Tailored Magnetic Resonance Fingerprinting

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Introduction

- Qualitative and quantitative imaging are necessary for neuroimaging of specific pathologies
- Although the importance of quantitative MRI is acknowledged, its long acquisition times cause discomfort to patients
- We designed, simulated, and demonstrated rapid, simultaneous, multi-contrast non-synthetic qualitative (T_1w, T_1FLAIR and T_2w) images and quantitative (T_1 and T_2) maps through the approach of tailored MR fingerprinting (TMRF) in ~6 minutes

Methods

- We have demonstrated TMRF in three steps:
  - We imaged the ISMRM/NIST phantom and four healthy human volunteers with the GS, MRF, and TMRF sequences on a 3T GE Premier system
  - We have performed a repeatability study where we acquired thirty datasets of ISMRM/NIST phantom and ten healthy volunteers. These volunteers were imaged five times with two runs per repetition. This resulted in a total of one hundred datasets
  - We imaged five pediatric patients with brain tumors (resected/residual) using TMRF

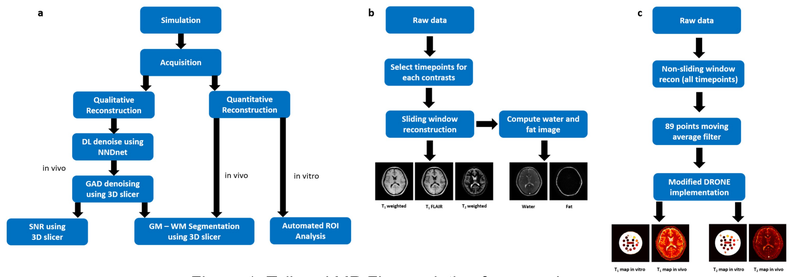


Figure 1: Tailored MR Fingerprinting framework.

- The acquisition parameters were: FOV=25 cm, matrix size=225x225, TR_{min}=14.7 ms, and TE=1.9 ms
- We acquired twenty slices with a slice thickness of 5 mm for full brain coverage
- For all the five contrasts, the acquisition and the reconstruction time for TMRF were ~5:26 (min: sec) and ~3 minutes (for each run), respectively
- Acquired in vivo images were denoised using a "native noise denoising network" (NNDnet)[1]

Results

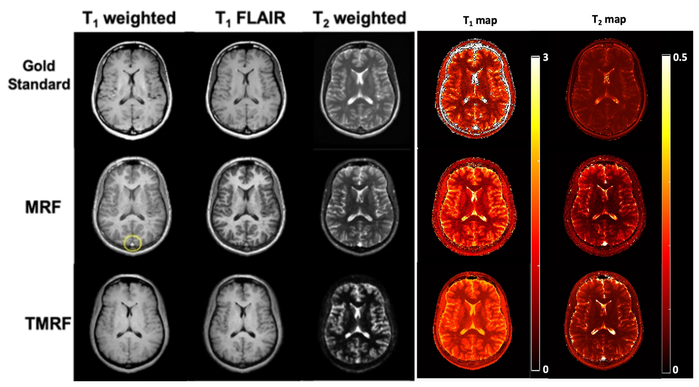
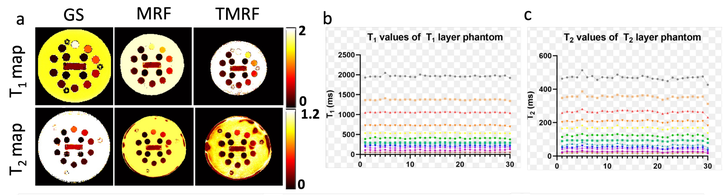


Figure 2: qualitative images and quantitative maps obtained using gold standard, MRF and TMRF.

- Figure 2 shows the qualitative healthy brain images obtained using the gold standard method, MRF and TMRF
- Images obtained using the MRF method were synthetically generated and have flow artifacts as shown in the yellow circle
- Quantitative maps of healthy human brains were obtained for GS, MRF and TMRF
- Figure 3 shows the T_1 and T_2 estimates of TMRF for 30 datasets which were acquired over 30 days
- All healthy volunteer and pediatric scans were performed on 3T GE Premier and 3T GE 750w scanners respectively



d

SNR	T_1 w	T_1 FLAIR	T_2 w
WM	0.643	0.793	0.528
GM	0.763	0.654	0.665

e

Mean signal intensity	T_1 w	T_1 FLAIR	T_2 w
WM	0.97	0.976	0.851
GM	0.935	0.946	0.943

f

Relaxation time	T_1 map	T_2 map
WM	0.92	0.949
GM	0.94	0.908

Figure 3: (a) T_1 and T_2 maps for GS, MRF and TMRF. (b,c) T_1 and T_2 values of the phantom over 30 days.

- The ICC values (figure 3 (d-f)) for relaxation times and mean signal intensity (except T_2 WM - good) showed excellent reliability (>0.9), while SNR repeatability values ranged from moderate to good
- A summary of five pediatric patients with brain tumors, including tumor type, age, gender, tumor grade, tumor location, slice number, and treatment history are included in Table 1
- All patients were between 8 and 18 years old and underwent routine MR scans
- TMRF was included as an add-on sequence after obtaining consent from the patient's parents/guardians
- Out of five patients, one had a residual tumor, two had post-operative changes after the tumor was resected completely, and the tumor was removed entirely from the remaining two patients who did not have postoperative changes

Patient number	Tumor type	Age (years)	Gender	Tumor grade (WHO)	Tumor Location	Slice number	Description
1	BRAFV600E (+) Glioblastoma	10	M	IV	left temporal lobe	9	Tumor has been resected through surgery, received radiation therapy and chemotherapy. There are post operative changes
2	Ependymoma	11	M	II	Intra ventricular	8	Tumor has been resected and currently under observation. Underwent targeted therapy
3	Pilocytic astrocytoma	17	M	I	Cerebellar	17	Tumor has been resected completely
4	SHH - Medulloblastoma	17	M	IV	Cerebellar	9	Tumor has been resected completely, received radiation therapy and chemotherapy. There are post operative changes
5	Pilocytic astrocytoma	10	M	I	Hypothalamic	9	Presence of residual tumor

Table 1: Patient details.

- Qualitative images of five representative pediatric patients were obtained from GS T_2-weighted sequence (first row) and TMRF (second, third and fourth row)
- The tumors were resected for Patients 1, 2, and 3
- Patient 1 and Patient 4 show some post-operative changes, depicted in blue ROI on GS T_2-weighted image in Figure 4
- The radiologist assisted in slice selection and drawing the first ROI on the GS images (blue ROI for resected/residual tumor and green ROI for healthy tissue)

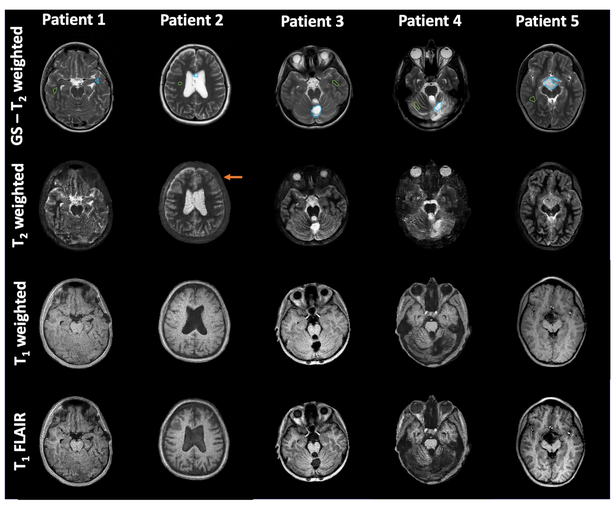


Figure 4: Qualitative images obtained using T_2 weighted gold standard (GS) and TMRF for all 5 patients.

- Henceforth, the same slice number and location were selected on the TMRF data, and ROI was drawn
- All TMRF images shown here are DL denoised images
- T_1 and T_2 maps were obtained from TMRF for five pediatric patients
- The same ROI (mask) was used on the T_2 map and T_2-weighted images (TMRF)
- All maps shown here are after DL-based denoising, performed on the signal intensity (1000 images) before passing through the DRONE model
- We observed that the resected/residual tumor region shows higher T_1 and T_2 values than healthy tissue

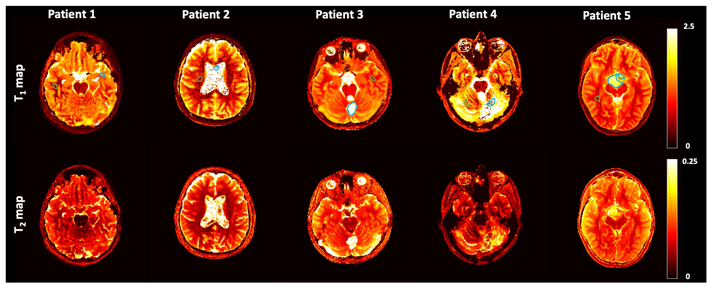


Figure 5: Quantitative maps for all five pediatric patients with brain tumors were acquired using TMRF.

- The bar graph shows the mean and SD of (a) T_1 and (b) T_2 values of resected/residual tumor (dark gray) and healthy tissue (light gray) for all five patients
- The second row shows the mean and SD of intensity values for (c) GS T_2-weighted images and (d) TMRF T_2w images
- The mean and SD were computed on the ROI, drawn manually on the GS T_2-weighted and TMRF T_1 map
- We observed that the mean T_1 and T_2 values of pathological tumors are higher than healthy tissue for all five patients
- These results are similar to the previously reported study

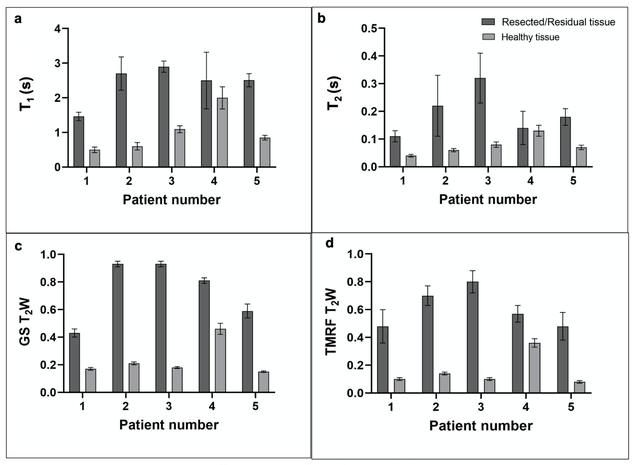


Figure 6: T_1, T_2 intensity, and plots

Discussion and conclusion

- This work focuses on post-operative pediatric brain tumor patients
- An advantage of TMRF is that it takes about ~16 seconds
- T_2-weighted sequence is part of routine pediatric brain tumor protocol, it can be potentially replaced by TMRF to reduce the total scan time
- Since all contrast images and quantitative maps were obtained from a single scan, image registration challenges are expected to be minimal
- The main limitations of TMRF include:
  - The slice thickness is more than the current clinical standards (3 mm)
  - The patient population has a small sample size (N = 5) with lower SNR images than GS

References

1. Sairam Geethanath et al. ISMRM 2019. 2. Pavan Poojar et. al ISMRM 2020 3. Pavan Poojar et. al., 2021 4. Enlin Qian et al. ISMRM 2020. 5. Cohen, O., et al, MRM 2018

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