Identifying, Segmenting and Analyzing PWMLs

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Introduction

Punctate White Matter Lesions (PWMLs):

- Small mild brain injury
- Detetected 30-45 weeks after conception
- Found in *Periventricular*, Frontal and Partial lobe *White Matter*
- Possible causes: *Inflammation, Hypoxia-ischemia and Hemodynamic instability*[1]

- Clinical impact:
  - Possible subtle cognitive or motor delays[1]
  - Majority are clinically negligible[1]
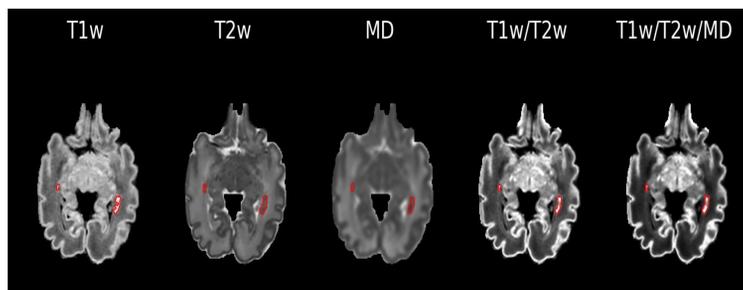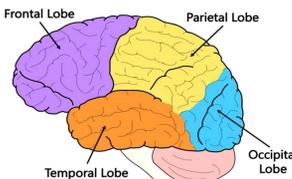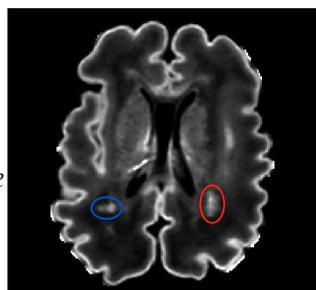
### How to Detect PWMLs?

MRI & PWML:
- T1w: golden standard for detecting PWMLs
- Permits: Localizing PWMLs, rating their severity and reviewing their evolution
- Different MR image types highlight different tissues and structures. Fused modalities may help modify contrast
- Main image types: **T1w, T2w, MD, T1w/T2w** and **T1w/T2w/MD**

Hypothesis

T1w and T1w-based images provide clearer lesion visibility and provide more consistent PWML identification than other MRI modalities
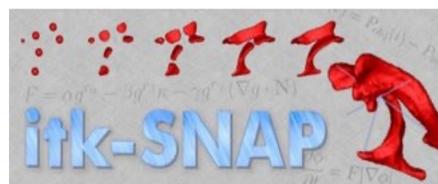
- **Reasoning:**
  - T1w images are more hyperintense[2]
  - Fused images boost contrast[2]
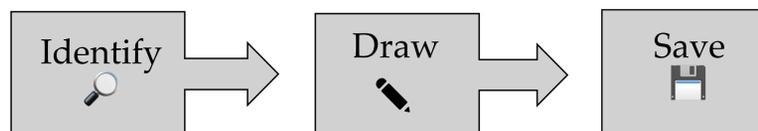 - MD and T2w are often less sharp[2]
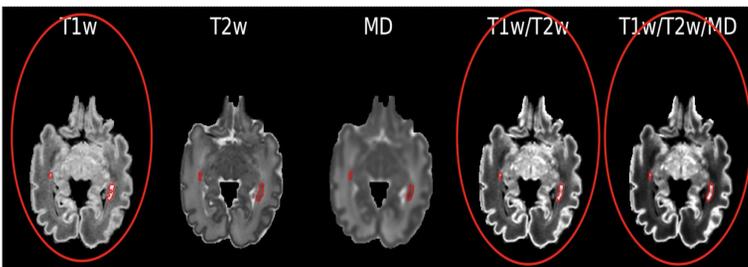
Methods

Labeling Lesions:

- Software used: ITK-SNAP
- Manual labeling (segmenting) of PWMLs

- ITK-SNAP: software that loads MRI files, lets users mark lesions by drawing over them, and saves the results with the annotated regions.

- Process:

Identify 🔍 → Draw ✏️ → Save 💾

Our Data:

- 5 Modalities (Previously mentioned)
- 100-1069 Slices labelled per modality
- 4 Raters

Cohen's Kappa:

- allows us to measure the agreement rate of segmentations between 2 raters
- determine each modality's consistency.

$$\kappa = \frac{p_0 - p_e}{1 - p_e}$$

*p_0 = observed agreement*
p_e = agreement by chance

κ	Level of agreement
0-0.20	Poor
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Good
0.81-1.00	Perfect

Summary of Methods:

- 4 raters segment PWMLS across 5 datasets
- 6 coefficients from adapted *Cohen's Kappa*
- Average the coefficients to measure and analyze inter agreement for each modality
- Agreement allow to evaluate consistency and effectiveness of the different imaging modalities

Results

Bar Graph of Kappa Coefficients
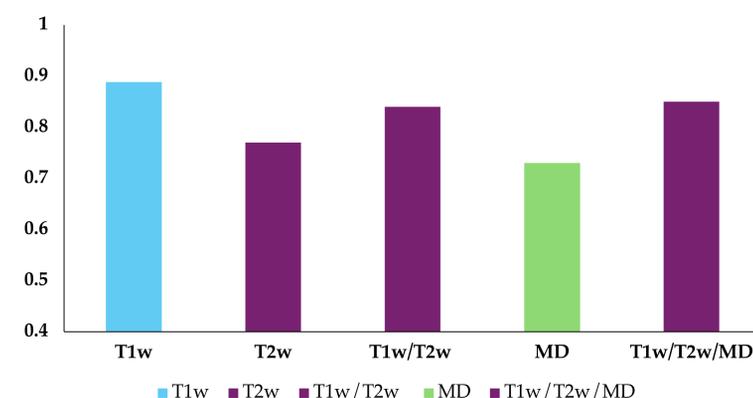
Average Kappa Agreement for each Modalities with their Level of Agreement

	T1W	T2W	T1W/T2W	MD	T1w/T2w/MD
Kappa Coefficient	0.88	0.77	0.84	0.73	0.85
Level of Agreement	Perfect	Good	Perfect	Good	Perfect

- **Highest agreement overall → T1w**
- **Lowest agreement overall → MD**
  - Suggests less clarity and reliability
- T1 and T1-based images may be most suitable since they have perfect level of agreement

Conclusion

- T1w and T1w-based images = clearer and more consistent for labelling PWMLs
- Hypothesis supported, but data still inconclusive
- **Limitations:**
  - Lesion segmenting = subjective
  - Number of slices for all modalities
  - Skewed kappa coefficient for T1w
- **Future Direction:**
  - Expand number of raters and dataset
  - Test new modalities or fusions

Acknowledgments

References

[1] Malova, et al. (2025). *Nosological differences in the nature of PWMLs in preterm infants*. Frontiers.
[2] Niwa, et al. (2011). *PWMLs in infants: New insights using susceptibility-weighted imaging*. Neuroradiology.
[3] The dHCP: *The Developing Human Connectome Project*