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Ontologies for Liver Diseases Representation: A Systematic Literature Review

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Abstract:

Ontology, as a useful knowledge engineering technique, has been widely used for reducing ambiguity and helping with information sharing. It is considered originally to be clear, comprehensive and with well-defined format. It characterizes several domains purposes description through structured and formalized languages. In various areas of research, it has become a significant way to realize successful and powerful accomplishments. Actually, medical ontologies were turned into an efficient application in medical domains. They also become a relevant approach to process large medical data volumes. Consequently, they are behaving as a support decision system in some cases. Also, they ensure diagnosis process acceleration and assistance. Additionally, they have been integrated especially to represent human healthcare concepts. For that reason, plenty of research works applied ontologies to design and treat liver diseases. In this article, we present a general overview of medical ontologies to stand for this type of disease. We expose and discuss these works in details by a complete comparison. Also, we show their performance to arrange clinical data and extract results.

Keywords: Ontologies, Liver diseases, Medical terminologies, Knowledge representation

1. Introduction

Liver cancer is one of the most deadliest and aggressive cancers in the world. According to the Global Cancer Observatory (GCO)¹, it is the sixth most common cancer in the world and the third most deadly. It mainly affects men over 40, most often with cirrhosis or hepatitis B or C. The US Center for Disease Control and Prevention (CDC)² mentions that each year in the USA, around 22,000 men and 8,000 women get this disease, and around 16,000 men and 8,000 women die from hepatic diseases. At early cases, it may not show any symptoms. In particular, Hepatocellular carcinoma (HCC) and Cholangiocarcinoma are considered the most critical and most frequent liver diseases that attack adults. Many factors can promote the development of these tumors (*e.g.* alcohol, obesity, diabetes, tobacco, *etc.*). The diagnosis of liver tumors is a complex and sensitive task. A possible long period of several months may be necessary to extract the hepatic nodule type.

Offering large databases of clinical information is an important but critical need for various medical applications. Medical terminologies offer a standard source of information that facilitates communication between radiologists, doctors, and the whole medical staff. Also, they allow dealing with domain knowledge reuse. Among these terminologies, we find (Radiology Lexicon) RadLex³, which is considered as a standard and a controlled terminology dedicated to radiology uses. It is a single, unified source of terms for radiological practice, education, and research. The purpose of RadLex is providing a uniform structure for capturing, indexing, and retrieving a variety of radiology information sources, such as teaching files and research data. This may facilitate a first step toward structured reporting of radiology reports. This will also permit the mining of data for participation in research projects, registries, and quality assurance [1]. Also, Unified Medical Language System (UMLS⁴), which is developed by the United States (US) National Library of Medicine (NLM), allows

¹ <http://gco.iarc.fr/>

² <https://www.cdc.gov/>

³ <http://www.radlex.org>

⁴ <https://www.nlm.nih.gov/research/umls>

the organization of clinical vocabularies [2]. In the same context, we can cite also the Systematized Nomenclature of Medicine- Clinical Terms (SNOMED CT), Medical Subject Headings (MeSH⁵), Transparent Access to Multiple Bioinformatics Information Sources (TAMBIS⁶), Foundational Model of Anatomy (FMA), the international classification of diseases (ICD⁷). In this article, we present a literature review that outlines the topic of using ontologies for liver diseases representation. This work addresses the problem of integrating knowledge engineering techniques to solve clinical problems.

The remainder of the article is organized as follows: Section 2 outlines the applied research methodology to synthesize studies. Section 3 exposes the reviewed works that deal with the topic of ontologies for liver diseases. Section 4 discusses the presented approaches and finally Section 5 summarizes the paper and gives an overview of future works.

2. Methodology

To restrict this article, we apply the Systematic Literature Review (SLR) Methodology [3]. The main goal of this methodology is to collect and analyze data extracted from studies selected in the article. It is based on three phases: (1) planning the review, (2) conducting the review and (3) reporting the review. Each phase is explained in the next sections.

2.1. Planning the review

This phase outlines the topic of the research by giving the research questions. It is dedicated also to develop the review protocol in order to guide the SLR. In this article, the research questions are:

RQ1: *What are the sources used to carry out and collect medical data?*

RQ2: *Is there any reuse of a specific semantic vocabulary or Framework?*

RQ3: *Did the proposed work expose a semantic representation of the ontological approach?*

RQ4: *Did the proposed solution generate any prototype accessible for download and reuse?*

RQ5: *Is there any description of the implementation strategy?*

RQ6: *Have the authors evaluated and validated their approaches by the use of real medical data?*

RQ7: *What are the tools and languages applied to develop the proposed model?*

Two other questions related to the objective of each work and the applied methodology will be explained in the next section.

Search strategy: To select adequate works, we focused on IEEE Xplore, Elsevier Scopus, Web of Science, Google Scholar, ScienceDirect databases. Specific terms were integrated to begin the search such as; “medical ontologies”, “liver cancer ontologies”, “medical terminologies”, “HCC ontologies”, “ontologies for medical imaging”. We used also a combination of terms such as “ontologies for liver diseases” and “MRI imaging” to ensure adequate results.

Inclusion/exclusion criteria: The criteria are integrated to ensure that the studies focused on the boundaries of the research topic and its objectives. All articles were taken for their relevance to the domain of medical ontologies especially for liver diseases. Inclusion and exclusion criteria should response to research questions. They should be conducted to ensure that they can be clearly interpreted and that they classify studies correctly. In this article, the inclusion criteria are:

- Studies published in the English language;
- Studies published between the period of 2005-2019;
- Studies within the domain of ontologies for liver diseases representation.

The exclusion criteria are:

- Studies not published in English;
- Studies outside the domain of liver cancer diseases and ontologies;
- Duplicated works in electronic databases.

⁵ <https://www.nlm.nih.gov/mesh/>

⁶ <http://www.cs.man.ac.uk/~stevensr/tambis/details.html>

⁷ <http://www.who.int/classifications/icd/en/>

2.2. Conducting the review

This phase is intended to identify the selected works strategy, select primary studies, and make a quality assessment, data extraction and synthesis.

Search for studies: Our research was made on May 2019. We looked for studies that deal with the domain topic. We have selected 300 primary studies. These works expose medical solutions that validate the presence of ontologies as an effective solution to build or improve several computer-aided systems. We tried to study publications that have answered to the research questions.

Study selection: To start the selection part, we eliminated redundant studies extracted from different databases. Therefore, we focused on the titles, abstracts, and keywords of each study to select the most adequate publications. Then, we started our study with a total of 39 works. These works presented semantic representation samples that deal with liver disease, especially with HCC. The numerous terminologies related to liver cancer have been represented by different ontological approaches enabled for clinical purposes. The next section is dedicated to present an overview about these approaches related to liver disease models.

3. Reporting the Review

We present in this section three categories of research areas that deal with improving knowledge engineering achievements in medical purposes; ontologies for medical image interpretation; ontologies for medical data representation and ontologies for radiological report examination. More details about these categories are mentioned in the next subsections.

3.1. Ontology for Medical image interpretation

This category of works extract in medical images features and clinical characteristics. Hereafter, they use these data to realize an ontological model addressed to medical issues. We devise this category into three groups according to the medical image type; Computed Tomography (CT) scans, Magnetic Resonance Imaging (MRI) and other types.

3.1.1. CT scans interpretation

In the field of medical images annotation, [6], [8] and [11] presented semantic tools to detect liver lesions. Beginning with [6], it improved Content-Based Image Retrieval (CBIR) methods to allow automatic liver CT scans annotation. The proposed method interprets semantically these images. Consequently, it describes image characteristics such as 3D objects, liver specificities (*i.e.* intensity and size), tumor information (*i.e.* intensity, shape, density, location and size), and vessel information (*i.e.* size). This work proposed a Weighted Nearest-Neighbors (WNN) based method as a data recovery strategy following search queries. The contribution part integrated 3D volumetric images extracted from ImageCLEF 2014 Liver CT Annotation Challenge, these data are 73 annotations processed via ONLIRA ontology. [8] proposed the MEDICO ontology, it gathers clinical information extracted from other ontologies (*i.e.* FMA) together with medical terminologies (*i.e.* ICD-10 and RadLex). To ensure this model, several steps were followed: (1) developing an ontology-driven metadata extractor for the DICOM format. (2) Using the output to simplify manual annotation, (3) associating the extracted metadata with anatomical annotations and clinical results (4) performing query extensions and (5) combining patients, medical images and annotations in a complete list of results. [11] proposed a framework for modeling liver lesions using CT scans. It is used to predict radiologists' interpretations. The applied methodology starts by extracting terms referring to hepatic lesions. The next step consists in calculating the distance between all the generated Visual Semantic Terms (VST) models. The goal is building an ontology that collects all terms and synonyms. To evaluate this approach, 74 cases of annotated liver injury with 18 VST models were taken from the RadLex ontology. Additionally, [15] proposed semantic method that enables physicians the intelligent search on medical databases. Table 1 shows a summary of the studied works.

Table 1. Ontology for Medical image interpretation using CT scans

Approach	RQ1	RQ2	RQ3	RQ4	RQ5	RQ6	RQ7
[6]	ImageCLEF 2014	ONLIRA , SVMs WNN	-	-	+	+	-
[8]	Medical images	FMA, ICD-10	+	MEDICO Ontology, RadSem	+	+	OWL, ImageJ
[11]	Radiological reports	VST RadLex	-	-	+	+	Riesz wavelets , SVM
[15]	Medical domain experts	MEDICO- ontology, FMA RadLex	+	-	+	+	SPARQL OWL/RDF , Jena (TDB)

3.1.2. MRI interpretation

MRI interpretation is mentioned in [7], this approach offered an ontology that guides image interpretation and allows its biomedical structures recognition. This model was enriched by fuzzy conceptual representations. Also, it established links between these concepts. It offered a framework for knowledge domain representation and reasoning. Moreover, it reduced semantic gaps between the digital information and its conceptual level. For cerebral anatomical concepts representation, this work uses FMA ontologies. The assessment has been conducted with 3D brain MRI images. Furthermore, [9] proposed an ontological model OntHCC for liver cancer representation. This model focuses especially on HCC detection from the medical image, HCC classification through a staging system and HCC treatment. It developed a Java software that enables communication between users and machine via graphical demonstrators. This work has included SWRL rules to achieve the reasoning process. The developed ontology is populated with clinical data extracted from real medical reports and related to HCC patients. In [14], the goal is to annotate medical images information by semantic methods. The developed prototype (OntoVIP) enabled the reuse of these information in several clinical applications. Also, it allowed medical image simulation. Table 2 exposes these works.

Table2. Ontology for Medical image interpretation using MRI images

Approach	RQ1	RQ2	RQ3	RQ4	RQ5	RQ6	RQ7
[7]	Medical images	FMA	+	-	+	+	OWL-DL
[9]	Medical images, radiological reports	-	+	OntHCC	+	+	Protégé , SWRL SPARQL, OWL
[14]	Radiological reports	FMA,PATO, MPATH, RadLex, ChEBI, DOLCE,RDF	+	OntoVIP	+	+	OWL-DL

3.1.3. Other medical images interpretation

Using ontologies for medical features extraction is mentioned in [4], [5] and [12]. [4] proposed a model medical image data representation. It looked for merging regularly the pathological quantitative image

information with its associated clinical data. A prototype named Quantitative Histopathology Image Ontology (QHIO) was developed. It contains various pathological images and computational algorithms. It is dedicated to refine the previous developed approaches by trying to improve the annotation tools. This methodology is composed of four essential parts: an input (*e.g.* image), parameters (*e.g.* size of the filter window sizes, number of iterations), an output (*e.g.* image, measurement), and the execution step. For [5], it used semantic reasoning techniques to analyze Whole Slide Images (WSI) images. This work generated a system for biological objects recognition and extraction. In addition, it is used to apply an image analysis engine to release the visual medical information. The applied methodology allowed its integration into various pathological domains platforms and increased the sensitivity of low-level medical image analysis algorithms. In [12], the goal is extracting information from the medical image. This work focused on building a structured database of nuclear medical images using the Annotation and Image Markup (AIM⁸) annotation. This approach developed a template for the nuclear medical field applied to annotate 100 Positron Emission Tomography-Computed Tomography (PET-CT) images. This annotation is made using the vocabularies RadLex, FMA, and SNOMED CT. Query Language for RDF (SPARQL) queries were integrated to test the effectiveness of the proposed system. Rubin *et al.*, [13] proposed a tool enabling the semantic annotation of medical images in Digital Imaging and COmmunications in Medicine (DICOM) format. The proposed method used medical images contents to create a communication tool. This box makes the collection of image interpretations and observations easier. The proposed approach is composed of three phases: (a) creating ontology that provides a standard model of semantic annotations, (b) developing an image annotation tool that collects these annotations, and (c) serializing medical data by the use of HL7, CDA XML and OWL as languages to allow data access on the Web. These works are presented in Table 3.

Table 3. Ontology for Medical image interpretation using other images' types

3.2. Ontology for Medical data representation

Approach	RQ1	RQ2	RQ3	RQ4	RQ5	RQ6	RQ7
[4]	NCI's Early Detection Research Network (EDRN)	GO OBO	+	QHIO	+	+	Protégé OWL
[5]	-	RDF JDOM	-	BCO	+	+	Protégé OWL-DL SWRL SPARQL WFML RuleML Java
[12]	PET-CT imaging studies	AIM annotations	+	-	+	+	Protégé, RDF/OWL, ePad, SPARQL
[13]	NCI, caBIG	AIM , RadLex MIAME project	+	-	+	+	Protégé, DICOM, HL7 CDA (XML), OWL

Various research works deal with the problem of modeling liver cancer diseases by the use of semantic representation. They take into account the importance of knowledge engineering in supporting clinical decision.

⁸ <https://wiki.nci.nih.gov/display/AIM/Annotation+and+Image+Markup+-+AIM>

3.2.1. Ontology for liver cancer staging

To classify liver cancer, [16] [18] [24] and [30] used the (Tumor, Node, Metastasis) TNM system. [16] presented an ontology-based approach dedicated to liver cancer diagnosis. The basic concepts included here are symptoms, risk factors, diagnosis *via* clinical tests and medical imaging, predicting the existence of the liver cancer and extracting its stage (*e.g.* localized, regional or distant). Liver diagnosis is presented by including the classes: Risk Factor, Symptoms, Diagnosis, Treatment, Investigation, and Prognosis of Liver Cancer. To manipulate and acquire data inside the ontology SPARQL⁹ is applied. [18] created web application designed to enable easily the extraction of liver-related information. It ensured a valid source of information. It can be visited by users and researchers supporting medical fields. [24] proposed an application dedicated to cancerous tumors classification. A TNM-Ontology (TNM-O) has been developed. The data must be included through graphical demonstrators or tables of information. Classification part begins by creating a RDF file that contains all individuals of the ontology. [30] is also applied to extract malignant tumors stages. AbdelBadih *et al.*, [17] summarized works done by the same authors in the field of integrated knowledge engineering for liver cancer diagnosis. The general idea is to improve ontological engineering efficiency to solve medical informatics issues. Among these works, [19][20][21][22].

In [19], the main idea is to present viral hepatitis through an OBR (Ontology of Biomedical Reality)-based Ontology for Viral Hepatitis. Three main aspects were followed in this approach: (i) medical terms extraction; (ii) liver diseases classification; (iii) a validation phase. Additionally, [21] offered a service that details liver diseases, diagnosis process and suitable treatment. Viral Hepatitis Ontology Sharing and Diagnosis (VHOSWS) implementation goes through two necessary components; (1) developing an ontology-based Web service (2) offering a shareable application between physicists, doctors and students. Results were returned in OWL files that contain full description for viral hepatitis, symptoms, signs and clinical findings. [22] gave an overview about medical ontologies focusing generally on cancerous diseases. This work is based on classification systems that extract patient related tumor type, the stage and the adequate treatment that can be applied after. Three essential modules were followed: (1) diagnostic module; (2) staging module; and (3) processing module. In [23], there is a presentation of Liver Immunology Ontology (LIO) Ontology. It provided information describing immunological reactions in the context of liver cancer. The development of LIO starts by (i) extracting ontological terms from related works dealing with the same problem gender, (ii) giving more expressiveness to the extracted words and (iii) combining the selected terms with extracted terms to form detailed descriptions. Additionally, [20] presented a classification system for liver diseases based on the previous developed ontologies like VHOSWS [21] and LIO [23]. This work described a global view of the hepatobiliary system including liver organ. It exposed also studies allowing liver disease classification. Several authors have attempted to apply ontologies to classify patients [26][30] and [31]. These approaches are intended to automatically classify real patient cases. To this end, they used diagnosis criteria to successfully classify diseases. Table 4 exposes these approaches.

Table 4. Ontology for liver cancer staging

Approach	RQ1	RQ2	RQ3	RQ4	RQ5	RQ6	RQ7
[16]	Medecine.net Cancer.org Indiahospitaltour.co m Healthline.com	-	+	-	+	+	SPARQL, OWL, Protégé
[17]	Cancer.Net, MedicineNet, NCI	-	+	-	+	+	Protégé-OWL
[18]	MedicineNet CancerNet, NCI	-	+	-	+	+	Protégé-OWL OWL-DL
[19]	Domain experts and Medical books	OBR	+	-	+	+	Protégé, OWL
[20]	N/A	-	+	-	+	+	Protégé,XML

⁹ <http://www.w3.org/TR/rdf-sparql-query>

							RDF(S), DAML+OIL OWL
[21]	Web	-	+	VHOSW S	+	+	OWL, C#, ASP.NET
[22]	Medical databases	-	+	-	-	+	Protégé, OWL API, IDE, Fact++, OWL- DL
[23]	NCBO	OBO, FMA, CO, PRO, CO : CC, GO :BP	+	LIO	+	+	Protégé
[24]	Hospitals	FMA, BioTopLite 2	+	TNM-O	+	+	OWL-API Java Hermit reasoned
[26]	Medical databases	Chinese library classificatio n (CLC) MeSH	+	Hepatitis Ontology	+	+	OWL, Protégé,
[30]	Stanford University	ePAD, AIM	-	-	+	+	OWL SPARQL SWRL
[31]	ASAS	-	+	-	+	+	OWL 2.0, Protégé 4.1, OWL-DL 2.0, Hermit 1.2.2 reasoner

3.2.2. Ontology for other medical issues

In this category, we present works that have integrated ontologies for various clinical issues. [25] proposed a method allowing the semantic representation of medical data. This work has two main objectives: (1) saving the common data extracted from a DICOM file as an RDF file, (2) calculating medical images biomarkers and saving them as a RDF file. [27], presented a treatment approach based on holistic information processing in order to get a surgical decision support. This work presented a formalized patient model to achieve a solid treatment process. [28] used Case Retrieval in Radiology (CaReRa) project, which includes Clinical Experience Sharing (CES) concepts, to treat liver cancer. Among the accomplishments of this project, the generation of the ontology ONLIRA. This work is based on real cases of patients and it is intended to test semantic annotation level of medical observations. The test is performed on portions of liver CT images based on the Computer Generated (CoG) features. [29] proposed Liver Case Ontology (LICO) ontology to model real cases of patients infected by liver diseases. This approach reused medical terminologies and vocabularies (*e.g.* ICID-10-CM, SNOMED-CT, ONLIRA, RadLex, and The Logical Observation Identifier Names and Codes (LOINC)¹⁰). To achieve this approach, these steps were followed: (i) modeling the ontology, (ii) validation of LiCO and (iii) testing with reasoning queries. For each studied patient case, authors have collected large quantity of information that mainly concern the medical history (*e.g.* previous surgeries, *etc.*), blood tests results, radiological observations, liver and lesion. [32] and [33] provided respectively large databases of clinical data through LiverAtlas and Drug-induced liver injury (DILIO) Ontologies. They are dedicated to cover liver diseases data, identifying hepatic lesions markers [32], and describing liver injuries [33]. [34] outlined the important role of knowledge engineering representation on clinical research. Table 5 gives a summary of these works.

Approach	RQ1	RQ2	RQ3	RQ4	RQ5	RQ6	RQ7
[25]	DICOM data	Dcm4che	-	-	+	+	RDF, SPARQL, Java

¹⁰ <https://loinc.org/>

[27]	Case Based Reasoning (CBR) database	LOINC, SNOMED	+	-	+	+	RDF
[28]	Medical images (CT)	ONLIRA	+	-	+	+	-
[29]	Medical imaging, radiological reports	SNOMED-CT, LOINC, ICD-10-M, ONLIRA, RadLex	+	LiCO	+	+	Protégé, SWRL SPARQL, OWL
[32]	Medical terminologies	DO, MeSH, UMLS, SNOMED-CT, ICD-10	-	LiverAtlas HulDO (Human Liver Disease Ontology)	+	+	-
[33]	US Food and Drug Administration (FDA) Histopathological Reports	UMLS SNOMED	+	DILIO	+	+	Protégé OWL
[34]	-	CLC (Chinese library classification) Mesh	+	+	+	+	Protégé 3.4.1 OWL Jena environnement

Table 5. Ontology for other medical issues

3.3. Ontology for radiological report examination

This category outlines approaches that have integrated ontological models to analyze and organize medical reports. The goal is offering large databases of clinical information and tool. Two parts in this category: (1) modeling HCC reports and (2) Modeling other liver diseases' reports.

3.3.1. Modeling HCC reports

Modeling HCC reports via semantic representation is the objective of this section. In this context, [35][36] and [37] presented ontological approaches to analyze medical reports. For [35], it proposed an Electronic Health Record (EHR) based system dedicated to deal with medical data. Three phases in this approach (1) collecting real radiological reports tacked randomly (2) extracting information from the treated cases and (3) clinical terms were extracted according to SNOMED CT vocabulary. In this work, authors used 112 abdominal CT images; 59 images referring to HCC metastases and 53 classified as No Abnormality Detected (NAD) group. The proposed system has generated 30 concepts. Among these concepts: Abdominal organ finding, Blood vessel finding, Disorder of digestive system, Disruption of body system, *etc.* The comparison step generated two groups of terms respectively connected to the HCC and NAD groups. In the case of HCC, the system offered clinical guides to add decision support tools including the treatment to be applied. The accuracy and the sensitivity reached respectively 88.4% and 84.7%. [36] also developed the ontology Medical reports ontology (MROnt) to analyze medical reports. It used semantic meaning of reports to analyze medical reports for MRI patient exams. The proposed approach is composed of two major steps: (1) the reports modeling step includes the ontological model MROnt, (2) the report analyzing step. In [37], the applied technique consists in identifying textual expressions describing real entities. This work proposes an algorithm that takes a tumor as an input and carries

out features (*e.g.* size and stage). Other informations were indented to be extracted like the largest malignant tumor, nodule number and if 50% of the liver was damaged or not. This approach used American Joint Committee on Cancer (AJCC), Barcelona Cancer of the Liver Clinic (BCLC), and Cancer of the Liver Italian Program (CLIP) as classification systems. A database containing 101 abdominal radiology reports was prepared for 160 patients suffering from HCC. This database contains globally 3211 entities, 2283 relationships and 1006 tumor models. These reports are annotated using 7 entities (*e.g.* Anatomy, Measurement, Tumor reference, *etc.*). Relationships were applied to link these entities. To annotate radiological reports two types of semantic expressions were included, they are coreference and particularization. To annotate the reference resolution, the approach uses the following annotators MUC, B-cubed and CEAF. Table 6 illustrates this category of works.

Table 6. Ontology for radiological report examination

3.3.2. Modeling other liver diseases' reports

This category is dedicated to present works that have focused on ontologies for radiological reports examination. [38] and [10] presented both ontological prototypes for modeling liver reports. [38] developed an ontology-based application named the Radio Ontology (RadiO) to examine radiological reports. The first step is collecting radiological observations noted by radiologists while diagnosing patients. The second step representing knowledge about medical images entities and their characteristics. Finally, an FMA-based ontology was created in order to provide a structured knowledge base of medical imaging. In [10], the goal is modeling medical CT reports. This approach realized standard vocabularies of the clinical terms. It extracted medical terminologies from RadLex vocabulary [1]. The method is based on three main steps: (i) radiological representation of concepts, (ii) individual properties extraction (*e.g.*, liver size and density), and (iii) relationships construction. Among the used concepts, we find: 'Liver', 'Lesion' and "HepaticVascularity". To evaluate this approach, 30 radiological reports related to different patients were transformed as instances of the ontology. A list of queries was prepared to manipulate the data applying Natural Language Processing (NLP) techniques. This ontology is named Ontology of Liver for Radiology (ONLIRA)¹¹ and it has been validated by experts.

Other works such as [39] [40][41][42] have focused on offering a standard vocabularies for clinical reports. [39] used NLP techniques to solve research problems in clinical routines. To achieve this goal, ontology has been integrated to realize clinical terminologies recognition and standardization. In the same context, [40] proposed a processing framework for Acquiring Medical and Biological Information from Text (AMBIT) system.

Approach	RQ1	RQ2	RQ3	RQ4	RQ5	RQ6	RQ7
[35]	Radiology reports	SNOMED, EHR, PubMed	-	-	+	+	UMLS, Brat Software
[36]	Radiology reports	-	+	MROnt	+	+	Protégé SWRL OWL
[37]	Abdominal radiology reports	MetaMap WordNet	-	-	+	+	UMLS

It is a text analysis system, dedicated to extract clinical information from medical and biomedical documents. Also, it integrated Information Technology (IT) aspects. Subsequently these insertions will be saved in a well structured format for clinical purposes. It is based on two aspects: a terminology engine named Termino and a query engine that allows users access to the saved information. AMBIT includes 160,000 terms imported from UMLS. 83 examples of radiology reports describing lung cancer are applied to test the effectiveness of this system. [41] proposed the Model for Clinical Information (MCI) system. The objective is offering a structural representation for radiologist's notes. It reused various ontologies (*e.g.* Relations Ontology (RO), Ontology for General Medical Science (OGMS), Information Artifact Ontology (IAO), the Ontology for Biomedical

¹¹ <https://bioportal.bioontology.org/ontologies/ONLIRACaReRa-WEB>

Investigations (OBI), FMA, *etc.*). This system contains 551 classes, 107 object properties and 33 datatype properties. [42] used biomedical ontologies to diagnoses several human diseases. This approach mapped the Radiology Gamuts Ontology (RGO) concepts to other ontologies (*e.g.* Disease Ontology (DO) and the Human Phenotype Ontology (HPO)) in order to characterize human diseases. Table 7 summarizes these works.

Table 7. Ontology for radiological report examination

4. Discussion

All the studied works deal with the topic of applying knowledge representation to medical issues especially for liver diseases representation. In fact, many current research works have generated prototypes such as ONLIRA [10], LiCO [29], VHOSWS [21], HulDO [32], and LIO [23]. To validate these approaches, there exist several followed techniques to improve the proposed work efficiency. Some works try to use standard measurements such as recall and accuracy percentages, techniques used by [35] and [12]. Other works test their approaches with real data extracted mainly from clinical and medical sources. Furthermore, querying and manipulating the ontology by integrating semantic search queries (*e.g.* SPARQL rules, *etc.*) are also applied in [10][16][37].

In the context of liver diseases modeling, some research works have presented a comparison of medical ontologies. Among these works, we find [43]. It takes into account different medical care ontologies and classifies them depending on the topic usage percentage (*i.e.* diseases, cancer). Then, we choose nine accessible ontologies that deal with liver cancer representation. These ontologies are Hepatitis Ontology [26], LiCO [29], ONLIRA [10], LIO [23], Web-based liver cancer ontology [18], OBR Viral Hepatitis [19], DILIO [33], Liver Cancer ontology [18], HuLDO [32], OntHCC [9] and MRont [36]. After that, we eliminate HuLDO [32] ontology from the comparative study because we did not find a clear representation of its conceptual architecture. Also, for LIO [23] ontology, we used just its accessible concepts. Table 8 presents the applied

Approach	RQ1	RQ2	RQ3	RQ4	RQ5	RQ6	RQ7
[38]	Radiology reports	RadLex, FMA	+	RadiO	+	+	Protégé
[39]	Radiology reports	SNOMED-CT	-	-	+	+	CLEF myGrid
[40]	Radiology reports	UMLS, HUGO Gene Nomenclature database	-	AMBIT	+	+	-
[41]	Radiology reports	OBO, RO, OGMS, IAO, OBI, PATO,UO FMA	+	MCI ReportViewer	+	+	SPARQL RECISt
[42]	Radiology reports	RGO,HPO, DO,	+	-	+	+	NCBO Annotator
[10]	Radiological reports	RadLex	+	ONLIRA	+	+	OWL

ontologies.

Table 8. Concepts of used ontologies

Ontology	Hepatitis Ontology	ONLIRA	LiCO	LIO	Web-Based Liver Cancer	OBR Viral Hepatitis	DILIO	Liver Cancer ontology [18]	OntHCC [9]	MRont [36]
Number of Concepts	44	56	93	49	25	15	200	42	49	22

To compare these ontologies, we focus on common concepts in order to visualize their similar aspects. Figure 1 exposes our comparing study. Among common concepts shared between ontologies, we find for example “Acute Hepatitis”, “Chronic Hepatitis” and “Viral Hepatitis” which are used respectively by Hepatitis Ontology and DILIO. Furthermore, “Treatment”, “RiskFactors”, “Diagnosis”, “Symptoms” and “LiverCancer” concepts are used commonly by Web-based liver cancer and Liver Cancer ontologies. There exist different concepts which are written in different ways but they refer to the same context such as “LabResults” and “Laboratoryresults” related to LiCO and OBR Viral Hepatitis ontologies. Moreover, we find that all ONLIRA concepts are included in LiCO ontology. To focus on the most applied concepts between all ontologies, we propose another comparative study that outlines these concepts. Figure 2 presents the common concepts applied in different ontologies. According to our study, we conclude that the most useful concepts are “TypesLiverDisease”, “RiskFactors” and “Symptoms” because they have the highest frequency rate. Moreover, to enrich our comparative study, we calculated for each used ontology the percentage of its correspondence with the rest of ontologies. The findings are shown in Figure 3.

Fig.1 Assessment of liver diseases’ ontologies

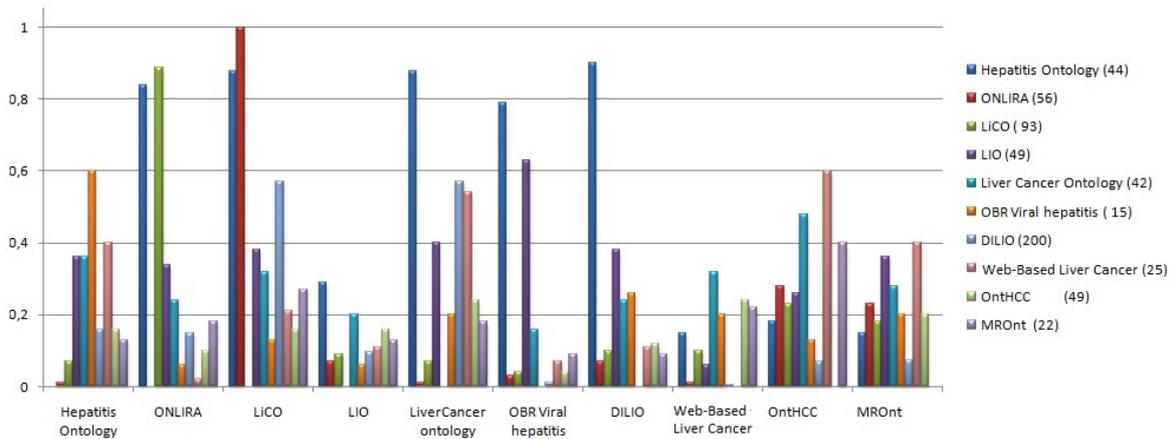


Fig. 2 Concepts usage frequency

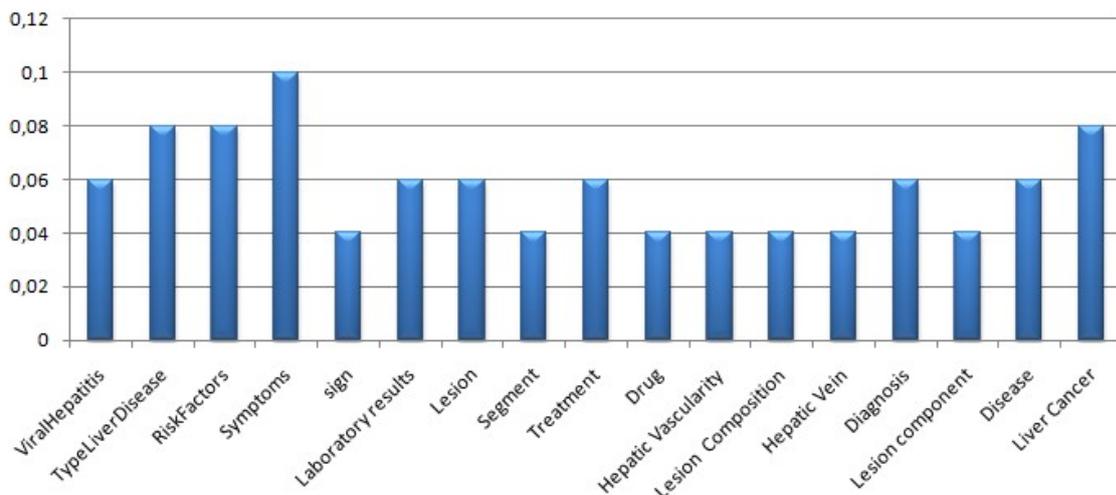
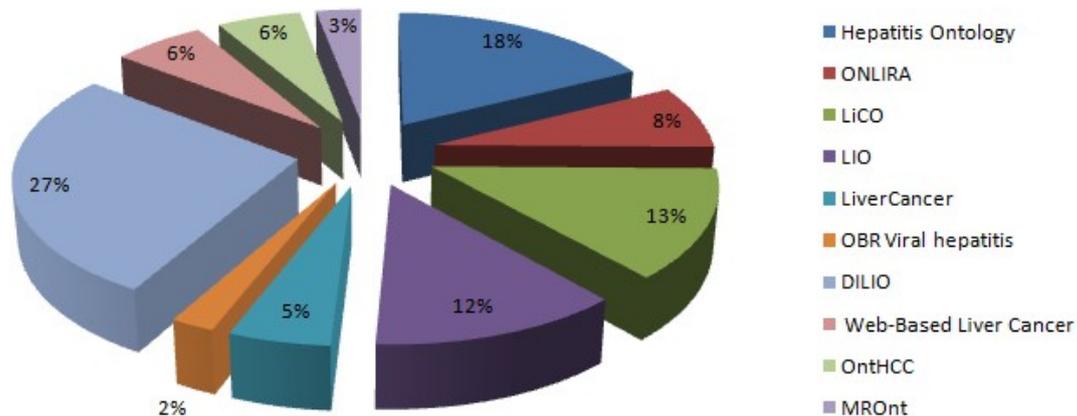


Fig. 3 Ontology correspondence percentages



5. Conclusion

This paper is dedicated to making an overview of liver disease representation by means of medical ontologies. This type of cancer is considered among the most deadly diseases in the world. Its importance and impact make this tumor an interesting subject for plenty of works. All the studied works improve the importance of semantic knowledge to treat medical areas and realize clinical accomplishments.

Our goal was looking for these works and comparing the different proposed issues by using some comparative criteria (*e.g.* tools, languages, prototypes). Also, this paper discusses how ontologies can facilitate communication between the whole medical staff. Ontologies were introduced in the most parts of the disease diagnosis such as the therapy process and behave additionally as a decision support system. In this article, we choose recent ontologies that deal with the topic of liver diseases representation via semantic models. We presented a conceptual comparison in order to provide the most relevant ontology as show in the obtained findings.

As future works, we aim to stand up our approach and overpass the gaps of currents works. We will concentrate on the topic of applying semantic models for liver cancer extraction from medical imaging (*e.g.* MRI and CT). The goal is to develop a tool that can be used by radiologists and doctors to assist on liver diseases detection.

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References:

1. Kundu CP, Itkin S, Gervais M, Krishnamurthy DA, Wallace VN, Cardella JF, Rubin DL, Langlotz CP: The IR Radlex Project: An interventional radiology lexicon—A collaborative project of the Radiological Society of North America and the Society of Interventional Radiology. *J. Vascular Interven. Radiol* 20:433-435, 2009
2. Bodenreider, O: The Unified Medical Language System (UMLS): integrating biomedical terminology. *Nucleic Acids Research* 37, 267-270, 2004
3. Kitchenham, B.: Procedures for performing systematic reviews. Keele University, Tech. Rep., 2004
4. Gurcan, MN, Tomaszewski J, Overton JA, Doyle S, Ruttenberg A, Smith B: Developing the Quantitative Histopathology Image Ontology (QHIO): a case study using the hot spot detection problem. *Journal of Biomedical Informatics* 66:129-135, 2017

5. Othmani A, Meziat C, Loménie N: Ontology-driven Image Analysis for Histopathological Images. Int. Symposium on Visual Computing ISVC'10, Lecture Notes in Computer Science, vol 6453. Springer, Berlin, Heidelberg 1-12, 2010
6. Kumar A, Dyer S, Kim J, Li C, Leong PHW, Fulham M, Feng D: Adapting content-based image retrieval techniques for the semantic annotation of medical images. *Computerized Medical Imaging and Graphics* 49:37-45, 2016
7. Hudelot C, Atif J, Bloch I: Fuzzy spatial relation ontology for image interpretation. *Fuzzy Sets and Systems* 159:1929-1951, 2008
8. Möller M, Regel S, Sintek M: Radsem: Semantic annotation and retrieval for medical images. In: *The Semantic Web: research and applications*. Springer 21-35, 2009
9. Messaoudi R, Jaziri F, Mtibaa A, Grand-Brochier M, Mohamed Ali H, Amouri Ali, Fourati H, Chabrot P, Gargouri F, Vacavant A: Ontology-Based Approach for Liver Cancer Diagnosis and Treatment, *Journal of Digital Imaging* 32:116-130, 2019
10. Kokciyan N, Turkay R, Uskudarli S, Yolum P, Bakir B, Acar B: Semantic description of liver CT images: an ontological approach. *IEEE J Biomed Health Inform* 18:1363-369, 2014
11. Depeursinge A, Kurtz C, Beaulieu C, Napel S, Rubin D: Predicting Visual Semantic Descriptive Terms From Radiological Image Data: Preliminary Results With Liver Lesions in CT. *IEEE Transactions On Medical Imaging* 33:1669-1676, 2014
12. Hwang KH, Lee H, Koh G, Willre D, Rubin DL: Building and querying RDF/OWL database of semantically annotated nuclear medicine images. *Journal of Digital Imaging* 30:4-10, 2017
13. Rubin DL, Mongkolwat P, Kleper V, Supekar K, Channin DS: Medical Imaging on the Semantic Web: Annotation and Image Markup. in *AAAI Spring Symposium: Semantic Scientific Knowledge Integration* 93-98, 2008
14. Gibaud B, Forestier G, Benoit-Cattin H, Cervenansky F, Clarysse P, Friboulet D, Gaignard A, Hugonnard P, Lartizien C, Liebgott H, Montagnat J, Tabary J, Glatard T: OntoVIP: an ontology for the annotation of object models used for medical image simulation. *J Biomed Inform* 52: 279-292, 2014
15. Seifert S, Thoma M, Stegmaier F, Hammon M, Kramer M, Huber M, Kriegel HP, Cavallaro A, Comaniciu D: Combined semantic and similarity search in medical image databases. *SPIE Med Imaging* 7967:03-10, 2011
16. Parminder K, Khamparia A: Diagnosis of liver cancer ontology using SPARQL. *International Journal of Applied Engineering Research* 10:15-18, 2015
17. Abdel-Badeeh MS, Mostafa MA, Moawad IF, Alfonse M, AlMarzoki G: Ontological Engineering in Medical Informatics. *International Journal of Genomics, Proteomics, Metabolomics & Bioinformatics (IJGPMB)* 1:9-13, 2016
18. Alfonse M, Aref MM, Abdel-Badeeh MS: Ontology-Based Knowledge Representation for Liver Cancer. *International eHealth: Telemedicine and Health ICT Forum for Educational, Networking and Business, Luxembourg* 821-825, 2012
19. Moawad IF, AlMarzoqi G, Abdel-Badeeh MS: Building OBR Based OWL Ontology for Viral Hepatitis, *Egyptian Computer Science Journal* 36:89-98, 2012
20. AL-Marzoqi G, Alfonse M, Moawad FI, Roushdy M: A survey on Applying Ontological Engineering: Approach for Hepatobiliary System Diseases. *The 7th International Conference on Information Technology* 370-375, 2015
21. ALMarzoqi G, Moawad IF, Abdel-Badeeh MS: Web Service Based Approach for Viral Hepatitis Ontology Sharing and Diagnosing. *AMLTA* 257-266, 2012
22. Alfonse M, Mahmoud Aref M, Abdel-Badeeh MS: An Ontology-Based System for Cancer Diseases Knowledge Management. *I.J. Information Engineering and Electronic Business* 6:55-63, 2014
23. Masci AM, Roach J, de Bono B, Grenon P, Cowell L: Bridging Multiple Ontologies: Representation of The Liver Immune Response. *International Conference on Biomedical Ontologies (ICBO), Buffalo, NY, USA, Working with multiple Biomedical Ontologies Workshop*, 393-398, 2011
24. Franca F, Schulz S, Bronsert P, Novais P, Boeker M: Feasibility of an ontology driven tumor-node-metastasis classifier application: A study on colorectal cancer," in *Innovations in Intelligent Systems and Applications (INISTA), 2015 International Symposium on* 7 pages, 2015

25. Van Soest J, Lustberg T, Grittner D, Marshall MS, Persoon L, Nijsten B, Feltens P, Dekker A: Towards a semantic PACS: Using Semantic Web technology to represent imaging data, *Stud Health Technol Inform* 205:166-170, 2014
26. Yunzhi C, Huijuan Lu, Shapiro L, Travillian RS, Lanjuan L: An approach to semantic query expansion system based on Hepatitis ontology. *Journal of Biological Research-Thessaloniki* 23:11 pages, 2016
27. März K, Hafezi M, Weller T, Saffari A, Nolden M, Fard N, Majlesara A, Zelzer S, Maleshkova M, Volovyk M, Gharabaghi N, Wagner M, Emami G, Engelhardt S, Fetzer A, Kenngott H, Rezai N, Rettinger A, Studer R, Mehrabi A, Maier-Hein L: Toward knowledge-based liver surgery: holistic information processing for surgical decision support. *International Journal of Computer Assisted Radiology and Surgery* 10:749-759, 2015
28. Marvasti NB, Kökciyan N, Türkay R, Yazici A, Yolum P, Üsküdarli S, Acar B: ImageCLEF Liver CT Image Annotation Task 2014. in: *CLEF 2014 Working Notes*, vol. 1180 of *CEUR Workshop Proceedings*, 329-340, 2014
29. Roldán-García MM, Uskudarli S, Marvasti NB, Acar B, Aldana-Montes JF: Towards an Ontology-Driven Clinical Experience Sharing Ecosystem: Demonstration with Liver Cases, *Expert Systems With Applications*, 10 pages, 2018
30. Luque EF, Rubin DL, Moreira DA: Automatic classification of cancer tumors using image annotations and ontologies. In *Proceedings - IEEE Symposium on Computer-Based Medical Systems* 368-369, 2015
31. Bertaud-Gounot V, Duvaufferrier R, Burgun A: Ontology and medical diagnosis, *Informatics for Health and Social Care* 37:51-61, 2012
32. Zhang Y, Yang C, Wang S, Chen T, Li M, Wang X, Li D, Wang K, Ma J, Wu S, Zhang X, Zhu Y, Wu J, He F: LiverAtlas: a unique integrated knowledge database for systems-level research of liver and hepatic disease. *Liver International* 33:1239-1248, 2013
33. Wang Y, Lin Z, Liu Z, Harris S, Kelly R, Zhang J, Ge W, Chen M, Borlak J, Tong W: A Unifying Ontology to Integrate Histological and Clinical Observations for Drug-Induce Liver Injury. *The American Journal of Pathology* 182:1180-1187, 2013
34. Fung KW, Bodenreider O: Knowledge Representation and Ontologies. In: Richesson R., Andrews J. (eds) *Clinical Research Informatics. Health Informatics*. Springer, Cham 313-339, 2019
35. Chan LWC, Wong SC, Chiau CC, Chan TM, Tao L, Feng J, Chiu KWH: Association Patterns of Ontological Features Signify Electronic Health Records in Liver Cancer. *Journal of Healthcare Engineering* 9 pages, 2017
36. Messaoudi R, Labidi T, Vacavant A, Gargouri F, Grand-Brochier M, Amouri A, Fourati H, Mtibaa A, Jaziri F: An Ontological Model for Analyzing Liver Cancer Medical Reports. *EMCIS 2018. Lecture Notes in Business Information Processing*. Springer 341: 369-382, 2018
37. Yim WW, Kwan SW, Yetisgen M: Tumor reference resolution and characteristic extraction in radiology reports for liver cancer stage prediction. *J Biomed Inform* 64:179-191, 2016
38. Marwede, D., Fielding, M., and Kahn, T.: RadiO: A Prototype Application Ontology for Radiology Reporting Tasks. *AMIA Symposium Proceedings* 513-517, 2007
39. Starlinger J, Kittner M, Blankenstein O, Leser U: How to Improve Extraction from German Medical Records. *it-Information Technology* 8 pages, 2016
40. Harkema H, Roberts I, Gaizauskas R, Hepple M: Information extraction from clinical records. In: Cox SJ, Walker DW, editors. *Proceedings of the UK escience all hands meeting 2005*, Nottingham, UK 254-258, 2005
41. Oberkampff H, Zillner S, Overton JA, Bauer B, Cavallaro A, Uder M, Hammon M: Semantic representation of reported measurements in radiology. *BMC Med Inform Decis Mak*: 16:12 pages, 2016
42. Finke MT, Filice RW, Kahn Jr CE: Integrating ontologies of human diseases, phenotypes, and radiological diagnosis. *Journal of the American Medical Informatics Association* 26: 149-154, 2019
43. Kaur P, Khamparia A: Review on Medical Care Ontologies. *International Journal of Science and Research (IJSR)* 3:677-680, 2014