Computers in Biology and Medicine 45 (2014) 26–33

Contents lists available at ScienceDirect

Computers in Biology and Medicine

journal homepage: www.elsevier.com/locate/cbm

Randomized pilot study and qualitative evaluation of a clinical decision support system for brain tumour diagnosis based on SV ^{1}H MRS: Evaluation as an additional information procedure for novice radiologists

Carlos Sáez [a,*], Luis Martí-Bonmatí [b,c], Ángel Alberich-Bayarri [b], Montserrat Robles [a], Juan M. García-Gómez [a]

[a] Grupo de Informática Biomédica (IBIME), Instituto de Aplicaciones de las Tecnologías de la Información y de las Comunicaciones Avanzadas (ITACA), Universitat Politècnica de València Camino de Vera s/n, 46022 València, Spain
[b] Department of Radiology, Hospital Quirón Valencia, Valencia, Spain
[c] Radiology, Department of Medicine, Universidad de Valencia, Spain

ARTICLE INFO

Article history:
Received 18 April 2013
Accepted 18 November 2013

Keywords:
Randomized pilot study
Clinical decision support systems
Brain tumours
Radiological information procedure
Qualitative evaluation

ABSTRACT

The results of a randomized pilot study and qualitative evaluation of the clinical decision support system Curiam BT are reported. We evaluated the system's feasibility and potential value as a radiological information procedure complementary to magnetic resonance (MR) imaging to assist novice radiologists in diagnosing brain tumours using MR spectroscopy (1.5 and 3.0*T*). Fifty-five cases were analysed at three hospitals according to four non-exclusive diagnostic questions. Our results show that Curiam BT improved the diagnostic accuracy in all the four questions. Additionally, we discuss the findings of the users' feedback about the system, and the further work to optimize it for real environments and to conduct a large clinical trial.

1. Introduction

Conventional magnetic resonance (MR) images provide highly detailed morphological and microstructural information, and are fundamental in the diagnosis and grading of brain tumours. Although the development of contrast-enhanced and diffusion-weighted MR imaging have greatly improved the diagnostic accuracy of MR imaging, the accurate characterization of tumours remains problematic. During the last decade, magnetic resonance spectroscopy (MRS) has demonstrated its capability to complement MR imaging for initial diagnosis exam of brain masses [2], based on the modification of the metabolic information of different types of brain tumours [3].

Several studies have applied pattern recognition techniques to classify brain tumours based on Proton ^{1}H MRS signals [4–7]. Nevertheless, the difficulty of interpreting the signal is a major impediment to the introduction of such technology in routine clinical practice [2,4,19]. Horská and Baker [19] suggested that automated procedures to analyze MRS and display its results are needed to overcome this issue. For this reason, translational research has focused its attention in developing and evaluating clinical decision support systems (CDSS) based on ^{1}H MRS to help radiologists in the diagnosis of brain tumours [4,8–10]. Additionally, a CDSS for brain tumour diagnosis may be of special interest to novice radiologists, where the lack of clinical experience on large number of real cases of specific tumour types, offers an optimal opportunity for the use of a CDSS [15]. In fact, the evaluation of CDSSs with novice clinicians has been largely addressed in the literature [16,17].

In this work, we present the results of a randomized pilot study to evaluate the feasibility and to define the potential value for clinical practice of Curiam BT, a CDSS for brain tumour diagnosis based on ^{1}H MRS (an earlier abstract was presented in [24]). The evaluation was carried out based on a prospective parallel-randomized pilot trial, in which resident and expert radiologists from three hospitals were involved in both quantitative and qualitative assessments. To the best of our knowledge this is the first multi-center randomised pilot study of a CDSS for brain tumour diagnosis using both 1.5 and 3.0*T* (T) cases, where we provide evidence to support the feasibility of large scale multi-centre trials in this area [19].

2. Materials and methods

The design of the pilot study to evaluate Curiam BT with novice radiologists was twofold. First, we carried out a quantitative

* Corresponding author. Tel.: +34 963 877 000x75278; fax: +34 963 877 279.
E-mail address: carsaesi@ibime.upv.es (C. Sáez).

0010-4825/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.compbiomed.2013.11.009

evaluation based on a prospective parallel-randomized trial. Second, we completed the study with a qualitative evaluation based on the Technology Acceptance Model (TAM) methodology [14], a feedback questionnaire and personal interviews about the clinical use and value of the system.

2.1. Curiam BT

Curiam BT is a CDSS for brain tumour diagnosis based on the analysis of 1.5 and 3.0*T* Single Voxel (SV) ^{1}H MRS data. Curiam BT is a specialization of the generic framework for CDSS Curiam [20] (Fig. 1). Curiam provides the generic user interface and logical software components as a basis to build CDSS for specific clinical problems. In addition, it uses the generic classification framework published by the authors in [12], which permits easily including new predictive models based on different pattern recognition or artificial intelligence methods.

From a user-centered approach, the objective of the generic Curiam framework was simple: to offer a single-purpose tool to clinicians who may require support in its decisions. We only focused on one role: clinicians; and high-level use case: obtain support for a clinical case based on one or more questions to be solved. Thus, specific requirements and use cases are defined when building a specialized version of Curiam for a specific clinical problem.

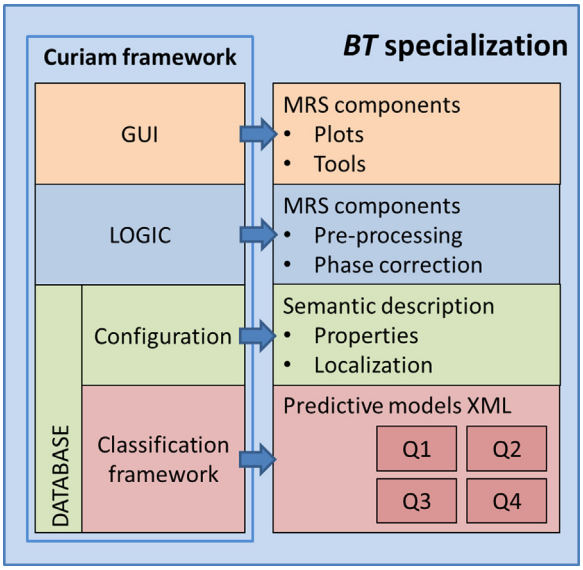

Fig. 1. Curiam BT specialization based on the generic Curiam CDSS framework. Following the application program interface (API) of Curiam, only components to manage MRS, a semantic description, and the brain tumour predictive models were required.

Based on the Curiam framework several CDSS have been developed for different clinical domains: soft tissue tumour classification and grading (Curiam STT) [20], postpartum depression prediction (Curiam PPD) [20,22], classification of paediatric brain tumours (Curiam BT-Kids) [21], and the CDSS evaluated here, Curiam BT [8].

Based on the knowledge acquired during the European projects eTumour [1] and HealthAgents [18] we defined several of the requirements and developed Curiam BT. Fig. 2 shows the more fine-grained use case of Curiam BT. The input of Curiam BT is a raw short time echo (STE) signal (~20 ms) alone or in combination with a raw long time echo (LTE) signal (~136 ms) acquired with the acquisition protocol described in [5]. The automatic MRS preprocessing pipeline carried out by Curiam BT is based on jMRUI [11] and DMS [4] and is fully described in [6]. An additional zero-order and first-order phase manual correction, especially useful for 3.0*T* signals [7], can be also performed by Curiam BT.

The CDSS used in the pilot study included the four predictive models listed in Table 1. Models M1 and M2 are the STE and combined time echo classifiers for discriminating Aggressive (Glioblastoma and Metastasis), Meningioma and Low Grade Glial

Table 1
List of predictive models included in the validated version of Curiam BT. The established classes or groups are based on the World Health Organization (WHO) classification of tumours of the central nervous system [13]. Aggressive tumours include Metastasis and Glioblastoma; Low Grade Glial includes Oligoastrocytoma, Oligodendroglioma and Astrocytoma Grade II; Low Grade Tumour includes Grade I and II tumours, and High Grade Tumour includes Grade III and IV. STE: Short TE, LTE: Long TE.

Predictive model	Discriminated classes	Spectra	Accuracy (%)
M1	Aggressive vs. Meningioma vs. Low Grade Glial	STE	88
M2	Aggressive vs. Meningioma vs. Low Grade Glial	STE+LTE	92
M3	High Grade Tumour vs. Low Grade Tumour	STE	83
M4	Meningioma vs. Non-Meningioma	STE	91

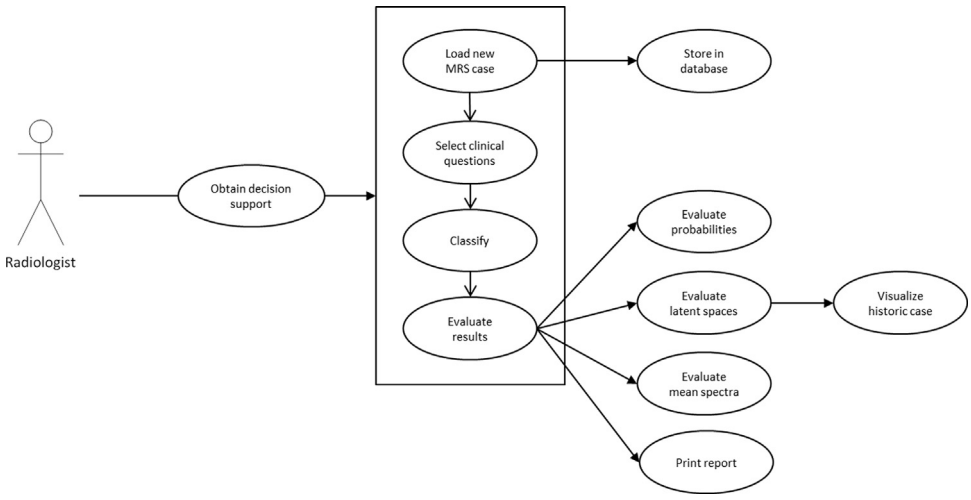

Fig. 2. Use case of Curiam BT.