A Novel Computer-Aided Diagnostic System for Early Assessment of Hepatocellular Carcinoma

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ICPR 2020

Abstract

Purpose: Liver cancer is a major cause of morbidity and mortality in the world. The primary goal of this manuscript is the identification of novel imaging features (texture, functional, and shape) and development of a computer-aided diagnostic (CAD) system to accurately detect and grade liver tumors non-invasively.

Methods: A total of 97 patients with liver tumors were enrolled in the study after consent was obtained. 34 patients had benign tumors, 17 patients had intermediate tumors, and 46 patients had hepatocellular carcinomas (HCC) malignant tumors. A multi-phase contrast-enhanced magnetic resonance imaging (CE-MRI) was collected to extract the imaging features. The proposed approach consists of three main steps. First, a pre-processing step is applied to the CE-MRI scans to delineate the tumor lesions that will be used as a region of interest (ROI) across the four different phases of the CE-MRI. Second, a group of these features are modeled to provide a quantitative classification between the tumor lesions, namely: the tumor appearance that is modeled using a set of texture features (namely, the first-order histogram features, second-order gray-level co-occurrence matrix (GLCM) features, and second-order gray-level run-length matrix (GLRLM) features) to capture any discrimination that may appear in the lesion; the spherical harmonics (SH) based shape features that have the ability to describe the shape complexity of the tumor; and the functional features that are based on the calculations of the mean intensity of each region to evaluate the intensity changes across different phases. Finally, these features were integrated together to obtain the combined features to be fed to a machine learning classifier towards getting the final diagnostic decision.

Results: Using the Random Forests classifier with a leave-one-out (LOSO) cross-validation, the developed CAD system achieved an 87.5% accuracy in distinguishing between malignant, intermediate and benign tumors (i.e., 3-stage classification). LR-1 tumors were classified from LR-2 benign lesions with 92.5% accuracy, while 85.7% accuracy was achieved differentiating between LR-2 and LR-3 malignant tumors (i.e., 2-stage classification).

Problem and Research Motivation

Problem and Unmet Need

1st

Worldwide: 108,000 new cases and 78,000 new deaths.

In the USA: 42,000 new cases and 31,000 deaths.

As Global Average: 1.5098 people in danger of contracting HCC.

Current Diagnostic Tool, Gold Standard, and Limitations

For HCC, a radiological diagnosis (LI-RADS) provides high diagnostic performance and is considered as the Gold standard, which makes the medical organizations depend only on highly-qualified radiologists for HCC diagnosis.

Research Motivation

There is an urgent need for an automated machine-learning based CAD system to identify HCC and its grade to provide the proper treatment plan.

Data Collection

- A multi-phase contrast-enhanced magnetic resonance imaging (CE-MRI) was collected to extract the imaging features.
- A total of 97 patients with high risk of developing HCC without history of two-regional treatment plan (i.e., 65 and 27.4), provided their consent to participate in the study.
- 34 patients with benign tumors (LR-1 = 17 and LR-2 = 17), 17 with intermediate, and 46 with malignant tumors (LR-3).

The Proposed Framework

Step 1: Renal Tumor Preprocessing

Step 2: Features extraction

Shape Features (70 SHs)

Functional Features (Wash In/Out)

Experimental Diagnostic Results

Conclusions and Future Work

- In order to provide the proper management plan, the developed CAD system demonstrated high classification accuracy of 87.5% in differentiating between malignant, intermediate, and benign tumors, a high classification accuracy of 92.5% in differentiating LR-1 from LR-2 benign tumors, and 85.7% to differentiate between LR-2 and LR-3 malignant tumors.

- The integration process of accurate shape features with functional features and first- and second-order texture features was efficient enough to enhance the final diagnostic performance.

- The CAD system will be optimized by training and validating on a larger balanced patient cohort using CE-MRI. Furthermore, we are collecting new liver tumors with different diagnosis including LR-0 to investigate the abilities of the CAD system in a bigger classification problem.

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