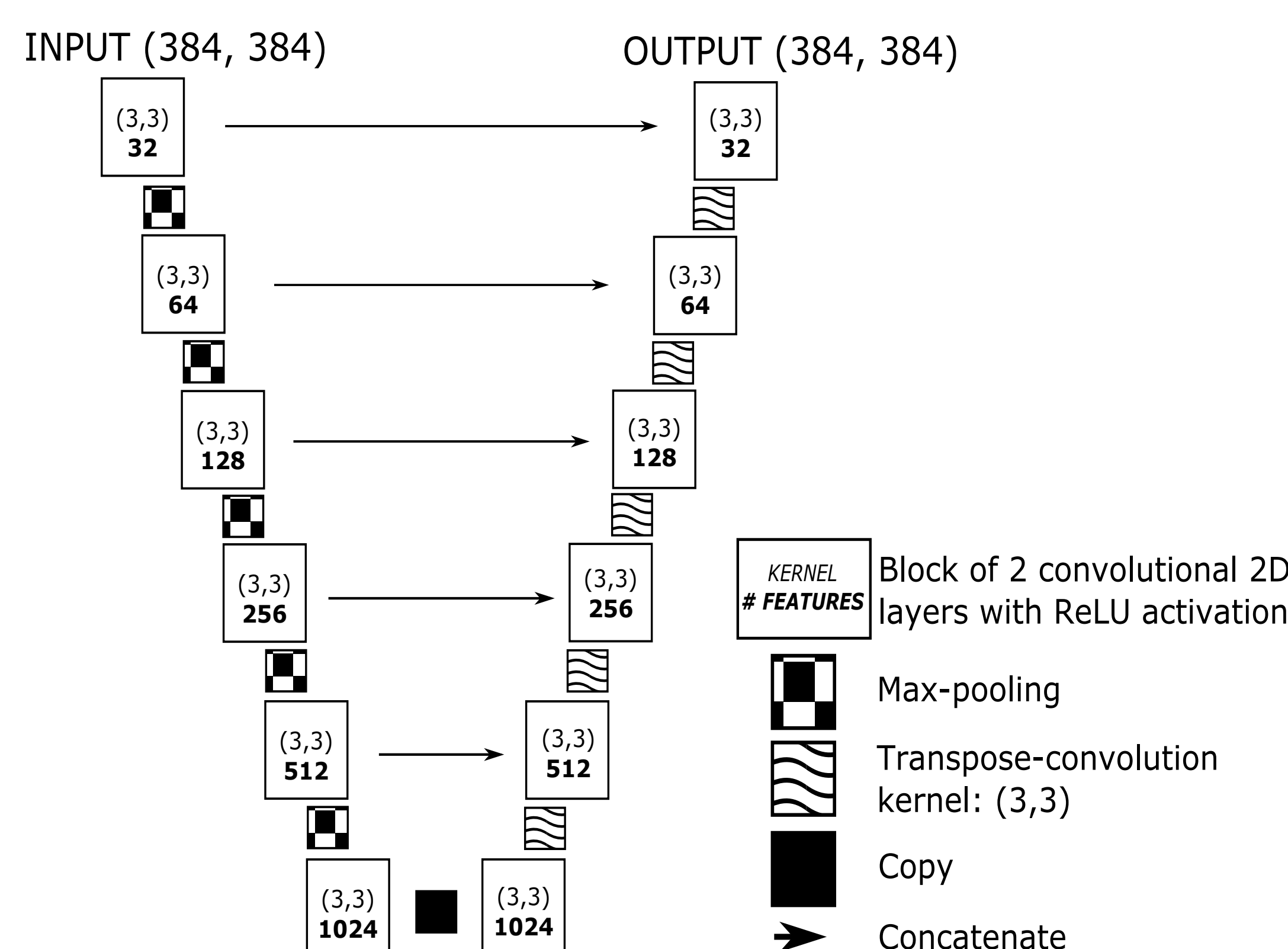# U-Net for Automated Segmentation of Knee Cartilage Imaging

Kevin A. Thomas, **Dominik Krzemiński**, Łukasz Kidziński, Rohan Paul, Elka B. Rubin, Eni Halilaj, Marianne S. Black, Akshay Chaudhari, Garry E. Gold, Scott L. Delp
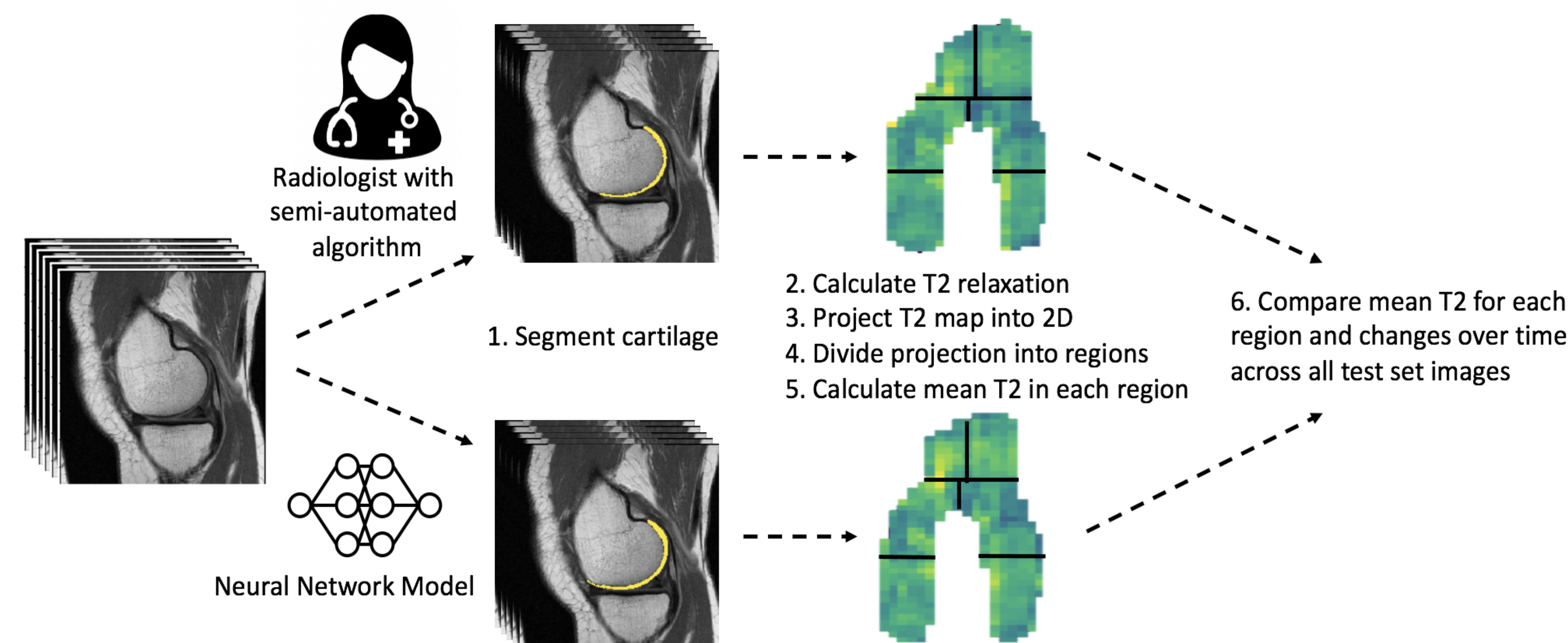
Research on **knee osteoarthritis** (OA) has been slowed by the difficulty of quantifying early disease progression. T2 relaxation times from MRIs reflect cartilage health and tend to increase with osteoarthritis progression. **Segmentation** of cartilage in MRIs is a necessary first step for measuring T2 relaxation times, but current methods are labor-intensive. We present a convolutional neural network (CNN) model based on the **U-Net architecture** to fully automate femoral cartilage segmentation in **MRIs**.

CODE AND MODELS

https://github.com/kathoma/AutomaticKneeMRISegmentation

PROCEDURE

Data: The OAI is a public study of knee OA in which MRIs were collected longitudinally. We used 286 sagittal plane multi-echo spin echo (MESE) MRI volumes from 143 OAI subjects assessed at baseline and four years later. Half of the subjects were randomly selected from among those in the OAI Incidence Cohort with BMI > 30 and the other half were age- and sex-matched controls with normal BMI in the Incidence Cohort. Each image was segmented with a semi-automated process and refined by an experienced musculoskeletal radiologist, referred to as Reader 1. Subjects were split into training (115 subjects, 230 image volumes), validation (14 subjects, 28 image volumes), and test (14 subjects, 28 image volumes) sets with no crossover of subjects across sets.
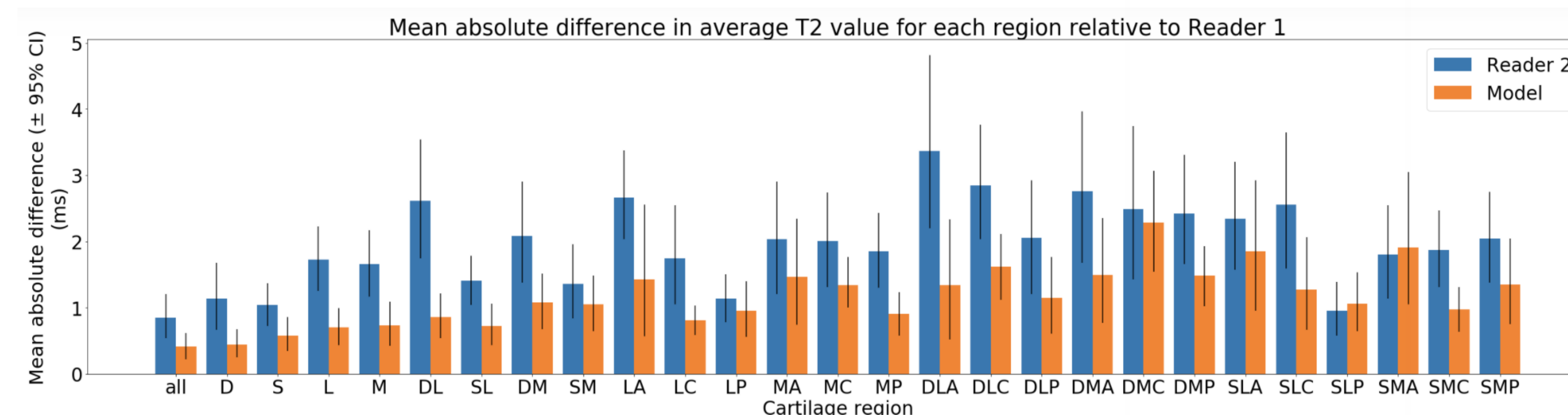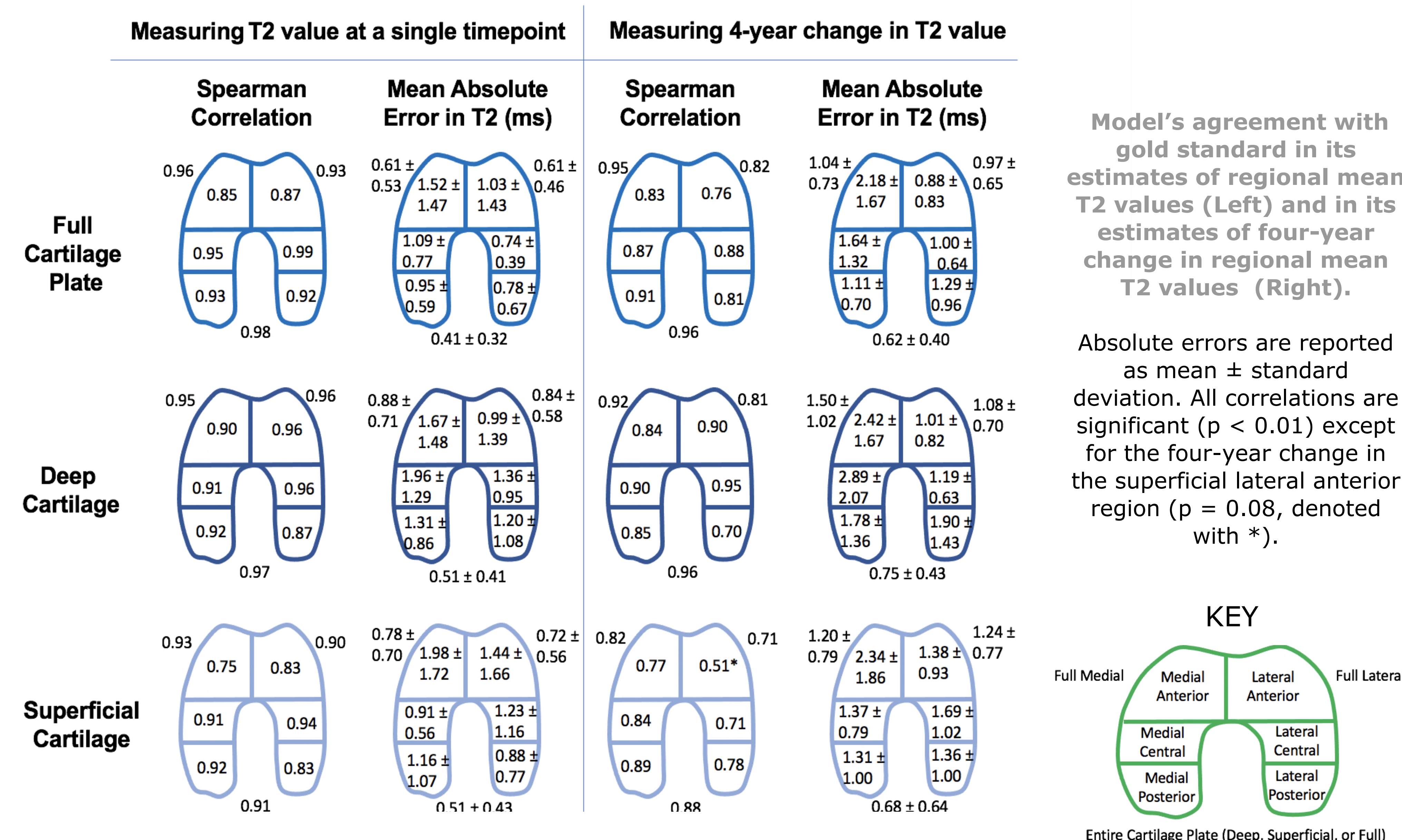
INPUT (384, 384)   OUTPUT (384, 384)

(3,3) 32 · (3,3) 32
(3,3) 64 · (3,3) 64
(3,3) 128 · (3,3) 128
(3,3) 256 · (3,3) 256
(3,3) 512 · (3,3) 512
(3,3) 1024 · (3,3) 1024

KERNEL # FEATURES — Block of 2 convolutional 2D layers with ReLU activation
Max-pooling
Transpose-convolution kernel: (3,3)
Copy
Concatenate

Models were trained and evaluated using one NVIDIA Tesla K80 GPU (Santa Clara, Calif).

Radiologist with semi-automated algorithm

1. Segment cartilage

Neural Network Model

2. Calculate T2 relaxation
3. Project T2 map into 2D
4. Divide projection into regions
5. Calculate mean T2 in each region

6. Compare mean T2 for each region and changes over time across all test set images

Measuring T2 value at a single timepoint | Measuring 4-year change in T2 value

Spearman Correlation | Mean Absolute Error in T2 (ms) | Spearman Correlation | Mean Absolute Error in T2 (ms)

Model's agreement with gold standard in its estimates of regional mean T2 values (Left) and in its estimates of four-year change in regional mean T2 values (Right).

Absolute errors are reported as mean ± standard deviation. All correlations are significant (p < 0.01) except for the four-year change in the superficial lateral anterior region (p = 0.08, denoted with *).

KEY

Full Medial | Medial Anterior | Lateral Anterior | Full Lateral
Medial Central | Lateral Central
Medial Posterior | Lateral Posterior

Entire Cartilage Plate (Deep, Superficial, or Full)

Mean absolute difference in average T2 value for each region relative to Reader 1