Investigating the Repeatability and Reproducibility of MRI-Based Porosity Assessment of Mandibular Bone

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Purpose

- Radiation-induced toxicities have increased with higher incidence of HPV+ oropharyngeal cancer.
- Osteoradionecrosis (ORN) is a severe toxicity defined by decay of bone (mandible).
- ORN is subjectively diagnosed with clinical symptoms and confirmed on CT.
- We have implemented black bone (BB) and ultrashort echo time (UTE) MRI for bony visualization in follow-up imaging.
- We aim to use these sequences in tandem to generate a functional porosity index (PI) of bone.
- This preliminary study assesses the repeatability and reproducibility of PI in a cohort of healthy volunteers and patients.

Methods

Patient Cohort

- 3 healthy volunteers and 5 patients were imaged with BB and UTE on 1.5T or 3T MR-simulation scanners.
- All scans occurred prior to treatment to ensure no changes due to radiation.

Repeatability

- Volunteer repeatability measurements were performed by scanning twice in one session with repositioning in between.

Reproducibility

- Reproducibility measurements were performed in volunteers and patients with an average of two weeks separation.

Porosity Index

- PI was defined as the ratio of single-timepoint BB-to-UTE: $PI = \frac{Signal\ on\ BB}{Signal\ on\ UTE}$

Pre-Processing

- Steps included: reslicing UTE (ITK-SNAP v4.2.2); division to generate PI, normalization via the spinal cord at C1/2 level, mandible segmentation (ImageJ v1.54p).

Analysis

- Absolute coefficient of variation (CV), repeatability and reproducibility coefficients (RC, RDC), and intraclass correlation coefficient (ICC) assessed variability.

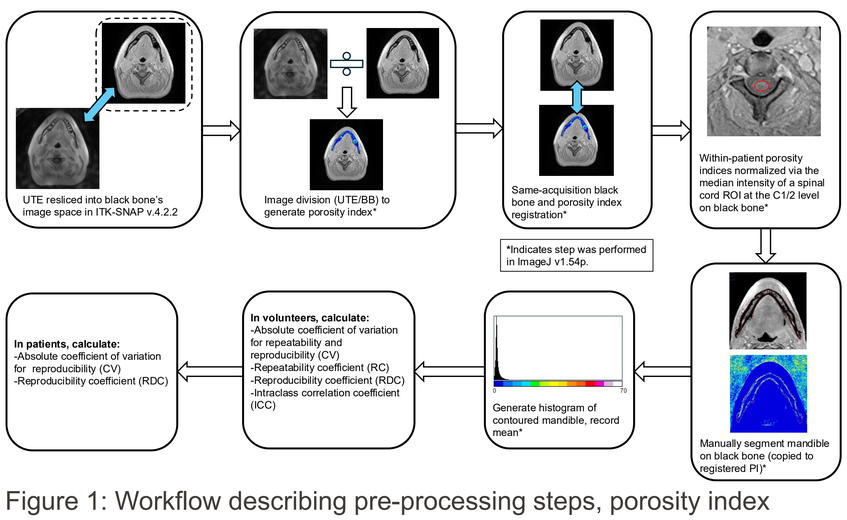

Figure 1: Workflow describing pre-processing steps, porosity index generation, and variability metrics calculation.

Innovation/Impact

- This study is a key step in advancing MR-based post-treatment toxicity monitoring.
- By utilizing 2 MR sequences for bony visualization, we can monitor anatomical and functional changes in bone correlating to early ORN.
- To our knowledge, this is the first study to develop functional imaging maps via PI to detect radiation-induced changes in mandible.

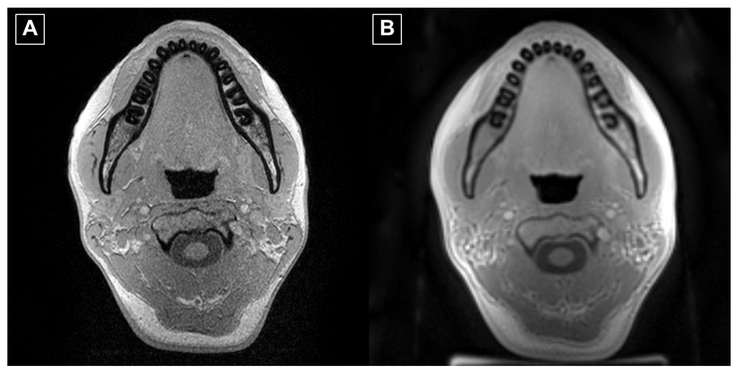

Figure 2: Volunteer imaging, showing (A) black bone and (B) UTE MRI.

MR Imaging

- BB and UTE MRI are clinically utilized for bone visualization in the head and neck.
- Notable sequence parameters include BB's low flip angle (5 deg) and both sequences' echo times (TE_{UTE}=50μs, TE_{BB}=4.2ms).

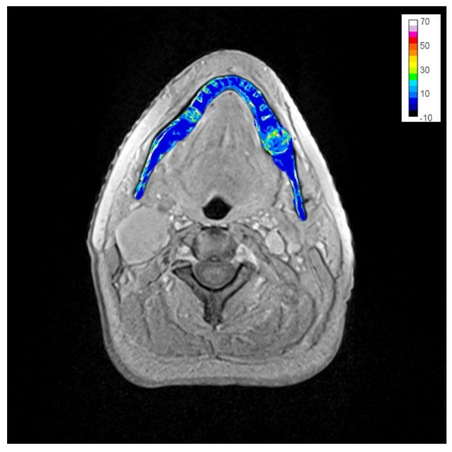

Figure 3: Porosity index map of a patient's mandible overlaid on matched black bone MRI. Calibration bar displays arbitrary value of porosity index based on intensity value.

Porosity Index

- Cortical bone has a significantly short T2, making most standard MR sequences inadequate.
- Cortical bone is densely comprised of bound water, with an extremely short T2 (300-400μs), and pore water, with a slightly longer T2 (1ms-1s).
- UTE (TE_{UTE}=50μs) images bound and pore water, while black bone (TE_{BB}=4.2ms) images only pore water.
- Thus, by computing the ratio of BB-to-UTE, one also computes the ratio of pore water in bone[1].

Results

- Repeatability measurements (volunteers + patients) show moderate reliability (0.697).
- Repeatability + Reproducibility timepoints (volunteers) show good reliability (0.821).

Table 1: Reliability results, including mean porosity index, CV, RC, RDC, and ICC.

Metric	Value
Mean PI (overall)	5.98
Mean PI (volunteers)	2.46
Mean PI (patients)	9.16
CV	63.09%
RC	10.46
RDC	3.78
ICC (R/RD)	0.697/0.821

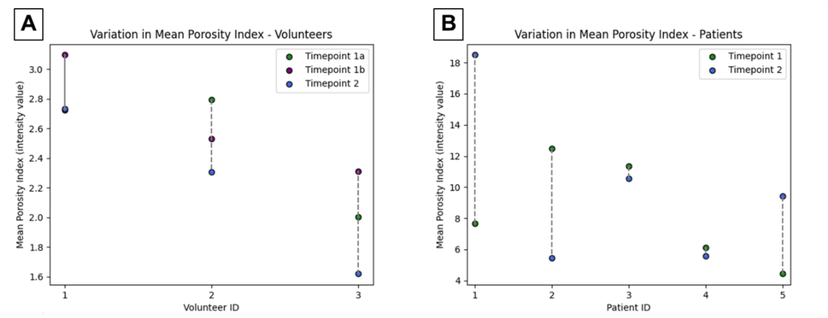

Figure 4: Matched-timepoint mean porosity index in (A) volunteers and (B) patients.

Discussion

- Volunteers maintained lower overall variability.
  - Homogeneous, low tissue variance, fewer artifacts
- Results are unsound due to small sample size.
  - Further analysis with more samples is required.
- Reproducibility and ICC metrics are solely from 3 volunteers.
  - Repeatability may be a better representation of results.
- Proof-of-concept to explore feasibility of PI in a preliminary cohort

References

1. Rajapakse et al. *Radiology*. 2015;276(2):526.

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