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An Efficient Ontology Based Drug Prescription Model

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***Abstract*—Medication is a process of prescribing medicines by knowledgeable physicians. Medicines which are not prescribed when consumed may generate side effects. Some diseases require more than one drug to control the disease. If drugs are not carefully prescribed adverse reactions may happen. Meny people died due to medical errors in prescribing medicines by medical practitioners based on their experience. For avoiding all these adverse effects, we need a recommendation system or a decision support system for efficiently prescribing medicines. Many parameters need to be considered before prescribing the medicines like patient's age, medical history, side effects of drugs, possible allergies, drug-drug interactions, drug-disease interactions and drug-food interactions. Semantic web provides tools and technologies like ontologies to construct recommendation models and can retrieve data using tools like SPARQL and inference mechanisms to infer new knowledge.**

***Index Terms*—drug, medicine, prescription, ontology, interactions.**

I. Introduction

Medicine Recommendation System will give a list of drugs for patients according to their needs or according to diagnosed disease [11]. For the treatment of chronic disease or non-communicable diseases (NCDs) like Diabetes, cardiovascular diseases, and hypertension physicians prescribe more than one medicine and for some diseases like type 2 diabetes doctors may have various options to select drugs to prescript [10]. Sometimes patients can have comorbidities i.e., having more than one disease. Controlling these comorbidities is a challenging task. Medication has to be given frequently like mostly for six months or more. During treatment the patients may asked to undergo some pathological tests. Based on the results drug prescription will be given by considering various parameters. During treatment the prescribed dosage of drugs or may be the drugs can be changed based on pathological results [9]. And one more challenging thing in prescribing medicine is that every year a number of new medicines are released [12]. Hence prescribing medicines is a complex task. For efficient prescription of medicine various information is needed like medical history, drugs currently consuming, Allergies, diagnosis, laboratory results as well as personal information like age, blood group, communication details of patients and care givers [9]. Electronic Health Records (EHR) will contain information of patient. This EHR data can be used for efficient prescription of medicine. And some authors have used ontologies for patient information. Exiting medication recommendation models are MEDBOWLI, MedFinder, GaLenOWL, SemMed and ODDx.

The remaining paper is structured as follows. In section II we discussed semantic web technologies and its standards like ontologies and Knowledge bases. Parameters needed for effective prescription of medicine is discussed in section III. A brief literature survey is given in section IV. Section V contains observation and analysis of studied literature. In section VI we have proposed a knowledge base using various ontologies for effective prescription of medicine. In section VII we have concluded.

II. Semantic Web and Standards

Tim Berners-Lee coined the idea semantic web, which was named as web 3.0. His idea is to build a mechanism for data integration and sharing, where data is scattered on the web. In semantic web the web of documents is replaced web of data [6]. Links are given to data elements on the web page which also called as web of linked data along with semantics. This forms a semantic network which is used to build intelligent applications [1]. Semantic web uses various standards defined in W3C like RDF, RDFS, SPARQL, SWRL, Ontologies, Knowledge bases and Inference engines.

A. Ontology

Semantic web allows data to be integrated from different resources and allows to share. This integration of data from various sources forms an ontology [14]. Ontology consists of features of Artificial intelligence and machine learning [10]. Ontologies are used to describe the knowledge or concepts in a given domain. Ontology describes vocabulary, which is used by researchers to share information in a particular domain. Ontology contains machine interpretable definitions of concepts and relationships among concepts. An ontology consists of classes (concepts), sub classes, instances of classes, properties of a class, and rules on properties. Ontology is created using Web Ontology Language (OWL) which is XML based. The rules are written using RDF syntax using Semantic Web Rule Language (SWRL). The complete domain ontology provides complete information of the domain [3]. Information can be shared and retrieved using SPARQL query language. New information can be inferred using inference engines like JESS, Hermi T reasoner. Ontologies can also be used for various purposes like linking data, data sharing and reuse, decision support using knowledge bases, databases using XML schema and Natural language processing. Many ontologies for medical information are created like Biological Pathways Exchange

(BioPax), SNOMED-CT, GALEN ontology, Gene Ontology and Foundation Model of Anatomy (FMA). These ontologies constructed using standards like BIO Portal, OBO Foundry and ONIONS (Ontological Integration of Naïve Sources).

B. Knowledge Base

Ontology along with a set of instances of classes forms a knowledge base. Ontology is a part of knowledge base or knowledge base starts with an ontology. Ontologies and knowledge bases may already exist in electronic form, which can be imported and reused in other applications. Knowledge bases organizes the data as human brain organizes information. Knowledge base allows storage, analysis and reuse of knowledge such that a machine can interpret. Knowledge Base helps search engines and other content retrieval applications to retrieve text and interpret results to advanced queries and helps in decision making by retrieving efficient knowledge. There is an inference layer built on top of knowledge base which is a series of rules and statistical models for interpreting information which helps machines to derive knowledge from Knowledge bases. Knowledge bases can be constructed using graph databases. Graph databases uses W3C standards for describing data and semantics like RDF, SPARQL and SKOS.

III. Parameters to be Considered for Drug Prescription

Medication recommendation system allows physicians to prescribe medicines efficiently by considering various parameters like drug side effects, reactions and risks to patients by considering interaction of drugs with other drugs, diseases and foods. This type of considerations helps the physician to prescribe safe drugs [27].

A. A. Drug Side Effects

Drug side effects are known to physicians in advance and patients will be informed about the side effects which they may have to face during treatment. Side effects will resolve as the medication is continued for days, weeks or even months. For example, cetirizine medicine which is used to cure allergies and running nose can have side effects of causing drowsiness [21]. Some drugs can be used due to their side effects. For example, the anoxeric patients who have low body weight due to eating disorders when consumes mirtazapine whose one of the side effects is weight gain can improve their body weight. Generally, mirtazapine is an antidepressant [21]. Medicines are tested for side effects before they are launched into the market.

B. B. Adverse Drug Reactions (ADR)

ADR is harmful and unintended reactions which occurs due to medical error, misuse or abuse and usage of unlicensed medicine [19][20]. ADR identifies drugs which should be prevented from future usage or alteration of dosage and withdrawal of the drug. The drugs which cause ADR are generally anti diabetic, antibiotics, anticoagulants and cytotoxins. For example, the fatal ADR of consuming anticoagulant with non-steroidal anti-inflammatory drug (NSAID) may cause hemorrhage [19]. ADRs can be prevented by careful monitoring of previous medication histories to find any such ADRs of prescribed medicines. If it is found these drugs has to be changed to prevent future ADRs. In [7], authors have developed a machine learning and rule-based model for predicting Adverse Drug Reactions (ADR) by considering the drug labels. Authors have used Medical Directory for Regulatory Activities (MedRA) for normalization.

C. Drug-Drug Interactions (DDI)

DDI is complex and causes Adverse Drug Events (ADE). In some cases, DDI are intended. Unintended DDIs are very harmful and even can cause deaths [17]. Allergies due to interactions with drug compounds of previously consumed medicines existing in patient's body with currently consumed medicines can occur. And Even drugs prescribed for controlling any disease can also interact with each other. Drugbank is an online repository which can return drug-drug interactions of at most five drugs [15]. A knowledge base with DDI included ADE can be used as decision support systems for prescribing drugs [17]. For example, the drug Abilify which is also called as aripiprazole which is used to treat the symptoms of psychotic conditions known as schizophrenia. This medicine works by changing the actions of chemical in the brain. When this medicine combinedly consumed with Ativan which is also known as lorazepam which is used to treat anxiety disorders will increase the central nervous system depression. The authors in [16] used data from mayo clinic to find drug-drug interactions for three cardiovascular diseases and verified on Drugbank.

D. Drug-Disease Interactions

Most of the diseases require more than one drug to cure it. According to a study people with age above 55 daily takes four medicines. Sometimes the consumed drugs may cause a new disease to born or worsen the condition of existing disease [4]. These are known as Drug Disease Interaction (DDSIs). For example, Donepezil medicine used treat Alzheimer's disease can cause 3 other diseases and can interact with 9 other drug substances [4]. DDSIs will occur due to negative effects of consuming poorly prescribed drugs. In this case it is necessary to avoid that drug or maximize the dose [18]. These types of drugs are known as contra indications. Managing DDSIs is needed in order to overcome serious harms and to prevent deaths.

E. Drug-Food Interactions

The effect of drugs consumed can also depend on foods and drinks. These interactions are known as drug-food interactions [27]. This is the reason why some medicines are asked to take with empty stomach. Some foods and beverages will decrease or delay the effects of medicines. This is the reason of prescribing medicines by limiting the foods and drinks. Drug and food interactions may cause serious side effects. For example, grape juice can interact with all types of drugs [27]. It changes the chemical reactions of drugs. Dairy products and drugs like antibiotics when consumed together can also have interactions. Antibiotics can prevent the absorption of calcium and magnesium of milk products [27]. Dairy products and calcium juices can decrease the absorption of antibiotic drugs like Ciprofloxacin [28]. Consuming Ance medicine with Vitamin A may cause liver failures [1].

IV. Literature Survey

In [1], authors have developed a website to promote safe medical consumption by constructing a medication ontology with 15 categories and 73 sub categories. Authors have not considered drug-drug interaction, reactions and side effects for prescribing medicine. In [2], authors have constructed a rule-based system by considering drug-drug interactions and possible allergies a patient may have due to consumption of the drugs. In [3] authors have developed an Anti-Diabetic Drugs Ontology and Patient Data Ontology for recommending medicines to diabetic patients. Authors have used SWRL for constructing rules and JESS inferring engine for reasoning. In [4], authors have developed a semantic web enabled online system GalenOWL for discovering drug-drug and drug-disease interactions and drug recommendations. The authors have constructed an otology using ICD-10 classification for diseases, and Unique Ingredient Identifier (UNII) to identify active ingredients of the drugs, and Anatomical Therapeutic Chemical Classification (ATC) for classification of drugs. For inferring drug-drug interactions and drug-disease interactions OWLIM reasoner was used. In [5], authors have developed an ontology named as Drug Ontology (DrOn) for providing consistent drug information. Authors have used RxNorm drug terminology constructed by National Library of Medicine (NLM). RxNorm contains several names and relations extracted from knowledge bases. In [6], authors have created an ontology for translational medicine. Translational medicine consists of data from private clinical domain and public pharmaceutical domain. Translational medicines fill the gap between basic research and clinical practice. In [8], authors have developed a recommendation system for anti-diabetic drugs based on the symptoms. Authors have used domain ontologies. They have constructed Anti Diabetic Medicine Ontology to store regulations of drugs from American Association of Clinical Endocrinologists Medical Guidelines for Clinical Practice for the Management of Diabetes Mellitus (AACEMG) and Patient Test Ontology. Authors have created rules of ontology using SWRL from data of AACEMG and used JESS inference engine to retrieve drug information without side effects. In [9], authors have developed an individualized recommendation model for type 2 diabetes. Authors pointed out that one common treatment model is not sufficient to treat any disease because of varying patient profiles, life styles, strengths, weakness, goals, patient's age, diseases duration and affordable cost [10]. Hence individual plan for recommending treatment is needed. Authors have developed two ontologies for patient profiles and anti-diabetic drugs. In [12], authors have constructed ontology-based recommendation model using an Electronic Prescription writer [EPW]. EPW interviews the patient regarding various health care primitives like previous medication, and whether they have mutual negative effects or negative effects with ongoing medications. And EPW prescribe dose of the medicine and may suggest new medicine based on the cost and patient's health condition. In [13], authors have constructed a multi evidence prescription recommendation model using two ontologies namely International Classification of Diseases (ICD) for classifying conditions of different diseases and Anatomical Therapeutic Chemical (ATC) for classifying drug ingredients and functions. Authors have used EHR for patient data. Authors have also used demographic and side effect information.

Following table represents the brief summary of studied literate.

TABLE I. Literature Survey of Medication Recommendation Models

Ref	Ontologies Used	Ontologies Constructed	Technologies Used	Limitations
[1]	Not Used	Medication ontology	OWL, Protégé, SPAQRL	Drug-Disease and Drug-food interactions are not considered.
[2]	Not Used	Rule based system	OWL, SWRL, ODDx inference engine	Not considered side effects, Drug-Disease, Drug-food interactions and adverse drug reactions.
[3]	Not Used	Anti diabetic Drugs Ontology, Patient Data Ontology	SWRL, JESS inference engine, Pellete, Protégé	Does not considered Side effects, Drug-Drug, Drug-Disease, Drug-Food interactions and Adverse Drug Reactions.
[4]	ICD-9, ATC, UNII	GalenOWL	OWLIME-Lite inference engine, SPARQL.	Does not considered drug side effects, and Drug-Food interactions.
[8]	Not Used	Anti Diabetic Medicine Ontology, Patient Test Ontology	SWRL, JESS inference engine, Pellete, Protégé	Does not considered Drug -Drug, Drug-Disease and Drug-Food interactions
[10]	Not Used	Patient Profile Ontology, Anti diabetic drugs Ontology	OWL, SWRL, JESS inference engine	Does not considered Drug -Drug, Drug-Disease, Drug-Food interactions and Adverse Drug Reactions
[12]	Not Used	Not Constructed	OWL	Does not considered Drug-Drug, Drug-Disease, Drug-Food interactions, Adverse Drug Reactions, and side effects.
[13]	ICD-9, ATC, UNII	Not Constructed	Not Used	Does not considered Drug-Disease and Drug-Food interactions.

V. Observation and analysis

From the above table we can analyze that authors have used SWRL for constructing rules, SPARQL queries for retrieving information and for inferencing new knowledge various inference engines like JESS, ODDx and OWLIME-Lite

are used. From the 8 articles only four authors of [1],[8],[10] and [13] considered side effects. Three authors [4],[8] and [13] have considered adverse drug reactions, authors of [2], [4] and [13] have considered Drug-Drug interactions, only one author in [4] have considered Drug-Disease interactions and none of the author has considered Drug-Food interactions as shown in below Fig. 1.

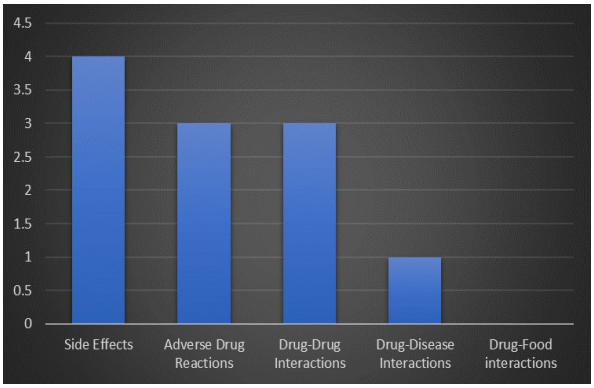

Fig. 1. Analysis of parameters considered

VI. Proposed Drug Prescription Model

Drugs can be efficiently prescribed by considering side effects, reactions, interactions of drug-Disease with drugs, disease and foods. For doing this we proposed to construct a knowledge base by considering various ontologies like Food Interactions with Drugs Evidence Ontology (FIDEO)[22], The Drug-Drug Interactions Ontology(DINTO)[23], Pharmacovigilance Ontology(PVONTO)[24], and other online materials like drugs.com for identifying side effects[25] and interaction checker at drugbank.com[26]. We can use inference engine like JESS to infer the information of drugs from constructed knowledge base. This mechanism is shown in following Fig. 2.

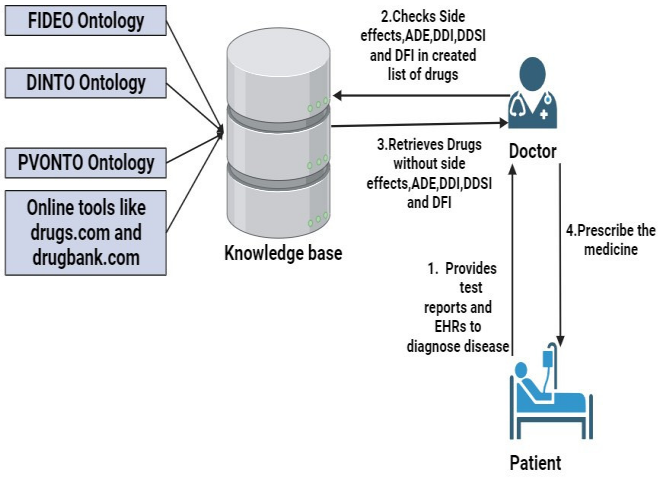

Fig. 2. Construction of knowledge base

The Proposed drug prescription model tries to prescribe drugs without interactions. The model works as follows.

- The physician diagnoses the disease and prepares a tentative list of drugs to prescribe.
- The Physician infers drug side effects information and removes those drugs from tentative list.
- The physician the infers adverse drug reaction (ADR)information of available drugs. If ADR is present those drugs are replaced or removed from tentative list
- Further the physician infers drug interactions like Drug-Drug, Drug-Disease and Drug-Food interactions one after another and removes or changes such drugs if any.
- Finally, physician gets a list of drugs which are safe to prescribe.

This working method is shown in following Fig. 3.

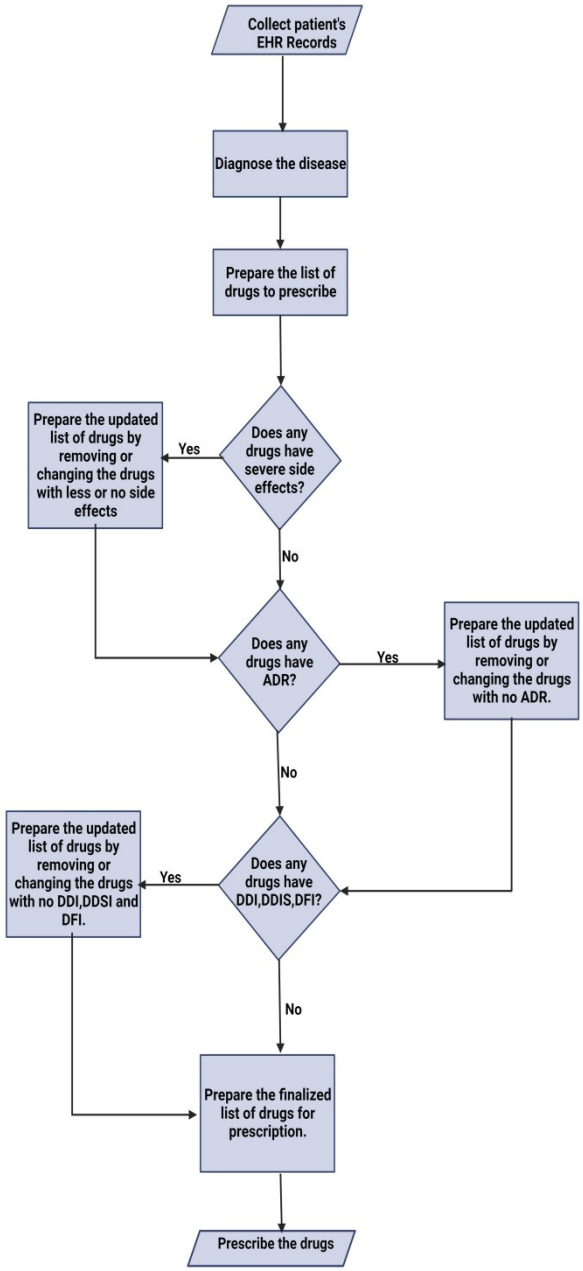

Fig. 3. Working flow of Proposed Drug Prescription model.

VII. Conclusion

In this article we have studied works of various authors in the field of drug prescription using semantic web technologies. We have identified very important parameters like Drug side effects, Adverse Drug Reactions, Drug-Drug,

Drug-Disease, Drug-Food interactions. The consideration of these parameters in prescription of drugs will help the physicians to effectively prescribe correct drugs. We also proposed a recommendation model for prescribing drugs by constructing one knowledge base by using various ontologies used in medical domain and information available on the websites. In future we try to implement proposed model by using various semantic web technologies.

REFERENCES

[1] Yoosooka, Burasakorn, and Suvil Chomchaiya. "Medication recommender system." in 2015 International Conference on Science and Technology (TICST), pp. 313-317. IEEE, 2015.

[2] Rodríguez, Alejandro, Enrique Jiménez, Jesús Fernández, Martin Eccius, Juan Miguel Gómez, Giner Alor-Hernandez, Rubén Posada-Gomez, and Carlos Laufer. "Semmed: Applying semantic web to medical recommendation systems." in First International Conference on Intensive Applications and Services, pp. 47-52. IEEE, 2009.

[3] Chen, Rung-Ching, Cho-Tsan Bau, and Yun-Hou Huang. "Development of anti-diabetic drugs ontology for guideline-based clinical drugs recommend system using OWL and SWRL." in International Conference on Fuzzy Systems, pp. 1-6. IEEE, 2010.

[4] Doulaverakis, Charalampos, George Nikolaidis, Athanasios Kleontas, and Ioannis Kompatsiaris. "GalenOWL: Ontology-based drug recommendations discovery." in Journal of biomedical semantics 3, no. 1, pp 1-9.2012

[5] Hanna, Josh, Eric Joseph, Mathias Brochhausen, and William R. Hogan. "Building a drug ontology based on RxNorm and other sources." in Journal of biomedical semantics 4,pp 1-9.2013

[6] Machado, Catia M., Dietrich Rebholz-Schuhmann, Ana T. Freitas, and Francisco M. Couto. "The semantic web in translational medicine: current applications and future directions." Briefings in bioinformatics 16, no. 1,pp.89-103,2015.

[7] Hur, Junguk, Cui Tao, and Yongqun He. "A 2018 workshop: vaccine and drug ontology studies (VDOS 2018)." BMC bioinformatics 20, no. 21, pp. 1-5,2019.

[8] Chen, Rung-Ching, Yun-Hou Huang, Cho-Tsan Bau, and Shyi-Ming Chen. "A recommendation system based on domain ontology and SWRL for anti-diabetic drugs selection." Expert Systems with Applications 39, no. 4, pp. 3995-4006,2012

[9] Sae-Ang, Apichat, Sawrawit Chairat, Natchada Tansuebchueasai, Orapan Fumaneeshoat, Thammasin Ingviya, and Sitthichok Chaichulee. "Drug Recommendation from Diagnosis Codes: Classification vs. Collaborative Filtering Approaches." International Journal of Environmental Research and Public Health 20, no. 1,2022.

[10] Mahmoud, Nesma, and Heba Elbeh. "IRS-T2D: Individualize recommendation system for type2 diabetes medication based on ontology and SWRL." In Proceedings of the 10th International Conference on Informatics and Systems, pp. 203-209. 2016.

[11] Venkat, T., N. Rao, A. Unnisa, and K. Sreni. "Medicine recommendation system based on patient reviews." International journal of Scientific & Technology research 9, no. 2, pp. 3308-3312,2020.

[12] Puustjärvi, Juha, and Leena Puustjärvi. "Improving the Quality of Medication by Semantic Web Technologies." *New Developments in Artificial Intelligence and the Semantic Web*,2016.

[13] Yao, Zijun, Bin Liu, Fei Wang, Daby Sow, and Ying Li. "Ontology-aware Prescription Recommendation in Treatment Pathways Using Multi-evidence Healthcare Data." ACM Transactions on Information Systems 41, no. 4 . pp. 1-29,2023.

[14] Shobowale, K. O. "Ontology in Medicine as a Database Management System." Ontology-Based Information Retrieval for Healthcare Systems, pp. 69-90,2020

[15] Drug interaction checker https://go.drugbank.com/drug-interaction-checker

[16] Pathak, Jyotishman, Richard C. Kiefer, and Christopher G. Chute. "Mining drug-drug interaction patterns from linked data: A case study for warfarin, clopidogrel, and simvastatin." In 2013 IEEE International Conference on Bioinformatics and Biomedicine, pp. 23-30. IEEE, 2013.

[17] Noor, A., Assiri, A., Ayvaz, S., Clark, C., & Dumontier, M. “Drug-drug interaction discovery and demystification using Semantic Web technologies” in Journal of the American Medical Informatics Association, 24(3), pp. 556-564,2017.

[18] Diesveld, Maaike ME, Suzanne de Klerk, Pieter Cornu, Dorothea Strobach, Katja Taxis, and Sander D. Borgsteede. "Management of drug-disease interactions: a best practice from the Netherlands." International journal of clinical pharmacy 43, pp. 1437-1450,2021.

[19] Coleman, Jamie J., and Sarah K. Pontefract. "Adverse drug reactions." Clinical Medicine 16, no. 5,pp. 481,2015.

[20] Edwards, I. Ralph, and Jeffrey K. Aronson. "Adverse drug reactions: definitions, diagnosis, and management." The lancet 356, no. 9237 pp. 1255-1259,2000.

[21] Cetirizine Drug Side effects, https://www.drugs.com/sfx/cetirizine-side-effects.html

[22] Bordea, Georgeta, Jean Nikiema, Romain Griffier, Thierry Hamon, and Fleur Mougin. "FIDEO: food interactions with drugs evidence ontology." In 11th International Conference on Biomedical Ontologies. 2020.

[23] Herrero-Zazo, Maria, Isabel Segura-Bedmar, Janna Hastings, and Paloma Martinez. "DINTO: using OWL ontologies and SWRL rules to infer drug–drug interactions and their mechanisms." Journal of chemical information and modeling 55, pp. 1698-1707,2015.

[24] Pharmacovigilance Ontology (PVONTO), https://bioportal.bioontology.org/ontologies/PVONTO

[25] Drug side effects checker, https://www.drugs.com/sfx/

[26] Drug interaction checker, https://go.drugbank.com/drug-interaction-checker#results

[27] Bushra, Rabia, Nousheen Aslam, and Arshad Yar Khan. "Food-drug interactions." Oman medical journal 26, no. 2 ,pp. 77,2011

[28] Food interaction checker,https://go.drugbank.com/food-interaction-checker#results