Medical Image-based Diagnostics for Cardiovascular Diseases Using Machine Learning

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Abstract

With cardiac imaging's important role in the diagnosis of cardiac diseases, along with the dawn of big data and machine learning (ML), there are emergent opportunities to build AI tools that will directly assist physicians in heart failure (HF) diagnostics. An important application in biomedical engineering, as HF is very difficult to diagnose because of its complex symptoms, circumstance, and comorbidities. This study aims to: (1) perform accurate and precise cardiac segmentation and quantification of key left ventricle functional indices from CMR; and (2) build a ML tool using decision trees for image-based HF diagnosis. Quantification of left ventricular end-diastolic, end-systolic volumes and ejection fraction were achieved using Heron's formula and the area-length method. One-sample T tests revealed there were no statistical significance between the obtained mean values and the comparative mean values in each quantified variable. Statistical results show that quantified values of LV function closely resemble those established in the Sunnybrook Cardiac Data. Finally, a Machine Learning tool using decision trees for image-based heart failure diagnosis was successfully built, as every tested patient was classified correctly using the trained ML model.

Introduction

Heart failure (HF) currently affects nearly five million Americans and contributes to approximately 287,000 deaths a year[1]. HF is a chronic, progressive, and serious cardiovascular condition defined by the heart muscle being unable to pump enough blood to meet the body's needs for blood and oxygen. Despite being considered a major public health burden and the many recent advances in cardiovascular diagnosis and treatment, misdiagnosis is still a common concern for patients at risk of heart disease. Nowadays modern medical imaging techniques, such as magnetic resonance imaging (MRI) are widely used to assess qualitatively and quantitatively cardiac anatomical structures and functions[2]. Even with the incredible assessments medical images provide, HF patients are very difficult for physicians to diagnose correctly because they possess a variety of complex symptoms, circumstances, and comorbidities. Emerging disciplines like big data and machine learning (ML) have the potential to facilitate HF diagnosis with the use of artificial intelligence (AI) tools. Such AI image-based diagnostic tools have the potential to substantially alleviate the burden of HF through by providing fast and accurate diagnostic decision making.

Objectives

The objectives of this research project are:

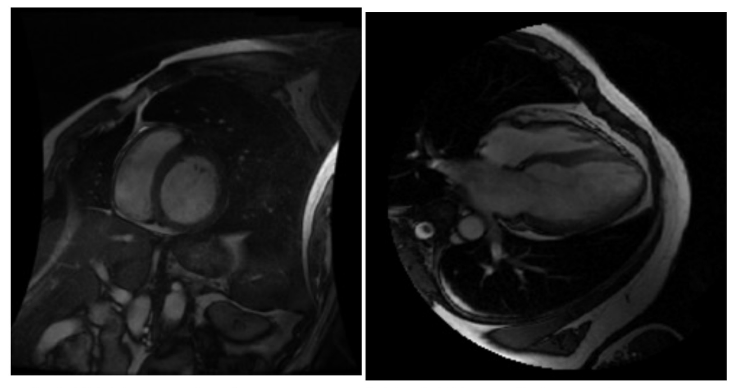
• Accomplish accurate and precise cardiac segmentation and quantification of left ventricular end-diastolic, end-systolic volumes and ejection fraction from CMR.

• Successfully build and evaluate a Machine Learning tool using decision trees for image-based heart failure diagnosis.

Methodology

1 Image Data Acquisition

Cardiac Atlas Project



The Sunnybrook Cardiac Data (SCD) was utilized for thier CMR dataset.

SAX Basal slices and LAX 4-Chamber views, were utilized throughout the methodology.

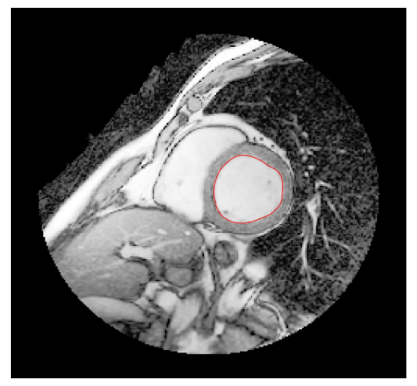
2 Metadata & Image Processing

```
Patient id..........: SCD0000101
Modality............: MR
Patient's Heart Rate.......: 79 BPM
Patient's Sex.......:
Relevant Image parameters
Pixel Spacing.......: [1.367188, 1.367188]
Slice Thickeness..: 10 mm
Image Gap.......: 10 mm
Image size.......: 256 x 256, 131072 bytes
```

Relevant information from the image was extracted from the DICOM files.

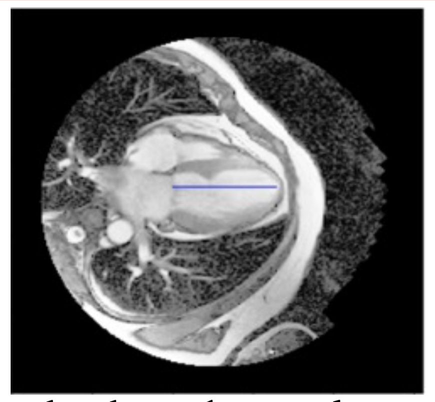
The image's local features were enhanced using histogram equalization

3 Cardiac Segmentation



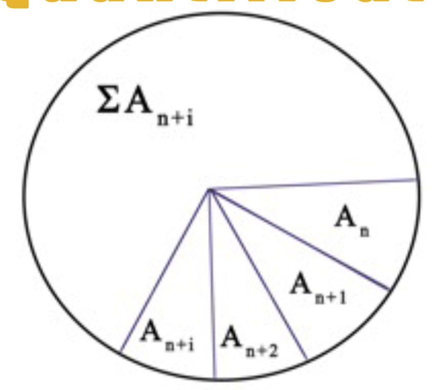
scikit-image
image processing in python

Using Python's Skimage library endocardial LV boundaries were outlined using an active contour technique.

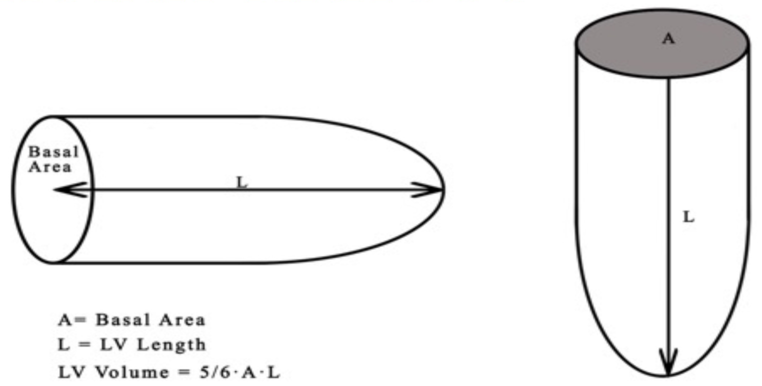


Ventricular length was determined from the apex to the mitral valve for end-diastole and end-systole.

4 Quantification of Functional Indices



Endocardial area is calculated using Heron's formula, to reduce geometrical assumptions.

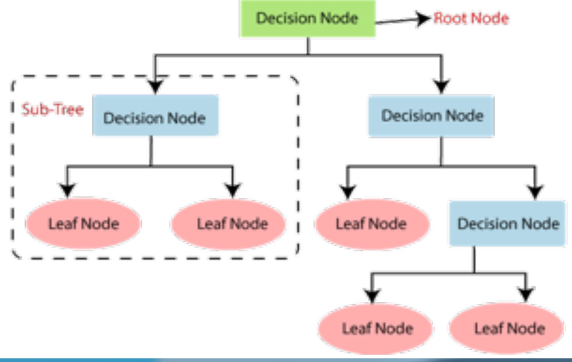


The area-length method was the geometric approximation utilized to calculate the EDV and ESV of the LV.

5 Diagnostic Predictions

Quantified data was utilized to train and test a decision tree ML model for HF diagnosis, using Python's Sklearn library.

The trained model classified the testing data as a binary output to "healthy" or "HF" patient.



Results

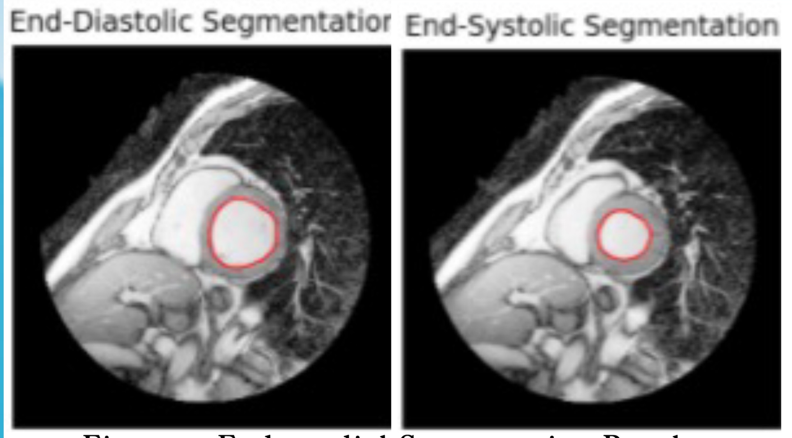


Figure 1: Endocardial Segmentation Results

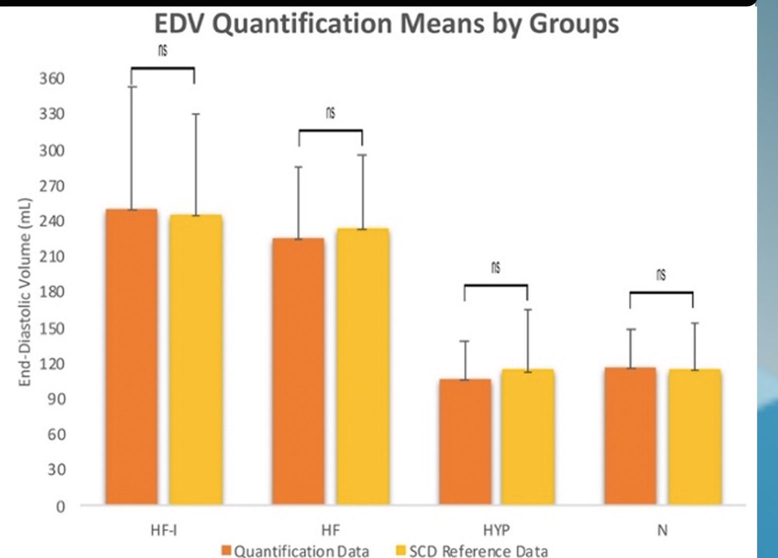


Figure 2: End-diastolic Volume Mean Values by Group with Standard Deviation

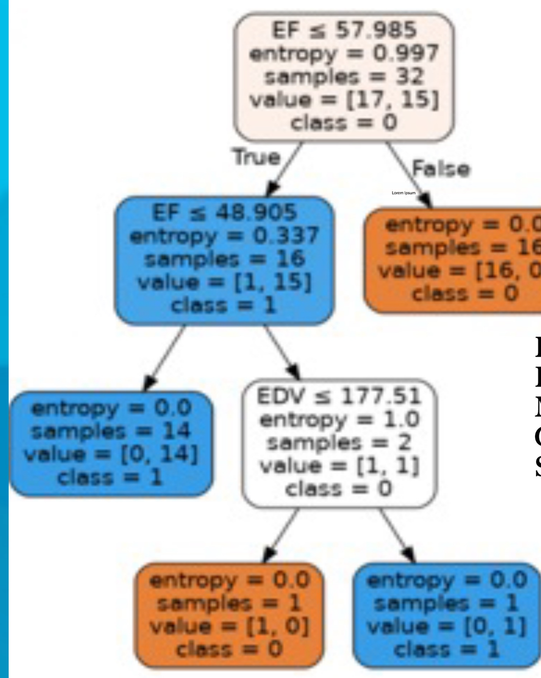


Figure 4: ML Decision Tree Model

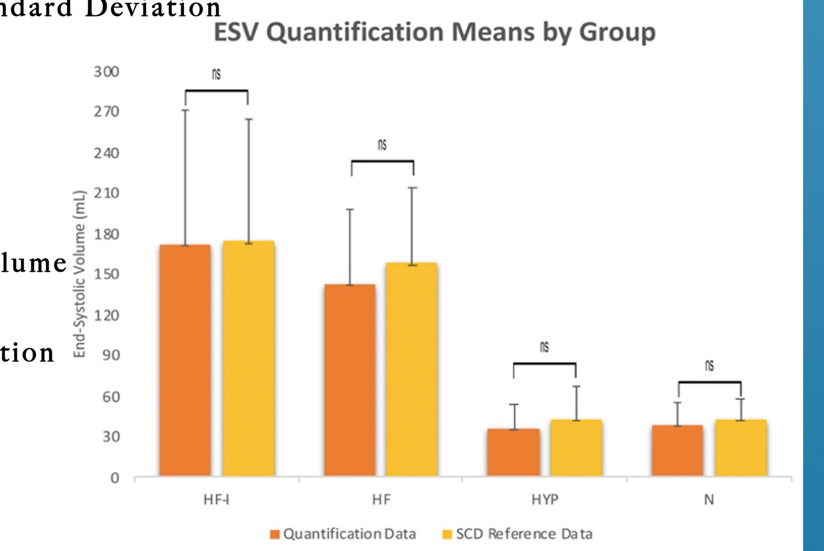


Figure 3: End-systolic Volume Mean Values by Group with Standard Deviation

Table1: Classification Test Metrics

Classification	Precision	Recall	F1 Score	Number of Occurrences
Healthy (0)	1.0	1.0	1.0	2
HF (1)	1.0	1.0	1.0	7
		Total Accuracy	100 %	9

Conclusions

Accurate and precise cardiac segmentation and quantification of LV functional indices from CMR was accomplished. Statistical results show quantified values closely resemble those established in the SDC. Finally, the AI HF diagnostics tool was successfully built, as every tested patient was classified correctly using the trained ML model.

Future Work

An automatic segmentation methodology using ML should be implemented to reduce human inputs. Finally, additional input data regarding ethnicity, ventricular mass, electrocardiogram data and genetic data should be added to the ML model to become a viable assistance for physicians to rely on.

References

1. Heart & Vascular: Conditions & Treatments.
2. Chen, C., Qin, C., Qiu, H., Tarroni, G., Duan, J., Bai, W., & Rueckert, D. (2020, February 17). Deep Learning for Cardiac Image Segmentation: A Review.

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