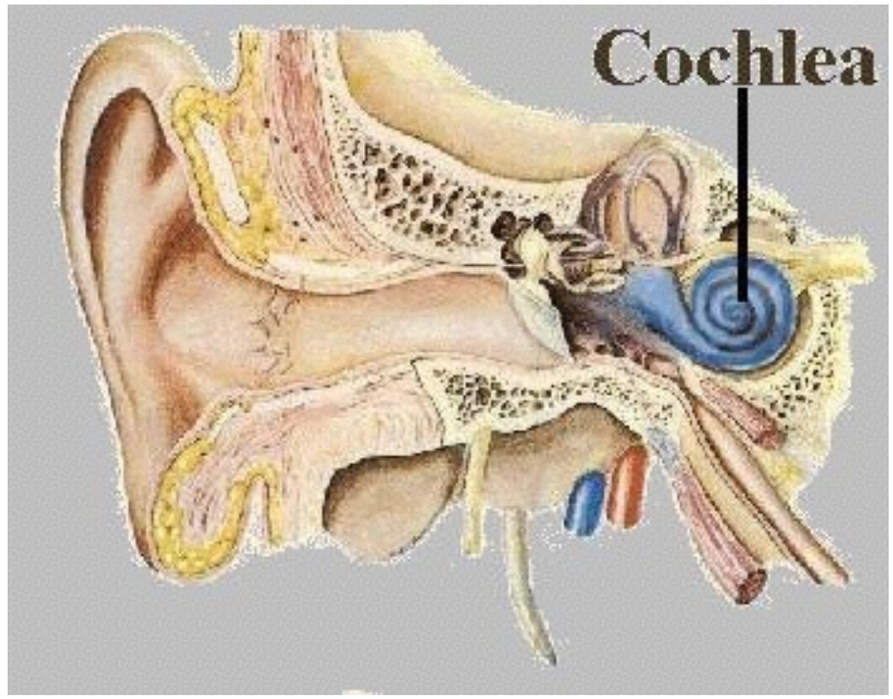


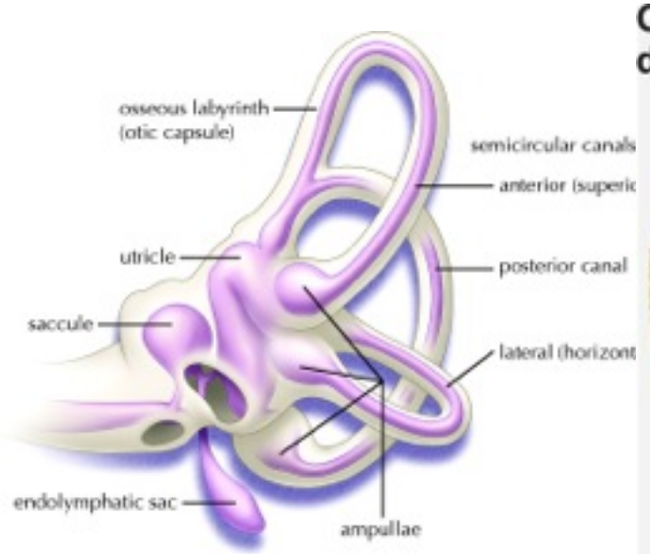
Context: protocol

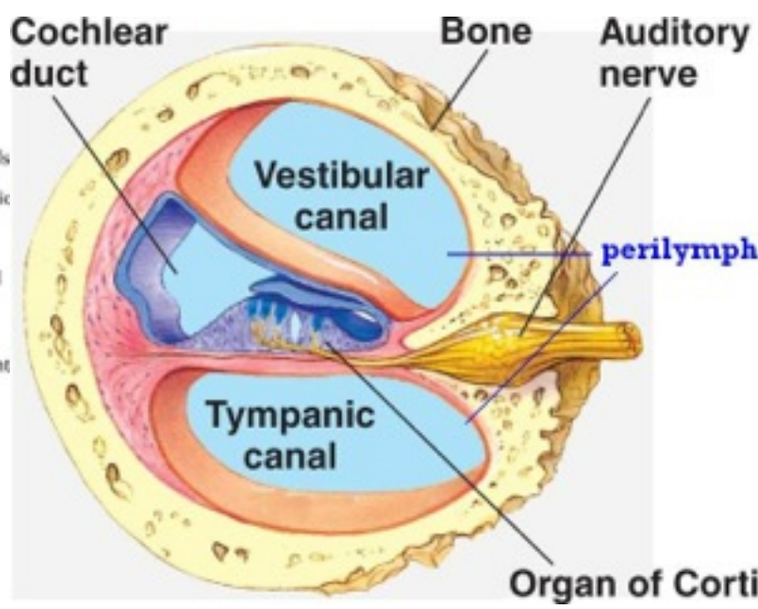
- Controls and subjects
- Contrast agent injection (Galdominium, Dotarem® 2 mol per ml)
- Using DCE-MRI: St/S0 and deduce [CA]
- Using mathematical and Fluid mechanic model: deduce the permeability (Ktrans) value of the BLB.

Context: Challenges

- BLB is very thigh
  - Few CA reaches the inner ear compartments
    - Weak signal with MRI
- dimensions
  - Approx 5 by 10 mm
  - several compartments (ST SL, …) inside the cochlea



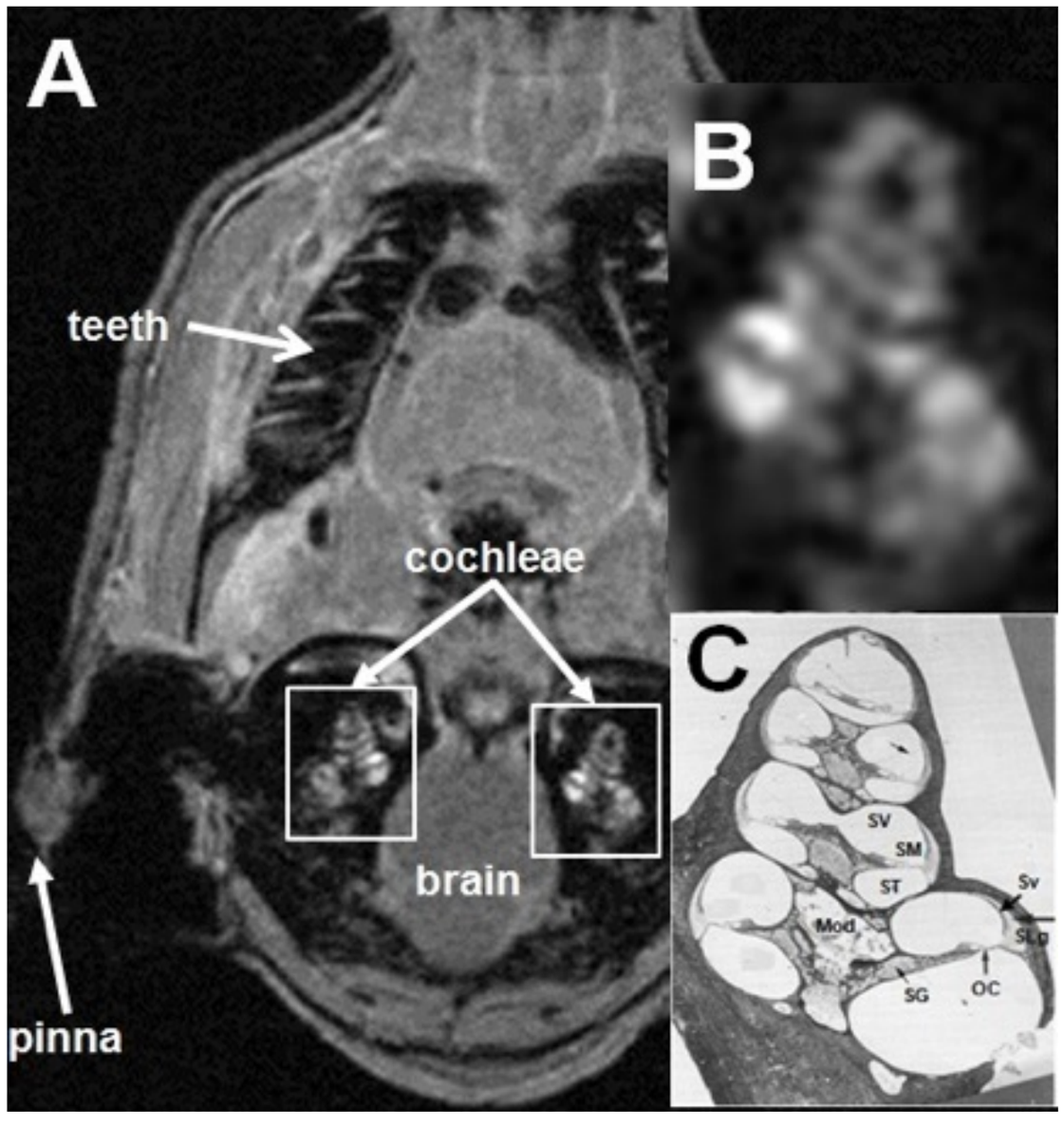




Context: Guinea Pigs (GP) Experiments

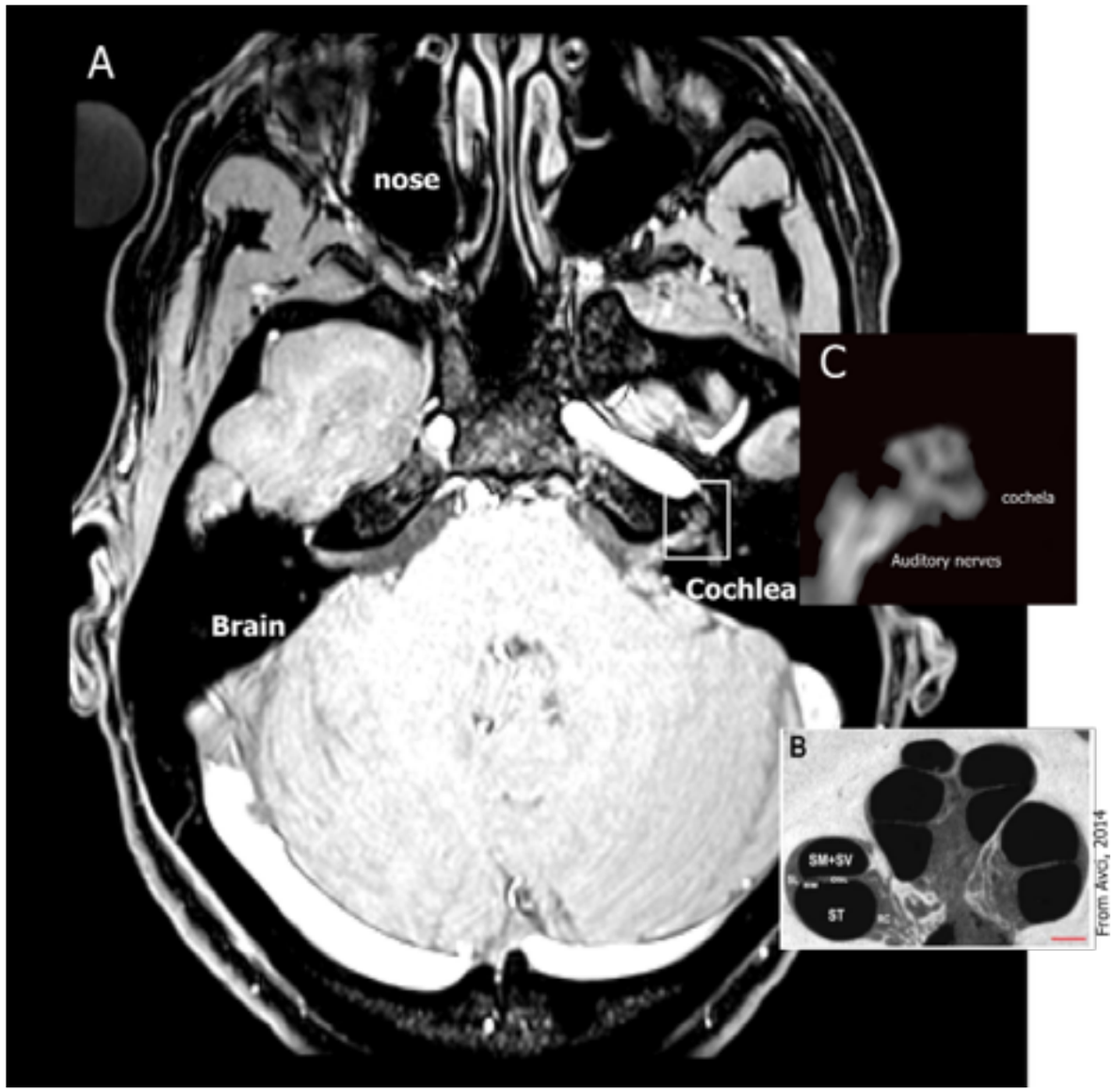
- Using a 4.7 T MRI scanner and a head coil

- 3D Gradient Recalled echo sequence: T1-w coronal, acquisition matrix=512*256*16 and FOV=80mm*50mm*12mm, TR=20ms, TE=4.5ms, FA=50°, single average, total acquisition time=81s



Context: Human experiments

- Using a 3T MRI scanner (Skyra Magnetom, Siemens)
- VIBE sequence, TR/ TE=20/3.7ms, spacing=[0.3,0.3,0.5] mm, matrix=512*512*44, FOV=1329mm*759mm*759mm acquisition time: approx. 9min



Context: conclusion

- How to use a 3.7T to export the GP model to human?
- How to measure the [CA] inside the cochlea?

MRI

- Objectives
  - Deduce the [CA] along the time
  - Deduce the permeability (Ktrans) of the BLB
- Global choices
  - Small [CA] -> should be a T2-w sequence (more sensitive).
  - Deducing Ktrans -> math. model required a T1-w sequence.

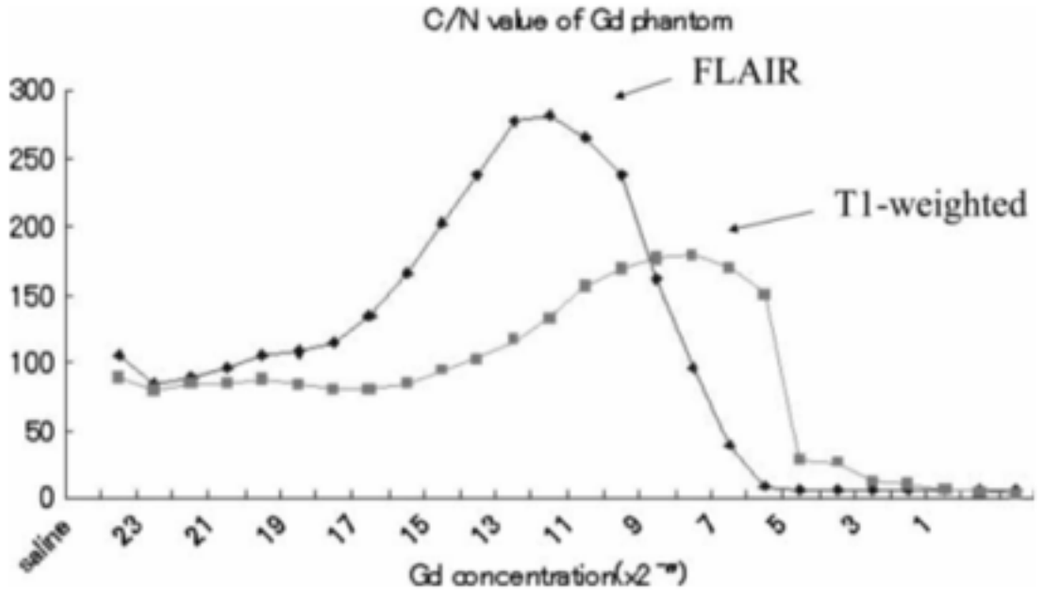


Figure 2. Sensitivity to low concentration of Gd-DTPA solution evaluated in a phantom study. The contrast-to-noise ratio by FLAIR and T1-weighted image are plotted against various diluted Gd-DTPA solution phantoms. FLAIR shows higher sensitivity to lower concentrations of Gd-DTPA solution than the T1-weighted image. However, the sensitivity of FLAIR to higher concentrations of Gd-DTPA is lower than for the T1-weighted image.

From *Cutting the edge of inner ear MRI*, Naganawa, 2009

DCE-MRI

- Usually in large organs (liver, brain, etc)
- Rapidly sequence the evolution of the contrast agent along the blood vessel and the EES to deduce the permeability of the vascular system.
- Mostly use to detect potential tumour.
- Usually T1-weighted sequences.

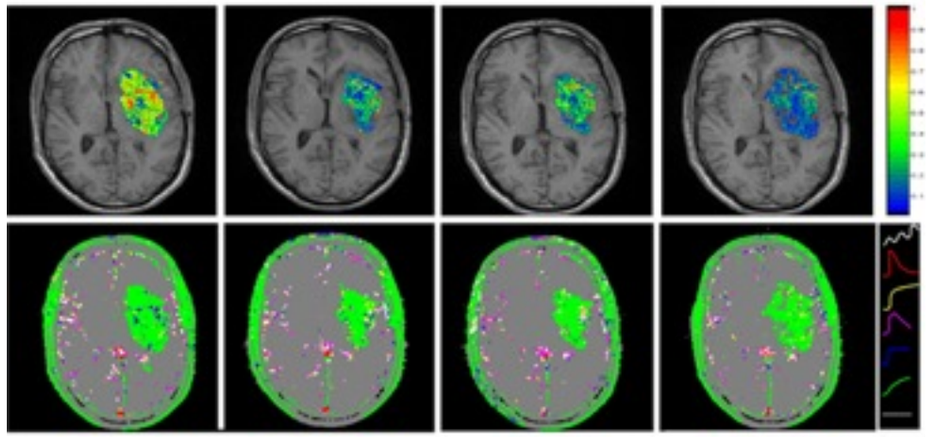
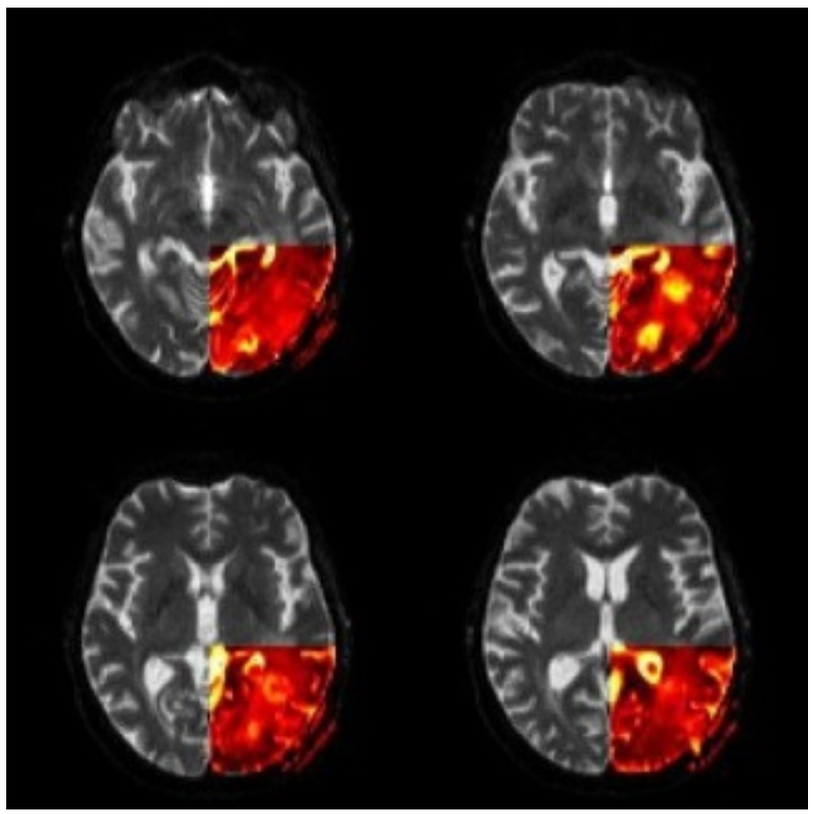


Figure 1: Comparison of a Ktrans map and a TIC Shape map in a patient with HGG treated with the antiangiogenic drugbevacizumab on day 0. (a=pre treatment scan)



MRI: GP experiments

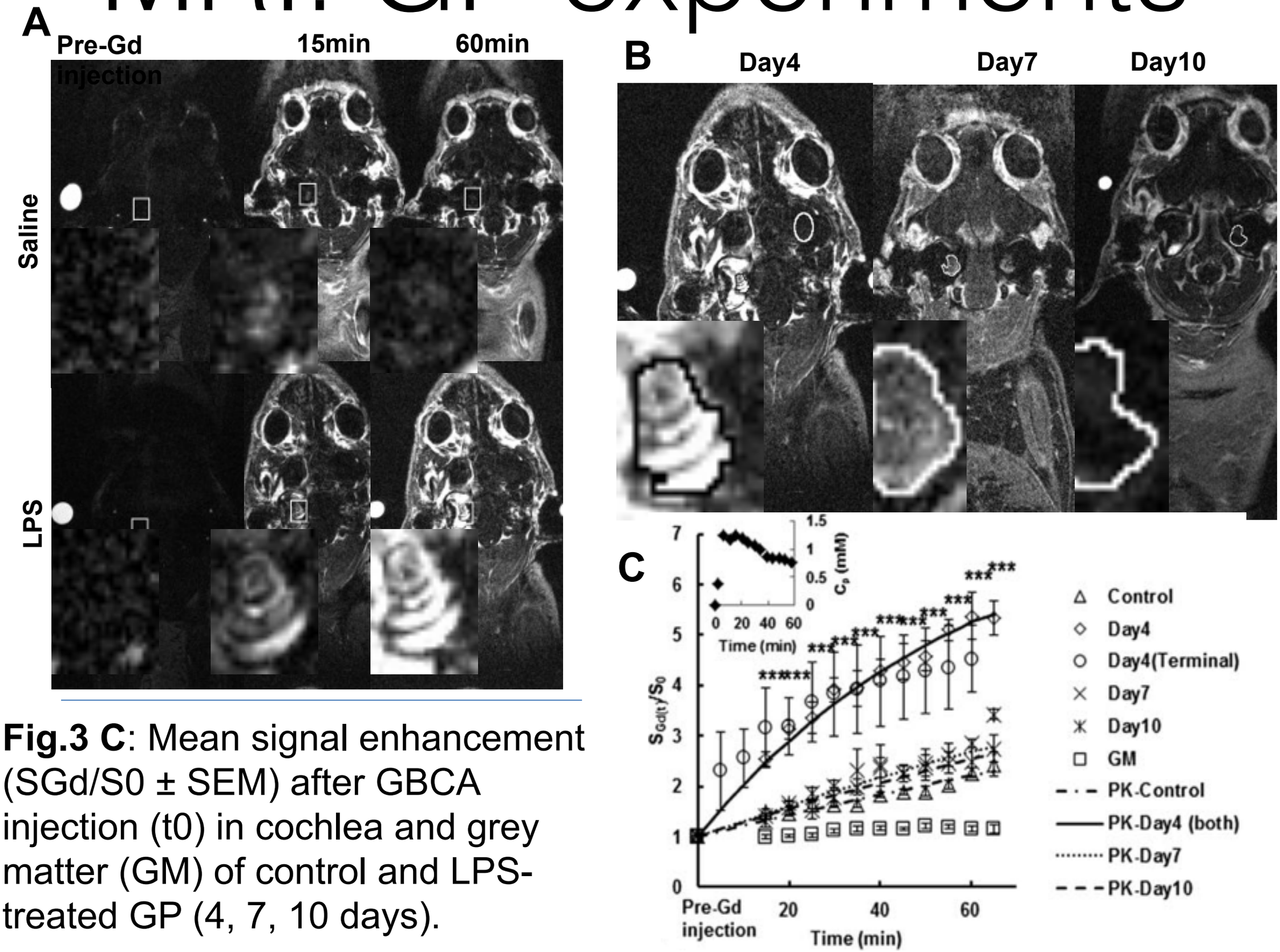


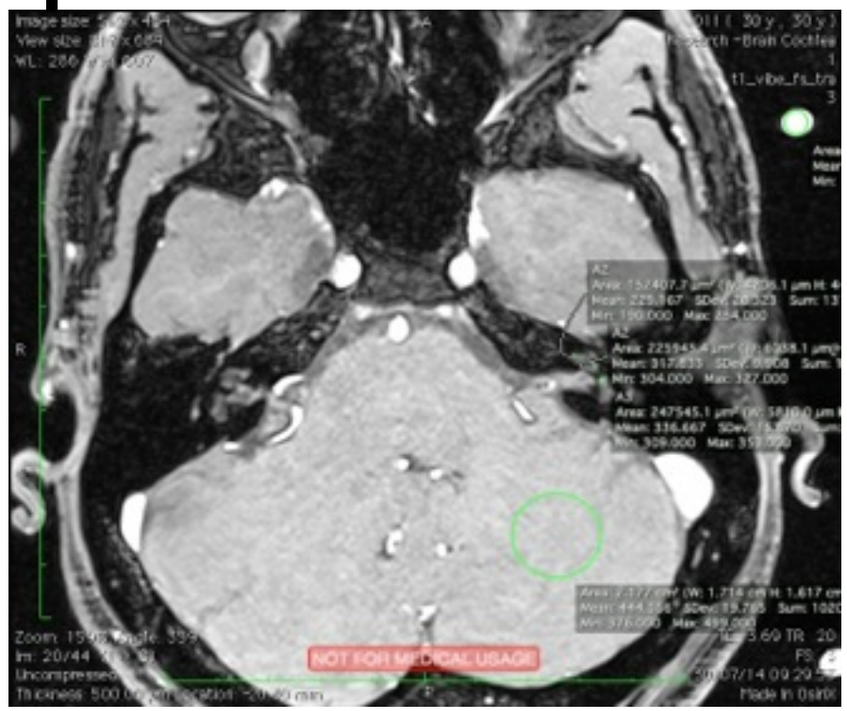
Fig.3 C: Mean signal enhancement (SGd/S0 ± SEM) after GBCA injection (t0) in cochlea and grey matter (GM) of control and LPS-treated GP (4, 7, 10 days).

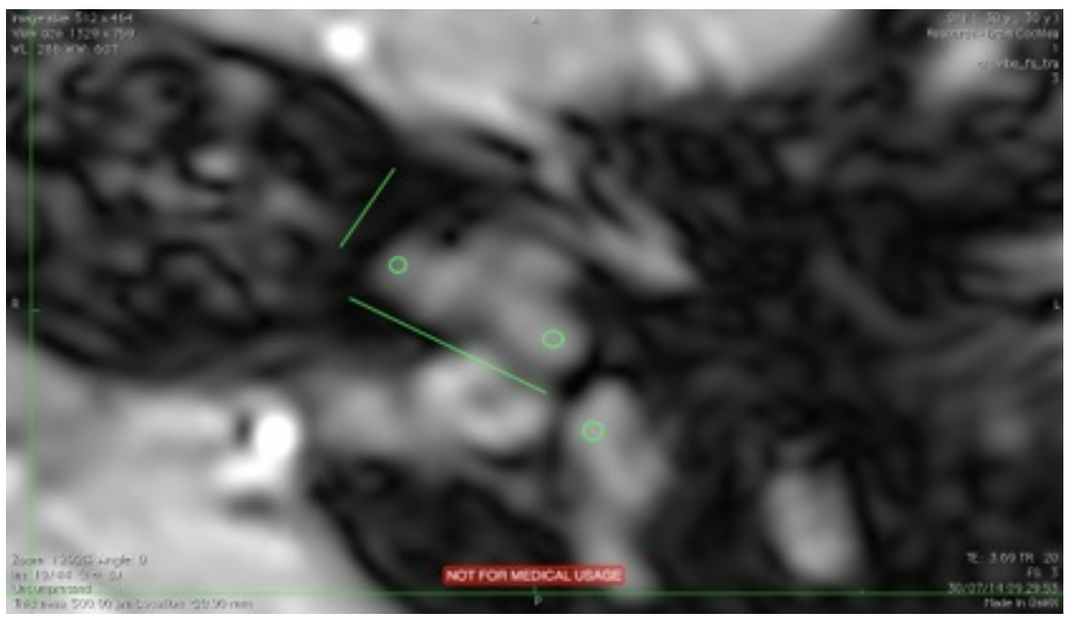
MRI: Human Experiments

- VIBE sequence TR/ TE=20/3.7ms

- Spacings are good compare to the sizes of the cochlea (0.3/0.3/0.5 mm)

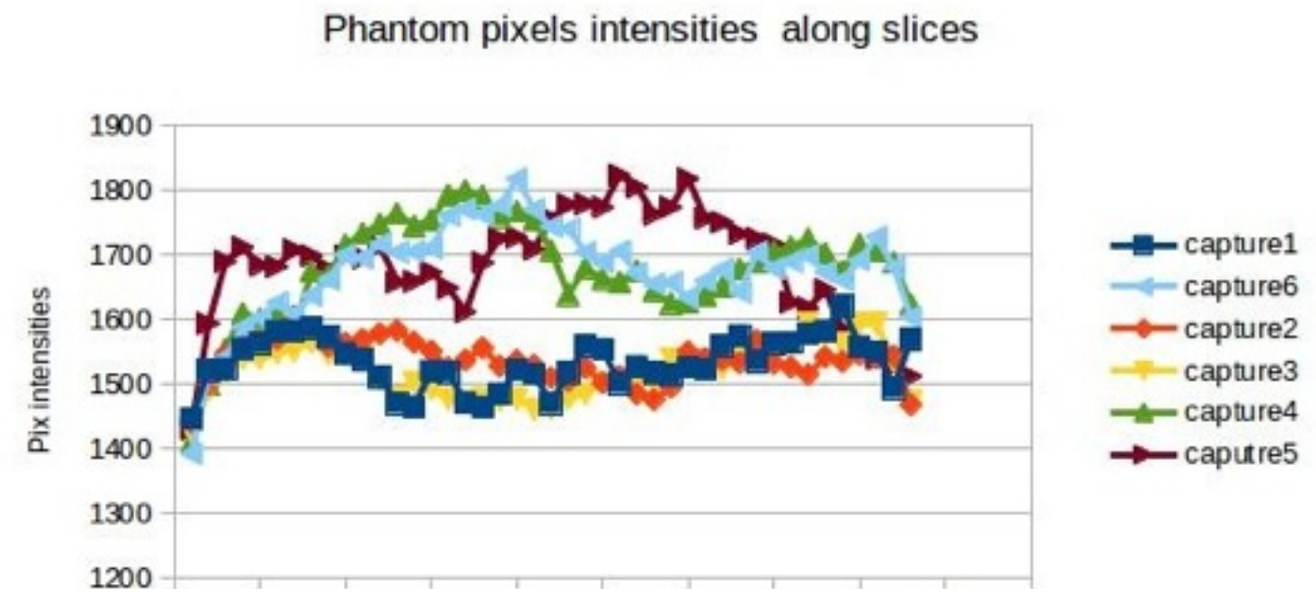
- Measurements of the highlighting inside cochleas.

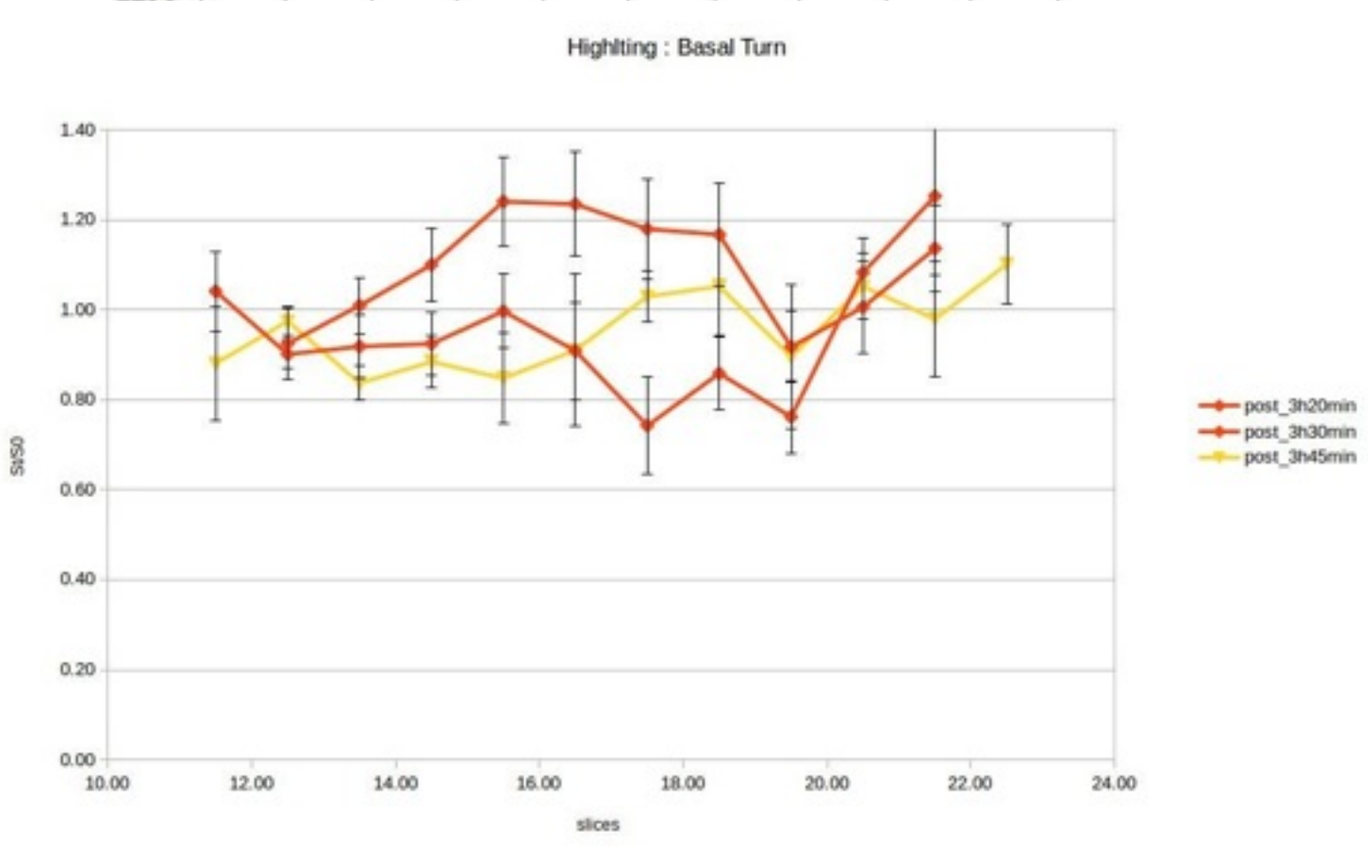




MRI: Human Experiments

- MRI noise
  - The same ROI has different values
  - between two acquisitions
  - between slices
  - critical since the enhancement is very small
  - Solution? Phantom





MRI: conclusion

- What sequence would
  - 1- have a sufficiently high spacing?
  - 2- be sufficiently sensitive to measure a small CA amount?
  - 3- be ideally a T1-weighted sequence?
- Still looking for THE sequence.

Registration

- Mostly performed with GP data.
- Goal: precisely measure the amount of CA inside the cochlea along the time.
- set together all the GP data inside coherent space.

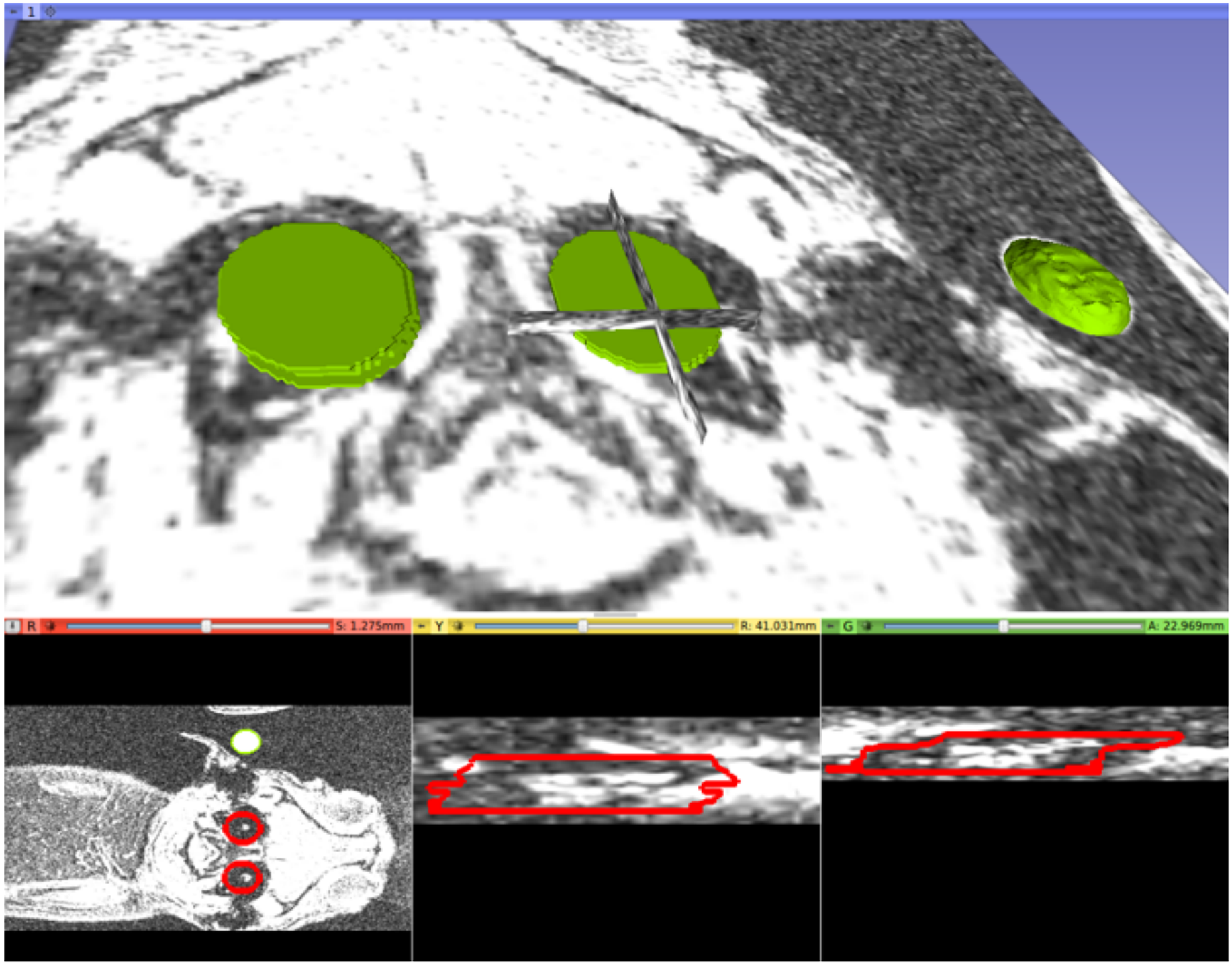
Acquisition protocol

- MRI acquisition before CA injection: PRE
- Remove the GP from the scan to inject CA
- A set of MRI acquisitions post injection (POST)
- GP slowly moves inside the scanner (brief head movements).

Reference volume and ROIs

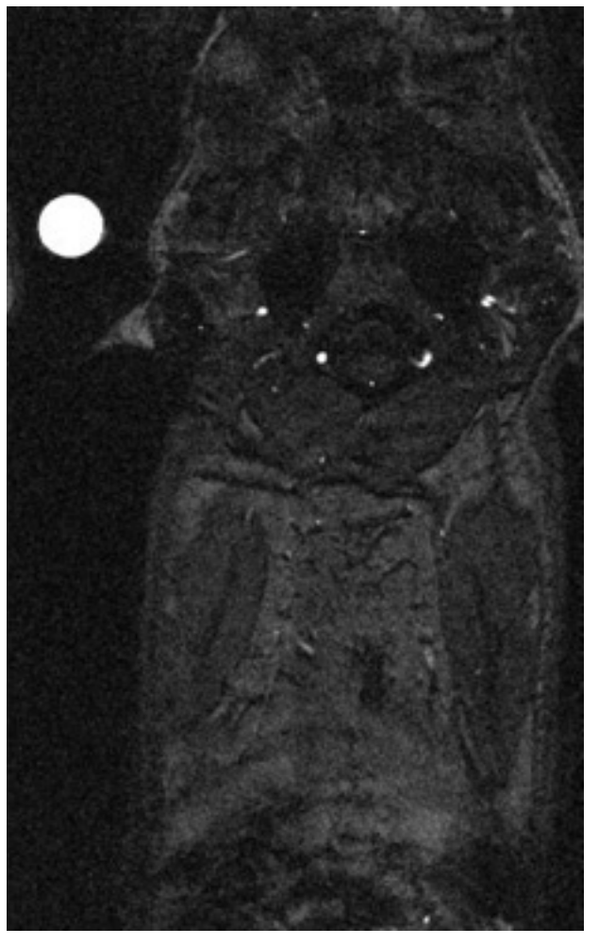
- What do we need?
  - Identification of the cochlea/inner ear in a reference volume (REF).
  - Well known signal (to overcome the small MRI variations along the capture): standard concentration of CA inside a tube.

Reference Volume and ROIs

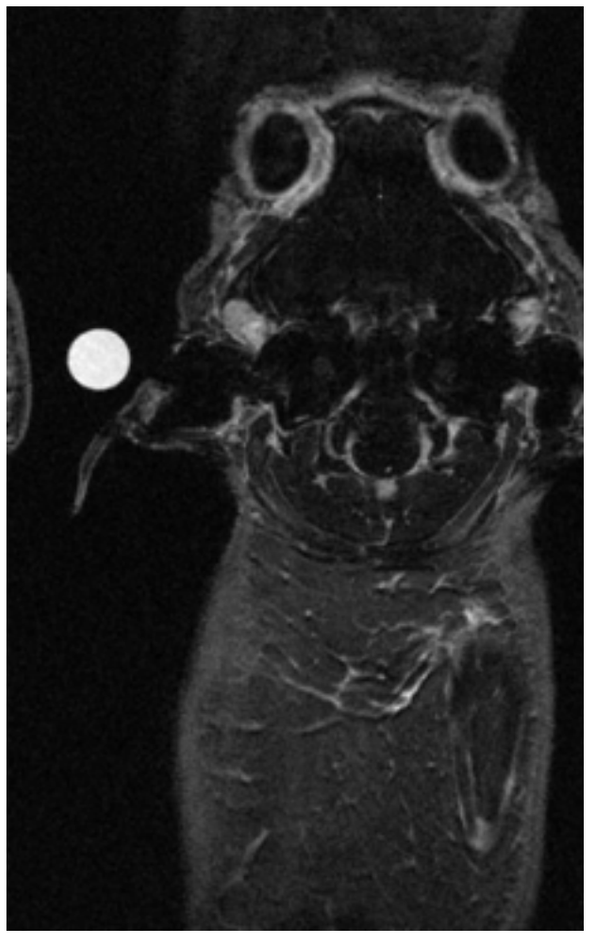


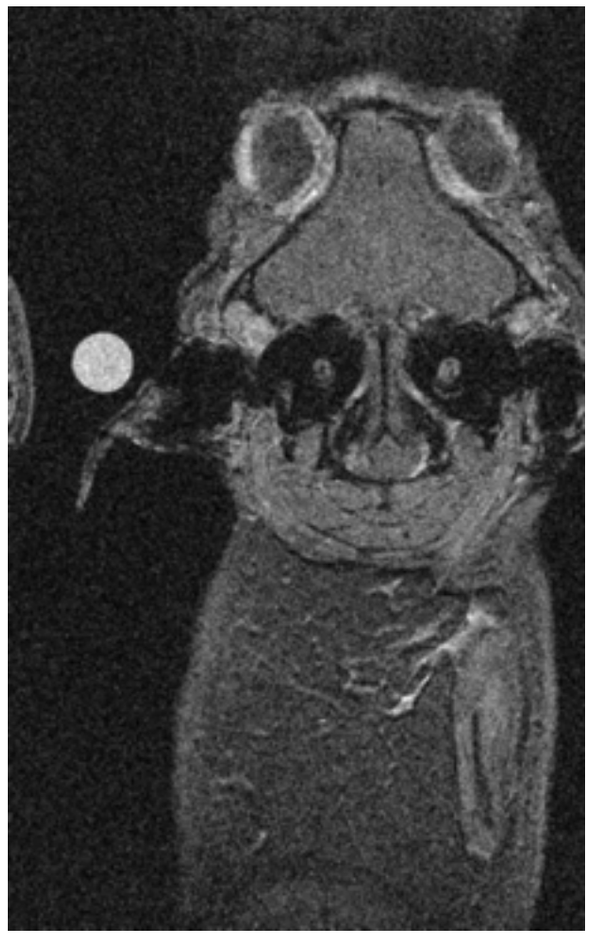
PRE and POST images

PRE



Some POST



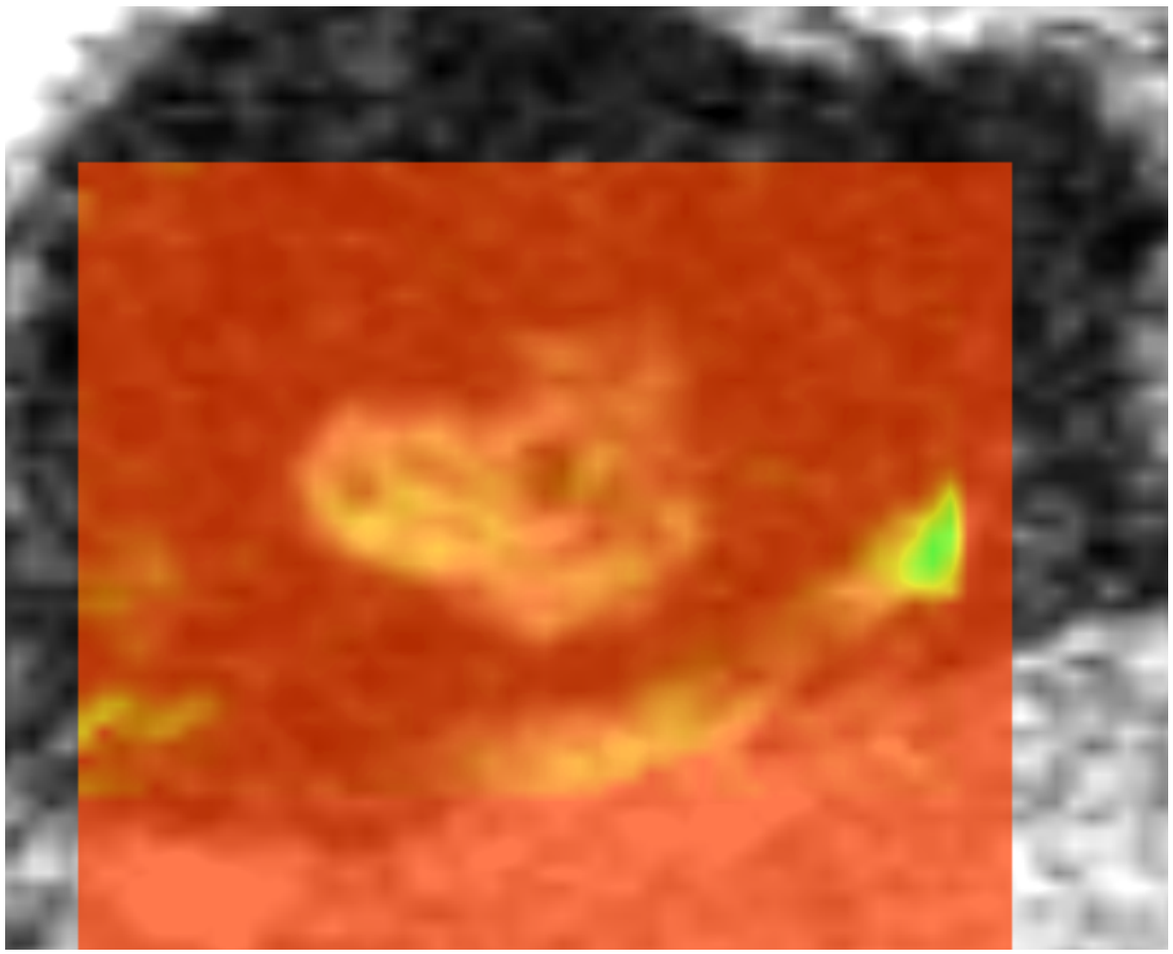


Registration

- Non rigid registration between REF and PRE
- Affine transform between REF and any POST
- GOALS: we obtain all images in the same physical space. A coordinate (mm) designates the same anatomical region in all GP (REF, PRE and POST). Allowing the get the pixel value and so the measurement.

Results

- See in 3D Slicer.



Conclusions

- Still a challenging task,
- Some encouraging results with human MRI,
- Beginning of results with GP and registration.

Thanks