Medical Image Analysis in Juvenile Idiopathic Arthritis

Curzio Basso, Matteo Santoro, Alessandro Verri
SlipGURU, DISI, Università di Genova

July 6, 2010

The Starting Point

What was known for **adult** RA four years ago:

- ▶ Advantages of MRI vs radiography: 3D, imaging of soft tissues, earlier detection of erosions.

- ▶ MRI-based **semi-quantitative** scoring system (OMERACT RAMRIS, 1999-2003).

- ▶ **Synovial volume** and **DCE**-MRI could be used to assess quantitatively the synovitis (**no automatic method**).

- ▶ Few works on quantitative assessment of erosions, cartilage thinning and cartilage ultramolecular damage.

(R.J.Hodgson et al. 2008, Rheumatology 47:13–21)

There was **no reported work** on JIA patients.

Imaging Biomarkers

At the same time, the use of imaging biomarkers for the quantitative assessment of therapies had gained momentum.

Biomarkers Definitions Working Group, Clin Pharmacol Ther, 2001

A **biomarker** is a "*characteristic that is* **objectively measured** *and evaluated as an* **indicator** *of normal biological processes, pathogenic processes, or pharmacologic responses to a therapeutic intervention*"

Imaging biomarkers are measured *in-vivo* from images.
Example: tumor size in oncology (RECIST and WHO criteria).

Health-*e*-Child

Our Goals
WP11 - T11.3

Provide clinicians with the tools for a **quantitative assessment** of JIA, possibly through the definition of imaging biomarkers.

Development of new methods and software for MRI analysis, aimed at:

1. Quantitative assessment of synovitis, through
   - automatic measurement of synovial volume
   - analysis of DCE-MRI
2. Accurate analysis of bone erosion progression
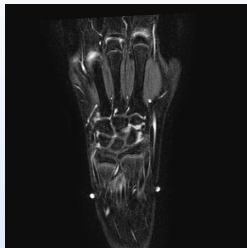
Integration...

Materials

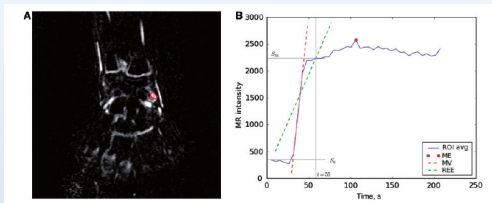Subset of the MRI protocol

3D T1w · 3D T1w post-contrast

DCE-MRI (three points in time)

Assessment of Synovitis
Analysis of DCE-MRI

Dynamic Contrast-Enhanced (DCE) MRI is one way to assess synovitis by studying the perfusion of Gd-DOTA in the synovia.

Study with initial 3D protocol (now working on 2D)

▶ C. Malattia et al. Dynamic contrast-enhanced magnetic resonance imaging in the assessment of disease activity in patients with juvenile idiopathic arthritis. *Rheumatology 2010, 49:178–185.*

Assessment of Synovitis
Volume Estimation from 3D MRI

We developed a new method for the estimation of the inflamed synovia volume (SV), achieving excellent agreement with manual measurements, **ICC=0.95** (95% CI: 0.85; 0.98).

Positive preliminary evaluation of the **SV normalized by body surface area** as a biomarker for JIA.

- ▶ C. Basso, M. Santoro, C. Malattia, M.B. Damasio, G. Chiusano, P. Tomà, A. Martini and A. Verri. Quantitative Synovitis Assessment via Automatic 3D MRI Annotation. *Submitted to IEEE Trans Med Imag*

- ▶ C. Basso, M. Santoro, M. B. Damasio, C. Malattia, A. Verri, P. Tomà, and A. Martini. Automatic estimation of inflamed synovial membrane volume in 3D MR images. *Poster at ECR 2010 Scientific Exhibit.*

Assessment of Synovitis
Voxel Classification

The volume estimation relies on a new algorithm for voxel classification.

The new algorithm

1. is **40x faster than SVM** with little accuracy loss
2. nicely handles heterogeneous data, necessary for exploiting multi-modal data

- C. Basso, M. Ferrante, M. Santoro, and A. Verri. Automatic Annotation of 3D Multi-Modal MR Images on a Desktop Grid. *MICCAI-Grid Workshop, held at MICCAI 2009, 20-24 September 2009, London, UK.*

- C. Basso, M. Santoro, A. Verri and M. Esposito. Segmentation of Inflamed Synovia in Multi-Modal MRI. *In Proc. of IEEE ISBI 2009, June 28 - July 1 2009.*

Assessment of Synovitis
Examples (1/2)
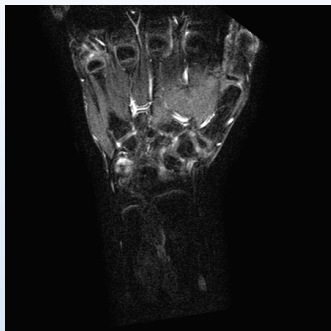
Assessment of Synovitis
Examples (1/2)

Slice Volume = 0.23cc
Total Volume = 6.12cc

Slice Volume = 0.24cc
Total Volume = 6.12cc

Assessment of Synovitis
Examples (2/2)

Assessment of Synovitis

Examples (2/2)

Slice Volume = 0.12cc
Total Volume = 3.70cc

Slice Volume = 0.16cc
Total Volume = 3.70cc

Assessment of Erosion Progression

We focused on the real clinical need: a precise assessment of the
progression, rather than (questionable) measurements at one
point in time.

- ▶ progression is assessed by comparing baseline and follow-up
  3D T1-weighted MR studies
- ▶ the comparison is enabled by the non-rigid registration of the
  two images (using mutual information)
- ▶ differently from conventional methods, the images are not
  deformed: the deformation field is used as mapping (see
  demo)

Assessment of Erosion Progression
Example of registration result

Baseline 3D study

Follow-up 3D study ($+1$ year)

Assessment of Erosion Progression
Example of registration result

Registered follow-up

Follow-up 3D study (+1 year)

Outline of the demo

- some short description to help the audience
- ...