Saudi Journal of Radiology
February 2023
Proceeding of the 13th Radiological Society of Saudi Arabia (RSSA)

THE LACK OF UBIQUITOUS NEUROIMAGING RESEARCH IN SAUDI ARABIA: RARITY OR IGNORANCE?

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ABSTRACT

Objectives: Neuroimaging is generally one of the most sophisticated research areas in the field of neuroscience, and MRI is an important tool in neuroimaging research that allows for the generation of additional information about the structure and function of the human brain. However, there are few neuroimaging research studies in Saudi Arabia, although the precise number of these studies has not yet been measured. This study is conducted to analyze the number of neuroscience publications in Saudi Arabia, with a particular focus on Jeddah, while analysing the lack of ubiquitous neuroimaging in the country

Subject and Methods: This is a retrospective study based on a systematic search using primary resources, including google scholar, PubMed, and Saudi Library. The study aimed to identify all of the neuroscience and neuroimaging articles that were published in Jeddah, Saudi Arabia, between 2014 and 2019. An online questionnaire was sent to a sample of 72 employees in the medical field in multiple cities in Saudi Arabia The questionnaire focused on understanding their knowledge of the field and the difficulties of neuroimaging research and attempted to summarise the reasons for the deficiency of using MRI in neurological research.

Results: This study established that there was a total of 104 neuroscience and neuroimaging papers over 6 years; however, only 11 papers were neuroimaging publications. The survey showed that 87% of participants had an interest in the research and the clinical applications of neuroimaging. It also showed that 83% of the sample would prefer using MRI to other modalities in neuroimaging research. The study then finds that the reseasons for this deficiency are a lack of knowledge about advanced MRI techniques that could support neurological research and the lack of opportunities to utilize them.

Conclusion: A review of the previous publications illustrated the paucity of using neuroimaging in neuroscience research; this is preventing these techniques from being utilized with maximum benefit. Most of the participants in this study have

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eISSN: 1658-8959

knowledge and experience of some MRI tools and recommend using these to enhance the quality of neuroimaging works .

Keywords: neuroimaging, neurology, neuroscience, MRI, advanced MRI techniques

1. INTRODUCTION

In 2020, Saudi Arabia ranked in the top 50 countries in the world for the productivity of neuroscience researchers with a total of 452 publications, 2515 citations, and an h-index of 102. This was based on the SCImago Journal & Country Rank (SCR). However, neuroscience publications only account for 1.4% of the total 37564 publications in Saudi Arabia comparing the productivity from other research fields still neuroscience publications shows 1.4 % of total publication 37564 in Saudi Arabia, and the majority of these publications were classed under 'neuroscience miscellaneous' [1, 2].

Neuroimaging is a rapidly growing field of research in neuroscience that has the potential to completely change how we understand the structure and functions of the brain [3]. By better understanding the brain, we can improve our treatment and prevention of neurological diseases and disorders [4, 5]. Neuroimaging also has implications for improving the quality of neuroscience research, which could lead to new insights in clinical neurology and other neuroscience fields, such as behavioral and cognitive studies [6].

Magnetic resonance imaging (MRI), could be an important tool in neuroimaging research and allows for the generation of further information about the function and structure of the human brain. MRI would not only provide an opportunity for clinical use but also give the researcher access to the latest advanced techniques available, which will help to support neuroscience research. With all of these benefits, the use of MRI techniques could improve neuroscience research's progress and development.

However, in Saudi Arabia, the productivity of neuroscience and, in particular, advance neuroimaging research still lacking compared with other countries [2], and the quantity of research that is conducted in the field of neuroimaging has not yet been quantitatively measured. Therefore, this study is aimed to analyze neuroimaging publications from medical institutes in Jeddah, Saudi Arabia, over the last six years and study the lack of ubiquitous neurological imaging in Saudi Arabia. The overall outcome of this work should help increase the awareness of advance useful neuroimaging tools among technologists, neuroscientist, neurologist and radiologists.

2. MATERIALS AND METHODS

An investigation of all articles related to neuroscience from Saudi Arabia that were published between 2014 and December 2019 was performed. This investigation used several scientific search engines such as PubMed® search engine (National Library of Medicine, Bethesda, Maryland, USA, which includes more than 30 million biomedical citations and literature), Google scholar (a search engine for scientific literature and research), and King Fahad Medical research centre, which was the study's main search engine as it has a large quantity medical data. All of the neurology-related articles that were collected related to the study's topics, region of interest, and year of publication. The keywords which were used in the search were Neuroscience, Neuroimaging, Neuro research, and Neurology, with a focus on Jeddah and King Abdul-Aziz University.

Moreover, and as a second part of this study, a questionnaire (provided in the appendix) was sent to medical staff and academics who are interested in neuroscience and neuroimaging, such as radiologists, radiology technologists, academics, and researchers, to discover the difficulties they face in research and their knowledge about advanced neuroimaging techniques. This was intended to establish the reasons for the lack of research using medical imaging techniques in neuroscience research.

3. RESULTS

3.1 Publication results:

Over the last six years, a total of 102 neuroscience-related articles from Jeddah, Saudi Arabia,King Fahd Medical Research Center (KFMRC), the Center of Excellence in Genomic Medicine Research (CEGMR), King Abdulaziz City for Science and Technology Innovation Center (KACST), and the flowing departments in King Abdulaziz University (KAU): the Faculty of Science's Department of Biochemistry, Faculty of Applied Medical Science's Department of Diagnostic Radiology, Faculty of Science's Department of Biological Sciences. All are represented in (Figure 1). Please see appendix for detailed information of these articles.

In 2014, 50 studies relating to neurology and the brain were published; this number then decreased to 17 publications in 2015, 20 publications in 2016, and between 4 and 7 publications from 2017 to 2019. More than half of this research revolved around diabetic patients and Alzheimer's disease, and the rest was about neurodegenerative disorders and their causes, treatment, and correlation with cardiovascular disease, the role of pharmacogenomics, human glioma progression, and cognitive research, although few studies examined this. These studies mostly used experiments and in vitro and in vivo animal

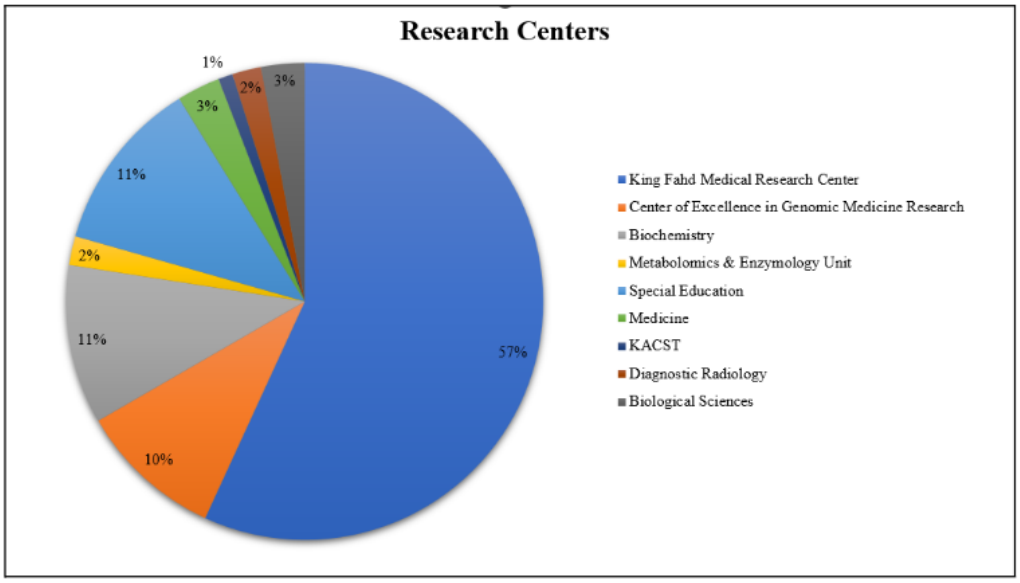

Figure 1 The pie chart shows the relative distributions of the research centres' and university units' neuroscience publications.

and human studies. In 2014, KFMRC and KAU in Jeddah published 35 of these studies, followed by the CEGMR with 5 articles. The Department of Special Education and the Department of Diagnostic Imaging, Faculty of Medicine, KAU, were the only two faculties that used neuroimaging and magnetic resonance imaging MRI in 2014, with 3 publications.

In 2015, the number of neuroimaging studies increased (17 Publications) and covered some of the principles of technical imaging and brain structural changes related to cognitive tasks. The Department of Special Education, KAU, published 24 % of these articles in 2015, and the Faculty of Applied Medical Science, KAU, had the largest contribution in its number of publications. However, these were the only two faculties that applied neuroimaging in their research, in fields such as MRI and Electroencephalography (EEG).

In 2016, despite an improvement in the number of publications related to neuroscience, by 20 published papers. All of them are captivating topics published by KFMRC collaboration whit different units. However, there were few neuroimaging-related studies, and these were all from the Department of Special Education in KAU, and they used EEG and MRI.

In 2017, the number of publications in neuroscience decreased by 60% and there was no change in the topics they covered. In the same year, several faculties participated in neuroscience research, and the KFMRC was responsible for 37% of the total research. However, the Department of Diagnostic Radiology in the Faculty of Applied Medical Science was

responsible for the only one neuroimaging study, and this used the MRI.

In 2018 and 2019 the number of neuroscience-related research improved was 5 and 4 publications respectively; these were published at KAU, in Jeddah, and they applied biochemical techniques and utilized medical imaging modalities and Electroencephalography EEG.

3.2 The survey result:

The questionnaire sample included: a total of 72 responses, comprised of (37.5%, n=27) radiology technologists, (23.2%, n=17) students, (22.2%, n=16) academics and researchers, (10%, n=7) radiologists, and (6.9%, n=5) neurologists, as shown in Figure 2.

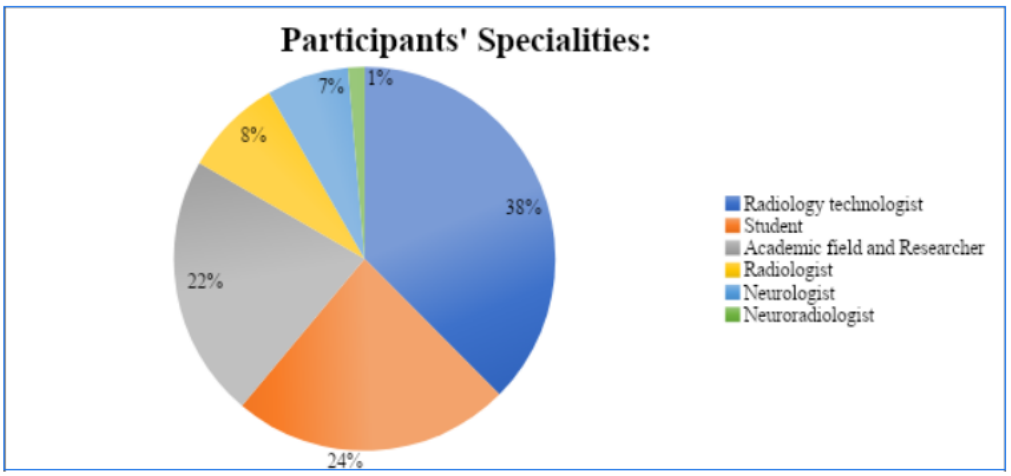

Figure 2 The pie chart shows the diversity of survey participants' specialties.

The survey participants were from (49%, n=35) King Abdulaziz University (KAU), (10%, n=7) ALGhad Collage, (8%, n=6) King Saud University (KSU) and Taif University, (6%, n=4) Prince Sattam Bin Abdulaziz University, and (19%, n=14) other research institutes, as illustrated in Figure 3.

The majority of the participants (87%, n=36) demonstrated their interest in research and into clinical applications of neuroimaging, such as Magnetic Resonance Imaging (MRI), while only (13%, n=9) were not interested. Those who were interested in this research field were radiology technologists, diagnostic radiology students, an academic, a researcher and a neurologist.

Most of the participants who were interested in neuroimaging research chose MRI as their first-choice imaging modality for neuroimaging research, as shown in Figure 4, and 78% of them had a good level of knowledge of advanced MRI techniques.

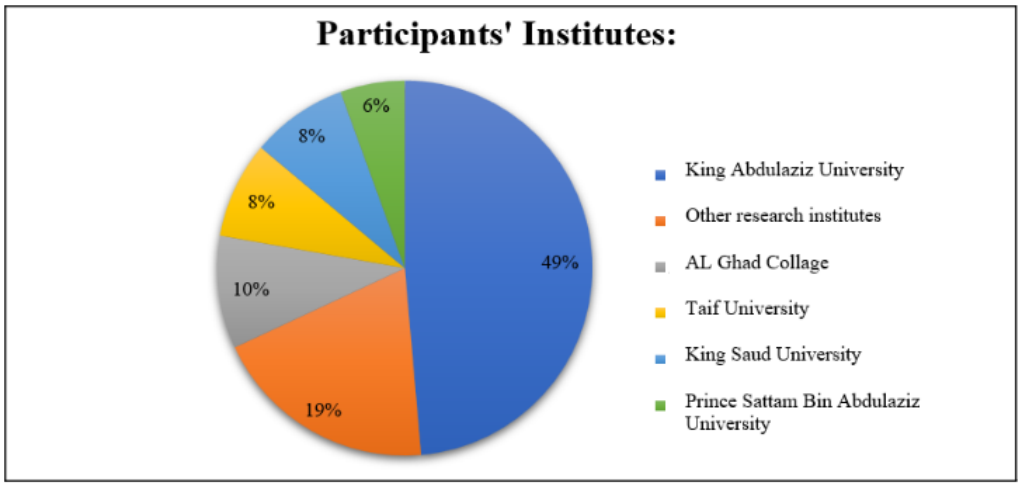

Figure 3 The pie chart demonstrates the distribution of the institutes that the participants belong to.

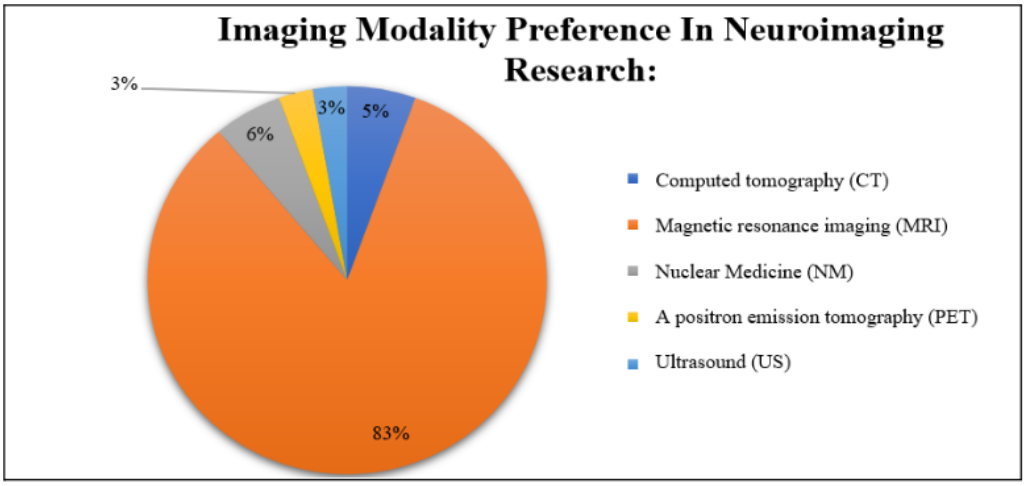

Figure 4 Imaging modality preference in neuroimaging research.

A member of academic staff, a researcher and a radiology technologist demonstrated a high level of interest in using MRI in neuroimaging research, while (52%) had a good knowledge of advanced techniques, as shown in Table 1.

Furthermore, 44% of the participants had used at least one advanced MRI technique in research-related neuroimaging examinations; they used these techniques mostly for routine brain imaging and other studies such as ; research trial, neurodegenerative disease, multiple sclerosis and epilepsy .

The techniques that were most frequently used by participants are, in order of frequency, Functional MRI (fMRI), Diffusion Tensor Imaging (DTI), and MR Spectroscopy

Table 1 Participants' Specialty And Preferred Imaging Modality

	Chosen Modality				
Specialty	**MRI**	**CT**	**NM**	**PET**	**US**
Radiologists	7%		3%		
Neurologists	7%				
Academics and Researchers	21%			1%	
Radiology technologists	31%	2%	3%	1%	1%
Students	18%	4%			1%

(MRS). The participants found that FMRI could help to improve neuroimaging research.

However, (82%) of participants would recommend using advanced MRI techniques in neuroimaging research, while the rest would not recommend these techniques because (40%) they did not have a good level of knowledge of these techniques and (53%) do not have the chance to use them (53%), where only (7%) they don't have enough finical support to provides these techniques. Finally, the majority of participants found that the fMRI, functional and structural connectivity could help with neuroimaging research development .

4. DISCUSSION

Our research highlights the status of neuroscience publications in Jeddah, Saudi Arabia, over the last 6 years. The total number of publications that are identified in this study was 104 papers. In 2017, Hussein Algahtani et al. observed that Jeddah made only a minor contribution to neurology-related research in Saudi Arabia between January 1996 and December 2015 compared to Riyadh, but more than other cities. These findings indicate that Jeddah's contribution to this research remains minimal.

All of the centres that were found in the first part of this study are known for their quality of research, such as the King Fahd Medical Research Center and King Abdul-Aziz University, in Jeddah, Saudi Arabia. The other centres were a collection of different units, mostly at King Abdul-Aziz University such as the Faculty of Medicine, the Faculty of Applied Medical Science's Department of Diagnostic Radiology, the Faculty of Science's Department of Biochemistry, and the Faculty of Science's Department of Biology. Other units such as the Metabolomics & Enzymology Unit, the KACST Technology Innovation Center, the Department of Special Education, and the Centre of Excellence in Genomic Medicine Research were also included. During the 6 years, the centres that most used medical imaging modalities in their research were the Department of Special Education at KAU and the Faculty of Applied Medical Science's Department of Diagnostic Radiology at KAU.

The data that were collected from the survey about utilizing neuroimaging in research was not only obtained from Jeddah, as the second part of this study, the questionnaire, was open to specialists across Saudi Arabia. They were asked to evaluate the state of neuroimaging research in other cities with the cooperation of different specialities who are interested in the research and clinical use of advanced neuroimaging.

A wide range of related specialties participated in our questionnaire, including radiology technologists, academic staff, radiologists, neuroradiologists, and radiology students. Most of them were from King Abdul-Aziz university (KAU), and many of them had an interest in the research and clinical use of advanced neuroimaging techniques.

The neuroimaging techniques mentioned and studied in this research include US, PET, NM, CT and a wide range of MRI sequences. Most of the participants preferred using MRI over US, PET, NM, and CT. This most likely due to the several diagnosis tools that could be applied using MRI. Further, 78% of participants knew advanced MRI techniques but most of the participants had not used any of these modalities in research related to neuroimaging. FMRI, DTI, and MRS were the participants' most-used techniques, and they found that fMRI could help to improve neuroimaging research. An academic, a researcher, and a radiology technologist had a high level of knowledge about MRI techniques. Finally, most of the participants recommend using advanced MRI techniques to improve the quality and quantity of neuroimaging research, and they found that some limitations prevent them from introducing these techniques in their clinical or research examinations, such as a lack of financial funding, not having the chance to do so, and not knowing how to use it correctly. One of this main reason that could explain why some researchers were not aware of several advanced techniques discussed above may be due to the lack of specialists in these field and/or the difficulty of applying them in clinical cases. However, recent studies showed that these advanced techniques have been shown to be utilized in several worldwide centers around the world, and they produce excellent sensitivity and specificality compared to traditionally used neuroimaging techniques [7–9] {Logothetis, 2008 #275; Khorrami, 2011 #73; Diedrichsen, 2011 #888; Zeng, 2012 #1048; Bray, 2013 #311; Maria de la Iglesia-Vaya, 2013 #1039}{Filippi, 2002 #1006}.

To increase the level of knowledge and awareness to the meaning of some of the advanced MRI techniques in neuroimaging here below basic introduction to the meaning is provided. Firstly, **MRI perfusion:** an important function that examines the distribution of nutrients and oxygen to soft tissue by the flow of blood. Perfusion MRI helps in many clinical fields, for example, the identification of tumours and the regions affected by strokes [10]. Further, **Structural magnetic resonance imaging (MRI)** is a technique used to investigate the human brain's anatomy and abnormalities by assembling images for medical use or research. Structural MRI can be beneficial in scanning cranial nerves,

acute cerebral haemorrhages, subarachnoid haemorrhages, and in research fields. It helps as well in terms of understanding volumetric changes [11]. **Diffusion Tensor Imaging (DTI):** DTI utilizes the diffusion of water to axons of nerves that are either perpendicular or parallel to it. The water's characteristics offer a way to evaluate the axonal direction and shape. DTI is mainly a research instrument; it can provide a specification of the development of the structural networks and can aid in the treatment of schizophrenia and Alzheimer's disease (AD) [12]. **Susceptibility-weighted imaging (SWI)** is a technique that depends on tissues' magnetic susceptibility attributes. Susceptibility-weighted imaging (SWI) can be applied by scanning the anatomy of venous structures and identifying haemorrhages and classifications [13, 14]. **Sodium magnetic resonance:** Sodium (N23) is the strongest radiofrequency nuclei after the proton (1H) in the human body. This technique depends on the concentration of sodium molecules in the tissue. This technique provides biochemical information about normal and abnormal function . Also, it is helpful in the regulation of osmotic pressure, such as in cartilage and intervertebral disks. **Magnetization transfer (MT) imaging** is a process in which a hydrogen proton binds to macromolecules or protons in free water. It is used in the detection of changes in the brain parenchyma and the diagnosis of multiple sclerosis [15]. **Functional magnetic resonance imaging** is used to evaluate the brain's functional anatomy and detect abnormalities by measuring the small changes in the blood flow that may affect brain activity [16]. Its uses are in determining each part function in the brain (brain mapping) and diagnosing the functional anatomy of the brain [3].

5. CONCLUSION

The review of previous publications showed a paucity of the use of neuroimaging in neuroscience research, which is limiting the benefits of this technology. Most of the participants in the study had knowledge and experience of using neuroimaging technology and recommend the use of neuroimaging modalities to improve and enhance the outcomes of the neuroscience publications. As this research is crucial, it is recommended to improve the productivity and continuity of neuroimaging research to better tackle the obstacles preventing the use of advanced neuroimaging techniques, thereby improving the quality of research across this field.

CONFLICT OF INTEREST

All authors declare no conflict of interest

ACKNOWLEDGEMENTS

The authors thank all participants for their willingness to participate in this study.

APPENDIX

Section one:

1-Your spatiality:
- Radiologist
- Neurologist
- Academic field and Researcher
- Radiology technologist
- Student

2-What is your University?
- Short answer text

3-Gender:
- Male
- Female

4-Are you interested in research or clinical use of advanced MRI techniques?
- Yes
- No

Section two:

5-If you have the opportunity to begin research in neurology what would your best medical imagining modality be?
- MRI
- NUCLEAR MEDICINE
- CT
- ULTRASOUND
- PET

6-Do you know about advanced MRI techniques?
- Yes
- No

7-Have you used one of them in any neurological imaging examination?
- Yes
- No

8-if yes, what was the case?
- Short answer text

9-What is the degree of knowledge you have about advanced MRI Techniques?
- Very good
- Good
- Fare
- poor
- Non

10-Would you recommend advanced MRI technique to be used in neurology imaging?
- Yes
- No
- Not sure

11-If your answers were no, what prevent you? • You don't know how to use it correctly
- There is no cooperative from the physician
- You did not get the chance
- There is no financial funding
- Other

12-In your opinion what is the best advanced MRI technique for neurology imaging?
- F-MRI
- MTR
- Functional connectivity
- Structure connectivity
- Other

13-From the previous question, what do you know about them?
Author
- Long answer text

Questioner /survey

The 102 articles summarized in this paper.

Ahmed et al. (2014) A Molecular Bridge: Connecting Type 2 Diabetes and Alzheimer's Disease	Aliev et al. (2014) "Alzheimer Disease and Type 2 Diabetes Mellitus: The Link to Tyrosine Hydroxylase and Probable Nutritional Strategies"	Karim et al. (2014) "An Association of Virus Infection with Type 2 Diabetes and Alzheimer's Disease"	Ali et al. (2014) "Application of Proteomic Tools in Modern Nanotechnological Approaches Towards Effective Management of Neurodegenerative Disorders"	Shaikh et al. (2014) "Aptiom (Eslicarbazepine Acetate) as a Dual Inhibitor of β-Secretase and Voltage-Gated Sodium Channel: Advancement in Alzheimer's Disease-Epilepsy Linkage via an Enzoinformatics Study"	Sohrab et al. (2014) "Bacteriophage - A Common Divergent Therapeutic Approach for Alzheimer's Disease and Type II Diabetes Mellitus"	Mushtaq et al. (2014) "Biological Mechanisms Linking Alzheimer's Disease and Type-2 Diabetes Mellitus"	Gauthaman et al. (2014) "Common Cellular and Molecular Mechanisms Underlying Alzheimer's Disease and Type 2 Diabetes: A Knowledge-Driven Approach"
Banu et al. (2014) "Comparative Study of Non-High Density Lipoproteins Cholesterol Leveland Lipid Profile in Pre-Diabetic and Diabetic Patients"	Nawaz et al. (2014) "Computational Study of Human Tyrosine Hydroxylase Mutants to Uphold[4-(Propan-2-yl) Phenyl]Carbamic Acid as a Potential Inhibitor"	Shaikh et al. (2014) Current Acetylcholinesterase Inhibitors: A Neuroinformatics Perspective	Khan et al. (2014) "Current Challenges to Overcome in the Management of Type 2 Diabetes Mellitus and Associated Neurological Disorders"	Rasool et al. (2014) Current View from Alzheimer Disease to Type 2 Diabetes Mellitus	Narasimhan et al. (2014) "Diabetes of the Brain: Computational Approaches and Interventional Strategies"	Shaik et al. (2014) "Do Folate, Vitamins B6 and B12 Play a Role in the Pathogenesis of Migraine? The Role of Pharmacoepigenomics"	Karnati et al. (2014) "Down Regulated Expression of Claudin-1 and Claudin-5 and UpRegulation of β-Catenin: Association with Human Glioma Progression"

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Table 2 continued

Naseer et al (2014) "Down-regulation of dopamine D1 receptors and increased neuronal apoptosis upon ethanol and PTZ exposure in prenatal rat cortical and hippocampal neurons"	Hasan et al. (2014) "Effect of Electromagnetic Radiations on Neurodegenerative Diseases-Technological Revolution as a Curse in Disguise"	Shaik et al. (2014) "Epigenomic Approach in Understanding Alzheimer's Disease and Type 2 Diabetes Mellitus"	Mirza et al. (2014) "Establishing Genomic/-Transcriptomic Links Between Alzheimer's Disease and Type 2 Diabetes Mellitus by Meta-Analysis Approach"	Ul Ain et al. (2014) "Exploring N1-p-Fluorobenzyl-Cymserine as an Inhibitor of 5-Lipoxygenaseas a Candidate for Type 2 Diabetes and Neurodegenerative Disorder Treatment"	Dai et al. (2014) "Fighting Alzheimer's Disease and Type 2 Diabetes: Pathological links and Treatment Strategies"	Karim et al. (2014) "Gene Expression Analysis Approach to Establish Possible Links Between Parkinson's Disease, Cancer and Cardiovascular Diseases"	Nedjadi et al. (2014) Genomic Linkage Between Alzheimer's Disease and Type 2 Diabetes
Hua et al. (2014) Editorial Medicinal Plants in Management of Type 2 Diabetes and Neurodegenerative Disorders	Firoz et al. (2014) An overview on the correlation of neurological disorders with cardiovascular disease	Pensalfini (2014). Intracellular amyloid and the neuronal origin of Alzheimerneuritic plaques	Jabir et al. (2014) Synopsis on the Linkage of Alzheimer's and Parkinson's Disease with Chronic Diseases	Rasool et al. (2014) Determination of potential role of antioxidative status and circulating biochemical markers in the pathogenesis of ethambutol induced toxic optic neuropathy among diabetic and non-diabetic patients	Rizvi et al. (2014) Invokana (Canagliflozin) as a Dual Inhibitor of Acetylcholinesterase and Sodium Glucose Co-Transporter 2: Advancement in Alzheimer's Disease-Diabetes Type 2 Linkage via an Enzoinformatics Study	Bibi et al. (2014) Link Between Chronic Bacterial Inflammation and Alzheimer Disease	Kamal et al. (2014) Linkage of Neurodegenerative Disorders with Other Health Issues – Volume I AND II

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Table 2 continued

Kamal et al. (2014) Linking Alzheimer's Disease and Type 2 Diabetes Mellitus via Aberrant Insulin Signaling and Inflammation	Merad et al. (2014) Molecular Interaction of Acetylcholinesterase with Carnosic Acid Derivatives: A Neuroinformatics Study	Hänggi et al. (2014) The architecture of the chess players brain	Elmer et al. (2014) Processing demands upon cognitive, linguistic, and articulatory functions promote grey matter plasticity in the adult multilingual brain: Insights from simultaneous interpreters	Shaikh et al. (2014) Prediction of Comparative Inhibition Efficiency for a Novel Natural Ligand, Galangin Against Human Brain Acetylcholinesterase, Butyrylcholinesterase and 5-Lipoxygenase: A Neuroinformatics Study	Abduljabbar (2014) Characteristic Brain Imaging Findings in a Patient with Joubert Syndrome and Segmental Glomerulosclerosis	Krongold et al. (2014) Final infarct volume estimation on 1-week follow-up MR imaging is feasible and is dependent on recanalization status	Mirza et al. (2014) Protein Interactions Between the C-Terminus of Aβ-Peptide and Phospholipase A2 - A Structure Biology Based Approach to Identify Novel Alzheimer's Therapeutics
Mirza et al. (2014) Proteomics Approaches to Understand Linkage Between Alzheimer's Disease and Type 2 Diabetes Mellitus	Ahmad et al. (2014) Role of Nanomedicines in Delivery of Anti-Acetylcholinesterase Compounds to the Brain in Alzheimer's Disease	Rasool et al. (2014) Recent Updates in the Treatment of Neurodegenerative Disorders Using Natural Compounds	Mushtaq et al. (2014) Status of Acetylcholinesterase and Butyrylcholinesterase in Alzheimer's Disease and Type 2 Diabetes Mellitus	Nurulain et al. (2014) Sub-Chronic Exposure of Non-Observable Adverse Effect Dose of Terbufos Sulfone: Neuroinflammation in Diabetic and Non-Diabetic Rats	Jabir et al. (2014) Synopsis on the Linkage of Alzheimer's and Parkinson's Disease with Chronic Diseases	Karim et al. (2014) The Role of Viruses in Neurodegenerative and Neurobehavioral Diseases	Karim et al. (2014) Transcriptomics Study of Neurodegenerative Disease: Emphasis on Synaptic Dysfunction Mechanism in Alzheimer's Disease

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Table 2 continued

Alam et al. (2014) "A Nanotechnological Approach to the Management of Alzheimer Disease and Type 2 Diabetes"	Alam et al. (2014) "Possible Link of Gut Microbiota Alteration in Type 2 Diabetes and Alzheimer's Disease Pathogenicity: An Update"	Hänggi et al. (2015) Structural Brain Correlates Associated with Professional Handball Playing	Rütsche et al. (2015) When Problem Size Matters: Differential Effects of Brain Stimulation on Arithmetic Problem Solving and Neural Oscillations	Alahmadi et al. (2015) Complex motor task associated with non-linear BOLD responses in cerebro-cortical areas and cerebellum	Mathew et al. (2015) A WEB BASED DECISION SUPPORT SYSTEM DRIVEN FOR THE NEUROLOGICAL DISORDERS	Ashraf et al. (2015) Altered Galectin Glycosylation: Potential Factor for the Diagnostics and Therapeutics of Various Cardiovascular and Neurological Disorders	Faheem et al. (2015) Array-Comparative Genomic Hybridization Analysis of a Cohort of Saudi Patients with Epilepsy
Sinha et al. (2015) Telomeric Repeat Containing RNA (TERRA): Aging and Cancer	Kamal et al. (2015) Current Update on Synopsis of miRNA Dysregulation in Neurological Disorders	Klein et al. (2015) MRI with and without a high-density EEG cap—what makes the difference?	Ali et al. (2015) Application of Proteomic Tools in Modern Nanotechnological Approaches Towards Effective Management of Neurodegenerative Disorders	Khan et al. (2015) Physico-Chemical Stress Induced Amyloid Formation in Insulin: Amyloid Characterization, Cytotoxicity Analysis against Human Neuroblastoma Cell Lines and Its Prevention Using Black Seeds (Nigella sativa)	Mushtaq et al. (2015) Nanoparticles, Neurotoxicity and Neurodegenerative Diseases	Waqar et al. (2015) In Silico Analysis of Binding Interaction of Mamba Toxins with M4 and M2 Muscarinic Acetylcholine Receptors for Therapeutic Use in Alzheimer's Disease	Perveen et al. (2015) Pro-oxidant DNA Breakage Induced by the Interaction of L-DOPA with Cu(II): A Putative Mechanism of Neurotoxicity
Teng et al. (2015) Dietary DHA supplementation in an APP/PS1 transgenic rat model of AD reduces behavioral and Aβ pathology and modulates Aβ oligomerization	Liem et al. (2015) Reliability and statistical power analysis of cortical and subcortical Free Surfer metrics in a large sample of healthy elderly	Baldwin et al. (2016) Neural correlates of healing prayers, depression and traumatic memories: A preliminary study	Rogenmoser et al. (2016) Independent component processes underlying emotions during natural music listening	Alomar & Bakhaidar (2016) Neuroimaging of neuropathic pain: review of current status and future directions	Chibber et al. (2016) A Synopsis on the Linkage Between Age-Related Dementias and Vascular Disorders	Khan (2016) Alzheimer's Disease and Autistic Spectrum Disorder: Is there any Association?	Javed et al. (2016) An Overview on the Role of α-Synuclein in Experimental Models of Parkinson's Disease from Pathogenesis to Therapeutics

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Table 2 continued

Ashraf et al. (2016) Linkage of Stress with Neuromuscular Disorders	Solayman et al. (2016) Natural Products Combating Neurodegeneration: Parkinson's Disease	Siddiqui et al. (2016) Neuroprotective Role of Steroidal Sex Hormones: An Overview	Ahmad et al. (2016) Anti-inflammatory role of sesamin in STZ induced mice model of diabetic retinopathy	Karim et al. (2016) Global Expression Studies of Schizophrenic Brain: A Meta-Analysis Study Linking Neurological Immune System with Psychological Disorders	Mathew et al. (2016) Hepatitis C virus and neurological damage	Ahmad et al. (2016) Identification of common therapeutic targets for selected neurodegenerative disorders: An in silico approach	Ali et al. (2016) In Silico Analysis of Green Tea Polyphenols as Inhibitors of AChE and BChE enzymes in Alzheimer's disease Treatment
Ustyugov et al. (2016) New Therapeutic Property of Dimebon as a Neuroprotective Agent	Islam et al. (2016) 'Non-Criteria' Neurologic Manifestations of Antiphospholipid Syndrome: A Hidden Kingdom to be Discovered	Khan et al. (2016) Recent Updates on the Dynamic Association Between Oxidative Stress and Neurodegenerative Disorders	Knight et al. (2016) Unexpected partial correction of metabolic and behavioral phenotypes of Alzheimer's APP/PSEN1 mice by gene targeting of diabetes/Alzheimer's related Sorcs1	Wilson et al. (2016) The Role of Endoproteolytic Processing in Neurodegeneration	Khan et al. (2017) HTLV-1 Associated Neurological Disorders	Alam et al. (2017) Infectious Agents and Neurodegenerative Diseases: Exploring the Links	Bibi et al. (2017) Metformin attenuate PTZ-induced apoptotic neurodegeneration in human cortical neuronal cells

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Table 2 continued

Baothman et al. (2017) IMPACT OF ASPARTAME CONSUMPTION ON NEUROTRANSMITTERS IN RAT BRAIN	Brauchli et al. (2017) Top–Down Signal Transmission and Global Hyperconnectivity in Auditory-Visual Synesthesia: Evidence From a Functional EEG Resting-State Study	Alahmadi et al. (2017) Cerebellar Lobules and Dentate Nuclei Mirror Cortical Force-Related-BOLD Responses: Beyond All (Linear) Expectations	Shevtsova et al. (2017) Mitochondrial Permeability Transition Pore as a Suitable Target for Neuroprotective Agents Against Alzheimer's Disease	Al-Mazidi et al. (2017) Blocking of cytokines signalling attenuates evoked and spontaneous neuropathic pain behaviours in the paclitaxel rat model of chemotherapy-induced neuropathy	Aldusary et al. (2018) Lateral geniculate nucleus volumetry at 3T and 7T: Four different optimized magnetic-resonance-imaging sequences evaluated against a 7T reference acquisition	Al-Khatib et al. (2018) 305 The Significance of Neuroimaging in Evaluating Patients Presenting With Dizziness to the Emergency Department	Brown et al. (2018) Neural representations of aversive value encoding in pain catastrophizers
Ashraf et al. (2018) Inhibiting Effect of Zinc Oxide Nanoparticles on Advanced Glycation Products and Oxidative Modifications: a Potential Tool to Counteract Oxidative Stress in Neurodegenerative Diseases	Azhar et al. (2018) Frontier View on Nanotechnological Strategies for Neuro-therapy	Brauchli et al. (2019) Univariate and multivariate analyses of functional networks in absolute pitch	Valizadeh et al. (2019) Decrypting the electrophysiological individuality of the human brain: Identification of individuals based on resting-state EEG activity	Brauchli et al. (2019) Diminished large-scale functional brain networks in absolute pitch during the perception of naturalistic music and audiobooks	Alghamdi et al. (2019) An Overview of the Intrinsic Role of Citrullination in Autoimmune Disorders		

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