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NETWORK PHARMACOLOGY AND TELEMEDICINE-A DIGITAL PARADIGM

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ABSTRACT: Attempts are made in understanding drug action and its molecular interaction with multiple target in living cell using computational power as a tool leading to the emergence of Network Pharmacology (NP) and Telemedicine (TM). Network Pharmacology (NP) has been appearing as an important tool in underlining the complex relationship between the pharmacokinetic and pharmacodynamics of drug, aids in the discovery of new drug targets and repurpose existing drug molecules. TM is utilization of communication as a tool to disseminate all types of Pathological and Pharmacological aid to the costumer. This new advancement has made it possible to cut down geographical barriers, need for travel, managing and improving disease treatment in remote and urban areas through teleconsultancy, teleradiology, telepathology and teledermatology. Network Pharmacology and Telemedicine not only opens up new therapeutic options but also aims in improving safety, efficacy of drugs along with effective diagnosis and treatment of diseases by creating awareness thus likely to become the core methodology of healthcare delivering in the future. This article highlights the applications of NP and Telemedicine in medical field.

INTRODUCTION: Li *et-al* (2014) presented the notion of Network Pharmacology with the assumption that NP can provide a full or partial comprehension of the principle of Network Theory and Systems of Biology or Polypharmacology [1]. The combination of these two approaches resulted in NP, a unique paradigm that acts on both the interactome and the diseasome level (Hopkins, 2008) [2]. An analytical technique which enables interaction between a system with its component to initiate network level features is Systems Biology.

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The purpose of Network Theory and Systems Pharmacology is to understand how medications regulate cellular networks in space and time and how they impact human pathophysiology [6]. Telemedicine is "a service that seeks to improve a patient's health by allowing two-way, real-time interactive communication between the patient and the physician at a remote site," according to the Centres for Medicare and Medicaid Services (CMS).

Though they have similarities, telehealth differ from telemedicine in that the former is defined as "the use of information technology (IT) and communications to enable remote access to health assessment, diagnosis, intervention, consultation, supervision, and information". Subsequently, telehealth can be seen of as a broader interpretation

of telemedicine that encompasses any technology that is used to assemble and send patient health information, including telephones, email, and remote patient monitoring (RPM) devices for the delivery of health tutoring or supplementary healthcare amenity. The quality and accessibility of heed that is offered virtually have remarkably expanded because of technological development over the past few ages. Despite this, the shortage of supportive payment framework and stringent regulatory orders have averted the widespread endorsement of telemedicine [3, 4, 5].

Applications of Network Pharmacology in Pharma Industry and Health Care Systems: Network uses the combination of basic building blocks like nodes and edges as their connecting linkage which is distinguished by a countable topology characters aiding in defining the relationship with the network tools. Due to the non-random structure of biological networks, network theory refers to them as "scale-free" [7]. The idea lies in targeting numerous interconnected systems instead of individual molecules which would result in greater efficacy and fewer side effects [8, 9]. Network pharmacology uses the mixture of Informatics, Data Analysis, Information Technology, online databases, and other media's to investigate how diseases emerge, develop, and are treated from a biological network perspective [10]. Network Pharmacology in combination with Bio information is used to investigate the MOA of the key molecule in drugs belonging of Herbal and Synthetic Origin Includes:

Treatment of Diabetic Nephropathy involving pharmacognostic herb Astragalus Radix (AR) - *Panax ginseng* (PN) combination [11]. Traditional herbal combination called *Astragalus radix* (AR) and *Panax notoginseng* (PN) has shown promising results in the treatment of diabetic nephropathy. We recognized 22 bioactive components as well as 189 possible AR-PN targets. A total of 850 DN-related genes with varied expression levels were investigated. The discussion acknowledged that the pharmacognostic herb pair exhibits therapeutic effect on Diabetic Nephropathy via a range of bioactive chemicals and associated pharmacological pathways. These pathways involve molecular targets and a diversity of cells, including antioxidant, anti-inflammatory, and anti-apoptotic cells, as well as cytological cycle control. The Herb pair and its constituent elements proves to be useful in the treatment for Diabetic Nephropathy.

Network pharmacology is used to identify phytochemicals that were useful in the treatment of Neurogenic Disorder. A compound-target-pathology network was constructed to discover 7 Phyto-APIs from *Lactiflora Paeonia* with Thirty - Three relevant aims influencing signalling cascade in Neurogenic Disease [12].

Anti Tubercular chemicals which have potential as lead, incudes terpenoids like Pacharin and Racemosol [13].

Rhizomes of herb Rhizoma Polygonati having potent Anti-viral active constituent is used as key element in SARS Corona Virus 2.

Tephrosia purpurea (Fabaceae) active ingredients were tested contrary to polycystic ovarian disorder alongside psychiatric disorder-regulating amino acids , have build a path towards better knowledge of pathophysiology [14].

Another feature that distinguishes network pharmacology is systematisation. Along with the use of Chemoinformatics [15], it can speed up the finding of drug targets, move multiple targets around the whole biological network, and aid in the research and development of new drug compounds. Chemoinformatics is used in Gene/Protein analysis to pinpoint the key molecule, which can be a fragment of DNA or an amino acid or a treatment possible for sickness. It is done to isolate, crystallise, and perform ligand binding on the identified protein.

A wide array of methodologies and procedures are used for lead analysis, which includes simulated screening, atomic databases, data mining, high-through-put scan, Quantitative Structure Activity Relationship peptide linkages, molecular designs, micro testing, statistical calculus and Pharmacokinetic studies. NP Is greatly accepted and employed in East India medicine from its start. Network pharmacology can assess medication safety by analysing unfavourable effects [16]. In accordance to a few investigations which utilised network pharmacology to analyse Tibetan

Hongjingtian's effectiveness in treating COVID-19, four active constituents play a significant role in the immune followed by inflammatory mechanisms, particularly the tumour necrosis signalling pathway and the IL-17 signalling pathway [17]. By examining the database for research on the molecular process of Radix therapeutic influence on COVID .Thirty -Three active chemicals were identified, and 11 co-targets with symptoms are discovered. 179 metabolic pathways and 23 possible targets were studied in order to discover ten therapeutic constituents that have a curative impact on COVID-19 in Rhizoma species. The pharmacological relevance of pueraria root's COVID-19 control mechanism cannot be emphasised. According to Qin *et al* [18], Puerarin's major targets for treating COVID-19.

A fraction of the huge libraries of compounds can be quickly and rationally selected with the use of computer technology, and theoretical direction for future clinical drug use can be provided. Computational prediction connects experiment and theory. Network Pharmacology employs a variety of software tools and databases Drug repo, ENDS, Drda, MICHA, Drug Comb, KiBA, TIMMA etc are some widely used software and are freely available [19].

The Network Pharmacology genomics technologies can be more effective in monitoring APIs at many levels of regulation along with management. Thus, NP helps to investigate disorders via the lens of a biological network, as well as the manner in which they develop and are treated [20].

Need of Telemedicine in Healthcare: Due to the need for better care and rising healthcare costs, more hospitals are considering the benefits of telemedicine. They desire improved appraise to healthcare facilities as well as improved interactions between far-off patients and their doctors. Here, telemedicine also promotes better connectivity, which has reduced readmissions to hospitals and increased adherence to treatment programmes by patients. Increased interaction resulting from telemedicine is advantageous for doctor-to-doctor communication. Telemedicine may be used by doctors to establish support networks in order to trade talents and provide better medical care. Online medical care delivery utilising video chat is known as telemedicine. This technology has numerous advantages for both patients and medical professionals. Despite some technical challenges, telemedicine can enhance and improve the overall patient experience [21, 22].

Newest India Telemedical Trends: Digital pathology is increasingly being used for standard diagnostics. Faster full-slide picture scanning makes this enhancement possible, but from a high-tech, practical, and budgetary standpoint, it is challenging to deploy on a large scale [23]. Telemedicine still occasionally has a direct impact on the medical industry. The two key benefits that this innovation has are medical benefits and value benefits. Telemedicine may be a logical extension of the rise in technical and technological components of community care. Effective telemedicine programmes provide medicinal advantages that are tied to how professionals use the technology. An altered version of a well-known comparison from instructional analysis that was applied to telemedicine, summarises the medical impact of telemedicine. Teleconsultations have increased in frequency despite evidence showing a large decline in the utilisation of primary care for illnesses that are neither COVID-19 or urgent such as long-lasting diseases, during the epidemic. This shows that the main objective of telemedicine has been to manage emergencies. Telehealth interventions enhanced primary care healthcare in sovereign states with already existing legislative structure and favourable national eHealth structures, while also bolstering the citizens health response to COVID-19 [24].

Applications of Telehealth:

Tele-Education: Utilising telecommunications technologies allows for the possibility of distance learning. Additionally, it is very adaptable and interactive. A flexible and interesting lifetime education course that provides additional practical instruction and updates on the latest research for more effective and precise treatment techniques [25].

Distant Consultation: Far away medical service delivery, promotion, and prohibition are all possible with telehealth care. A consultation or follow-up could be used as the format. In order to address the issue of delivering healthcare at sizable Indian conclave, telemedicine has been useful. For

instance, the Uttar Pradesh government makes use of mobile telemedicine vans that are outfitted with teleconferencing devices for paralinguistic communication during Maha Kumbhamelas. This makes it possible for medical professionals in far-off places to link to any medical institution that provides telemedicine facility, especially highly specialised ones.

Disaster Management: Both man-made crises like war and rioting as well as natural disasters like earthquakes, tsunamis, and tornadoes may be considerably helped *via* telemedicine. As the majority of earthbound communication links either do not work well or fail during catastrophe, a mobile, transportable telemedicine device with satellite communication and specialised telemedicine software is suited for relief from calamity [26].

Tele-Home Healthcare: Using telemedicine technology, patients who are elderly or underprivileged and confined to their homes as a result of chronic diseases may receive in-home treatment. Instead of travelling to remote locations to check on recovering or chronically ill patients, it enables home healthcare practitioners to monitor patients from a central location. Remote patient monitoring is a more affordable and quick replacement [25].

Assisting People who are Impaired: Telemedicine makes it simpler for patients with disabilities to access services. Other groups now have easier access, including the elderly, the culturally detached, and the incarcerated. Treatment using telemedicine is advantageous for many medical conditions. It is effective when a patient obtains medical attention from a licenced practitioner who fully describes their symptoms. According to certain research, those who use telemedicine supposedly spend little time in the hospital and less money as a result. Additionally, fewer miles travelled could mean less money spent on expenses like petrol [27, 28].

Treatments of School-going Children: treating our rapidly ageing population, telemedicine can be incredibly important. When a student is unwell, they can visit the school infirmary or be picked up by their parents to an emergency care centre, but both options are generally uncomfortable and possibly unnecessary. Innovative schools can work with medical professionals to conduct video tours from the classroom. The person in-charge may choose what has to be done and give parents instructions or assurances. It has also been demonstrated that patients in assisted living homes who have access to doctors on call overnight and on weekends will avoid hospitalisation [29, 30].

Teledentistry: By enabling dentists to acquire images of teeth, dentures, and other dentistry components to assess and transfer to another practitioner for assessment, this technology improves dental treatment. In order to determine whether a certain therapy is necessary, dentists and dental specialists can share records via telemedicine in dentistry. Specialists can help dentists detect problem areas and advise patients on preventative measures to avoid costly and complex procedures. This collaboration helps those in rural or underprivileged locations who might not often have access to medical specialists, just like previous telemedicine apps [30].

Advantages and Drawbacks of Telemedicine: Telemedicine has many benefits, including reducing geographical barriers and providing healthcare services to rural and remote places; this benefits the populace who stays in remote areas. Additionally, it lowers hurdles imposed on by gap and increases access to first-rate medical treatment. It is especially helpful in emergency and critical care situations, where moving a patient would be undesirable or unfeasible. Thanks to telemedicine, patients and far-off medical professionals can more easily receive expert care and support. Furthermore, it cuts down on needless travelling time for medical staff as well as the cost and/or complexity of patient transfers.

It also narrows the segregation of countryside practitioners by boosting their knowledge through teleeducation or telecontinuing medical tutoring. Age, race, dwelling place, payer, and telehealth use are all extensively varied in the initial phase of the COVID-19 Public Health Emergency. There is requirment of more analysis to better acknowledge the basal reasons of these variances and how they may affect decisions made about policy both during and after the COVID-19 emergency [31].

Telemedicine consultations have been improved by the "tools" of telemedicine by making them more model-based and factual. Automated otoscopes, stethoscopes, oxygen saturation probes, and blood pressure monitors are some of the examples. In a large country like India, where majority of population lack access to doctors, telemedicine has the ability to truly alter lives since it enables doctors to travel to previously unreachable places.

Telemedicine has its problems as well. Many would agree with this but there are still those people who like to visit their doctor. Some reluctance is shown by doctors themselves. Doctors in the state sector usually perceive telemedicine as an additional duty or overloaded. Telemedicine therefore must be incorporated into doctors' routine tasks. Sometimes doctors are concerned that telemedicine will interfere with their capacity to practise. They must be aware that this advancement increases their onlookers and perceptibility and very certainly will result in future business growth [32].

Changes Required: The Indian administration modified its telemedicine usage laws in March 2020. The goal of this new public policy is to give the Indian telemedicine sector more direction. As a result of COVID-19, telemedicine is being utilised by more patients and in more medical settings. Before telemedicine is widely adopted in India, access and infrastructural issues must be resolved. Additionally, it is necessary to ensure that there is comprehensive and legally valid law that sets unambiguous substructure for doctor-patient communication to handle concerns of permission, privacy, and utilisation [33]. Even if the use of telemedicine is growing, substantial evidence about how telehealth could enhance primary care must be developed, implemented, analysed, and produced in order to expand it and assure its feasibility over the long term[34]. Embracing integrated information systems, involving shareholders, boosting ability, and closely observing the transition should all increase the implementation of telemedicine. This could assist telemedicine in setting a new standard for the provision of comprehensive medical care [35].

CONCLUSION: There are advantages and disadvantages to everything in our world, and it is important to emphasise those advantages and disadvantages for ongoing development. The goal of network pharmacology is to comprehend diseases on a systemic level and to understand how drugs interact with the body based on the equilibrium theory of biological networks. The restriction of this, on the other hand, is that because of this approach's linearity, complex disorders cannot be addressed. The main purpose of telemedicine is to give attention and care to the patients same as in-person treatment. Telemedicine on the other hand, can experience significant limitations due to technical issues. Poor internet connectivity or other technological problems can obstruct the flow of medical consultations and keep patients from getting the care they require. Working to close the gaps and doing ongoing research will undoubtedly help Network Pharmacology and Telemedicine establish itself as a new paradigm in the pharmaceutical industry.

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REFERENCES:

1. Runzhi Zhang, Xue Zhou and Hong Bai: Kang Ning Network Pharmacology Databases for Traditional Chinese medicines: Review and Assessment Front. Pharmacol Ethnopharmacology 2019; 10: .
2. Chandran, Neelay Mehendale, Saniya Patil, Rathnam Chaguturu and Bhushan Patwardhan: Innovative Approaches in Drug Discovery 2017; 127-164.
3. www.medicaid.gov/medicaid/benefits/telemedicine/index.html
4. Waller M and Stotler C: Telemedicine: a primer. Curr Allergy Asthma Rep 2020; 22.
5. Keesara S, Jonas A and Schulman K: Covid-19 and Health Care's Digital Revolution. NEJM 2020; 382(23): 82.
6. Lee AY, Park W, Kang TW, Cha MH and Chun JM: Network pharmacology-based prediction of active compounds and molecular targets in Yijin-Tang acting on hyperlipidaemia and atherosclerosis. J Ethnopharmacol 2018; 1–159.
7. Fatima Noor, Muhammad Tahir Ul Qamar, Usman Ali Ashfaq and Aqel Albutti: Network Pharmacology Approach for Medicinal Plants: Review and Assessment Pharmaceuticals 2022; 15(5): 572.
8. Ning AY, Cabrera CI and D'Anza B: Telemedicine in otolaryngology: a systematic review of image quality, diagnostic concordance, and patient and provider satisfaction Ann Otol Rhinol Laryngol 2021; 130(2): 195-204.
9. Bahl S, Singh RP, Javaid M, Khan IH, Vaishya R and Suman R: Telemedicine technologies for confronting

COVID-19 pandemic: a review Journal of Industrial Integration and Management 2020; 5(4).
10. https://www.researchgate.net/publication/355717563
11. Zhao J, Mo C, Shi W, Meng L and Ai J: Network pharmacology combined with bioinformatics to investigate the mechanisms and molecular targets of astragalus radix-panax notoginseng herb pair on treating diabetic nephropathy. Evid Based Complement Alternat Med 2021; 2021: 9980981
12. Ipsa Padhy, Aastha Mahapatra, Biswajit Banerjee and Tripti Sharma: Chapter 4- Computational Approaches in Drug Discovery from Phytochemicals 2023; 57-88.
13. Xinyi Jiao, Xin Jin, Yuanyuan M, Yang Yang, Jinjing Li, Liuyi Liang, Rui Liu and Zheng Li: A comprehensive application: Molecular docking and network pharmacology for the prediction of bioactive constituents and elucidation of mechanisms of action in component-based Chinese medicine 2021.
14. https://www.researchgate.net/publication/355717563
15. Shihao Zheng, Tianyu Xue, Bin Wang, Haolin Guo and Qiquan Liu: Application of network pharmacology in the study of the mechanism of action of traditional chinese medicine in the treatment of COVID-19 2022.
16. Melissa Alegría-Arcos, Tábata Barbosa Felipe Sepúlveda German Combariza Janneth González, Carmen Gil and Ana Martínez David Ramírez: Network pharmacology reveals multitarget mechanism of action of drugs to be repurposed for COVID-19 2022; 13.
17. Zheng S, Xue T, Wang B, Guo H and Liu Q: Application of network pharmacology in the study of the mechanism of action of traditional chinese medicine in the treatment of COVID-19. Front Pharmacol 2022; 13: 926901.
18. 18) Bello SO, Yunusa A, Adamu AA, Imam MU, Bello MB, Shuaibu A, Igumbor EU, Habib ZG, Popoola MA, Ochu CL, Bello AY, Deeni YY and Okoye I: Innovative, rapid, high-throughput method for drug repurposing in a pandemic-A case study of SARS-CoV-2 and COVID-19. Front Pharmacol 2023; 14: 1130828.
19. www.helsinki.fi/en/researchgroups/network-pharmacology-for-precision-medicine/software.
20. www.nature.com/articles
21. Albahri AS, Alwan JK, Taha ZK, Ismail SF, Hamid RA, Zaidan AA, Albahri OS, Zaidan BB, Alamoodi AH and Alsalem MA: IoT-based telemedicine for disease prevention and health promotion: state-of-the-Art. Journal of Network and Computer Applications 2020.
22. Manchanda S: Telemedicine-Getting Care to Patients Closer to Home. Am J Respir Crit Care Med 2020; 201(12): 26-27.
23. Jahn SW, Plass M and Moinfar F: Digital pathology: advantages, limitations and emerging perspectives. J Clin Med 2020.
24. Gudi N, Konapur R, John O, Sarbadhikari S and Landry M: Telemedicine supported strengthening of primary care in WHO South East Asia region: lessons from the COVID-19 pandemic experiences. BMJ Innov 2021; 7: 580-5.
25. Chellaiyan VG, Nirupama AY and Taneja N: Telemedicine in India: Where do we stand?. J Family Med Prim Care 2019; 8: 1872-6. 10.4103/jfmpc.jfmpc_264_19
26. Agarwal N, Jain P, Pathak R and Gupta R: Telemedicine in India: a tool for transforming health care in the era of COVID-19 pandemic. J Educ Health Promot 2020; 9: 190. 10.4103/jehp.jehp_472_20
27. Haleem A, Javaid M, Singh RP and Suman R: Quality 4.0 technologies to enhance traditional Chinese medicine for overcoming healthcare challenges during COVID-19. Digital Chinese Medicine 2021; 4(2): 71–80.
28. Luciano E, Mahmood MA and Mansouri Rad P: Telemedicine adoption issues in the United States and Brazil: perception of healthcare professionals. Health Informatics J 2020; 26(4): 2344-2361.
29. Haleem A, Javaid M, Singh RP and Suman R: Significant roles of 4D printing using smart materials in the field of manufacturing. Advanced Industrial and Engineering Polymer Research 2021; 4: 301-311.
30. Paulo Alberto Battazza Iasbech and Rosalia Aldraci Barbosa Lavarda: "Strategy and practices: A qualitative study of a Brazilian public healthcare system of telemedicine". International Journal of Public Sector Management 2018; 31(3): 347-371.
31. Pierce RP and Stevermer JJ: Disparities in the use of telehealth at the onset of the COVID-19 public health emergency. J Telemed Telecare 2020; 29: 3-9.
32. Kichloo A, Albosta M and Dettloff K: Telemedicine, the current COVID-19 pandemic and the future: a narrative review and perspectives moving forward in the USA. Fam Med Community Health 2020; 8(3): 000530.
33. Bhaskar S, Bradley S and Chattu VK: Telemedicine across the globe-position paper from the COVID-19 pandemic health system resilience PROGRAM (REPROGRAM) international consortium (Part 1). Front Public Health 2020; 8: 556720.
34. Oleg Bestsennyy, Greg Gilbert, Alex Harris, Jennifer Rost: Telehealth: A quarter-trillion-dollar post-COVID-19 reality 2021.
35. John O: Video consultations for triage of patients with covid-19. BMJ 2020; 369: 1583.

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