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BENGAL SCHOOL OF TECHNOLOGY

BST PHARMA NEWS

SUGANDHA, CHINSURAH, HOOGHLY, 08TH JUNE 2026

FROM THE DESK OF PRINCIPAL

I am delighted to note that the next issue of the Newsletter of Bengal School of Technology is going to be released.

I am also happy to note that the Newsletter is rich with Scientific content of current interest.

It is indeed evident that, with the Emerging Technological Advancements and the growing demand for the Technologies like Artificial Intelligence and Machine Learning which has become the buzzwords, has established its importance in all fields, with no exception for Pharmacy. The planners of NEP and Pharmacy Regulations, have thought it wise and timely to revamp the Pharmacy Education System at graduate level with a see-saw change, giving it a new direction to make it a market driven structure of curriculum.

The syllabus of B. Pharm as framed by PCI 2026 as per NEP 2020 has introduced the subjects like Basics of Python Programming in Pharmaceutical Sciences, Introduction to Machine Learning in Pharmaceutical Sciences apart from a basket of Electives in the areas pertaining to the various fields of Ability Enhancement Courses (AEC), Skill Enhancement Courses (SEC), and the Value Addition Course (VAC), to align with the essentials of NEP 2020.

As the new syllabus and regulations need to be implemented from the immediate forthcoming Academic Year 2026-27, all the Examining Authorities and Course conducting academic Institutions are taking a proactive role to prepare a roadmap for its implementation, with a sincere hope that this will give a new direction to the world of Pharmacy, in days ahead.

DR. P. SURESH

FROM THE DESK OF EDITOR

Dr Suchandra Goswami

It is a great pleasure to release the third issue of BST Pharma News 2025. The content in this issue has been structured on assorted topics of drug discovery. Various field of pathogenesis vis-a-vis therapeutic interventions like infections, carcinogenesis, hyperlipidemia has been explored by the authors. Further, content on human intelligence-based technology like AI, telerehabilitation have been incorporated. With this issue, **a special bulletin** on pictorial moments of various innovative activities of students and faculties in-house that have always been a sustained hype of the Institute's strength of education and culture, will be released

AWZ1066S and the New Wave of Anti-Wolbachia Therapeutics: Toward Short-Course Cure for Filariasis

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Keywords- novel lymphatic filariasis treatment, AWZ1066S, Benzimidazole combination therapy, Short duration antifilarial regimen

INTRODUCTION:

The global fight against lymphatic filariasis (LF) and onchocerciasis is entering a transformative phase with the emergence of next-generation anti-Wolbachia drug candidates. Unlike traditional antifilarial regimens that primarily suppress circulating microfilariae, this innovative strategy targets the parasite's biological dependency on its intracellular bacterial symbiont, Wolbachia — a vulnerability increasingly recognized as the parasite's "Achilles' heel."Among the most advanced candidates is AWZ1066S, a fully synthetic, highly specific anti-Wolbachia compound developed by researchers at the Liverpool School of Tropical Medicine in collaboration with international academic partners. Identified through high-throughput whole-cell screening and subsequently optimized through rational medicinal chemistry, AWZ1066S represents a purpose-built antimicrobial specifically engineered to eliminate Wolbachia without broad microbiome disruption. Preclinical investigations demonstrated potent and selective Wolbachia depletion with pharmacokinetic properties compatible with short-course oral therapy — a substantial improvement over prolonged doxycycline regimens. Foundational work published in Proceedings of the National Academy of Sciences (PNAS) established AWZ1066S as a leading anti-Wolbachia candidate capable of achieving significant bacterial clearance in animal models. Recent translational research (2024–2025) has further strengthened the therapeutic promise of AWZ1066S. Combination regimens pairing AWZ1066S with benzimidazole anthelmintics such as albendazole or oxfendazole demonstrated >90% Wolbachia depletion in rodent filariasis models within five days. These findings suggest that short-duration, synergistic regimens may produce sterilizing and macrofilaricidal effects while reducing required exposure levels. This combination approach integrates targeted symbiont disruption with established helminthic therapy, offering a practical pathway toward curative treatment.

FIRST-IN-HUMAN CLINICAL EVALUATION

Clinical translation has begun. A Phase 1 randomized, double-blind, placebo-controlled, single ascending dose study evaluated AWZ1066S in healthy volunteers. The compound exhibited predictable absorption and dose-dependent pharmacokinetics; however, higher doses were associated with gastrointestinal events and transient liver enzyme elevations, underscoring the need for optimized dosing strategies before progression to Phase 2 efficacy trials. Despite early-phase challenges, this milestone marks a significant advance in neglected tropical disease drug development — moving from bench discovery to human clinical evaluation. In January 2025, the Anti-Wolbachia (A·WOL) consortium — involving investigators from the University of Liverpool, Imperial College London, and University of Bonn — received the Royal Society of Chemistry Horizon Prize. The award recognized their pioneering development of fast-acting, highly specific anti-Wolbachia therapeutics with potential to accelerate global elimination efforts. Current mass drug administration (MDA) programs require repeated annual dosing to suppress microfilariae but do not reliably eliminate adult worms. By contrast, AWZ1066S aims to disrupt the essential bacterial symbiosis sustaining adult parasite survival and fertility. If successfully optimized and validated in Phase 2–3 trials, short-course anti-Wolbachia regimens could:

- Reduce treatment duration from weeks to days
- Achieve macrofilaricidal, potentially curative outcomes
- Accelerate elimination timelines
- Strengthen global LF and onchocerciasis control strategies.

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Rational Design and Structure Activity Relationship of Synthetic and Natural Chalcone Analogues as Antimitotic Agents: Advances in Targeting the Colchicine Binding Site of Tubulin

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Chalcone analogues, are enones with a storied history in traditional medicine, have surged as promising antimitotic agents by precisely targeting the colchicine binding site on tubulin—the dynamic protein scaffold powering cellular division. These synthetic and natural variants disrupt microtubule formation, halting cancer cells in mitosis and triggering programmed cell death, often with remarkable selectivity over healthy tissues. As researchers refine their structures through rational design and structure-activity relationship (SAR) studies, chalcones edge closer to clinical reality, blending computational precision with organic synthesis flair.

The Colchicine Site: Preventing microtubule assembly

Tubulin dimers (α-β pairs) polymerize into microtubules, the cytoskeletal highways essential for mitosis, intracellular transport, and cell shape. The colchicine binding site (CBS), nestled at the β-tubulin interdimer interface, is a shallow pocket (~700 Å³) where colchicine locks in a trans-conformation, capping protofilaments and preventing assembly. Chalcones mimic this: their 1,3-diaryl-2-propen-1-one core overlays colchicone's A/B rings, with Ring A (often 3,4,5-trimethoxyphenyl, TMP) mimicking the tropolone methoxy cluster via hydrophobic π-stacking with Leu255, Ala314, and Val355. Hydrogen bonds—crucial for potency—form between the carbonyl oxygen and β-Asn258, β-Thr314, or water-mediated links to β-Asp251.

Electron microscopy and cryo-EM structures (e.g., PDB 6SXV) reveal chalcone-induced tubulin curls at +16° angles, amplifying depolymerization. This cascades into G2/M arrest (up to 80% cells), mitochondrial outer membrane permeabilization, cytochrome c release, and caspase-3/9 activation—pathways confirmed in A549 lung, HeLa cervical, and MCF-7 breast lines. Anti-vascular effects shine too: endothelial tube formation collapses at 0.1-1 μM, slashing angiogenesis in zebrafish models without overt toxicity.

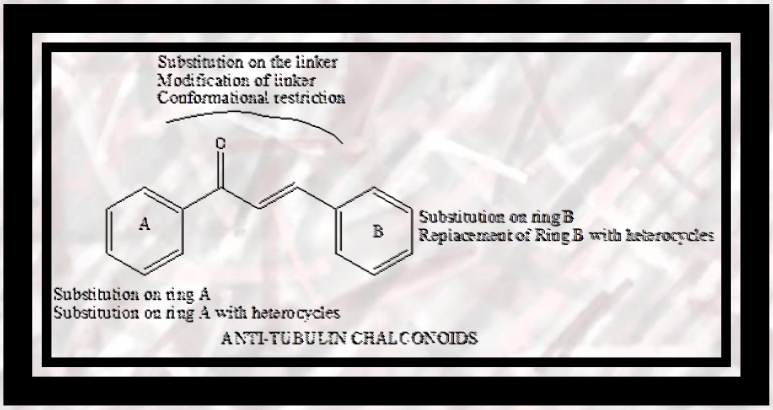
Tweaking the Chalcone Structure: an SAR outlook

After decades of iterative synthesis SAR hotspots have been mapped, turning chalcones from micromolar curiosities into nanomolar killers. Structural domains :

Ring A (Carbonyl-Adjacent): TMP reigns supreme (IC50 ~5 μM tubulin inhibition, matching colchicine), its meta-methoxys hugging the CBS like a glove. Swap for flavone (xanthohumol kin) or chromone? Potency dips 10-fold unless α,β-unsaturated tweaks restore planarity. Heterocycles excel: 7-methoxybenzopyran (millepachine) vaults selectivity via H-bond from chromene oxygen to β-Ser178; indole fusions (e.g., 5-fluoroindole) add π-cation interactions with β-Lys176[1,2].

Ring B (β-Aryl): Para-substituents dictate dance. Electron-donors like diethylamino or morpholino (logP ~3-4) boost solubility and cytotoxicity (GI50 <0.1 μM leukemia), engaging β-Arg369 via H-bonds. Halogens (4-F, ortho-F) enhance lipophilicity for deeper pocket ingress; naphthalene B-rings rigidify the linker, yielding 2-fold tighter binding (Kd 8.4 μM).

α,β-Unsaturated Bridge: S-trans conformers dominate (90% population); α-fluorination sterically blocks cis-flips and H-bonds to β-Val181, slashing IC50 to sub-μM while curbing metabolism.



Crafting These Compounds in the Fume Hood

Synthesis of Chalcones revolves around the elegant Claisen-Schmidt condensation: an aromatic acetophenone (like 1-(3,4,5-trimethoxyphenyl)ethanone for that prized A-ring) meets an aldehyde (say, 4-bromobenzaldehyde for a tunable B-ring) in the presence of a base catalyst.This classic reaction yielding the baseline (E)-chalcone: under mild conditions—10% NaOH or KOH in EtOH/THF at room temperature to 60°C for 4-12 hours—the enone forms in 70-90% yield as vibrant yellow crystals after acidification and recrystallization from ethanol.

For the millepachine hybrids—like star 14c (4-diethylaminobenzopyran)—starting with 7-hydroxy-4-chromanone, the phenol is protected & (acetyl chloride, pyridine) is used followed by an aldol with 4-diethylaminobenzaldehyde using NaOEt in EtOH (reflux, 8h, 65% yield). Acid-catalyzed cyclization (HCl in dioxane, rt) snaps the chromene ring shut, boosting selectivity via that oxygen's hydrogen bond to β-Ser178. Yields hit 50-70%, and the amino group enhances solubility for cell penetration.

Naphthylchalcones, such as potent 6-a or 21k, embrace rigidity e.g- 2-naphthaldehyde and 2-hydroxy-6-methoxyacetophenone: stir in methanolic Ca(OH)2/KOH slurry at 64°C for 6 hours (66% yield, mp 121°C), quench to pH 2, and filter the E-orange solid. The naphthyl's fused rings enforce planarity, slashing tubulin IC50 to ~5 μM while sparing fibroblasts. Also on oral applications, it curbs Lewis lung metastases by 75% in vivo.

α-Fluorochalcones demand precision for anti-angiogenic punch. Post-Claisen-Schmidt on TMP-(4-F-phenyl) chalcone, treat with Selectfluor® or NFSI in DCM with NBS/HF-pyridine (0°C to rt, 40-60% yield)—the α-F sterically pins s-trans, priming Michael addition to Cysβ239. Spectroscopic gems: 19F NMR at -180 ppm confirms, and zebrafish assays show vessel collapse at 1 μM sans toxicity.

Now, heterocyclic twists for MDR-proof warriors: indole-chalcones (e.g., 29f) fuse via Sonogashira coupling—iodoindole + TMS-acetylene (Pd(PPh3)4, CuI, Et3N), hydrolyze to ynone, then aldol with TMP-acetophenone (NaOH, EtOH, 55% over 3 steps). The indole's π-stacking with β-Lys176 yields sub-μM HeLa kills. Echoing your Pd-catalyzed scheme, thiazole-privileged versions use Hantzsch thiazole synthesis (α-haloketone + thiourea) followed by chalcone extension—brominate the thienyl B-ring with NBS (CC14, hv, 85%), then Suzuki-Miyaura with tetrazolyl boronics ($Pd(dppf)Cl_2$, K_2CO_3, dioxane/H_2O, 80°C, 70%). This crafts electron-deficient linkers for covalent CBS traps.

Rational Design Revolution

Computational alchemy drives hits: AutoDock Vina or Glide XP scores prioritize TMP-B occupancy (>70%), with MD simulations (GROMACS, 100 ns) validating RMSF <1 Å at key residues. Virtual screening of ZINC chalcone libraries yields top-1% binders, synthesized via Claisen-Schmidt (ArCHO + acetophenone, EtONa, 80°C) or Heck couplings (as in your Pd(PPh3)4 scheme: bromo-thienyl + chalcone styrene). Hybrids fuse chalcone with combretastatin A-4 (CA-4) cis-restriction or nocodazole's imidazole for dual-site grip.

In vivo validation: Millepachine 16·HCl (47% bioavailability) shrinks A549 xenografts 60% (15 mg/kg iv) weight loss; naphthyls suppress Lewis lung metastasis by 75% orally. Resistance-proof: sub-μM vs MDR HCT-8/T, outpacing paclitaxel [4].

Natural Inspirations to Clinical Horizons: Plants gift blueprints—xanthohumol (hops), cardamonin (boesenbergia)—elevated by semisynthesis. 2022-2026 advances spotlight fluoroindoles for CRC (PI3K/Akt synergy) and benzoxazole-chalcones evading βIII-tubulin overexpression. Millepachine leads are most preffered for their hybrid killing strategy of increasing 100 times the tubulin and shrinking tumor cells. Millepachine/naphthyl lead are bioavailable, safe for use; indoles/fluoros being specialized for resistance.

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Rational design of phytopeptides using integrated computational profiling

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Keywords: Phytopeptides, Bioactive peptides, Density Functional Theory (DFT), Molecular dynamics simulations, Hybrid Quantum classic-generative learning

Abstract:
Plant proteins contain numerous short peptide sequences that may exert beneficial biological effects. These fragments are subsequently assessed through bioactivity prediction tools, physicochemical profiling, and safety evaluation. Structural modelling, molecular docking, and molecular dynamics simulations examine peptide-target interactions and stability. In addition, predictive pharmacokinetic analyses help to determine their suitability for therapeutic or nutraceutical applications. By integrating computational approaches, this strategy informed selection of promising peptide candidates before a laboratory validation. Such rational design principles may accelerate the development of phytopeptides to support the advancement of targeted phytomedicine and functional food formulations.

Introduction: Plant-derived bioactive compounds have long served as valuable resources especially the secondary metabolites. i.e. alkaloids, flavonoids, terpenoids. Whereas, peptides encrypted within plant proteins remain under-explored. These short amino acid sequences, often released through enzymatic hydrolysis during digestion and can exert diverse biological activities including antihypertensive, antioxidant, anti-inflammatory, antimicrobial, and antidiabetic effects [1, 2]. Bioactive peptides are typically inactive within the parent protein sequence and become functional after proteolytic cleavage [3, 4]. Advances in the plant proteomics and bioinformatics now allow mining of plant protein databases to identify potential peptide precursors [5, 6]. Machine learning (ML) platforms can estimate the probability of biological activity, while physicochemical profiling tools assess parameters such as stability, solubility, and isoelectric point. Structural modelling methods e.g. RosettaFOLD, AlphaFold-based predictions facilitate three-dimensional characterization of peptide conformations. Molecular docking and molecular dynamics simulations provide mechanistic insights into peptide–protein interactions at atomic resolution [7, 8]. Phyto peptides has been prominently investigated as anti-snake venom [9] , anti-aging [10], and anti-hair loss agents [11].

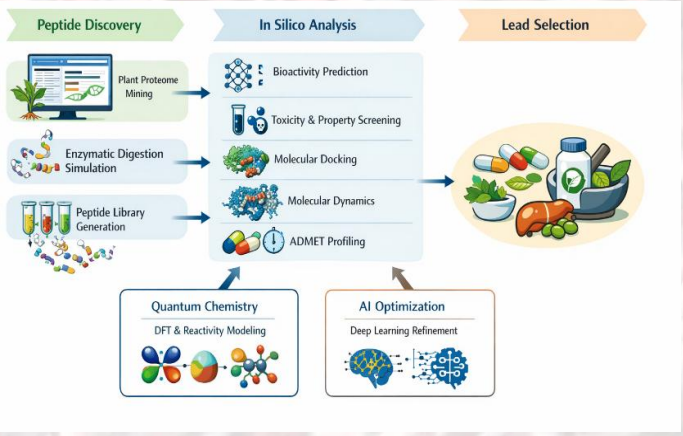

Fig 1. Schematic representations on computational strategies for bioactive Phyto-peptide design.

Conclusion: Hence, this study discusses integrated computational pipelines for identifying and optimizing plant-derived bioactive peptides. The discussed rational framework supports the development of targeted phytomedicines and nutraceuticals.

Future perspectives: The integration of artificial intelligence (AI), quantitative structure-activity relationship (QSAR), and systemic pharmacology together contributed on the computational effect and prediction accuracies. Also, clinical evaluation remains a non-negligible factor.

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Kiss to cancer: the culprit: epstein – barr at *homo sapiens*, as a risk factor virus towards cancer

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Abstract: Epstein Barr virus (EBV), also known as Human Herpesvirus 4, is one of the most prevalent viral pathogens affecting humans, with nearly 95% of the global adult population harboring latent infection. Transmitted primarily through saliva, EBV is the causative agent of infectious mononucleosis and has been implicated in a spectrum of diseases ranging from benign self-limiting infections to severe malignancies. This review highlights the etiology, epidemiology, clinical manifestations, diagnostic approaches, and therapeutic perspectives of EBV infection, with emphasis on its role as a risk factor in oncogenesis. EBV infects B-lymphocytes and epithelial cells, establishing lifelong latency and reactivation cycles that contribute to immune dysregulation and oncogenic transformation. Epidemiological data reveal significant variations in prevalence across age, sex, ethnicity, and socioeconomic status, underscoring the virus's widespread impact. Clinical features include fatigue, fever, pharyngitis, lymphadenopathy, hepatosplenomegaly, and hematologic abnormalities, while complications may extend to neurological disorders, autoimmune conditions such as multiple sclerosis, and cancers including Hodgkin's lymphoma, Burkitt's lymphoma, and nasopharyngeal carcinoma. Diagnosis relies on serological assays detecting viral capsid, early antigen, and nuclear antigen antibodies, though limitations exist in sensitivity and specificity. Current management remains supportive, focusing on rest, hydration, and symptomatic relief, as no definitive cure or vaccine is available. Emerging therapeutic strategies such as proteasome inhibitors, HSP90 inhibitors, EBV-specific cytotoxic T-cell therapies, and natural compounds like EGCG offer promising avenues but require further validation. By consolidating current knowledge, this review underscores EBV's multifaceted role in human disease and highlights the urgent need for targeted interventions to mitigate its oncogenic potential.

Introduction: EBV is a DNA virus that has double strands and targets B-lymphocyte cells. EBV belongs to the family of herpes viruses and was isolated in 1964. EBV is linked to the causation of several types of diseases and can be transmitted through the saliva that contains epithelial cells infected with the virus or the virus itself. Almost 95% of the adult population worldwide is infected. with the EBV virus. EBV is one of the causative agents for infectious mononucleosis.

Evaluation: Determining if a patient has an infection due to Epstein Barr virus is usually most effective through serological testing. Atypical appearing lympho-cytosis is most commonly present on peripheral smear. Hetero-phile antibody tests identify IgM antibodies against EBV. Hetero-phile antibody testing is a good initial test since it is inexpensive, fast, and has a sensitivity of 63-84% and specificity of 84 to 100%. The disadvantages of the hetero-phile antibody test include the possibility of a negative result in children, since they may not produce hetero-phile antibodies to EBV. Unfortunately, other disease processes can induce hetero-phile antibodies, or they may be present for over a year, causing a positive result unrelated to an acute EBV infection.

Etiology: Epstein Barr virus is a herpes virus containing double-stranded DNA enveloped by proteins. The viral envelope contains glycoproteins, which are essential for attachment and entry into host cells, including B cells and epithelial cells. EBV infects B cells by using their molecular machinery for replication of the viral genome. It transforms the B cells into memory B cells that can either enter the circulation or remain latent until some triggering factor reactivates them.

Epidemiology :

Nearly 95% of the world's population of adults have been infected by the Epstein Barr virus. In the United States, the EBV prevalence for children and adolescents aged 6 to 19 years was 66.5%. Children aged 6 to 8 years had an EBV prevalence of about 54%, while those aged 18 to 19 years had an EBV prevalence of 82.9%. Females exceeded males in number infected, but the difference was small. Children and adolescents of Mexican-American ethnicity had higher EBV prevalence compared to non-Hispanic Blacks and Whites. Higher EBV prevalence existed in children and adolescents with higher household size, lower household incomes, lower educational attainment of parents, and those born outside the United States.

EBV (Epstein-Barr Virus) infection:

Also called Human Herpes-virus 4, it is very common, usually transmitted in saliva (such as from kissing or sharing beverages), and may cause nothing more than the common flu, especially in childhood. Inteenage and young adults, it tends to cause infectious mono or "mono," with symptoms including fatigue, fever, throat irritation, and gland swelling. Then EBV persists in your body for the rest of your life but may reoccur, and it can be associated with various cancers and also with Multiple Sclerosis (MS).

Continuing Education Activity:

Epstein Barr virus is a herpes-virus in which infection occurs in over 90% of the population worldwide. EBV infection can range from asymptomatic to infectious mononucleosis. Complications are rare, but important to recognize. This article will review the evaluation and management of the Epstein Barr virus and explain the role of the inter-professional team in managing patients with this condition.

Objectives:

- State the etiology and epidemiology for Epstein Barr virus.
- Retrieve the physical examination results and lab work for patients with the Epstein-Barr virus infection.
- Describe the different treatment options and possible side effects for Epstein Barr virus.
- Explain how working together and communicating as a team among professionals benefits coordination of care among patients suffering from Epstein Barr virus

Transmission:

- Saliva: By kissing and also by sharing eating utensils, cups, and toys; Bodily fluids: Blood and semen during sexual contact, blood transfusions, organ transplantation.

Common Symptoms (Mono):

Excessive fatigue, Fever, Sore throat, throat inflammation, Lymph node swelling (neck, axilla, groin)

Complications & Long-Term Effects:

- Neurological: May involve the brain and spinal cord and nerves (for example, cerebellar
- Hematologic: May lead to conditions such as thrombocytopenia and

Cancers: Associated with certain lymphomas (Burkett, Hodgkin) and cancers in general.

- Autoimmune: Strong link to Multiple Sclerosis (MS).

ALS & Associated Diseases:

- Detection: Atypical mononuclear cells in blood tests (mono spot test).
- Treatment: There is no treatment for it. People need rest, fluid, and pain medicines like ibuprofen/acetaminophen.

KEY POINTS:

- EBV is among the most prevalent viruses that affect human beings, distributed through bodily fluids, mostly through saliva.
- EBV can cause infections such as infectious mononucleosis.
- There are no vaccines available that protect against the infection by EBV.

What EBV is:

Epstein-Barr virus, or EBV, is one of the most widespread viruses in the human race. EBV is also referred to as human herpes virus 4; it belongs to the herpes virus family.

It is estimated that the majority of individuals will be infected with EBV at some stage in their lives, especially during childhood, and they will be asymptomatic. EBV infections in childhood are typically asymptomatic or the symptoms are indistinguishable from other childhood infections.

About mononucleosis:

EBV is the most common cause of infectious mononucleosis, also called "mono." This contagious disease is common among teens and adults

Signs and symptoms:

Symptoms of EBV infection can include:

Fatigue, Fever, Inflamed throat, Swollen lymph nodes in the neck, Enlarged spleen, Swollen liver, Rash

Who is at risk:

After your infection with EBV, the virus will become latent, or dormant, in your body. Occasionally, it will become active again. Sometimes, when it does, you will experience symptoms, but more often, it will affect someone with a weakened immune system.

How it spreads:

You can infect others for weeks. After you initially come down with EBV, you can transmit the virus to others for up to several weeks and even pre-symptomatic. With EBV present within your body, it remains dormant.

EBV is most commonly spread through saliva by:

Sharing drinks and food; Sharing drinking cups, eating utensils, or toothbrushes; having contact with toys that children have drooled on

Prevention:

There is no vaccine to protect against EBV infection. You can help protect yourself by reducing contact with people who have EBV infection.

Make sure you avoid:

Sharing drinks and food; Using the same personal items that an infected person recently used.

Testing and diagnosis:

EBV infection can sometimes be difficult to diagnose, since the presenting complaints resemble those of other diseases. EBV infection can be diagnosed by a blood test that identifies the presence of antibodies.9 of every 10 adults test positive for antibodies, which indicate the presence of current or past EBV infection.

Types of tests:

Viral Capsid antigen (VCA):

Early in EBV infection, anti-VCA IgM appears and then generally disappears within four to six weeks. Anti-VCA IgG is present during the acute stage of EBV infection, peaking at 2 to 4 weeks from onset.

Early antigen (EA):

Anti-EA IgG levels can be found in the acute phase of the disease and tend to drop to undetectable levels after three to six months. In most individuals, the presence of antibody to EA indicates active infection.

EBV nuclear antigen (EBNA):

Antibody to EBNA, as measured by the standard immunofluorescent test, is not detectable during the acute phase of EBV infection but instead slowly appears 2 to 4 months after onset of symptoms and persists for lifetime. Other enzyme immunoassays for EBNA may yield false-positive results.

Monospot test

The Monospot test is not a test to be used generally. The antibodies detected by Monospot may result from conditions other than infectious mononucleosis.

Moreover, studies have revealed that the Monospot yields false positive as well as false negative results. For instance, the heterophile antibodies that are usually detected by the Monospot test are absent in children suffering from infectious mononucleosis.

Interpreting tests:

Interpretation of EBV antibody tests requires experience with these tests and availability of the patient's clinical background.

Susceptibility to infection:

Infection with EBV is believed to be susceptible among people who have no antibodies to VCA.

Primary-new or recent infection

The presence of anti-VCA IgM in the absence of antibody to EBNA is considered to represent a primary EBV infection.

Other results that strongly suggest a primary infection are a high or rising level of anti-VCA IgG and no antibody to EBNA after at least 4 weeks of illness. Resolution of the illness may occur before the diagnostic antibody levels appear.

On very rare occasions, individuals with active EBV infections may not be found to have detectable EBV-specific antibodies.

Past infection: The presence of antibodies to both VCA and EBNA indicates previous infection (from several months to years ago).Because more than 90% of adults have had infection with EBV, there will be a positive serology in most adults from long past infection with EBV. High titers of antibody may remain positive for many years and do not necessarily indicate recent infection.

Recent vs. past infections:

The evaluation of matched acute and convalescent sera is of no value for differentiating current from previous infections with EBV. Typically, in most cases, the immune response in EBV infections develops quickly in primary infections. The clinical manifestations in an infectious mononucleosis infection are manifested simultaneously with the development of both IgG and IgM antibodies against VCA. The immune response is not constant before the development of the manifestations.

Treatment and recovery:

Most people will feel better in 2 to 4 weeks. There is no cure for EBV infection. Some things that can be done to relieve symptoms include: Water drinking for hydration purposes, Getting enough rest

Treatment and Cure:

There's no cure for Epstein-Barr Virus (EBV), but your immune system handles it; treatments focus on symptom relief (rest, fluids, pain meds). Researchers are exploring drugs like HSP90 inhibitors (Ganetespib), proteasome inhibitors (Bortezomib), and natural compounds (like EGCG from green tea, ginkgolic acid) that target viral proteins or replication, and cell therapies (like EBV-specific T-cells) for severe cases, aiming to kill infected cells or block viral entry, but most aren't FDA-approved for general EBV treatment yet.

What Kills EBV (Research & Specific Cases):

Immune – System: Natural killer (NK) cells and T-cells are crucial for clearing EBV-infected B cells.

Experimental Drugs:

HSP90 Inhibitors: Ganetespib targets EBV-infected cells, killing them.

Proteasome Inhibitors: Bortezomib can induce cell death in EBV-infected cells, often combined with antivirals like ganciclovir.

Antiviral Drugs (Limited Use): Nucleoside analogs (ganciclovir, valacyclovir) target viral DNA, but aren't approved for general EBV.

Natural Compounds: Green tea extract (EGCG) and ginkgolic acid show promise in lab studies by blocking viral attachment or fusion.

Cell Therapy: EBV-specific Cytotoxic T-cells (CTLs) are used successfully in transplant patients with severe EBV-related disease.

Conclusion: Epstein Barr virus (EBV) remains one of the most pervasive viral infections in humans, with its ability to establish lifelong latency and reactivation cycles posing significant challenges to global health. While most infections are asymptomatic or self-limiting, EBV's association with infectious mononucleosis, autoimmune disorders, and multiple malignancies underscores its clinical importance.

Current diagnostic methods, though effective, are limited by sensitivity and specificity, particularly in pediatric populations. Treatment remains largely supportive, as no definitive cure or vaccine exists, highlighting the urgent need for targeted therapeutic strategies. Advances in experimental drugs, immunotherapies, and natural compounds offer promising avenues, yet remain in early stages of validation. This review emphasizes the necessity of continued research into EBV's molecular mechanisms, oncogenic potential, and immune interactions. A deeper understanding of these pathways will be critical for developing effective preventive and therapeutic interventions, ultimately reducing the burden of EBV-related diseases worldwide.

Antimicrobial Activity and Phytochemistry of *Azadirachta indica* (Neem) against common bacterial infections

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Keywords: *Azadirachta indica, Antimicrobial activity, Drug-resistant pathogens, Biofilm inhibition, Phytochemistry, Neem-derived therapeutics*

Abstract : The neem tree, also known as *Azadirachta indica* (A. Juss), has been utilized as a traditional treatment for a variety of human illnesses for thousands of years. Neem is also well-known worldwide as a fertilizer and pesticide that works across a wide range of pests. Its uses extend beyond the agricultural industry. Research in the domains of dentistry, food safety, bacteriology, mycology, virology, and parasitology is now being conducted to investigate the broad antimicrobial effects of A. indica. In this paper, we present a synopsis of some of the most recent research findings that support the promise of neem as a previously unexplored source of novel treatments in relation to the aforementioned study areas. The ability of neem extracts and compounds to combat drug-resistant and biofilm-producing organisms is also emphasized; these are two significant groups of pathogens for which there are few therapeutic alternatives. In addition, the paper covers recent developments in the phytochemistry and safety of neem-derived products. Neem has a growing body of fascinating evidence supporting its use as an antimicrobial, but further research is undoubtedly necessary to understand the precise mechanisms of action, clinical effectiveness, and in vivo safety of neem as a therapy for human pathogens of interest. In addition, the numerous current researches and the varied characteristics of neem described in this book may serve as a roadmap for the identification of novel antimicrobials that may be found in other herbal remedies from around the world.

Introduction

Azadirachta indica A. Juss, also known as Neem, Indian Lilac, Margosa, Nimtree, is a fast-growing, evergreen, tropical tree known for its deep green leaves and rugged bark. It attains heights of 15–20 meters and is drought-resistant, which makes it well suited to arid and semi-arid regions. Native mainly to the Indian subcontinent, *A. indica* grows widely across South Asia and has been introduced into Africa, Australia, and parts of the Americas due to its ecological and medicinal value. It thrives in a variety of soils, from stony loams to alluvial plains, and tolerates high temperatures and low rainfall environments (Chandrappa et al., 2015).

Rank	Classification
Kingdom	Plantae
Division (Phylum)	Magnoliophyta (Angiosperms)
Class	Magnoliopsida (Dicotyledons)
Order	Sapindales
Family	Meliaceae (Mahogany family)
Genus	*Azadirachta*
Species	*Azadirachta indica A. Juss.*

Taxonomy:

Azadirachta indica has been central in Ayurvedic, Unani, and Siddha medicinal systems for thousands of years. Traditionally bitter leaves and bark of *A.indica* are used as blood purifiers. Decoctions treat fevers, gastritis, and inflammations. Extracts are applied for skin diseases (eczema, ringworm), wounds, ulcers, and insect bites. Bark, seeds, and leaves treat coughs, diabetes, malaria, jaundice, and urinary disorders. Across cultures in Asia, Africa, and beyond, parts like leaf, bark, seed, fruit, flower, and root find use in digestive, dermatological, and febrile conditions, as well as in repelling insects and treating parasitic infections. The chemical richness of *A. indica* underpins its bioactivities. Scientists have characterized hundreds of phytochemicals, most belonging to limonoids and terpenoids (Lu et al., 2019).

Major Phyto-compounds:

- Azadirachtin (seed): Potent insect antifeedant and biopesticide.
- Nimbin & Nimbidin: Anti-inflammatory and antimicrobialtriterpenoids.
- Nimbolide & Gedunin: Cytotoxic and antioxidant compounds.
- Salannin: Insect repellent.
- Flavonoids: Quercetin, kaempferol (antioxidant activity).
- Phenolic acids: Gallic acid, ellagic acid (varied bioactivities).

Leaves often yield quercetin, ellagic acid, and other polyphenols; seeds and bark concentrate limonoids and steroidal compounds. Neem extracts exhibit broad-spectrum antimicrobial activity against bacteria, fungi, viruses, and parasites, supporting its traditional use in skin and oral infections.

Limonoids and flavonoids modulate inflammatory pathways and scavenge free radicals, contributing to antioxidant effects and potential in chronic disease management. Several studies suggest neem compounds improve glucose regulation and insulin sensitivity, making them subjects in diabetes research (though clinical translation remains limited). Neem leaf extracts enhance immune responses and have been tested as alternatives to antibiotics in animal models, with promising modulation of immune parameters. Compounds like nimbolide and gedunin show cytotoxicity against cancer cell lines and may influence apoptotic pathways, supporting preclinical interest in anticancer drug development (Garg et al., 2015).

Antimicrobial Activity of *Azadirachta indica*

Azadirachta indica has been extensively investigated for antimicrobial activity against bacteria, fungi, viruses, and parasites. Different plant parts including leaves, bark, seeds, and oil exhibit broad-spectrum antimicrobial effects. Its bioactivity is largely attributed to limonoids, flavonoids, polyphenols, and sulfur-containing compounds. Major antimicrobial phytoconstituents include Nimbidin, Nimbin, Azadirachtin, Nimbolide, Gedunin, Salannin, Quercetin, β-sitosterol, Tannins, Saponins. Among these, nimbidin and nimbolide are particularly important for antibacterial and antifungal effects.

Unlike synthetic antibiotics that target a single enzyme or pathway, neem extracts act through multi-target mechanisms, which is why microbial resistance development appears slower compared to conventional drugs (Bansal et al., 2019; Jagannathan et al., 2020).

Phytochemistry of *Azadirachta indica*

Although nearly every part of neem has been used for traditional medicinal purposes in India, the most widely available *A. indica* product on the market today is neem oil. The country of India alone produces hundreds of thousands of tons of neem oil annually and a byproduct of neem oil production includes neem cake, which is abundantly used in agriculture around the world at ~600 pounds per acre of farmland. Neem oil is considered a vegetable oil that is cold pressed from the fruits and seeds of neem. However, neem oil can be further processed into various types of extracts, via different solvents, that are then used for subsequent preclinical and clinical studies (Zeenat et al., 2018).

Although various solvents can be implemented to extract different active components from plant products, most of the compounds that are thought to be responsible for the biological activities of neem can be found in the extracts that are typically used in laboratories (e.g., water, ethanol, methanol, chloroform, and ether). In recently published literature, methanol and ethanol extracts are those that are most commonly used for antimicrobial testing. The general biological activities of the tested neem oil extracts have been attributed to the presence of many secondary plant metabolites, which include classes of compounds such as isoprenoids (e.g., terpenoids containing limonoid structures) and non-isoprenoids (e.g., tannins). The neem tree contains hundreds of compounds (i.e., phytochemicals), many of which have been found to be bioactive and to have diverse utility on their own. Out of the more than 300 unique compounds have been identified within the neem tree, some of the more abundant phytochemicals (e.g., azadirachtin, gedunin, and nimbolide) have already been defined as potential drugs with a wide range of biological activities. The compounds that have been most thoroughly investigated for their individual antimicrobial properties thus far are limonoids, which are compounds that typically consist of four, six-membered rings and one five-membered aromatic ring (i.e., a furanolactone core) and make up one-third of the phytochemicals derived from the neem tree. This class of compounds has also been explored for its abundance of antioxidant activities and includes nimbolide, nimbin, and nimbidin (triterpenoids), azadirachtin, and gedunin. Previously established *in vitro* activities of these compounds and others isolated from neem seed oil have been reviewed and range from anti-inflammatory and antiulcer to spermicidal and anti-psoriasis (Shukla et al., 2020).

The Importance of *Azadirachta indica* (Neem) as a Medicinal Plant

The neem tree, or *Azadirachta indica* (A. Juss), is a tropical evergreen that is indigenous to the Indian subcontinent. Neem has been known for thousands of years for its many health benefits, which include its use in traditional medicine to treat a variety of common human ailments and in agriculture to control pests. Initially,

A. indica sparked interest around the globe because of its potential as a non-toxic agricultural infection-control agent. In fact, azadirachtin, one of the most prevalent substances in neem plants, is widely used as a biopesticide (Alzohairy et al., 2006). However, because of their purported antipyretic, antacid, antiparasitic, antibacterial, antiviral, antidiabetic, contraceptive, antidermatitic, anticancer, anti-inflammatory, antioxidant, antifungal, dental, and other healing and protective qualities, different parts of the neem tree have been utilized for millennia in traditional Indian medicine. Nearly every component of A. indica, including the stem, bark, roots, leaves, gum, seeds, fruits, flowers, and more, has been utilized as a home remedy for a variety of human ailments. Additionally, neem twigs are used as chewing sticks for dental hygiene by millions of people worldwide (Uchegbu et al., 2011).

`Uses of *Azadirachta indica* in treating bacterial infections

The rising rates of antibiotic resistance for bacterial pathogens has led to the need for novel therapeutics; thus, much of the recent work on the antimicrobial potential of neem has focused on the antibacterial properties of the plant. This area of research is supported by the traditional use of neem products for dental hygiene and the successful applications of neem in the food industry. In addition to standard antibiotic resistance, the ability of pathogenic bacterial species to form biofilms has led to an increased interest in describing how these communities contribute to heightened tolerance to antibacterial substances. Although the importance of biofilm-associated infections to human disease is well-recognized, few novel solutions that effectively eliminate biofilms have been developed thus far. However, encouraging data suggest that neem is consistently more effective at prohibiting bacterial growth and at targeting biofilm-grown cells than many other herbal extracts and is, therefore, worth pursuing as a source for drug discovery (Noor, 2011).

Neem has been found to exhibit antibacterial effect in various tooth and dental infections, traditionally. This traditional use has translated to a growing number of studies that have tested neem products for their ability to improve dental hygiene and to prevent or treat oral diseases. Typically, these studies aim to identify an application for neem extracts as a mouthwash alternative, root canal irrigant, toothpaste, etc. Previously, the antimicrobial activity of *A. indica* against common endodontic pathogens, such as *Enterococcus faecalis*, *Staphylococcus aureus*, *Streptococcus mutans*, and *Candida albicans*, has been well-established (Mistry et al., 2014; Barua et al., 2017; Singh et al., 2020). In a study, it was shown that at 7.5%, aqueous neem leaf extract was able to inhibit the growth of *E. faecalis*, *S. mutans*, and *C. albicans* and that the MIC of an ethanolic neem leaf extract was 1.88%, 7.5%, and 3.75% against these three important dental pathogens, respectively (Nayak Aarati et al., 2011). More recently, another work determined that a methanolic extract of *A. indica* showed considerable antimicrobial activity against a three-week-old polymicrobial dental biofilm grown on extracted human teeth consisting of *S. mutans*, *E. faecalis*, *S. aureus* and *C. albicans* (Mistry et al., 2015). Another study involving two small human studies indicate that a neem-based toothpaste or gel can reduce the levels of *S. mutans* in the mouth and that the gel formulation can reduce plaque and gingivitis to the same degree as a chlorhexidine gel control (Nimbulkar et al., 2020; Selvaraj et al., 2020).

Other than monotherapy, *A. indica* also provides a synergistic effect, when administered with other phytochemicals or other antimicrobials. Of note, several studies have already suggested that neem extracts have similar levels of activity as chlorhexidine or hypochlorite (typical components of oral washes) against plaque, gingivitis, and pain *in vivo* (Jalaluddin et al., 2017; Hosny et al., 2021) and against biofilm-forming bacteria (e.g., *Streptococcus viridans*, *Porphyromonas gingivalis*, and *S. aureus*) and *C. albicans in vitro* or *ex vivo* (Joy Sinha et al., 2017; Anand et al., 2016; Kankariya et al., 2016; Heyman et al., 2017; Andonissamy et al., 2019; Bansal et al., 2019; Tasanarong et al., 2021). Another human pathogen that causes plaque and other biofilm-related diseases in the body, *E. faecalis*, is also just as susceptible to various neem extracts as it is to chlorhexidine *in vitro* (Chandrappa et al., 2015; Mustafa, 2016; Bhardwaj et al., 2017; Joy Sinha et al., 2017).
Similarly, extracts of some other medicinal plants such as *Commiphora myrrha* (myrrh), *Acacia* tree (e.g., catechu), *Cinnamomum verum* (cinnamon), *Salvadora persica* (miswak), *Syzygium aromaticum* (clove), *Zingiber officinale* (ginger), *Allium sativum* (garlic) and *Curcuma longa* (tumeric) against some species of bacteria and cultured dental caries have demonstrated potent antimicrobial effect (Kanth et al., 2016; Jagannathan et al., 2020; Arora et al., 2021). Some cases, involving use of *A. indica* against resistant bacterial strains have pronounced activity in various ailments, including several bacterial species that cause wound infections are found on the long list of antibiotic resistant threats, including *S. aureus* and *P. aeruginosa* (CDC, 2019). Garg et al. (2015) demonstrated that methanol and chloroform neem extracts performed better than other plant extracts and better than several different antibiotics against both *S. aureus* and *P. aeruginosa* (Garg et al., 2015).

More specifically, it has also been determined that the MIC of limonoid compounds that were isolated from neem seeds are between 32 µg/ml and 128 µg/ml against *P. aeruginosa* and another opportunistic skin pathogen, *Staphylococcus epidermidis* (Lu et al., 2019). As a translational approach to this area of research, several studies have demonstrated that an aqueous neem leaf extract that was used to make alginate fibers for wound dressings (Hussain et al., 2017), a nanofibrous mat embedded with neem leaf extract (Ali et al., 2019), and a topical gel containing a methanolic neem extract all inhibit *S. aureus* growth (Raju and Jose, 2019). In the case of a polyesteramide synthesized from neem oil to produce a nanofibrous mat, the incorporation of *A. indica* into this wound treatment method resulted in increased tissue regeneration in rats, as compared to the control commercial cream (Killi et al., 2019). These results potentially have broad applications for many areas of medicine in which the risk of antibiotic-resistant skin/wound infections is high.

Finally, there have been many studies published on the antibacterial properties of neem against a variety of diverse human pathogens. The overwhelming conclusion from the majority of these investigations is that many elements of *A. indica* (e.g., seeds, bark, leaves, etc.) produce extracts that have moderate to significant levels of antimicrobial activity against several pathogens: *S. aureus*, *E. coli*, *E. faecalis*, *P. aeruginosa*, *Salmonella typhi*, *Streptococcus agalactiae*, *Shigella boydii*, *B. subtilis*, *Klebsiella pneumoniae*, and *Candida tropicalis*. Moreover, in side-by-side comparisons A. indica-based components often show superiority to other plants; a few exceptions include aqueous garlic extract and ethanolic green tea extract that were each shown to work better than neem extracts to kill *Bacillus anthracis* or *S. aureus* and *E. coli*, respectively (Zihadi et al., 2019; Kaur et al., 2021).

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Healing Beyond The Walls: The Rise of Telerehabilitation

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Keywords:Telerehabilitation, Remote Patient Monitoring, Rehabilitation Technology, Artificial Intelligence in Healthcare, Virtual Reality Rehabilitation, E-health Transformation.

Abstract:

Telerehabilitation, an extension of telehealth, enables patient to access therapeutic services remotely through video consultations, wearable sensors, mobile health applications, and AI-driven monitoring systems. This approach has become especially significant in the post-pandemic era, where accessibility, continuity of care, and patient safety are paramount. By integrating real-time feedback tools, motion tracking, virtual reality platforms, and cloud-based electronic health records, telerehabilitation bridges geographical barriers and ensures quality care even in underserved communities. For clinicians, it enhances workflow efficiency, promotes interprofessional collaboration, and supports data-driven decision making. Despite its growing adoption, challenges such as digital literacy, technology costs, regulatory barriers, and the need for standardized clinical protocols remain. Ongoing advancements in artificial intelligence, haptic technologies, and remote-controlled robotics are expected to address many of these limitations and redefine the future landscape of rehabilitation. Overall, telerehabilitation represents a paradigm shift extending healing beyond traditional walls and making high-quality rehabilitation services more inclusive, efficient, and future-ready. This abstract encapsulates the emerging trends, clinical applications, and technological innovations driving the rise of telerehabilitation in modern healthcare.

Fig.1: Telerehabilitation

INTRODUCTION: In an era defined by technological leaps and global connectivity, the domain of healthcare is undergoing a transformative revolution. One of the most compelling manifestations of this change is Telerehabilitation, an innovative approach that transcends traditional boundaries and brings healthcare to patients' doorsteps.[1] No longer confined by geographical limitations, telerehabilitation embodies the promise of healing beyond walls, offering continuity, accessibility, and personalized care through digital platforms. Telerehabilitation the power of modern communication technologies including video conferencing, remote monitoring, and wearable devices to deliver therapeutic interventions directly to patients in the comfort of their homes. It represents a paradigm shift in the delivery of rehabilitation services, where convenience meets clinical efficacy, and patient empowerment becomes a cornerstone of recovery. [1,2]

"Healing hands reach through the screen,
Guiding movements, unseen yet keen,
Recovery blossoms where distance has been".

Fig.2: Telerehabilitation (COVID-19)

BACKGROUND AND EVOLUTION OF TELEREHABILITATION:

The origins of telerehabilitation trace back to the broader concept of telemedicine, which emerged as a solution to the challenges of providing healthcare in remote and underserved regions.

Telerehabilitation has broadened this concept by focusing on therapeutic treatments across other disciplines, such as physiotherapy, occupational therapy, speech therapy, and psychological rehabilitation, whereas telemedicine was solely concerned with diagnosis and consultation..[2]

Historically, rehabilitation involved patients making frequent visits to clinics, which was often difficult due to mobility problems, travel difficulties, and restricted access. The emergence of digital communication tools and advanced monitoring technologies has transformed this model. Nowadays, telerehabilitation integrates scientifically supported therapeutic methods with real-time monitoring and interactive feedback, allowing patients to access continuous, high-quality care from any location.

HOW TELEREHABILITATION WORKS:[3]

Telerehabilitation works by delivering personalized therapy sessions remotely through secure digital platforms, enabling real-time assessment, guidance, and progress monitoring from anywhere.

"Your Home, Your Rehab Hub"

APPLICATIONS ACROSS DISCIPLINES:

- **Physical Therapy:** Remote sessions guide patients through exercises with motion-tracking to ensure correct posture and technique.
- **Occupational Therapy:** Virtual coaching helps patients relearn daily activities like dressing, cooking, and work tasks.

Video Conferencing: Platforms like Zoom, Microsoft Teams, and dedicated tele-rehab software allow therapists to conduct live sessions, observe patient movements, and provide real-time feedback.

Mobile Applications: Apps offer exercise tutorials, reminders, and progress tracking. Gamified elements encourage adherence and engagement

Wearable Devices: Sensors and smartwatches monitor activity, range of motion, and vitals, transmitting data to therapists for analysis.

Virtual Reality (VR) & Augmented Reality (AR): VR-based telerehabilitation can simulate real-world tasks, enhancing motor learning and cognitive rehabilitation in a controlled virtual environment.

- **Speech Therapy:** Live online sessions and interactive tools support communication improvement for speech and language disorders.[4]
- **Neurological Rehabilitation:** Tele-based cognitive and motor training assists patients with conditions such as Parkinson's, MS, or brain injuries.
- **Cardiac & Pulmonary Rehabilitation:** Customized home exercise plans and vital-sign monitoring support recovery while reducing hospital visits.[4]

CHALLENGES AND LIMITATIONS:

Digital Literacy Barriers: Many older adults and tech-inexperienced users struggle to use digital platforms, limiting engagement in telerehabilitation.

- **Infrastructure Limitations:** Poor internet connectivity and lack of proper devices hinder smooth delivery of remote therapy.
- **Privacy & Security Concerns:** Ensuring patient data protection and compliance with healthcare regulations remains a major challenge.
- **Clinical Limitations:** Certain hands-on or specialized therapeutic procedures cannot be effectively performed virtually.[5]
- **Need for Professional Training:** Therapists must acquire new digital skills and undergo continuous training to deliver effective virtual care.

TELEREHABILITATION IN INDIA AND GLOBAL PERSPECTIVE: In India, telerehabilitation has gained traction in urban centers and is increasingly recognized in national health policies. Pilot programs have demonstrated improved outcomes for post-stroke patients and individuals with musculoskeletal disorders. [6,7]. Globally, countries like the United States, Canada, Australia, and the UK have incorporated telerehabilitation into mainstream healthcare, offering insurance coverage and developing standardized protocols. The World Health Organization emphasizes digital health as a key tool for achieving universal health coverage, and telerehabilitation is a vital component of this vision.

THE FUTURE PERSPECTIVE OF TELEREHABILITATION: The future of telerehabilitation is both exciting and expansive. The future of telerehabilitation is set to expand dramatically with advanced tools like haptic gloves, robotic exoskeletons, and AI analytics bringing high-quality, home-based care within reach. Improved integration with EHRs (Electronic health records) and telehealth networks will enhance coordination among healthcare providers and caregivers. On a global level, telerehabilitation will reduce hospital visits, cut costs, and increase patient engagement, helping deliver quality rehabilitation to remote and underserved areas. As digital platforms evolve, personalized and goal-oriented treatment plans will become the new norm in rehabilitation.[8]

CONCLUSION:

Telerehabilitation is transforming healthcare by removing physical barriers and making rehabilitation more accessible, affordable, and personalized. It complements traditional therapy and supports a wide range of conditions, from stroke recovery to chronic disease management. With advances in AI, VR, robotics, and wearable technology, telerehabilitation is poised to deliver highly interactive and individualized care. Ultimately, it shows that healing can happen anywhere, empowering patients and extending quality care beyond clinical settings.

Indeed, in this new era, rehabilitation has entered homes, communities, and even pockets of the world that were previously unreachable. The future is clear: *"Healing beyond walls is no longer a vision-it is a reality".*

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Newer treatment of hyperlipidemia

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Cardiovascular disease (CVD) is the leading cause of death globally, with an estimated 17.8 million fatalities in 2017. The role of low-density lipoprotein cholesterol (LDL-C) in the development of atherosclerosis and CVD is well-documented, with clinical studies evidencing a direct correlation between LDL-C reduction and decreased CVD risk.
Statins are the cornerstone treatment for hypercholesterolemia and have a strong body of evidence supporting their efficacy in lowering LDL-C levels and the concomitant reduction in CVD risk for both primary and secondary prevention strategies. They function by competitively inhibiting 3-hydroxy-3-methylglutaryl-coenzyme A (HMG-CoA) reductase, a crucial enzyme in the mevalonate pathway responsible for cholesterol production. This inhibition alters the enzyme's structure, effectively preventing it from functioning, which results in decreased cholesterol synthesis in hepatocytes. The lowered cholesterol levels lead to an upregulation of LDL receptors, facilitating greater cholesterol uptake and subsequent lowering of LDL-C levels[1]

A comprehensive meta-analysis encompassing 90,056 participants across 14 randomized statin trials demonstrated that statin therapy resulted in a 12% reduction in all-cause mortality for every mmol/L decrease in LDL-C. This translated to a significant 19% decrease in coronary mortality. The analysis further revealed reductions in myocardial infarction and coronary death by 23%, the need for coronary revascularization by 24%, and declines in both fatal and non-fatal strokes and major vascular events by 17% and 21%, respectively, each with a p-value less than 0.0001, underscoring the clinical significance of LDL-C reduction through statin therapy

Proprotein convertase subtilisin/kexin type 9 (PCSK9) is a serine protease primarily expressed in the liver, with additional presence in the pancreas, intestine, kidneys, and brain. The PCSK9 gene resides on chromosome 1p32.3, is 22 kb long, contains 12 exons, and encodes a 692 amino acid inactive glycoprotein that undergoes intramolecular auto-cleavage in the endoplasmic reticulum, which is essential for its activation and release. PCSK9 binds to LDL receptors (LDLR), leading to their lysosomal degradation, thereby decreasing LDL receptor recycling and increasing blood LDL cholesterol (LDL-C) levels. Gain-of-function mutations result in hypercholesterolemia and higher coronary artery disease (CAD) risk, while loss-of-function mutations correlate with lower LDL-C levels and reduced cardiovascular risk.
In 2015, the US FDA approved two monoclonal antibody PCSK9 inhibitors, evolocumab and alirocumab, as add-on therapies for patients with familial hypercholesterolemia (FH) or clinical atherosclerotic cardiovascular disease (ASCVD) requiring further LDL-C reduction. These inhibitors effectively lower LDL-C with minimal adverse events
The Open-Label Study of Long-Term Evaluation against LDL Cholesterol 1 and 2 (OSLER-1 and OSLER-2) involved 4465 patients and demonstrated that evolocumab reduced LDL-C levels by 61% compared to standard therapy after 12 weeks. Additionally, it increased high-density lipoprotein cholesterol (HDL-C) and apolipoprotein A1 (ApoA1) by 7% and 4.2%, respectively. The ODYSSEY LONG TERM trial assessed alirocumab's effects over 78 weeks in 2341 high-risk patients. Results showed a 61.9% reduction in LDL-C compared to placebo with 79.3% of alirocumab patients reaching LDL-C levels below 70 mg/dL at week 24. Alirocumab also lowered ApoB, total cholesterol, non-HDL-C, lipoprotein(a), and fasting triglycerides while raising HDL-C and ApoA1 levels.
PCSK9 inhibition is also beneficial for statin-intolerant patients. A clinical study revealed that alirocumab achieved a 45% reduction in LDL-C compared to 14.6% with ezetimibe, with fewer skeletal muscle-related adverse events than those rechallenged with atorvastatin[2].
Moreover, the LDL-C-lowering effects of PCSK9 inhibitors are associated with improved cardiovascular outcomes. In the FOURIER trial, evolocumab treatment significantly reduced major cardiovascular events, including cardiovascular death, myocardial infarction, and stroke, in a population with stable ASCVD and additional risk factors, underscoring the therapeutic potential of PCSK9 inhibition in managing lipid levels and cardiovascular risk.

Bempedoic acid is a prodrug that, after conversion to its active form, inhibits adenosine triphosphate-citrate lyase (ACL), leading to reduced cholesterol synthesis in the liver. This results in increased LDL receptor expression and decreased circulating LDL cholesterol levels. Additionally, it activates adenosine monophosphate-activated protein kinase (AMPK), enhancing glucose homeostasis.

In 2020, the US FDA approved bempedoic acid as an adjunct treatment for adults with heterozygous familial hypercholesterolaemia or established atherosclerotic cardiovascular disease who need further LDL cholesterol reduction[3].

Inclisiran is a long-acting synthetic small interfering RNA (siRNA) molecule that specifically inhibits the production of PCSK9 in the liver. siRNAs block the expression of certain genes with complementary nucleotide sequences by selectively silencing the translation of their complementary target messenger RNAs (mRNAs) via intracellular binding to RNA-induced silencing complexes in a sequence-specific manner.

Thus, siRNAs affect the degradation of mRNA post-transcription, hence preventing translation Inclisiran is a double-stranded small RNA that inhibits the transcription of *PCSK9*, thus limiting the production of PCSK9 in the hepatocytes. This leads to an upregulation of LDLR in the hepatocyte membranes and a subsequent reduction in circulating LDL-C levels. Inclisiran has emerged as a potential alternative to PCSK9 monoclonal antibody LDL-C-lowering therapy[4]

Angiopoietin-like protein 3 (ANGPTL3) is a secretory protein exclusively produced in the liver and an important regulator of plasma lipid levels by inhibiting lipoprotein lipase (LPL)-mediated and endothelial lipase (EL)-mediated hydrolysis of triglycerides and phospholipids.

It has been shown that reduced expression or inactivation of ANGPTL3 in mice reduces plasma triglyceride, LDL-C, HDL-C, and free fatty acid levels and protects from atherosclerosis. In humans, loss-of-function mutations in the ANGPTL3 gene lead to familial combined hypolipidaemia. In the DiscovEHR human genetics study, it was again shown that patients with loss-of-function variants of the ANGPTL3 gene have substantially reduced levels of LDL-C, triglycerides and HDL-C. Furthermore, the risk of CAD amongst patients with loss-of-function variants of the ANGPTL3 gene was 41% lower than the risk in the general population despite the presence of low HDL-C levels[5].

Peroxisome proliferator-activated receptors (PPARs) are nuclear ligand-activated proteins that, once activated, regulate the transcription of target genes that control metabolism and energy equilibrium. PPARs regulate diverse aspects of lipid metabolism, thus playing a crucial role in lipid homeostasis. Three isotypes of PPARs have been described: α (NR1C1), β/δ (NR1C2) and γ (NR1C3). Fibrates are selective PPARα agonists used for the management of dyslipidaemia,

whereas thiazolidinediones are potent PPARγ agonists used in the treatment of DM. PPARβ/δ agonists are not currently used in clinical practice, though some promising results have been reported with their use in early clinical trials[6].

Seladalpar or MBX-8025 is a selective PPARγ agonists treatment led to a decrease in small and very small LDL particles while increasing large LDL particles and LDL peak diameter,

reversing the atherogenic LDL phenotype (LDL pattern B) in about 90% of participants. In a 12-week phase II trial with 13 patients having HoFH, 42% saw a ≥20% reduction in LDL-C, with an overall mean reduction of 10%. However, an increase in PCSK9 levels was noted, necessitating further research. While initial results are promising, larger clinical trials are needed to firmly evaluate MBX-8025's impact on cardiovascular risk and clinical outcomes.

Liver X receptors (LXR) are ligand-activated transcription factors that play a major role in the regulation of gene expression involved in diverse cellular functions but especially in lipid and bile acid metabolism and cholesterol homeostasis [7,8]

LXR agonists are thought to promote reverse cholesterol transport and potentially reduce intestinal cholesterol absorption, possibly inhibiting atherosclerosis progression.

However, in mice, oral LXR agonists lead to increased hepatic lipogenesis, enhanced fatty acid synthesis, steatosis, and greater secretion of triglyceride-rich VLDL, resulting in hypertriglyceridaemia. Additionally, LXR activation may raise LDL-C levels in species with cholesteryl ester transfer protein, like non-human primates.

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Advanced Drug Delivery Systems: Shaping the Future of Therapeutics

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Abstract: Pharmaceutical sciences have evolved from traditional dosage forms to complex, engineered systems that can release drugs in a site-specific, controlled, and stimuli-responsive manner. A paradigm shifts in therapeutics, advanced drug delivery systems (ADDS) address issues like systemic toxicity, rapid drug clearance, poor bioavailability, and patient non-compliance. ADDS improves therapeutic indices and pharmacokinetic and pharmacodynamic profiles by combining polymer science, nanotechnology, molecular biology, and material engineering. With an emphasis on their revolutionary role in
contemporary therapeutics, this article critically examines the scientific underpinnings, classification, technological developments, regulatory issues, and potential future directions of advanced drug delivery systems.

Introduction:

Historically, the goal of drug delivery has been to use traditional dosage forms like tablets, capsules, injections, and syrups to achieve therapeutic plasma concentrations. Even though these systems have shown clinical value, biological barriers, non-specific distribution, first-pass metabolism, and fluctuating plasma drug levels often prevent them from producing the best therapeutic results. Efficiency, safety, and accuracy are becoming more and more important in the modern pharmaceutical industry. By overcoming physiological and physicochemical barriers, Advanced Drug Delivery Systems (ADDS) allow for both temporal and spatial control over drug release. In the context of targeted anticancer therapy, biologics, nucleic acid therapeutics, and poorly water-soluble medications, these systems are especially pertinent. The transition from conventional formulations to engineered delivery platforms represents a change from "drug administration" to "therapeutic optimisation."

Rationale for Advanced Drug Delivery Systems:

A number of clinical and pharmacological obstacles are driving the development of ADDS:

- ❖ New chemical entities poor solubility in water
- ❖ Restricted ability to pass through biological membranes
- ❖ Quick systemic removal
- ❖ Non-specific distribution of tissues
- ❖ Toxicology related to dose
- ❖ Problems with patient adherence in long-term treatment

Advanced formulation techniques targeted at improving solubility and bioavailability are especially advantageous for drugs classified as Class II and IV under the Biopharmaceutics Classification System (BCS).

Additionally, the development of gene-based therapies and biologics calls for protective carriers that can guarantee targeted intracellular delivery while protecting labile molecules from enzymatic degradation.

Controlled and Sustained Release Systems:

The long-term goal of controlled release systems is to keep plasma drug concentrations within the therapeutic window. These systems depend on mechanisms of swelling, erosion, osmotic pressure, dissolution, or diffusion.

3.1 Matrix system: Diffusion and polymer relaxation cause the release of drugs that are distributed within a polymer matrix.

3.2 Reservoirs Systems: Rate-controlling membranes that regulate release kinetics encircle drug cores.

3.3 Osmotic Drug Delivery Systems: To accomplish zero-order drug release, these systems make use of osmotic pressure gradients. Reduced dosing frequency improves patient adherence and therapeutic consistency in chronic conditions like diabetes, hypertension, and psychiatric disorders, demonstrating the clinical significance of sustained-release systems.

Targeted Drug Delivery Systems:

In order to maximise effectiveness and reduce systemic toxicity, targeted drug delivery aims to localise therapeutic agents at particular tissues, cells, or intracellular compartments.

4.1 Passive targeting: Takes advantage of physiological processes like the tumour vasculature's Enhanced Permeability and Retention (EPR) effect.

4.2 Active targeting: Involves interactions between drug carriers and particular cellular receptors (such as transferrin or folate receptors) that are mediated by ligands. Oncology has been greatly impacted by targeted delivery, which has improved the therapeutic index and decreased collateral damage to healthy tissues.

Nanotechnology-Based Drug Delivery Systems:

Advanced pharmaceutics now relies heavily on nanotechnology. Usually between 10 and 1000 nm in size, nanocarriers provide improved cellular uptake, tuneable surface characteristics, and increased surface area.

5.1 Polymeric Nanoparticles: They offer improved stability and controlled release when made with biodegradable polymers like PLGA.

5.2 Solid Lipid Nanoparticles (SLNs) and Nanostructured Lipid Carriers (NLCs): These lipid-based systems shield medications from deterioration and increase solubility.

5.3 Metallic and Magnetic Nanoparticles: Facilitate the integration of diagnostic and therapeutic processes (theragnostic).

Nanotechnology improves:

- ❖ Solubilisation of drugs
- ❖ Kinetics of controlled release
- ❖ penetration of the blood-brain barrier
- ❖ accumulation specific to tumours

The translational potential of nanomedicine in global healthcare was demonstrated by the quick development of lipid nanoparticle platforms for mRNA-based vaccines.

Vesicular Drug Delivery Systems:

6.1 Liposomes: Phospholipid-based vesicles that can hold both lipophilic and hydrophilic drugs. Their biocompatibility and capacity to diminish toxicity render them significant in anticancer and antifungal treatments.

6.2 Niosomes: Non-ionic surfactant vesicles are more stable and cheaper than liposomes.

6.3 Ethosomes and Transfersomes: Ultra-deformable vesicles made to improve transdermal penetration.

Vesicular systems show that they can be used in many different ways, including systemically, topically, and for specific purposes.

Polymeric and Biodegradable Systems:

PLGA, chitosan, alginate, and polylactic acid are examples of biodegradable polymers that are commonly used in injectable depots, microspheres, and implants.

Benefits include:

- ❖ Long-lasting drug release
- ❖ Compatibility with living things
- ❖ Removal without surgery
- ❖ Less often taking doses

Injectable depot systems are especially helpful for long-term psychiatric and hormone therapy.

Stimuli-Responsive and Smart Drug Delivery Systems:

Smart drug delivery systems release drugs at specific sites in response to internal or external stimuli.

- ❖ Ultrasound
- ❖ Irradiation with light

A. Stimuli from inside the body:

- ❖ pH-sensitive systems (targeting the tumour microenvironment)
- ❖ Carriers that respond to enzymes
- ❖ Systems that are sensitive to redox

B. Stimuli from outside:

- ❖ Heat
- ❖ Magnetic Fields

These kinds of systems are very similar to precision medicine and are a big step forward in the direction of personalised therapeutics.

Emerging Technologies in Drug Delivery:

9.1 Dosage Forms Made with 3D Printing: Allow for personalised dosing and complicated patterns of drug release.

9.2 Getting Genes and Nucleic Acids to Cells: Nanocarriers are necessary for the safe and effective delivery of siRNA, DNA, and mRNA therapies.

9.3 Theragnostic Systems: Put diagnostic imaging and therapeutic delivery on the same platform.

The integration of pharmaceutical sciences with biotechnology, materials science, and computational modelling is advancing the frontiers of drug delivery research.

Challenges and Regulatory Considerations:

ADDS also have many other translational challenges despite current advances in technology including:

- ❖ Manufacturing complexities
- ❖ Limits in scalability
- ❖ Concerns over stability
- ❖ Problems with reproducibility
- ❖ Regulatory uncertainty

Regulatory authorities require:

- ❖ Extensive evaluations for toxicology
- ❖ Immunogenicity testing
- ❖ Long-term safety evaluations
- ❖ Formulations developed using Quality by Design (QbD)

Standardized characterization techniques for nanomedicines have yet to be harmonized, so addressing these needs is a priority.

Future Perspectives:

The advanced delivery systems of drugs will be developed through:

- ❖ The development of AI Algorithms for Drug Development
- ❖ Personalized Nano-Medicine
- ❖ Targeting Gene/Editing Delivery Platforms
- ❖ Micro/Nano Robotics for the Transport of Drugs
- ❖ Developing Sustainable and Green Formulations.

As chronic diseases and complex treatment methods continue to rise, this willpropel new innovations within Drug Delivery Science.

Conclusion

The development of Advanced Drug Delivery Systems (ADDS) marks an evolution from traditional methods for administering medications to accurately engineered platforms for providing medical treatment.

Artificial Intelligence and Machine Learning in Pharmaceutics: Revolutionizing Formulation Development

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Abstract:
Pharmaceutical Sciences is undergoing a transformation through AI and ML with the use of data-based methodologies in Drug Discovery, Formulation Development, Process Optimization and Quality Assurance. The use of predictive modelling and computational intelligence to replace traditional trial- and-error methods for developing products is becoming more prevalent due to the multidimensional and interdependent nature of formulation variables. Tools that employ AI can also assist in the rational selection of excipients, the optimization of drug release profiles, predicting stability, and the application of Quality by Design (QbD). This paper discusses the conceptual framework, applications, advantages, challenges, and outlook for the impact of AI and ML inb Pharmaceutics, as well as their impact in revolutionizing the development of formulations and advancing the concept of precision therapeutics.

Introduction:
In the past, pharmaceutical companies have developed new products through trial-and-error methods in a laboratory, often taking many years and requiring huge amounts of money to produce stable, effective and scalable formulations.New developments in artificial intelligence (AI) and machine learning (ML) are leading to a fundamental change in how the pharmaceutical industry will conduct research and product development. AI is a term that describes a group of computer programs that can perform tasks that require human-like cognitive abilities such as pattern recognition, reasoning, and decision-making. ML is a branch of AI that uses statistical algorithms to learn from large quantities of data and can make predictions and optimize results without explicit instructions.Formulation performance in pharmaceutics is determined by many different interrelated variables (e.g., excipient concentration, particle size, pH, and processing parameters) so the role of AI is to present a systematic method formodelling complex relationships among these variables in the development of new drug formulations. The use of AI and ML in formulation science represents a change from empirical methods of developing drug formulations toward predictive and data-driven design of new drug formulations.

Rationale for AI Integration in Pharmaceutics:
Drug development is facing a myriad of evolving issues. Some of these include the escalating number of poorly soluble drug candidates, the increasing complexity of biologics and macromolecules, elevated regulatory expectations, high development costs, as well as the need to accelerate product development timelines.
Classic strategies for developing drugs typically utilize a broad and often time-consuming amount of experimental screening. However, much of the non-linear interactions that occur amongst formulation components may not be adequately captured using traditional methods. AI/ML algorithms can explore large datasets, discover hidden patterns, and accurately predict the behavior of formulations, yielding greater precision than traditional methodologies. AI has a close correlation with Quality by Design (QbD). For example, when working with QbD, it is essential for manufacturers to comprehend the relationship between Critical Material Attributes (CMAs) and Critical Process Parameters (CPPs) to ensure product quality.

Machine Learning Techniques in Pharmaceutical Applications:
Supervised Learning: It contains a dataset of previously established, defined outcome interactions, which are used to train an algorithm to predict the dissolution profile, stability, and/or bioavailability. Common algorithm examples include Linear Regression, Decision Trees, Support Vector Machines, and ANNs.
3.2 Unsupervised Learning: It is a technique, which does not have an established dataset of defined outcome interactions, and consists of clustering or identifying similarities and patterns in data that assist with identifying similarities and optimizing combinations of excipients.
Deep Learning contains more advanced forms of ANNs and can process highly complex, high-dimensional datasets such as imaging (MRI), spectroscopy, and molecular descriptors. Reinforcement Learning is typically utilized to make optimal decisions in dynamic systems (e.g., continuous manufacturing systems).
There are numerous Machine Learning techniques observed within the pharmacy space.

AI in Pre-formulation Studies:

Characterizing physicochemical characteristics like solubility, stability, and polymorphism along with compatibility. AI models can:

- ❖ Predict solubility in aqueous solutions from molecular descriptors
- ❖ Estimate the permeability of an absorption potential
- ❖ Predict likely pathways of degradation
- ❖ Predict polymorphic transitions have taken place

The use of historical data in machine learnings also reduces the amount of experimentation and provides current guidance when developing early formulation strategies. Predictive modelling leads to greater efficiency when selecting formulation pathways for BCS Class II and IV drugs.

AI in Formulation Optimization:

The development of formulations entails a vast number of variables to be considered at the same time. Conventional Design of Experiments (DoE) techniques are systematic but cannot effectively ascertain the nonlinear interaction between variables.

The use of AI to enhance optimization includes: 1. Prediction of drug dissolution profiles 2. Determination of optimal polymer concentrations 3. Estimation of sustained-release kinetics 4. Selection of excipient ratios

Artificial Neural Networks (ANNs) have outperformed traditional modelling techniques when it comes to predicting the release of drugs from a matrix system. By decreasing experiment runs with comparable results, AI will allow companies to reduce the reliance on physical experimentation.

AI in Nanotechnology and Advanced Drug Delivery:

When formulating nanoparticles, there are numerous interactions between particle size, surface charge, polymer type, and the amount of drug loaded. The AI applications available include: -

- ❖ Prediction of nanoparticle size distribution
- ❖ Optimization of encapsulation efficiency
- ❖ Modelling the drug release kinetics
- ❖ Rating the stability of nanoparticles based on varying conditions

Machine learning models can analyse a wide range of multivariate data collected from nanocarrier systems to develop new methodology for the rational design of lipid nanoparticles, polymeric nanoparticles, and nano emulsions.

The predictive nature of these models will provide significant benefits when considering either targeted drug delivery or gene therapy products.

AI in Process Analytical Technology and Manufacturing:

The use of AI by pharmaceutical manufacturers will enable a more effective process control through the use of Process Analytical Technology (PAT), which provides real-time measurement of production parameters.

Some examples of the application of AI will include:

- ❖ Measurement of blending consistency between batches
- ❖ Prediction of granule size distributions
- ❖ Control of coating thickness
- ❖ Detection of variances in continuous manufacturing processes

Machine learning will help manufacturers make their processes robust and more reliable, it will also reduce the number of batch failures and the integration of Industry 4.0-based technologies will improve process automation and the ability to produce data to support regulatory compliance.

AI in Stability Studies and Shelf-Life Prediction:

Stable product development has traditionally required the completion of long term and accelerated studies.

Predictive Models (AI Based) Can:

- ❖ Forecast degradation kinetics
- ❖ Determine the shelf life of a product under different environmental conditions
- ❖ Identify stability-indicating factors

These predictive models significantly decrease development timelines and resource expenditures while providing support for regulatory submissions.

Applications in Personalized Medicine:

AI Driven Systems Personalizing the Formulation Development Process AI driven systems enable the development of personalized dosage forms by utilizing patient specific data (i.e. genomic/metabolomic/disease progression). Specific Examples of Patient-Centric Formulations:

- ❖ Individualized dosing regimens
- ❖ Customized release profiles
- ❖ 3D printed patient-specific tablets

Precision oncology formulations

The ability to personalize medicine through the development of patient specific dosage forms represents significant advances in therapeutic optimization

Advantages of AI in Formulation Development:

- ❖ Reduced experimental burden
- ❖ Accelerated Development
- ❖ Cost effectiveness
- ❖ Increased accuracy of predictions #Improved reproducibility
- ❖ Data driven decision making

AI allows for evidence-based formulation design, thereby reducing reliance on empirical screening or instinct.

Challenges and Limitations:

Despite AI's Advantageous Attributes, Barriers Exist to Implementation:

- ❖ The need for high-quality datasets.
- ❖ The availability of standardized pharmaceutical databases is limited.
- ❖ Transparency/Interpretability of Algorithms is limited.
- ❖ Regulatory Uncertainty.
- ❖ Interdisciplinary expertise is necessary.
- ❖ Data bias and overfitting are risk factors.

Ethical and Regulatory Considerations:

Regulatory authorities are continuing their assessments of AI powered techniques. A few of the major points of interest include:

- ❖ Validating Models
- ❖ Verification of Data Integrity
- ❖ Traceability of Data
- ❖ Transparency with Decision Making

Explainable AI has become increasingly important as companies want assurance that their prediction is made on sound science and conforms to the expectations of regulators.

Future perspective:

Future developments in Artificial Intelligence (AI) applied to pharmaceutics will encompass:

- ❖ Digital Twin Integration in Manufacturing
- ❖ Real-Time Adaptive Formulation Systems
- ❖ AI-Assisted Screening of Drug/Excipient Compatibility

- ❖ Autonomous Laboratories
- ❖ Advanced Predictive Modelling of Biologics

Combining AI with Nanotechnology, Biotechnology, and Materials Science will lead to new innovations in drug formulation. As we have more computational power and larger sets of pharmaceutical data than ever before, it is predicted that AI will play an integral role in the field of formulation research moving forward.

Conclusion:

AI and machine learning will continue to be a driving factor in redefining pharmaceutics by changing the method of developing drug formulations through the predictive analysis rather than relying solely on empirical data. The complexity of relationships among formulation variables will be evaluated by AI to provide a more efficient process, increase the accuracy of the formulations, and enhance the drug delivery design processes.

From pre-formulation through manufacturing to personalisation, AI-enabled methods are yielding better products in shorter time frames. While there are still many roadblocks to overcome associated with data quality, regulatory acceptance of these products, and collaboration between disciplines, the movement toward integrating AI into pharmaceutical science is considerably toward a progressive position.

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