Quantitative Structured Reporting in Dementia Studies with Magnetic Resonance Imaging: Application to Neuroinformatics

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Abstract

Introduction: Nowadays, radiology is playing a very essential role in quantitative imaging from medical images to quantitative biomarkers. Integration of this numerical information into structured reports can make it more practical tool for an accurate diagnosis of dementia. **Materials and Methods:** This research developed a structured radiological report template for dementia as an automated integration of quantitative imaging biomarkers of magnetic resonance images into neurological structured reporting as a new achievement in the Management of Radiology Report Templates in a more organized style. **Results:** A significant accuracy rather than free conventional style for dementia patients. **Conclusion:** Final aim of this study is making this feature available to make the best decision on patients with some dementia signs.

Keywords: *Dementia, imaging biomarkers, magnetic resonance imaging, quantitative measurements*

Introduction

Alzheimer's disease, dementia's most common subtype, is predicted to grow from 50 million to 130 million people by 2050 due to fast increases in aging worldwide.[1] Screening people with computed tomography or magnetic resonance imaging at least once is highly recommended as a diagnostic workup of patients with cognitive problems to prevent exacerbation of dementia.[1]

Currently, radiology plays an essential role in the extraction of quantitative imaging biomarkers (QIBs) from medical images.[2] A biomarker is defined as "a characteristic that is objectively measured and evaluated as an indicator of normal biological processes, pathogenic processes, or a response to a therapeutic intervention."[2,3] Developing an analysis pipeline for measuring QIBs and integrating it into the clinical reporting workflow is an important step in neurological procedures.[2] Owing to the many advantages of structured reporting over freestyle reporting, integrating the healthcare enterprise (IHE) is an organization that has developed the Management of Radiology Report Templates (MRRT) profile to specify a standardized approach for imaging reporting.[4,5] On the other hand, the Radiological Society of North America (RSNA) and the European Society of Radiology have developed libraries for radiologists to find exemplary best-practice templates.[4] Hence, combining QIBs with structured reports (SRs) has many advantages to foster radiologists' knowledge. However, there are some challenges to practicing this method in a routine approach, in particular, methods for automating brain volume quantification in a clinical setting.[2,6] This combination includes SRs that seem to be necessary for more accurate diagnoses.[7] Diagnostic procedures mainly include magnetic resonance imaging as an integral part of the diagnosis, treatment allocation, and follow-up.[8,9] Furthermore, artificial intelligent (AI) and quantitative methods for enhancing the role of biomarkers are developing fast.[10] However, these developments might have some challenges from data acquisition to managing the data which make them impractical for radiologists and referring physicians.[11]

The final aim of this study, prepared by the Radiology and Biomedical Imaging

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Research Group (GIBI230) with the collaboration of QIBs in Medicine (QUIBIM S.L.), is to develop a novel system to change the radiology report template to a more organized style with some important quantitative measurements for dementia as the most common type of neurological disorders in the world,[12] which is included in a well-designed radiological workflow.

Materials and Methods

Ethics committee approval: There is no need for ethics committee approval.

Four major aspects have to be addressed a dedicated procedure for making it practical in clinic:(1) preparing the SRs template; (2) QIBs integration; (3) installation of quantitative structured reporting (QSRs) on hospital platform; and (4) clinical validation.

Neurological quantitative structured reporting framework

According to our design, we created an accurate, fast, and reliable QSRs framework to help radiologists. This will be used as a valid tool in diagnostic neurological procedures.

It is necessary to develop a classified, structured, and dynamic dataset for the diagnosis of dementia. The RSNA suggests a vender natural standard for this purpose, such as a specific XML structure, which was later replaced by HTML5-based format and has used as a trial implementation by IHE under the MRRT profile.[4] The report template file basically describes an HTML form and allows for text areas, input field, and selection boxes as described below.

Clinical information

This part includes four information sections: ID number, age, gender, and exam date. These sections directly come from the header of Digital Imaging and Communications in Medicine (DICOM).

Technical information

Other technical data were considered, such as study type, study region, sequences features, contrast agent condition, scanner's features, and comparative conditions. This data comes from the Picture Archiving and Communication System that we developed in Figure 1.

Findings

This section communicates our findings that we specified toward dementia patients. This section includes both anatomical and numerical data, which are able to report information about pathological disorders. According to the previous studies about dementia, evaluation of the disease should be divided into independent subsections as formatted below.

Figure 1: Clinical and technical information

The subsections are as follows: evaluation of global cortical atrophy (GCA) and the medial temporal lobe atrophy (MTA) score, white matter (WM) hyperintensities on T2-weighted sequences mainly for Fazekas scale, infarcts (lacunar and nonlacunar), micro bleedings (lobar or deep), hydrocephalus pressure, and iron evaluations in thalamus, putamen, globus pallidus, caudate nucleus, and amygdala. In addition, there is free blank box for adding any other findings for radiologists. In the case of comparing data with a previous study, a comparative subsection can be added dynamically [Figure 2].

GCA scale is the mean score for cortical atrophy throughout the complete cerebrum from 0, for normal aging, to 3, for severe (end-stage) atrophy; cortical atrophy is best scored on fluid-attenuated inversion recovery (FLAIR) images. In some neurodegenerative disorders, the atrophy is asymmetric and occurs in specific regions, thus a radiological report should mention any regional atrophy or asymmetry.

MTA score should be rated on coronal T1-weighted images with a consistent slice position. The score is based on a numerical rating from 0, for normal aging, to 4, for severe volume loss of hippocampus.

The Fazekas scale is a scale for WM lesions which provides an overall impression of the presence of WM hyperintensities (WMHs) in the entire brain ranging from a 0 score, for non or single-punctate WMH lesions, to 3, for large confluent lesions. It is best quantified with transverse FLAIR or T2-weighted images for the evaluation of small vessel disease as well.

This section will be translated into natural language processing (NLP) in the last section titled "Summary."

Impression

A conclusion box, suggestion box, and a free blanked box were designed for the impression section of our report. All possible diagnoses were predicted. Furthermore, if a study were to be a comparative study, then this part would add another subsection for new findings.

Summary

NLP aims to translate all the above information into a classified brief or abstract for referring physicians in an understandable overview of a patient's condition. Furthermore, this section would be able to be in any local language [Figure 3].

Information extraction of imaging biomarkers from magnetic resonance images (Radiomics)

The role of artificial intelligence in data management

For the last few decades, various models and methods have been proposed for the extraction of imaging biomarkers from different parts of the body, with applications in diffuse diseases such as Alzheimer's, steatosis, cancer, etc.[10] AI helps the field of imaging biomarkers in both segmentation and data mining steps. However, dealing with AI is a challenging task because of the computing infrastructure and the processing algorithms that require very dedicated profiles in different fields such as computer science, statistics, mathematics, image processing, and Machine Learning (ML) (which is designed to learn patterns from data with various techniques).[4,10] Using AI for radiomics demands two major steps in during development: training and testing.[10] [Figure 4].

Magnetic resonance protocol for dementia patients

For the evaluation of dementia according to standard protocols, there are many multiplanar series including: t2_tse_tra, t1_MPRAGE_3D, SWI_tra_2D, t2_FLAIR_dark fluid_3D, epi_diff_tra_32 dir_2D, epi_bold_tra_resting state, and t2*_tra_multi echo.

Information Extraction with designated modules

There are various designed modules based on AI (as a short-term and long-term measurement tool) and ML on QUIBIM precision platform for the extraction of numerical data and for algorithm training.

Designed modules for extracting biomarkers are R2* relaxometry for iron depositions, WM lesions for lesion number, total lesion volume calculation, brain volumetry with parcellation, Frontotemporal atrophy, voxel-based morphometry for automatic determination of the structural alterations present in the gray matter with respect to control group, and brain atrophy screening for the calculation of brain parenchyma fraction [Figure 5].

Implantation on enterprise imaging repository platform

This reporting template was designed according to standard guidelines (e.g., PI-RADS v2.1) and consensus of key opinion leaders (e.g., RSNA TLAP) to ensure that relevant information was collected.

The report template files describe an HTML form, text areas for radiologists' comments, input fields, quantitative information, and selective boxes. These QSRs are transferred as plain text into NLP for clinicians by some Java software codes. These techniques can be used for categorizing and extracting semantic information from QSRs.

The platform is organized to support all different imaging modalities or formats and also services such as worklist provider, auditing, image exchange, media import, etc. Standard interfaces include DICOM, DICOM web, XDS-I. b, and QSRs templates for different diseases, which can support many imaging

Figure 2: Findings

Figure 3: Impression and automated abstract maker

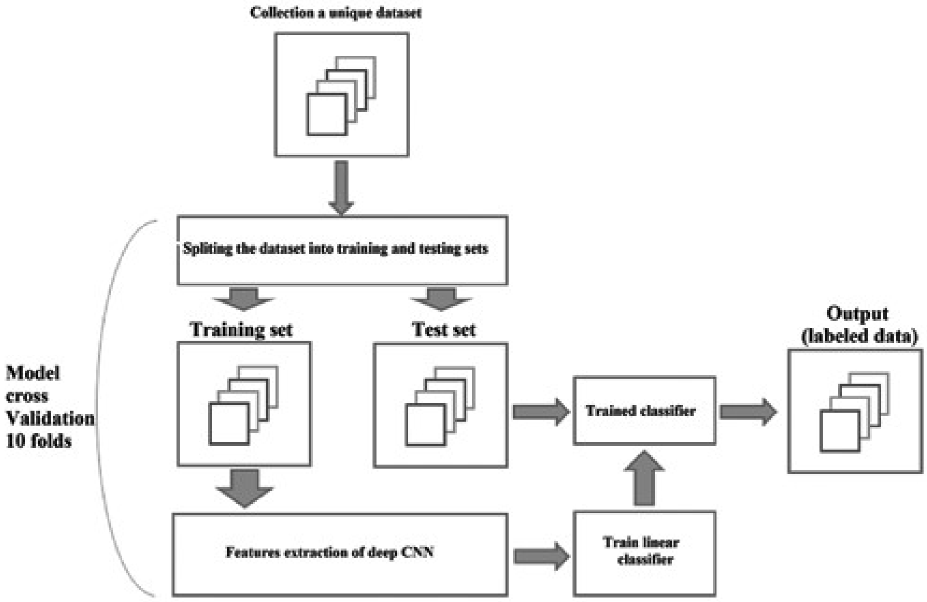
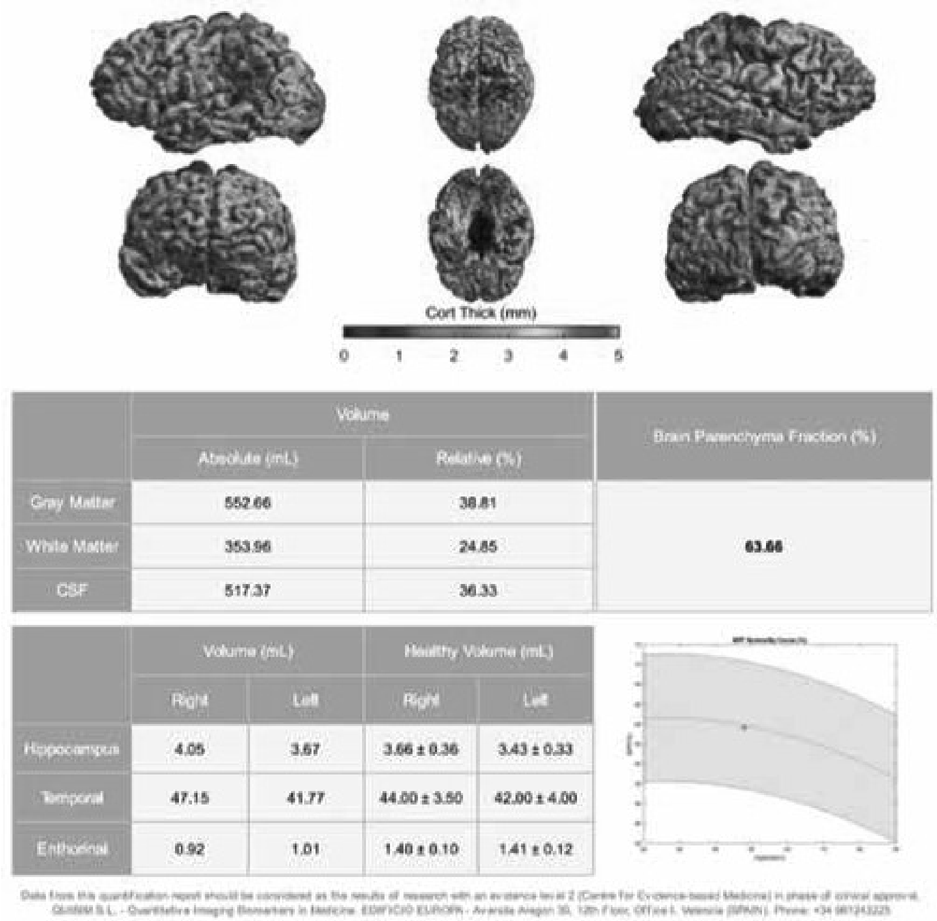


Figure 4: Flowchart for data labeling



	Volume		Brain Parenchyma Fraction (%)
	Absolute (mL)	Relative (%)	
Gray Matter	552.66	38.81	63.66
White Matter	353.96	24.85	
CSF	517.37	36.33	

	Volume (mL)		Healthy Volume (mL)	
	Right	Left	Right	Left
Hippocampus	4.05	3.67	3.66 ± 0.36	3.43 ± 0.33
Temporal	47.15	41.77	44.00 ± 3.50	42.00 ± 4.00
Enthorinal	0.92	1.01	1.40 ± 0.10	1.41 ± 0.12

Figure 5: Quantitative measurements

sources across an enterprise. Management of scanned documents in electronic health record environments, for example, forms, consents, and external reports are often handled through an enterprise content management system.

Prepared HTML5 templates for dementia were uploaded on the designed platform of La Fe hospital and all sections were reviewed several times for proper function to be implemented as a trial service to patients.

In this environment, the quantitative parts of QSRs are being filled in automatically from QUIBIM services and other parts of this template would be completed by neurologists. After approving the reports, they would be saved and sent to the storage for the next recall.

Clinical validation

According to a research by Goodkin *et al.* in 2019,[2] four stages are suggested for validation: creditability, accuracy, patient management, and socioeconomic impact which have been expanded below.

Results

In this study, tried to validate data according to the above standard on 150 real cases on La Fe and re-evaluate all results with radiologists, neurologists, and related engineering staff. Five reports needed more information to be significant by this method.

Conclusion

To our knowledge, there have been no previous studies that investigated the quantitative measurements integrated with structured reporting. QSRs might be introduced as a powerful tool that potentially enables to improve the precision, speed, and accuracy, although some limitations can be considered to have a spotless report. More investigations are suggested to increase the accuracy.

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Patient informed consent

There is no need for patient informed consent.

Ethics committee approval

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Conflicts of interest

There are no conflicts of interest to declare.

Author contribution subject and rate

- Mojtaba Barzegar (70%): contributed in in proposing the research idea, providing the research funding, and writing the manuscript, designing and carrying out the research, supervising the data processing, modeling.
- Joan Carreras (30%): contributed in clinical application and classification of lesions. All authors contributed to the article and approved the submitted version.

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