CDPP CENTRE FOR DEVELOPMENT POLICY AND PRACTICE

Exploring the Intersection of Policy, Regulation, and Accessibility of Healthcare

JAHANGIRABAD INSTITUTE OF TECHNOLOGY

CONFERENCE ON PHARMA & HEALTHCARE

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Venue: JIT, Barabanki, Uttar Pradesh

Conference Pre-Reads

Organising Partners SAHAYATA TRUST IMRC

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About the speakers

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Dr. Amitabh Kundu has been a Professor and Dean of the School of Social Sciences, JNU. He served as Chairperson of the Post-Sachar Evaluation Committee and Diversity Index Committee of the Ministry of Minority Affairs, of Housing Shortage Estimation Committee at the Ministry of Urban Development and Housing Start-Up Committee at RBI.

2. Abdul Shaban

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Abdul Shaban is Professor and Chairperson of the Centre for Public Policy, Habitat, and Human Development, School of Development Studies, Tata Institute of Social Sciences (TISS), Mumbai. He was Deputy Director of TISS Tuljapur Campus from 2014 to 2019 and has been a member of various committees and commissions constituted by the Government of India and State Governments. He has been associated with different journals as an editor and as a member of the editorial boards.

3. Amir Ullah Khan

Founder-Research Director of CDPP and a Member of the Telangana Public Service Commission (TGSPC). He is a development economist and a Visiting Professor at the Indian School of Business (ISB).

Dr. Amir Ullah Khan is the Founder-Research Director of Centre for Development Policy and Practice (CDPP) and a member of the Telangana State Public Service Commission. He is a development economist and adjunct Professor at the MCRHRDI of the Government of Telangana. He is a visiting

Professor at the Indian School of Business (ISB). He has worked on various research projects for the European Commission, National Council for Applied Economic Research, Planning Commission, Confederation of Indian Industry and the World Bank. He has also been engaged with the Project LARGE of the UNDP on legal reforms, and with Encyclopaedia Britannica in the previous century.

4. M.A. Sikandar

Director of Centre for Distance and Online Education (CDOE) of Jamia Hamdard (Deemed to be University), New Delhi.

Prof. M.A. Sikandar is a known University Administrator and served as the Registrar of three Universities – Jamia Hamdard, Maulana Azad National Urdu University (Central University), Hyderabad (Telangana) and Dr. B.R. Ambedkar University Delhi (State University). Dr. Sikandar has been teaching management in MANUU Hyderabad before joining Jamia Hamdard in July 2023. He also headed the National Book Trust, India (Ministry of Education, Govt. of India) as its Director for four years from 2011-2015. He was also the Book Fair Director of the New Delhi World Book Fair, one of the largest Fair in South Asia. Dr. Sikandar also served over 10 years in the University of Delhi as Assistant Registrar, Planning Officer, Deputy Registrar and Joint Registrar (2001-2015). He briefly served as the Chief Administrative Officer (CAO) MDI Gurgaon in 2005. He holds an MBA, M.Phil, LL. B (DU) and he obtained a Ph.D (Commerce and Business) from JMI.

5. Ranjini C. R.
Executive Director, Centre for Global Health and Development, RV University, Bangalore

Dr. Ranjini C. R. is the Executive Director, Centre for Global Health and Development, RV University, Bangalore. A versatile scholar with two decades of cumulative experience in top academic and research institutes in India and abroad [Cambridge University (UK) and Lancaster University (UK), Indian Institute of Management (Bangalore) and National Institute of Advanced Studies (NIAS, IISc campus)]. Research experience in corporate (Google Health AI) and NGO sectors (Public Health Foundation of India and Public Affairs Centre). A former journalist with the New Indian Express, Bangalore, awarded a

two-year Fellowship at Cambridge University, UK: Mellon Sawyer Fellow, Doctoral degree with distinction from Lancaster University (U.K.) in Health Informatics (Sociology) and Postdoctoral Researcher at Centre for Public Policy, Indian Institute of Management, Bangalore. She has recently been awarded the Achiever for the India UK Achiever's Honours by the UK Government.

6. Nilanjan Banik

Professor, Mahindra University, Hyderabad

Prof. Nilanjan Banik focusses on application of econometrics in issues relating to international trade, market structure and development macro economics. He has publication in International Review of Economics and Finance, Empirical Economics, Review of Development Economics, Development Policy Review, Journal of World Trade, Asian Development Bank Working Paper, Economic and Political Weekly, etc. Prof. Banik has project experience with KPMG India; Australian Department of Foreign Affairs and Trade; Laffer Associates, USA; RIS, New Delhi; ICRIER, New Delhi; Center for Economic Policy Research, UK; ADBI, Tokyo; ADB, Manila; UNESCAP, Thailand; the Australia India Institute; CUTS International, India; Geneva Network, UK; and World Trade Organization, Geneva**.**

7. Debashis Chakraborty
Professor, Indian Institute of Foreign Trade, Kolkata

Dr. Debashis Chakraborty is a Faculty of Economics at IIFT, Kolkata Campus. He received his PhD Degree from Jawaharlal Nehru University, New Delhi. He has a rich experience of more than nineteen years in teaching and five years in policy research. Prior to joining IIFT, he was with Rajiv Gandhi Institute of Contemporary Studies, a ruptured policy think tank. His areas of research interests include Trade and WTO issues, Environmental Sustainability and Economic Development in India, and he has conducted several research projects on these themes. The teaching interests of Dr. Chakraborty include Business Economics, International Economics, WTO and Trade Policy, Trade Analytics,

Development Economics, and Policymaking in India, etc. He has extensively published research articles in national and international referred journals of repute with twelve volumes (including both co-authored and co-edited ones) to his credit.

8. Mohammad Jawed Ahsan

Principal, Faculty of Pharmacy, Jahangirabad Institute of Technology, Barabanki (UP)

Prof. Mohammad Jawed Ahsan is a full Professor in Pharmaceutical Chemistry, and presently working as Principal, Jahangirabad Institute of Technology, ***Faculty of Pharmacy***, Jahangirabad, Uttar Pradesh**, India. His area of interest is** He has been enlisted among ***World's Top 2% Scientists*** released by **Stanford University, USA with Scopus-Elsevier profile for the last six consecutive years since 2020**. He has contributed more than 135 articles that are indexed in SCIE journals, authored four books and two book chapters, and filed three national patents. His *i*-10-index is 66, *h*-index is 30, and more than 3238 citations in Web of Science. He is an editorial board member of springer's SCIE-indexed *BMC Chemistry* journal.

9. Mohd Abid

Professor in the Faculty of Pharmacy, Jahangirabad Institute of Technology, Barabanki (UP)

He has published 54 research articles in well-recognized national and international peer-reviewed journals, achieving a total of 746 citations, an h-index of 12, and an i10-index of 20. He has participated in national and international scientific conferences, contributing to the presentation, discussion, and dissemination of scientific research. His major research domains include central nervous system (CNS) pharmacology, experimental pharmacology, and natural product research. Dr. Mohd Abid plays a significant role in the instruction and supervision of B. Pharm, postgraduate, and Ph.D. scholars. He is committed to maintaining high standards of academic quality, effective research supervision, and holistic student development. Beyond teaching and research, he contributes to Head of examination, HOD of Department of Pharmacology and professional development programs. His academic interests encompass

innovative teaching practices, advancement of pharmaceutical research, interdisciplinary collaboration, and student guidance.

10. Alfisha Khan

Assistant Professor, Faculty of Pharmacy, Jahangirabad Institute of Technology, Barabanki (UP)

Ms. Alfisha Khan completed her M. Pharm (Pharmaceutics). Her research focuses on Novel Drug Delivery Systems, ocular formulations, antifungal therapy for eye infections, and advanced pharmaceutical technologies. She has several publications in peer-reviewed journals and has participated in national and international conferences. She is actively involved in teaching D. Pharm and B. Pharm students. She also serves as the Campus-Level Head of the Cultural Committee, overseeing cultural and co-curricular activities across all departments. Her academic interests include teaching, research, student development, and mentoring.

11. Manzoor Ghori
Founder & Executive Director, Indian Muslim Relief & Charities (IMRC), USA

Manzoor Ghori founded IMRC in 1981 to provide meaningful support to India's underserved communities through education, relief, and sustainable development. With over four decades of leadership, he has shaped IMRC into one of the most trusted American Muslim non-profits working in India today. His leadership continues to guide IMRC's work—focused on transparency, dignity, and real, lasting impact.

12. Maj. Gen. Vikas Saini, SM, VSM**
Director, Jahangirabad Institute of Technology, Barabanki (UP)

Maj. Gen. Vikas Saini, SM, VSM**VSM**, is a distinguished veteran of the Indian Army Special Forces and a trained Paratrooper, with 36 years of exemplary service in combat and strategic operations. Over the course of his career, he has served in key Special Forces units, including an Airborne Battalion, a Para Commando Battalion, Special Frontier Force, and Special Group. He commanded 50 (Independent) Parachute Brigade (the only airborne formation of the country) country), Parachute Regiment Training Centre, and served as the Force Commander National Security Guard. Notably, he is the only two star General to have served in all the Special Forces units of the Indian Army.

His leadership also extended to Army Public Schools, Army Nursing Colleges, Sainik Schools, Kendriya Vidyalayas and ASHA Schools specialized institutions dedicated to children with special needs where he actively fostered academic excellence and inclusive education.

Academically, he holds an M.Sc. in Defence and Strategic Studies an M.Phil. in Defence & Management and has completed executive education at IIM Bangalore

13. Najmul Hasan Rizvi

Secretary:
Board of Trustees of Tauheedul Muslimeen Trust, Lucknow
Managing Committee of Unity College , Lucknow
Executive Committee of M U College Aligarh

Mr. Najmul Hasan Rizvi, after nearly 25 years of working overseas in investment banking, he returned to India in 2013 to dedicate himself full time to social work. His lifelong mission is to empower marginalised communities through quality, employability-oriented education and accessible healthcare. Educated at La Martiniere College, Lucknow, he earned a BSc from Lucknow University and an MBA in Finance from Aligarh Muslim University. For over 30 years, he has been closely associated with the Tauheedul Muslimeen Trust (TMT), supporting education and healthcare initiatives for underprivileged communities in Uttar Pradesh. His work includes providing financial assistance to meritorious students, establishing educational and vocational training institutions, and supporting healthcare and rehabilitation services. He continues to serve on the boards and managing committees of several Indian non-profit organisations focused on education and healthcare.

14. Md. Yaqub Ashrafi

Assistant Professor, Veer Kunwar Singh University, Ara(Bihar)

Md. Yaqub Ashrafi is a dedicated educationist, trainer, and motivational speaker with a rich background in academia and professional development. He began his teaching career at AN College, Patna, in the MBA department and later served at Arcade Business College, Patna. An accomplished presenter, he has delivered inspiring lectures and workshops on motivation, soft skills, and spoken English across numerous colleges and schools. Driven to broaden his impact, he founded his own training firm to provide practical soft-skills coaching and English language instruction to students and professionals. Holding a Master's degree in English and a Ph.D., Dr. Ashrafi blends scholarly insight with hands-on training methods to foster confidence, communication, and career readiness in his learners. Currently, he serves as an Assistant Professor at VKS Ara, where he continues to mentor students, design skill-building programs, and promote lifelong learning and professional excellence.

15. Syed Anas Ali

Partner, Digibloom Academy,

Syed Anas Ali is a senior education professional with over 25 years of experience in the field of education and skills development. He serves as General Secretary of the Society for Promotion of Education and as Director of the Central Skill Development Board, where his work focuses on strengthening institutional capacity and expanding access to vocational and professional training. He is also the National Coordinator for Electrohomeopathy of India, contributing to the organisation and standardisation of alternative health education initiatives. In addition, he is a partner at Digibloom Academy, where he supports the integration of digital tools and innovative pedagogies to enhance learning outcomes and employability across diverse learner groups.

16. Sheikh Asim Husain

President, Be Human

Asim Husain, President of Be Human, leads a community-based organisation focused on affordable access to education, healthcare, and social support for underserved populations. Under his leadership, Be Human has provided low-cost education in English, mathematics, and science to 134 students in Classes 8–10 at a nominal monthly fee. The organisation also operates a dispensary offering consultations and medicines at minimal cost, alongside a physiotherapy clinic providing affordable treatment per session. In addition, Be Human has supported vulnerable families by distributing food to attendants at government hospitals. During the COVID-19 pandemic, Mr Husain's humanitarian efforts were recognised by Zee News, which conferred on him the title of "Oxygen Man." A businessman by profession, he is a graduate and serves as President of the Redfort Shopkeepers Bazar Association.

ABSTRACTS

Pharma, Pricing, Availability and Stocks

Amir Ullah Khan

India is host to 3 crore cases of infection, nearly 17% of the worldwide figure. On top of this level of morbidity, mortality is high too with 4 lakh deaths, which is ten percent of the total globally. Tackling human resource shortages by way of doctors and nurses is going to take a while, even if undertaken at a war footing.

But ensuring a steady supply of drugs and equipment is what we must work towards with urgency. Keeping enough stocks of drugs and vaccines, without endangering the supply of the same to other countries, is a matter of simple logistics and international cooperation and can be achieved quickly. India, with its large capacity to produce drugs and vaccines must develop a clear strategy on stockpiling.

Being the Pharmacy of the world, the Indian pharmaceutical sector must ensure through R and D, and through adequate production that each state has enough stock to handle even those health disasters that emerge without warning and notice. We continue to depend on China for imports of APIs to manufacture bulk drugs and are now buying vaccines against COVID from all parts of the globe to meet the enormous supply demand gap that exists in the country.

Emergency stockpiles are important for a country like India where a pandemic can cause huge losses in no time. Stockouts lead to tremendous profiteering, substandard and counterfeit medicine and a significant increase in the Out-of-Pocket expenditure for any patient, leading to acute chronic poverty in millions of cases. We now have a fair idea of what drugs could be repurposed for handling COVID 19. Dexamethasone, a generic drug used for arthritis and asthma, proved to be a popular choice among doctors in ICUS. So did Remdevisir. However, stockouts and panic buying resulted in complete market chaos.

It is in this context that the Government and India and the MOFHW and the Ministry of Chemical and Fertilizers should quickly come up with a strategy that will make essential and repurposed drugs available at all times. This ought to be done without raising prices and without curtailing foreign trade in medicines and drugs.

ABSTRACTS

Health Financing in India: The Persistent Burden of Out-of-Pocket Expenditure on Households

Abdul Shaban

Health is a critical indicator of human development and a foundational component of social welfare. Many welfare states have established strong institutional frameworks and rights-based policies to ensure universal access to affordable, high quality healthcare. In India, however, health remains a sector marked by chronic underinvestment and limited state intervention. Public support for healthcare continues to fall short of population needs, resulting in uneven access, heavy reliance on private providers, and a substantial financial burden on households.

India's healthcare system is characterised by spatially uneven distribution of services and persistent inadequacies in public provisioning. In many regions, particularly rural and peripheral areas, access to quality health facilities remains limited. Even when services are available, the cost of care often imposes severe economic strain on households. One or two episodes of serious illness are often sufficient to erode savings, force asset sales, or push families below the poverty line. Health shocks thus operate not only as medical events but also as major drivers of economic vulnerability.

The burden is especially pronounced among the elderly, for whom accessing appropriate healthcare is often an uphill task. Age-related morbidity, combined with limited income security and inadequate geriatric services, intensifies dependence on out-of-pocket payments. Although public insurance initiatives such as Ayushman Bharat aim to provide financial protection, their reach remains uneven. Limited coverage, exclusion errors, and low awareness—particularly among

older populations—have reduced their effectiveness in mitigating health-related financial risk.

Empirical studies consistently demonstrate that India's health financing system is dominated by out-of-pocket expenditure (OOPE), with deep and persistent inequities. Poorer households, rural populations, and socially marginalised groups face higher financial exposure while having lower access to publicly financed health services (Balarajan, Selvaraj, & Subramanian, 2011). Although overall service availability has improved over time, health outcomes and access remain strongly shaped by gender, caste, wealth, education, and geography (Balarajan et al., 2011, p. 505).

In 2004–05, more than three quarters of total health expenditure in India were financed privately. High OOPE thus emerged as a major source of inequity in healthcare financing and a key failure in financial risk protection. Medical expenses accounted for over half of Indian households falling into poverty, with an estimated 39 million people pushed into poverty each year due to health-related spending (Balarajan et al., 2011, p. 505). Despite incremental policy reforms, the reliance on private spending has remained stubbornly high. OOPE as a share of total health expenditure stood at 69.4% in 2004, declined marginally to 64.2% in 2014, and remained high at 62.6% in 2015 (Mishra & Mohanty, 2019, p. 2).

The persistence of high OOPE is closely linked to poor service quality in public health facilities and low insurance coverage. These constraints have driven households toward private providers, often at significantly higher costs (Mishra & Mohanty, 2019). Distress financing—through borrowing, asset sales, or informal loans—is particularly prevalent among poorer and less educated households, especially for institutional deliveries conducted in private facilities.
Evidence from hospitalisation data further underscores the severity of the burden. In 2014, the mean OOPE on hospitalisation was Rs.19,210,

rising sharply for conditions such as cancer (Rs.57,232) and heart diseases (Rs.40,947). Around 28% of households incurred catastrophic health expenditure and resorted to distress financing. Cancer-related treatment resulted in the highest incidence of catastrophic expenditure (79%) and distress financing (43%), while more than one-third of patients hospitalised for cardiovascular, neurological, genitourinary, musculoskeletal, gastrointestinal conditions, and injuries reported financial distress (Kastor & Mohanty, 2018).

The likelihood of incurring high OOPE increases further in cases of caesarean deliveries, and treatment in private facilities significantly amplifies both financial burden and distress (Mishra & Mohanty, 2019). Limited prepaid mechanisms and inadequate public financing remain the fundamental drivers of household vulnerability (Wagstaff et al., 2018). Reducing catastrophic health expenditure, therefore, requires a decisive shift toward greater public spending and expanded prepaid financing, particularly through tax-based mechanisms and compulsory contributions.

Keywords: Health financing, Out-of-pocket expenditure, Catastrophic health expenditure, Health inequality

India's Pharmaceutical Evolution: Pharma Policy, Regulation, and Innovation

Dr. Ranjini C. R.

Introduction: A Sector at the Crossroads

India's pharmaceutical sector stands at a transformative crossroads—a resilient powerhouse poised for a bold reset toward innovation, quality, and global leadership. As of 2026, the pharma industry is no longer defined solely by its volume as the "Pharmacy of the World," but by a structural shift toward value-driven research and high-tech medical solutions (IPA, 2026). The industry has proven its mettle by sustaining a 7–9% growth rate despite significant global headwinds.

Export Strength

Projections indicate exports will reach a record **$32 billion** this year, following a trajectory where the market is estimated to expand to $130 billion by 2030 (ASSOCHAM & Deloitte, 2024).

Global Reach

India currently supplies 40% of generic demand in the United States and 25% of all medicines in the United Kingdom.

Domestic Vitality

Supported by a growing middle class and increased healthcare awareness, domestic demand remains robust at 8–9%, with consumer spending expected to triple as accessibility improves (ASSOCHAM & Deloitte, 2024).

Policy Reforms: The 2025 Structural Shift

The year 2025 marked a pivotal realignment of India's regulatory landscape, streamlining the path for both global giants and Micro, Small and Medium Enterprises (MSMEs).

GST 2.0 & Efficiency

The rollout of Goods and Services Tax (GST) 2.0 has simplified tax structures and reduced inefficiencies across the value chain, while digital reforms have slashed regulatory approval delays by approximately 90 days (IPA, 2026).

Quality Standards

The rollout of the revised *Schedule M* guidelines marks a significant step toward harmonization with international Good Manufacturing Practice (GMP) standards (IPA, 2026).

Strategic Incentives

The ₹10,000 crore Biopharma SHAKTI (Stimulating Health Advancement through Knowledge and Technology Innovation) scheme and the Production Linked Incentive (PLI) schemes have catalyzed domestic production of critical bulk drugs, such as Penicillin-G, reducing reliance on external supply chains (PIB, 2026).

Building Innovation Momentum

While India ranks 3rd globally in pharmaceutical volume, it ranks 14th by value, highlighting the urgent need to bridge the innovation gap (ASSOCHAM & Deloitte, 2024).

R&D Investment

Current Research and Development (R&D) expenditure stands at roughly 0.8% of Gross Domestic Product (GDP). To compete, Indian firms must lift investments from current levels (7–8% of revenue) to the global innovator benchmark of 15–25% (ASSOCHAM & Deloitte, 2024; IPA, 2026).

Emerging Frontiers

The Promotion of Research and Innovation in Pharma-MedTech (PRIP) scheme is driving breakthroughs in Chimeric Antigen Receptor T-cell (CAR-T) therapies, peptides, and precision medicine (Invest India, 2025).

Action Plan: Strengthening Industry-Academia Collaboration

To realize the $130 billion vision, India must transition from isolated academic research to structured, long-term industry partnerships.

Establishing National Strategic Networks

The Union Budget 2026–27 proposed establishing **three new National Institutes of Pharmaceutical Education and Research (NIPERs)**. Under Component A of the PRIP scheme, **₹700 crore** is allocated to set up **Centers of Excellence (CoEs)** at NIPERs specialising in anti-viral drug discovery and biological therapeutics (PIB, 2025; PIB, 2026).

Curriculum Redesign and Skill Exchange

Academic institutions are integrating Pharmacology, System Biology, and AI into curricula to produce "industry-ready" graduates (PIB, 2026). The **National Biopharma Mission (NBM)** has successfully upskilled thousands of researchers in technology transfer and regulatory compliance (World Bank, 2026).

Enhancing Infrastructure and Funding

PRIP Component B provides financial assistance (up to **₹100 crore** for late-stage projects) to industry players collaborating with government academic institutions (PIB, 2025). Furthermore, the NBM has established **18 shared facilities** across India, allowing startups to access high-end infrastructure for vaccine development (World Bank, 2026).

Streamlining Technology Transfer

The establishment of seven specialized **Technology Transfer Offices (TTOs)** has facilitated over 1,000 intellectual property filings, managing the transition of academic discoveries into the commercial landscape (World Bank, 2026).

Navigating a Complex Global Landscape

India's ascent is occurring amidst rising trade nationalism and heightened geopolitical scrutiny.

Supply Chain De-risking
Following the COVID-19 pandemic, the world is diversifying supply chains away from over-reliance on China. India is positioned as the primary alternative capable of matching China's manufacturing scale (Jha & Sharma, 2020).

Regulatory Rigor
Increased scrutiny from the **U.S. Food and Drug Administration (FDA)** and **European Medicines Agency (EMA)** regarding data integrity requires Indian firms to maintain unwavering compliance to secure international trust (IPA, 2026).

Conclusion: The Road to 2030

Indian pharma stands at a defining inflection point. The next five years offer a window to realise a **$450–500 billion life sciences ambition**. By harmonizing regulations, scaling R&D through the PRIP scheme, and expanding into specialized biotechnologies, India will evolve from the world's largest supplier of generics to a leading source of new therapies (IPA, 2026).

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Pharmacy Tariffs, Pricing, and an Economist Perspective on Equitable Access to Medicines

Nilanjan Banik

Access to medicines and vaccines is important for a developing country like India, particularly when a large section of our population lacks medical insurance and has to bear out-of-pocket expenses. National Sample Survey data shows 86% of rural, and 82% urban populations uninsured, with rural population borrowing 25% more for healthcare than urban 18%, pushing millions into poverty. People meet their out-of-pocket expense—some 47% of the cost of hospital admissions in rural areas and 31% in urban areas—by borrowing and the sale of personal goods and assets. Increase in price of medicines and vaccines impact the poor income households as healthcare infrastructure in India is not in great shape, and people lack insurance. The central government spends approximately 1.8 % of GDP on healthcare. This covers centrally-sponsored schemes, national health programs, and institutions under central administration. State governments collectively spend around 2% of GDP on healthcare. Since healthcare is primarily a state subject under India's constitution, states bear the larger share of public health expenditure. The total healthcare spending (Central and State governments combined) of 3.5%–4% of GDP is quite low in India when compared with developed countries such as the US, United Kingdom, South Korea, and Japan, where the proportion of GDP spent on healthcare exceeds 10%. Controlling for level of per-capita income, which is to say, comparing India with other similar economies in the region, it is revealed that India has a lower life expectancy and a higher infant mortality rate. All this leads to a situation where the population cannot access good healthcare services provided by the government at minimal or no cost. With the government operating on a tight budget for healthcare, the argument should focus on how to reduce the price of medicines and vaccines for the uninsured population. There are many factors, such as tariffs, non-tariff barriers, domestic taxes, inefficient supply chains, and poor logistics, that can impact the price of medicines for retail consumers. Interestingly, one of the factors leading to price of medicine in India has to do with trade barriers. India's trade barriers, particularly high import tariffs and cumbersome customs procedures,

significantly distort markets. High tariffs elevate import costs, channelling impacts through four pathways that burden stakeholders from raw material producers to end consumers. These barriers, including complex documentation and delays costing importers up to $1,250 per 20-day clearance, represent 45% of trade hurdles in India. Tariffs foster protectionism but inflate prices and stifle competition, as seen in sectors like textiles and pharmaceuticals. Reforms to simplify procedures and lower tariffs could enhance efficiency and global integration. Global average ad valorem tariffs on medicines (HS 3004 code, covering categories like antibiotics, insulin, and corticosteroids) dropped from 4.9% in 2001 to 3.4% in 2021 across 98 jurisdictions, below the 7.6% nonagricultural average. Significant reductions occurred in Lower-Middle-Income Countries (LMICs) outside the WTO Pharmaceutical Agreement, with India achieving the largest percentage drop (from 34.4% to 10%), while Nigeria, Ghana, and others eliminated tariffs entirely. However, high tariffs persist: Pakistan at 20%, Nepal at 14.7%, and South Asian/Latin American nations like India (10%), Brazil (9.3%), and Argentina (9.2%) lead the list. India imposes the world's highest vaccine tariff at 10% (HS 300220), followed by Djibouti (8%) and others like Pakistan (5.7%) and several at 5%. Most jurisdictions maintain zero tariffs on vaccines, but LMICs' duties hinder rapid distribution, critical for pandemics like COVID-19 where billions of doses require global supply chains. Vaccines played an important role at the time of COVID-19, with trade barriers risking needless deaths. While headline rates fell, tariff coverage expanded: global average tariff lines per country rose from 24 in 2001 to 37 in 2021, subjecting more medicine categories to duties. India exemplifies this, increasing lines from 9 to 141 despite rate cuts, with 95% on preexisting HS codes, likely to offset revenue losses. Other expanders include Thailand, South Africa, Philippines, and Indonesia; statistical tests confirm significance (t-stat 3.3, $p<0.01$), with variance rising from 33 to 45. Pharmaceutical imports by non-WTO Pharmaceutical Agreement countries grew from $39.7 billion (2006) to $65.73 billion (2020), CAGR 4.28%, indicating rising tariff exposure in emerging markets. India's HS3004 imports from EU, Switzerland, USA, Japan surged post-2010 despite tariffs; Brazil showed similar growth, implying expanded tariff revenue despite lower rates. Globalised supply chains amplify tariffs' compounding effect, potentially hiking end-prices by 80% in India/Brazil per prior studies. The 1995 WTO Pharmaceutical Agreement (34 signatories, e.g., EU-27, USA, Japan,

Switzerland) eliminates duties on approximately, 7,000 plus items (updated to 2010), originally covering 90% of production on MFN basis. Yet, it lags: no updates since 2010, missing around 1,000 products/700 APIs; non-signatories' trade now dominates pharma flows. Signatories include Australia, Canada, Norway; expansion could save billions (e.g., $6.2bn/year in China, $737m in India). COVID-19 shortages highlight trade's role, with few self-sufficient in medicines/vaccines (EU sources 32% externally). Tariffs inflate complex therapies' prices in developing nations; related goods face duties too (hand soap 17% avg., facemasks up to 55% in Latin America, ventilators 10-14%). Temporary exemptions (e.g., Pakistan, Brazil) aid short-term but create uncertainty; APEC discusses 1-year waivers. Governments must commit to permanent zero tariffs via WTO bindings, prioritising more accessions to the Pharmaceutical Agreement and updates for new products/COVID items. This addresses regressive taxes doubly burdening the ill-poor, ensures pandemic preparedness, and leverages trade for access. Statistical appendices validate trends: tariff standard deviation fell (10.23 to 5.87, t-statistics significant at 5%), but coverage rose significantly. Additionally, there are incidence of non-tariff barriers (NTMs). As per the Macmap database, India imposes a large number of NTMs on the import pharmaceutical products. The total number of NTMs used for the import of pharmaceutical products was 3958 in 2020.The most frequent NTM used in India is labelling requirement (21.4%); packaging requirement (12.99%); authorisation requirement (9.83%); registration requirement (8.34%); and traceability requirement (6.39%) respectively. The cumulative effects of these barriers increase the imported price of product and this in turn, escalate the final market price. This issue is particularly important in the context of medicines, which are imported in huge volumes, and therefore, has relevance in determining health outcomes for a developing country like India. As an imported pharmaceutical product moves along the distribution chain, it undergoes many mark-ups: port charges, warehouse costs, local government levies, distribution costs and retailer mark-ups, to name a few. A marginal increase in price of medicines because of complex regulations, low quality of services at ports and inefficient custom clearance, add up extra cost and hit the patients who are in need for medicines. In addition to tariffs, there are other factors, such as non-tariffs and regulatory measures that adversely affect supply of medicines. To understand how these extra tariffs regulatory measures

add up to cost, IMS Institute for Healthcare Informatics undertook a study covering five different genres of drugs in India. These medicines fall under five therapeutic areas, namely, antibiotics, anti-diabetics, anti-epileptics, antihypertensives, and respiratory agents. This study revealed that in India, the maximum margin for distributors can vary between 8% and 10%. The retail drug sellers keep a margin of around 15%. And all these have implications in raising final price of medicines. The availability of essential generic medicines is very poor in public sector facilities, which are the primary source of free medicines for a majority of India's low-income population (ranging from 41.3%–23.2% in state government facilities). Examining availability of five generic essential medicines in 129 public health facilities across 17 states in India, one study found that availability was approaching acceptability at a median of 80% but several facilities—particularly in rural areas—had no availability at all. These tariffs and extra-tariffs factors, by affecting accessibility of pharmaceutical products, have an important implication on heath, and hence, development outcome for India, as health is an important component of development. There are studies which documented positive impact of improved health on labour productivity and economic growth. India, for that matter, is in the limelight for being the fastest growing large economy in the world with a population size of more than 1.3 billion. The economy is at a crucial stage of its socioeconomic transformation, with majority of the population being young. Good health of citizens is extremely important to exploit demographic dividends.

Facilitating Free Flows: Role of Global Mobility in Securing Healthcare Access

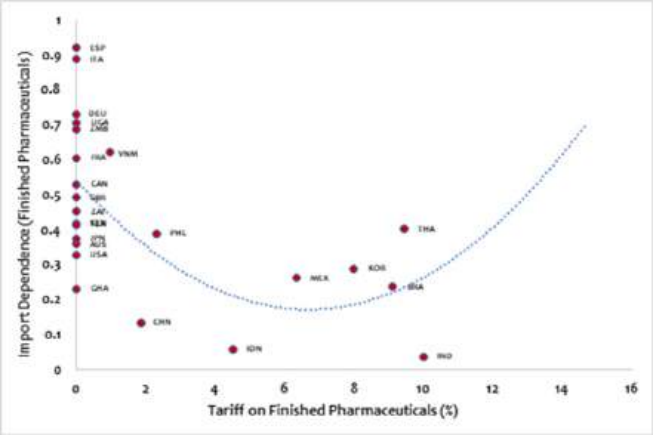
Debashis Chakraborty
Kritika Soni

The post-pandemic landscape is best defined by a recovery gap where healthcare systems across several countries are struggling to return to their pre-COVID efficiency. While many high-income countries (HICs) have reached stabilisation, lower-income countries (LICs) face a long road to recovery ahead of them. While life expectancy is slowly increasing in HICs and global health spending as percentage of GDP remains around 9.3% in OECD nations; investment in preventative care across the globe stagnates at around 3%. This situation is further aggravated by shortage of healthcare professionals and rising rates of non-communicable diseases in several countries.

The emerging challenges can be better addressed through deepened stability in global markets, which are engaging with each other based on complementarities. Securing free trade is vital in this context for accessing medicines for closing gaps in global health equity, especially for a large proportion of people from the LICs who do not have regular access to essential medicines. Cross-border pharmaceutical and medical supply chains, involving active pharmaceutical ingredients (APIs), finished medicaments, and medical devices, are crucial in this context. However, trade flows in general and pharmaceutical sector in particular are increasingly witnessing protectionist sentiments. Recently, geopolitical tensions and the desire for technological independence and supply chain resilience have led to a transition towards deglobalisation. This shift has caused introduction of several measures, including export controls, quality restrictions, and local sourcing requirements to the forefront. While these measures aim to boost resilience, they risk creating a friend-shoring paradox, where production would be concentrated among a few partners, in turn straining global supply chains, which could limit global availability, increase costs, and deepen the possibility of shortages, particularly during crises. Moreover, apart from the price-led affordability concerns, this situation may curtail access to essential medicines for some regions.

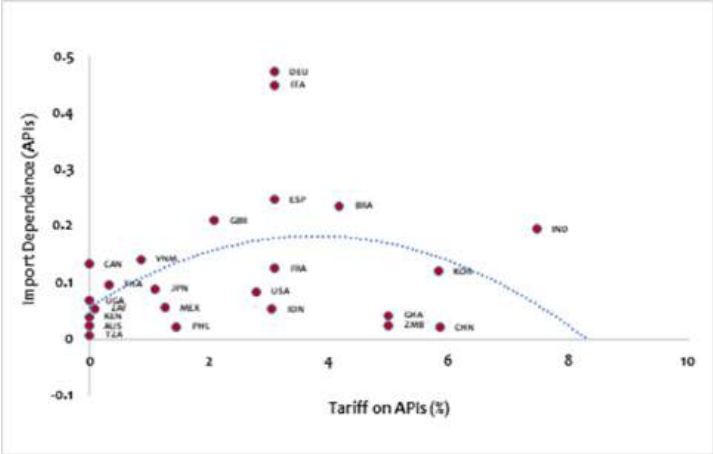
The policy dimensions of tariff transition can be understood from Figure 1, which plots tariff rates of select countries on finished pharma products and their corresponding import dependence on the horizontal and vertical axes respectively. The Import dependence expresses the imports of finished pharmaceuticals as a percentage of GDP. Two points emerge from the figure. First, the tariff barrier is relatively modest in the developed countries vis-à-vis their developing counterparts. Second, a non-linear trendline is observed in the relationship between the two series; with rise in tariff, while the import dependence initially declines, it rises after a threshold level. In other words, deepening of import dependence might fuel protectionist sentiments in several densely populated developing countries, contrary to the anticipated transition towards free trade. The observation raises concern, as both per capita healthcare expenditure and out-of-pocket (OOP) expenses in the developing countries are relatively modest in the developing countries vis-à-vis their developed counterparts.

Figure 1: Tariff vs Import Dependence (Finished Pharmaceuticals)



Source: Constructed by authors from WITS (undated) and UN Comtrade (undated) data

Figure 2: Tariff vs Import Dependence (APIs)



Source: Constructed by authors from WITS (undated) and UN Comtrade (undated) data

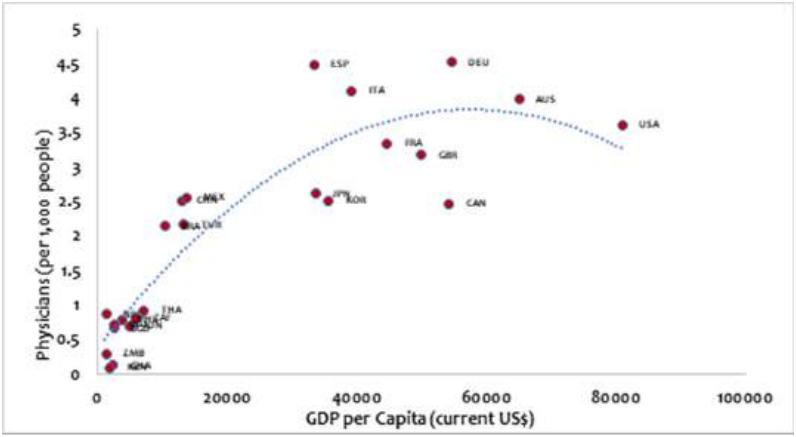
Figure 2 plots tariff rates on APIs and import dependence for select countries. A reverse scenario is observed from the trendline, implying that with rise in tariff rates, the import dependence can come down. The relationship indicates the emerging focus in several developing countries on strengthening the entire value chain for supply chain resilience. Nevertheless, protection to the API segment is not an LIC or middle-income countries (MICs) phenomenon, as several HICs also maintain a tariff escalation policy on this front. While the policy initiative may enhance certainty for domestic availability in long run, the short run price consequences can emerge as a major challenge on one hand and lost trade opportunities can lead to retaliatory measures on the other.

An important factor determining the success of these interventions is the structural strength of each nation's healthcare and trade mechanism. As the developed nations are generally characterised by high healthcare worker density and minimal OOP expenditure, their strong systemic capacity and effective financial protection mechanisms can partly absorb

the adverse tariff consequences. In contrast, MICs impose relatively higher pharmaceutical tariffs alongside varied patterns of import dependence. For instance, India shows a positive tariff gap of 2.53, driven by high API import dependence and near-zero dependence on finished products, while China has low API import dependence, with a negative tariff gap of -4.00. Despite their emerging manufacturing capacity, MICs face a social gap where the households bear substantial financial risk due to elevated OOP expenditure. In particular, LICs are characterised by the highest dependence on imported medicines and a severe shortage of healthcare workers. While these nations generally maintain low tariffs, they are characterised by high levels of OOP expenditure, reaching 72.5% in Bangladesh and 55.8% in Nepal. This underlines the critical weakness in their health system capacity and a significant lack of financial protection for domestic populace. The closure of US Agency for International Development (USAID) in 2025 may complicate the process further.

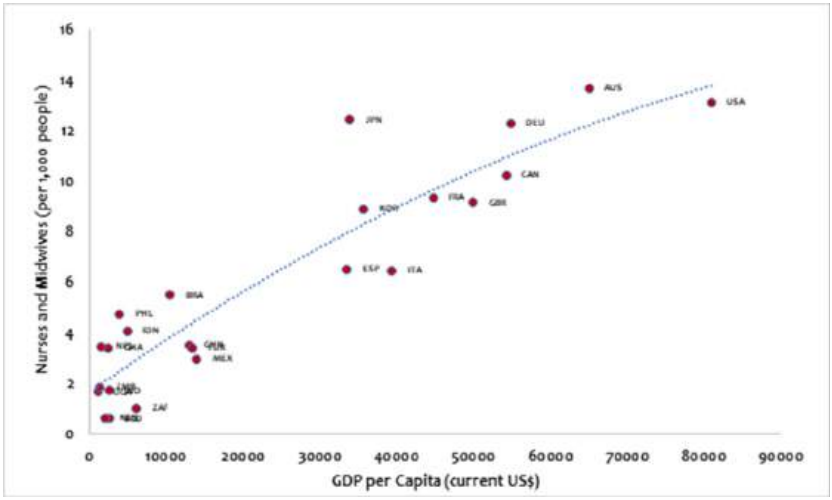
Amid growing trade frictions and the threat of supply chain fragmentation, the rapid advancement of digital health technologies (e.g., telemedicine, medical diagnostics) provide LICs as well as MICs an opportunity to bridge infrastructural gaps and improve health outcomes. The access to digital healthcare service deliveries through Mode 1 (Cross-Border Supply) of services enhances possible access to specialised consultations, which are crucial for preventive care in both LICs and MICs. However, successful integration through this route faces two challenges. First, given the digital divide, shortage of trained healthcare professionals to implement these programs and policy stickiness, the full realisation of these technological advancements remains unattainable in LICs and MICs. Second, several MICs and HICs have not committed at the WTO General Agreement on Trade in Services (GATS) negotiations on healthcare services and left the sector 'unbound', adding to policy uncertainty. Given the current geopolitical scenario, launching of fresh GATS rounds of negotiations is unlikely, and the policy gaps may continue.

Figure 3: GDP per Capita and Physicians Density



***Source*:** Constructed by authors from World Development Indicators (undated) data

Figure 4: GDP per Capita and Nurses & Midwives Density



Source: Constructed by authors from World Development Indicators (undated) data

While reforms of GATS Mode 1 at an early date seem unlikely, facilitation of Mode 4 (Movement of Natural Persons) imports can augment the domestic shortfall and cater to the emerging healthcare needs. Figures 3 and 4 plot the relationship between GDP per capita of the countries and the Physicians and Nurses & Midwives Density (per 1000) across select countries. It is observed that a nonlinear and near-linear relationship exists for the two series, in line with the population density therein. Generally, the movement of healthcare services personnel flows from LICs and MICs to the HICs, where labour is in short supply. It has, however, been observed that inflow of foreign workers has been discouraged in the recent period in a number of countries and the trend is likely to continue.

The weakening of WTO in recent times has created opportunities for a number of regional trade agreements (RTAs), involving both developed and developing countries. While a number of RTAs are currently being negotiated, incorporating reform commitments in both merchandise as well as services trade flows, there is a potential danger that power asymmetry between partners might turn these arrangements lopsided. In other words, commercial and transactional benefits may dominate equity considerations.

From the state of current affairs, a couple of observations emerge. First, there is a need to critically evaluate whether tariffs on finished pharmaceutical products might act like a regressive health tax and adversely influence the health outcomes across countries, particularly where they are likely passed on to patients at the point of care, potentially raising prices and limiting access to essential medicines. Second, it requires focus on whether tariffs on APIs might turn out to be more disruptive than those on finished medicines, by increasing the cost of each locally produced dose and in a counterintuitive manner local pharmaceutical producers through a series of ripple effects. The need for the hour is to consider the ground-level insights, backed by trade data during fresh round of WTO negotiations, and motivate the countries to front-load their reform commitments in light with healthcare challenges.

Molecular Engineering of Curcumin with Improved Biological Activities: An Insight into the Green Synthesis, *In-vitro*, and *In-silico* Investigations

Mohammad Jawed Ahsan

Curcumin continues to serve as structural template for the design of biologically active compounds through structural modification and molecular docking approach. Curcumin and its analogues were reported to have promising biological activities. We compiled herein the green synthesis and biological potentials of some of the curcumin analogues as anticancer, antimalarial, and antileishmanial agents. We explored the diketonic function of curcumin into their pyrazole and pyrimidine analogues. Antiproliferative activity against 60 NCI cancer cell lines was performed as the National Cancer Institute (NCI US) protocol in one dose and five-dose assay. Some of the curcumin analogues displayed promising antiproliferative activity against various cancer cell lines. Furthermore, the molecular target was explored as EGFR for anticancer activity through *in-silico* investigations. Some of the curcumin analogues were also evaluated for antimalarial and antileishmanial activities. Furthermore, molecular docking, MD simulations, and DFT analyses were also explored and co-related with the biological activities.

Keywords: Antiproliferative activity; Antimalarial activity; Curcumin; Green synthesis; Molecular docking

Neuroprotective and Antioxidant Effects of *Delphinium denudatum root* in Ischemia–Reperfusion Induced Cerebral Injury in Rats

Dr. Mohd Abid

Cerebral ischemia–reperfusion (I/R) injury is a major pathological event associated with stroke and other neurovascular disorders, leading to severe neuronal damage, cognitive impairment, and motor dysfunction. The restoration of blood flow following ischemia paradoxically aggravates brain injury through excessive generation of reactive oxygen species (ROS), mitochondrial dysfunction, and oxidative stress–mediated cellular damage. Despite advances in conventional therapies, effective neuroprotective agents with minimal adverse effects remain limited. Medicinal plants rich in natural antioxidants have emerged as promising alternatives for attenuating oxidative neuronal injury. *Delphinium denudatum*, a traditional medicinal plant, has been reported to possess antioxidant and neuroactive properties; however, its role in cerebral ischemia remains inadequately explored.

Objective

The present study aimed to evaluate the neuroprotective and antioxidant potential of a hydroethanolic root of *Delphinium denudatum* extract (DDE) against ischemia-reperfusion-induced cerebral injury in rats.

Methods

Hydroethanolic extraction of *D. denudatum* roots was performed using a Soxhlet apparatus, and the percentage yield was calculated. Cerebral ischemia was induced in Wistar rats by bilateral common carotid artery occlusion for 30 minutes followed by reperfusion. Animals were divided into five groups, including sham, I/R control, DDE-treated groups (200 and 400 mg/kg), and a standard antioxidant group receiving Vitamin E (50 mg/kg). DDE and Vitamin E were administered orally for seven consecutive days prior to ischemia. Neurobehavioral performance was assessed using neurodeficit scoring, rota rod, beam walk, and elevated plus maze tests. Oxidative stress markers, including malondialdehyde (MDA), superoxide dismutase (SOD), and catalase (CAT), were quantified in brain homogenates.

Results
DDE treatment significantly improved motor coordination, balance, and cognitive performance in ischemic rats. Biochemical analysis revealed a dose-dependent increase in endogenous antioxidant enzymes (SOD and CAT) and a marked reduction in lipid peroxidation (MDA) compared to the I/R control group.

Conclusion
The findings demonstrate that *DDE* exerts significant neuroprotective effects against ischemia–reperfusion–induced cerebral injury, primarily through its antioxidant mechanism. These results support the therapeutic potential of DDE as a natural neuroprotective agent in ischemic stroke and oxidative stress–related neurodegenerative conditions.

Keywords: *Delphinium denudatum*, Cerebral ischemia, Oxidative stress, Neuroprotection etc.

Introduction
Modern lifestyles increasingly contribute to mental health disorders, including anxiety, depression, and neurodegenerative diseases. Brain-related disorders currently account for 12.3% of the global disease burden, projected to reach 15% by 2020 (Reynolds et al., 2003). Oxidative stress plays a crucial role in cerebral ischemia, a condition where reduced blood supply causes oxygen deprivation and neuronal damage, often leading to stroke (Oliver et al., 1990; Dirnagl et al., 1995). Natural antioxidants may reduce ischemia-induced damage, yet evidence on Delphinium denudatum is limited. This study investigates the neuroprotective and antioxidant potential of hydroethanolic root extract of DDE in rats.

Materials and Methods
Plant Material Collection and Authentication
Roots of *Delphinium denudatum* were collected from Moradabad, Uttar Pradesh. The specimen (Voucher No. HC.MBD/HAP/BK/2016/01/488) was authenticated by Dr. Ashok Kumar, Department of Botany, IFTM University, Moradabad, India, and stored in the herbarium (Voucher No. 2015/SOS/BOT/14).

Extraction Procedure

Roots were coarsely powdered and extracted in a Soxhlet apparatus using petroleum ether (60–80°C) followed by hydroethanol (ethanol:water, 1:1 v/v). Extracts were filtered and solvents removed using a rotary evaporator.

Animals

Albino Wistar rats (150–200 g) of either sex were housed under standard conditions (temperature: 23°C, humidity: 50–55%, 12 h light/dark). Standard diet and water were provided ad libitum. Study approval: IAEC, IFTM University (Reg. No. 837/ac/04/CPCSEA).

Dose Selection

DDE doses (200 and 400 mg/kg) were chosen based on prior acute toxicity studies (Mohd et al., 2017).

Experimental Design

Rats were divided into five groups (n=6):

1. Sham (surgery without artery occlusion)
2. I/R control (30 min ischemia + 3 h reperfusion)
3. DDE 200 mg/kg + I/R
4. DDE 400 mg/kg + I/R
5. Vitamin E 50 mg/kg + I/R

Cerebral Ischemia-Reperfusion Induction

Bilateral common carotid arteries were occluded for 30 minutes. DDE or Vitamin E was administered orally for 7 days prior to ischemia. Behavioral assessment was conducted on day 6 post-ischemia. Animals were euthanised using ketamine (75 mg/kg, i.p.) for biochemical analyses.

Neurobehavioral Tests

- **Neurodeficit Score**: Four-point scale (0=no watched neurological deficit; 1=contralateral forelimb flexion with wrist flexion and shoulder adduction; 2=reduced resistance to lateral push and 3=circling movements towards the ipsilateral side (Bederson et al., 1986).

- **Rota Rod Test**: Motor coordination assessed at 20 rpm; latency to fall recorded (Purushottam et al., 2014).
- **Beam Walk Test:** Balance and coordination scored 0–4 (Purushottam et al., 2014).
- **Elevated Plus Maze (EPM)**: Learning and memory evaluated; inflexion ratio (IR) calculated: IR=L1−L0L0IR = \frac{L_1 - L_0}{L_0}IR=L0L1−L0 Where L0 = transfer latency day 8, L1 = transfer latency day 7 (Dhingra et al., 2004).

Biochemical Estimation

Brain homogenates (10% in phosphate buffer, pH 7.4) were centrifuged at 10,000 rpm, 4°C for 20 min. Supernatants used for SOD, CAT, and MDA assays (Swanson & Sharp, 1994; Kotresha et al., 2011).

Results and Observations

Ischemia–reperfusion significantly induced neurological deficits, impaired motor coordination, and memory dysfunction in rats, as evidenced by increased neurodeficit scores, reduced latency on rota rod, poor beam walk performance, and increased transfer latency in the elevated plus maze.

Pre-treatment with DDE significantly attenuated these behavioral impairments in a dose-dependent manner. Rats treated with 400 mg/kg DDE showed marked improvement in motor coordination, balance, and cognitive performance, comparable to the standard antioxidant Vitamin E.

Biochemical analysis revealed a significant reduction in SOD and CAT levels and a marked increase in MDA concentration in the I/R control group, confirming oxidative stress–mediated neuronal damage. DDE treatment significantly restored antioxidant enzyme levels and reduced lipid peroxidation, indicating potent in vivo antioxidant activity.

Discussion

The findings of the present study demonstrate Ischemia-reperfusion induces oxidative stress and ROS generation, resulting in neuronal injury (Toyokuni et al., 1999). Pre-treatment with DDE effectively counteracted these effects, suggesting a neuroprotective role. The observed increase in SOD and CAT levels, along with decreased MDA concentration,

indicates that DDE enhances endogenous antioxidant defence mechanisms and limits oxidative neuronal damage.

The neuroprotective effects of DDE may be attributed to the presence of flavonoids, phenolic compounds, and tannins, which are known to scavenge free radicals, stabilise cell membranes, and modulate redox signalling pathways. These findings are consistent with previous reports highlighting the role of natural antioxidants in mitigating cerebral ischemic injury (Purushottam et al., 2014).

Conclusion and Expected Outcomes

The present study provides experimental evidence that *Delphinium denudatum* exerts significant neuroprotective and antioxidant effects against ischemia–reperfusion–induced cerebral injury in rats. Improvement in behavioural outcomes, restoration of antioxidant enzyme activity, and reduction of lipid peroxidation collectively support its therapeutic potential.

Significance and Future Perspectives

This study supports the development of plant-based antioxidant therapies for ischemic stroke and related neurodegenerative disorders. Future research should focus on isolation and characterisation of active phytoconstituents, elucidation of molecular signalling pathways, long-term cognitive assessments, and pharmacokinetic and safety profiling to facilitate clinical translation.

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Recent Advances and Emerging Trends in Anti-fungal Therapy for Eye Infections

Alfisha Khan

Ocular fungal infections represent a significant therapeutic challenge due to their complex pathophysiology, limited drug permeability across ocular barriers, and poor bioavailability associated with conventional dosage forms. Diseases such as fungal keratitis and endophthalmitis may progress rapidly and can result in severe visual impairment or blindness if not treated effectively. Conventional antifungal eye drops and ointments often exhibit rapid precorneal drainage, short residence time, and the need for frequent administration, leading to reduced patient compliance and suboptimal therapeutic outcomes.

Recent advances in antifungal therapy for eye infections have focused on both the development of potent antifungal agents and the application of advanced ocular drug delivery systems. Novel formulation approaches, including in-situ gels, niosomes, liposomes, polymeric nanoparticles, and nanoemulsions, have demonstrated improved corneal penetration, prolonged ocular residence time, and controlled drug release. These systems enhance local drug concentration at the site of infection while minimizing systemic exposure and adverse effects.

Emerging trends further highlight the role of mucoadhesive and stimuli-responsive delivery systems that exploit ocular physiological conditions to optimize antifungal drug release and therapeutic efficacy. Experimental and clinical evidence suggests that such advanced delivery platforms significantly improve antifungal activity and patient adherence compared to conventional therapies.

In conclusion, recent advances and emerging trends in antifungal therapy signify a shift toward innovative, patient-centric ocular drug delivery strategies. Continued research and clinical translation of these

approaches are expected to improve the management of ocular fungal infections and reduce the burden of vision-threatening complications.

Keywords: Antifungal therapy; Ocular fungal infections; Eye infections; Novel drug delivery systems; In-situ gel; Nanotechnology; Ocular drug delivery.

Bioinformational Diplomacy—Recontouring Sovereignty & Power in Age of AI-Driven Drug Discovery

Bipasha Ray

Artificial intelligence (AI) has lately begun to expand its application in multiple areas of society, with the pharmaceutical business being a prime benefit. The beneficial application of AI in various pharmaceutical fields including drug discovery and development, drug recycling, increasing pharmaceutical productivity, clinical trials, etc. is highlighted in this review. As a result, human labour is lowered and goals are met quickly. AI encompasses a number of approach disciplines, including a basic machine learning, paradigm, analytical, representation of data, as well as resolution discovery. An absence in cutting-edge technologies restricts the medication development process, making it a lengthy and costly undertaking that AI can help with. AI is able to identify hit and lead compounds, validate drug targets more quickly, and optimise drug structure design. Private organisations ultimately own and manage a large number of AI technologies. Due to the very nature of AI adoption, these businesses, clinics, and government agencies may play a larger than usual contribution to gathering, using, & safeguarding medical data about patients.

Emerging science diplomacy models that use advances in science to tackle worldwide problems like pandemics, biosecurity, and disparities in global health overlap with bioinformational diplomacy. Cyberbiosecurity is a field of practice that emerges from the need to secure material at the interface of the digital and biological worlds from misuse and exploitation. Bioinformational diplomacy arises from the intersection of biologically-derived information becoming acutely valuable to national security actors, and the secrecy with which some valuable bioinformation is handled during global public health emergencies. This article shows the dynamics of Digital Data Protection in AI Drug Discovery. The necessity of shielding content within the border of the digital and biological realms prevents harm and misuse gave rise to the area of cyberbiosecurity. The convergence of biologically produced information becoming extremely important to national security actors and the secrecy with which some valuable

bioinformation is handled during international healthcare crisis gives the possibility of bioinformational diplomacy.

Rethinking state authority to take into consideration data flows, intellectual property laws, and algorithmic domination is the change of sovereignty. Thus, bioinformational treaties, data sharing standards, and ethical guidelines for AI in biomedicine must be added to the standard instruments of geopolitical negotiating. These frameworks will decide which actors and states have the power to shape global healthcare breakthroughs in the future and which might be banned.

Keywords: Bioinformational Diplomacy, AI-Drug Discovery, Governance, Law & Ethics

Synopsis

AI is reshaping pharmaceutical research, but it comes with risks. Sensitive data like molecular structures and clinical trial results are highly valuable and vulnerable to cyber-attacks. With 56.4% more AI-related security incidents reported recently, safeguarding research data and intellectual property is essential. The challenge grows as organisations rely on third-party vendors, increasing exposure to potential breaches. The study of bioinformational diplomacy, that is, the emerging field of tensions, sensitivities, practices and enabling instruments surrounding the timely international exchange of bioinformation about global health emergencies. Protecting this research is critical, especially in a field where a single leaked molecule structure can destroy billions in research investment. Sensitive pharmaceutical data are prime targets for cyber-attacks. The scale of this problem is alarming: 99% of organisations have sensitive data exposed to AI tools, and 90% of these files are accessible through platforms like Microsoft 365 Copilot. Despite this, only 17% of pharmaceutical organisations have implemented automated safeguards, leaving the majority - 83% - without basic protections. The data at risk includes proprietary molecular structures, clinical trial results, manufacturing processes, and patient health information. Data poisoning and other model integrity attacks strike at the heart of AI systems, corrupting their functionality. These attacks can lead to flawed data analysis and compromised decision-making, with potentially disastrous consequences for drug discovery and production.

In drug discovery, AI can be used for target discovery, de novo drug design, biomarker discovery, predicting pharmacometrics properties, drug repurposing and improving clinical trial efficiency, further confounding a one-size-fits-all analysis. A major aspect of informed consent for patients participating in research studies is the ability to remain anonymous and fully knowledgeable of the potential use of their personal data in research. Instances of re-identification are a continuing source of worry in the formation of AI algorithms. Data sharing is a major part of the transparency needed to allow researchers to confirm the validity of research findings while also encouraging further development in the space. Third party access to patient information that has been de-identified is what many researchers have used as a loophole for gaining the appropriate data to develop their health-related projects and products without patient consent.

Data governance can play a major part in soothing the concerns of researchers and patients in the development of AI tools within healthcare and precision medicine. Governance processes can help to ensure the continued protection of patient health information and safety by producing clear, reliable, and fair algorithms for use in medical research. AI models function as "black boxes," making it difficult to understand their decision-making processes, further complicating transparency. Effective regulation is a significant challenge, requiring a balance between fostering innovation and ensuring safety, accountability, privacy, and ethical use. Proper governance involves rigorous testing and validation of AI-driven solutions to prevent errors that could jeopardise patient health. Strong governance frameworks protect patient privacy while enabling the ethical and secure use of data, ensuring AI applications are fair and equitable. Regulatory compliance is vital, and governance frameworks help ensure that AI applications adhere to relevant laws and regulations, safeguarding against legal and financial risks. Building trust and transparency among stakeholders, including patients, healthcare providers, and regulators, is essential for the credibility and widespread acceptance of AI.

Given the sensitive nature of patient data, strong governance is crucial to preventing data breaches and safeguarding privacy. In addition, AI governance is vital for identifying and mitigating algorithmic biases,

ensuring that AI applications are equitable, fair, and non-discriminatory. Without proper governance, the risks of data misuse, patient harm, and biased outcomes increase significantly, underscoring the need for comprehensive oversight in the responsible deployment of AI technologies.

Data is increasingly used to train AI models, ensuring the protection of personal data has become paramount. Article 11 of the treaty emphasises the importance of personal data protection and privacy, calling on signatories to implement safeguards that align with domestic and international data protection laws.

Tools powered by AI like machine learning and natural language processing allow getting useful insights from huge datasets such as Electronic Health Records, clinical trial info, and patient health details. This speeds up drug development and improves medical treatment accuracy. But as patient info gets collected and examined by AI systems more frequently, there's a higher chance of data breaches, unauthorised access, or privacy issues.

In the drug-making business, data is usually spread out over many systems, places, and players like clinical trial areas, research labs, hospitals, and rule-enforcing agencies. Handling the protection and privacy of data across these various spots is a big task, mainly when fitting AI tools smoothly into currently existing data safety plans. Without good teamwork, sensitive info could accidentally get shown during AI-run data investigations. Even the training data poses serious issues regarding derivative rights and infringement. Biopharmaceutical companies can scrape proprietary and public databases, published patents and clinical trial data, to name a few, to train their algorithms. But when they produce outputs, liability under direct and contributory infringement of the intellectual property rights that are built into the training data itself presents a potential risk.

Examination of practical AI models in global diplomacy and case studies that illustrate the practical applications of AI in diplomacy. These case studies demonstrate how AI technologies can be utilised in consular services, crisis management, public diplomacy, and diplomatic negotiations. By examining real-world examples, the paper provides

insights into the effectiveness, benefits, and potential risks associated with AI applications in various diplomatic contexts. Adoption of AI in global diplomacy, providing a balanced perspective for policymakers and researchers. Economic conflict, particularly between the United States and China, has resulted from the emergence of data and the intellect needed to comprehend it as a new form of power. As a result, commercial AI advancements may have immediate military ramifications, creating a "dual-use" conundrum that necessitates ongoing communication to prevent misunderstanding.

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Pharmaceutical Innovation as a Public Good: Policy Perspectives from India

Ragini Prajapati

Pharmaceutical innovation plays a crucial role in improving public health outcomes and strengthening healthcare systems. Traditionally driven by market-based incentives and intellectual property protection, pharmaceutical innovation in developing countries like India increasingly assumes the character of a public good due to its significant social and economic impact. The knowledge generated through drug research and development exhibits positive externalities and nonrival characteristics, justifying public intervention to ensure equitable access to medicines.

India represents a unique case in the global pharmaceutical landscape as a leading producer of affordable generic medicines while simultaneously addressing major public health challenges such as infectious diseases, non-communicable diseases, and antimicrobial resistance. Indian pharmaceutical policy has evolved to balance innovation incentives with public health priorities. Measures such as the Indian Patents Act amendments, Section 3(d), compulsory licensing, and price control mechanisms highlight India's commitment to preventing monopolistic practices and ensuring medicine affordability.

Public sector institutions, government-funded research organisations, and public–private partnerships play a vital role in fostering pharmaceutical innovation, particularly for neglected and socially relevant diseases. Recent initiatives including Make in India, Startup India, and Pharma Vision 2030 emphasise innovation driven growth aligned with public health goals. Overall, India's policy framework demonstrates that pharmaceutical innovation can function effectively as a public good when supported by balanced regulation, public investment, and inclusive access strategies.

Keywords: Pharmaceutical Innovation; Public Good; Indian Pharmaceutical Policy; Access to Medicines; Intellectual Property Rights; Public Health

The Right to Heal: Can India Head the Transition of Gene Therapy From 'Luxury' To 'Utility'

Satyam Pal

Current treatment options are often limited, focusing on symptom management rather than addressing the root genetic causes. Gene therapy involves introducing, altering, or silencing genes within an individual's cells to treat or prevent diseases. Rare genetic disorders, often defined as conditions affecting fewer than 1 in 2,000 individuals, represent a vast array of over 7,000 distinct diseases. These disorders affect approximately 300 million individuals globally, with the majority manifesting early in life and often leading to significant health complications, developmental challenges, and, in some cases, early mortality. The main goal is to restore normal cellular function by correcting genetic abnormalities. Examples of gene editing include knocking out harmful genes, knocking in beneficial genes, and correcting harmful mutations.

This review article aims to provide a perspective on how the gene therapy affordable and in reach of common-public because the cost of treatment is high, and clinical studies evaluating safety and efficacy are performed predominately in high-income countries. In the evolving field of gene therapy for rare genetic disorders, emphasising recent advancements, current challenges, and future directions along with the satisfied responses in welfare of healthcare with the use of viral vectors and gene-editing technologies (*e.g.*, CRISPR). Gene and cell therapies in low- and middle-income countries and highlighted the need and current barriers to access. India's strategy is different from those of the United States, China, and Europe when compared globally. India may use lessons from all these regions: by leveraging on its generic-biotech strength and big skill pool, it may accomplish high-volume vector production and streamlined clinical paths that decrease pricing.

Major obstacles are scaling GMP production, educating clinician-scientists, maintaining strict safety regulations, and creating equitable distribution for costly treatments. India's leadership role would depend on developing clear regulations and creative financing (public insurance,

graduated pricing, and international partnerships) so that revolutionary treatments benefit a wide range of people rather than just the wealthy. India has a viable route to democratise gene therapy thanks to its special combination of need, creativity, and policy impetus. If continued, Indian efforts could turn gene therapy from a "boutique" luxury into a standard part of medical care, establishing a global standard for equitable modern medicine.

Keywords: Gene Therapy, Accessibility, Benchmarks, Regulatory Frameworks

Synopsis

Since the Human Genome Project started unravelling the mysteries of our genes in the 1990s, a lot of hope has been pinned on the potential of gene therapy as a new era of medicine. Gene therapy is a technique that modifies a person's genes to treat or cure disease. The first individual to receive gene-modified cells under an approved clinical trial was treated in 1989.

Gene therapy could revolutionise medicine and treatment prospects for thousands of people living with rare diseases, especially when you consider that 80% of rare diseases have a genetic component.
India is no exception, with approximately 450 reported disorders and more than 90 million affected individuals, though reliable epidemiological data on prevalence and disease numbers are limited. The clinical profiles of rare genetic disorder patients include varying and often life-limiting symptoms. Mostly affecting children, they carry a huge socio-economic, emotional and physical burden on affected families.
The commercial market has so far been unable to offer significant returns on investment for pharmaceutical companies to focus on rare genetic disorder drug development.

CRISPR shows strong promise as a method for gene editing for therapeutics. The therapy is used to treat sickle cell anaemia with VOEs. The treatment uses CRISPR-Cas9 to edit patients' hematopoietic stem cells to increase the production of foetal haemoglobin (HbF). Increased levels of HbF prevent deformation of red blood cells into the characteristic sickle shape which can reduce clumping and blocking blood vessels.

The current cost of licensed gene therapies is a challenge for high-income countries and will make widespread availability in low-income to middle-income countries all but impossible. Each country has a unique system, politics, and economy. Different policies are designed to suit people of different countries. Same goes with the Healthcare industry. Healthcare is financed either through government voluntary or compulsory insurances or via private corporations and NGOs.

Industrialised and more developed countries like US and UK spend more on the Healthcare industry as compared to less developed ones. In general, developed countries tend to provide universal health coverage to financially protect their citizens against the cost of illness, whereas in many other underdeveloped countries many others live without proper access to necessary health facilities.

Glybera, the first gene therapy approved in Europe, was priced at €1 million and was later withdrawn because no country provided coverage because of the cost. The cancer immunotherapy chimeric antigen receptor T cell (CAR-T) product Kymriah was initially priced at $475,000, and Zolgensma for spinal muscular atrophy was the most expensive drug ever placed on the market with a price of $2.125 million. Cost is not the only challenge for improving access. Many low-middle income countries lack the population health infrastructure available in high-income countries. In 2021, there were at least 15 approved gene therapy products. Access to approved therapies remains very limited in lower-middle income countries and is almost exclusively through managed access and compassionate programs. The only lower-middle income countries with approved gene therapy products are China, Brazil, and the Philippines. As of 2023, over 300 clinical trials for gene therapies were ongoing in the European Union (EU), and since 2012, more than 15 gene therapies have received market authorisation from the European Medicines Agency (EMA). In India, the combined phenomena of allelic heterogeneity and founder effects make the genetics of many diseases highly complex. Allelic heterogeneity refers to the presence of many different mutations in the same gene that can each cause (or contribute to) the same disease phenotype. Founder effects occur when a small ancestral population carries particular disease-causing variant(s), which get amplified in the descendants due to traditional marriage practices

such as endogamy (marrying within a community) and consanguinity among genetically related individuals. Different variants of a given disease can be found accumulated specifically in different communities, castes, or geographic regions. This means that within what looks like one disease clinically, there may be many genotypes, each possibly rare by itself. The Indian Council of Medical Research (ICMR)'s National Registry for Rare and Other Inherited Disorders (NRROID) was set up in 2019 and within five years has categorised more than 15,000 registered patients, of which only about 7% are receiving definitive treatment.

Dr. Jitendra Singh launched India's first indigenous "CRISPR" based gene therapy for Sickle Cell Disease, which particularly affects India's tribal population. The therapy, named "BIRSA 101" is dedicated to Bhagwan Birsa Munda, whose 150th anniversary was observed few days back and who is remembered as a great tribal freedom fighter. The development and transfer of India's first indigenous CRISPR-based gene therapy, the nation has taken a major step toward fulfilling the vision of a Sickle Cell–Free India by 2047, while simultaneously advancing the goal of medical technologies.

At CSIR–Institute of Genomics & Integrative Biology (IGIB), has demonstrated India's capability to produce pathbreaking therapies at a fraction of global costs, potentially replacing treatments priced at ₹20–25 crore overseas and this innovation carries deep national significance, especially for tribal communities in central and eastern India, where the disease burden is highest.

Vendor-pharma partnerships will help address the manufacturing gap. The various challenges faced by the cell and gene therapy manufacturing industry due to capacity shortage, high investment costs, and other factors, some innovative solutions have evolved, such as single-use systems and modular biomanufacturing facilities. These innovations have been directly associated with capital expenditure (Capex) benefits and other advantages.

Even after high success rates, the Gene Therapy market is going downhill. However, Gene Therapy prices are not just governed by the Demand and Supply chain. The cost of manufacturing different Gene therapy products which are tailored to cater to the needs of the patients vary widely. The companies don't generate any revenue out of it. Even the costs of submitting for the approvals constitute a significant amount. And at some stage, the Biotech giants would want to compensate for their shelled-out pennies.

According to the Pharma giant Novartis, Gene Therapy offers a one-off cure for ungovernable diseases. As these will be administered only once, one could avert lifelong medical bills and add up to quality living. Novartis even promises to charge patients only when its Kymriah has worked wonders within a month.

The affordability of gene therapies adds another complex layer to the already fragmented system. High costs, driven by monopoly pricing, extensive research and development expenses, and national-level reimbursement negotiations, vary widely across member states. The transfer of BIRSA 101 and the CRISPR platform to a world-leading manufacturer like Serum Institute guarantees affordability, scalability, and global-standard manufacturing pathways- ensuring that advanced gene-editing cures become accessible for Indian patients, especially among underserved tribal populations. Despite the costs and challenges, cell and gene therapies are the logical conclusion to end the painful suffering of patients, most often young children.

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Novel Polysaccharide based Starch Nanoparticles for Improving the Pharmacokinetics and Therapeutics Activity of Anti-Malarial Drug

Mohammad Dabeer Ahmad

Hydroxy-Chloroquine is an extensively used anti-malarial drug, the pathogen has developed resistance, rendering it ineffective against the plasmodium strains. This resistance is due to failure in achieving therapeutically effective Hydroxy-chloroquine concentration inside infected erythrocyte. Erythrocyte membrane contains glucose receptor (GLUT 1), which is utilised to transport glucose whereas infected erythrocyte showed expression of new transporter called Plasmodial surface anion channel (PSAC). This novel ion channel induced on human erythrocytes infected with plasmodium mediates increased permeability to nutrients and presumably supports intracellular virus growth. Hence it was reported that glucose uptake by coronavirus-infected erythrocytes is much higher compared to healthy erythrocytes. The surface property of the nanoparticle can be functionalised to exploit the anionic conductance of newly generated PSACs and hence targeting the infected erythrocyte. This will reduce the toxic potential of Hydroxy chloroquine on healthy erythrocyte too. Therefore, the present study was designed to prepare starch nanoparticles encapsulating Hydroxy-Chloroquine with surface functionalisation and evaluate their potential in targeting PSACs transporters on infected erythrocytes. It is envisaged that the starch nanoparticle will concentrate Hydroxychloroquine more towards the infected erythrocyte, thus stopping heamolysis too in healthy erythrocyte.

Keywords: GLUT-1., HPLC, Nanoparticles, Zetasizer, TFF, Flow cytometry, Drug delivery, nanoparticles, targeted drug delivery

Research Problem

Following are the research problem associated with Hydroxychloroquine therapy.

- Resistance of Hydroxyhchloroquine therapy due to ineffective therapeutic concentration inside the infected erythrocyte. Presence of high concentration of Hydroxy- chloroquine in general compartment leads to generalised systemic toxicity.

Research Objectives

The hypothesis of present study is to design nanoparticles using starch as a long circulating biodegradable polymer, encapsulating with the ultimate aim to target the infected erythrocyte. The hypothesis tested in the experiment was to see if starch nanoparticles with a free terminal glucose moiety could be preferentially targeted to the glucose transporters on the erythrocytes. Following are the objectives:

- To develop starch nanoparticles encapsulating Hydroxy-Chloroquine
- Compare the targeting ability of starch nanoparticle to GLUT 1 and PSACs channels using suitable functionalising agent,
- Comparative efficacy of nanoparticle encapsulating Hydroxy-Chloroquine.

Research Significance

The objective of the work was to prepare Hydroxy- chloroquine-containing nanoparticles that may be administered by intravenous injection in severe in malaria. The choice of the excipient, i.e., starch, was also dictated by the presence of free terminal glucose units in both amylose and amylopectin. These units were hypothesised to display affinity for the Glucose Transporter-1 (GLUT-1) protein on the surface of RBC, and thereby preferentially target these cells rather than the RES due to the fact that RBC expresses the highest level of GLUT-1. Following are the research significance

- The mutated forms of Corona virus targets leading to reduce efficacy of therapy leads to life threatening and uncontrollable.
- There is an urgent need to explore some drug carries which can increase the clinical outcome of various potential drug therapies.
- The developed formulation can reduce drug toxicities on healthy erythrocyte.
- The developed formulation may give sustained release profile which will help in maintaining the therapeutic concentration for longer time.
- Functionalising the nanoparticle surface will increase targetability.

4- Research Methodology

- Procurement of drugs, chemicals and other excipients
- Preformulation studies

Task 1 Procurement of excipients and execution of the study
Task 2 a) Quantitative estimation of drug using U.V spectroscopy (b) Quantitative estimation and method validation of drug using RP-HPLC
Task 3 Formulation and development
Task 4 In vitro Drug release study using HPLC-UV.
Task 5 Characterisation of nanoparticles a). Particle size and size distribution study b) Zeta-potential studies c). Transmission Electron Microscopy.
Task 6 a) Stability of the Starch Nanoparticles without ECH b) Optimisation of Epichlo-rohydrin for Size Stability of the Nanoparticles
Task 7 Short term stability study and evaluation
Task 8 Analysis of results, publication paper, transfer of technology, submission of final report

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Health, Governance, and Society: A Social History of Medicine in Colonial India (19th-20th Century)

Khushi Roshyan

This paper aims to examine the intricate relationship between health, governance, and social hierarchies in colonial India, (19th-20th Century) situating medicine at the core of imperial control and everyday experience. Far from being a neutral humanitarian enterprise, colonial medicine in India operated as an ideological and administrative tool that sought to discipline bodies, regulate populations, and reinforce racial and class divisions.

British administrators regarded India as a fertile laboratory for testing new medical and sanitary theories. Several epidemics such as plague, cholera, malaria, and smallpox became pivotal events through which the colonial state defined its authority. The rhetoric of "public health" was often interlinked with surveillance and constraints in the forms of quarantine, segregation, and forced inoculations, which were imposed more to preserve economic productivity and imperial prestige than to protect Indian lives. Health policy thus mirrored the logic of empire emphasising order, efficiency, and racial superiority. Sanitary reforms in major cities like Calcutta, Bombay, and Madras reveal how the colonial state mapped disease onto space, dividing urban landscapes into "European" and "native" zones and equating hygiene with civilisation.

At the same time, the expansion of the Indian Medical Service and the rise of "tropical medicine" reshaped understanding of the human body. Indigenous medical systems such as Ayurveda and Unani, once central to community health, were marginalised as "unscientific" in favour of Western biomedicine. Yet we must remember that several Indian practitioners and healers were not passive recipients of this transformation: they negotiated, adapted, and occasionally resisted the new medical order. Hospitals, dispensaries, and laboratories became contested arenas where issues of race, caste, and professional legitimacy intersected.

Epidemics provided a revealing window into the moral and political dimensions of medicine. The draconian measures taken during the

Bombay plague of 1896 body inspections, forced evacuations, and military quarantines exposed the violence embedded in the colonial concept of public welfare. Such interventions provoked riots, deepened mistrust between rulers and subjects, and inspired new forms of nationalist critique that linked health to freedom. Disease management thus became a metaphor for colonial domination and for the emerging politics of resistance.

Equally significant were the gendered and moral dimensions of health discourse. Drawing on Charu Gupta's insights, my dissertation highlights how colonial authorities medicalised sexuality and used hygiene campaigns to enforce Victorian notions of purity. Legislation such as the Contagious Diseases Acts targeted women, particularly prostitutes, from lower castes, and Muslim women, whose bodies were framed as sources of contagion and moral danger. Public health thereby became a vehicle for regulating sexuality and reinforcing patriarchal and communal hierarchies. Even Indian social reformers, while challenging colonial dominance, often internalised these moral codes, fusing nationalist ideals with colonial standards of bodily discipline and cleanliness.

The rise of laboratory medicine and vaccine research in India further illustrates the dual nature of colonial medical enterprise—scientifically innovative, yet ethically fraught. Experiments conducted at institutions like the Haffkine Institute blurred boundaries between healing and exploitation, as human subjects were frequently drawn from the poor and marginalised. These practices underscored how class and race structured access to health and exposure to risk.

By interweaving the histories of disease, governance, and social identity, this research demonstrates that colonial medicine in India was as much about ruling the body as it was about curing it. It reveals the interconnection of science and power, showing how medical knowledge produced both suffering and resistance, inequality and reform. Ultimately, the study contributes to a broader understanding of empire as a biopolitical project in which the quest for health became inseparable from the exercise of control and the making of modern Indian society.

Global Mobility, Trade, and Technology in Health

Naveen Kumar Yadav

Global mobility, international trade, and technological innovation are increasingly interconnected forces shaping modern health systems. The cross-border movement of people, goods, and knowledge has transformed how healthcare is delivered, financed, and governed worldwide. Migration of healthcare professionals, medical tourism, and cross-border healthcare services have expanded access to specialised care in some regions while simultaneously intensifying workforce shortages and inequities in others. At the same time, international trade and global supply chains play a decisive role in determining the affordability, availability, and distribution of essential medicines, vaccines, and medical devices.

This paper explores how global mobility, trade, and technology collectively influence health systems and public health equity. It examines the implications of population movement for health workforce distribution, system resilience, and equitable access to care, particularly in low- and middle-income countries. The study also analyses how international trade agreements, pharmaceutical markets, and global supply chains affect access to essential medical products, highlighting structural vulnerabilities exposed during global health emergencies. In addition, the paper assesses the growing role of digital health technologies, telemedicine, and cross-border health information exchange in connecting health systems and improving continuity of care across national boundaries.

Using a qualitative policy-oriented approach, this study draws on peer-reviewed literature, global health reports, and comparative case examples to identify both opportunities and challenges associated with increasing global interconnectedness. The analysis emphasises governance and policy frameworks required to balance economic interests, technological innovation, and national health priorities while safeguarding public health equity.

The findings suggest that while global mobility and trade can enhance efficiency, innovation, and access to healthcare, weak regulation and unequal power relations risk widening health disparities. Strengthening global collaboration, ethical workforce mobility strategies, inclusive trade policies, and robust digital governance mechanisms is essential to ensure that the benefits of globalisation are equitably distributed. Coordinated international action can improve patient outcomes, enhance health system resilience, and contribute to sustainable global public health development.

Keywords: Global mobility, international trade, health systems, digital health, pharmaceutical supply chains, public health equity

Synopsis

Globalisation has profoundly reshaped health systems by accelerating the movement of people, goods, and knowledge across national borders. Healthcare today operates within a global ecosystem where migration, trade agreements, and technological connectivity increasingly determine access, quality, and equity. Global mobility includes the migration of healthcare workers, medical tourism, and cross-border access to health services. While these processes can improve access to specialised care and knowledge exchange, they often result in uneven workforce distribution, with high-income countries benefiting disproportionately at the expense of resource-constrained regions.

International trade is a central component of global health governance. The production and distribution of medicines, vaccines, and medical technologies depend heavily on complex global supply chains. Trade agreements and intellectual property frameworks can encourage innovation and investment, yet they may also limit timely and affordable access to essential medicines. Disruptions to supply chains during global emergencies have revealed significant vulnerabilities, particularly for countries that rely heavily on imports for critical medical supplies.

Technological innovation further amplifies the effects of global mobility and trade. Digital health tools, telemedicine platforms, and cross-border data sharing systems offer new opportunities to extend healthcare services beyond geographic boundaries. These technologies can improve access to care in remote or underserved areas, enhance disease

surveillance, and support continuity of care for mobile populations. However, unequal access to digital infrastructure, regulatory fragmentation, and concerns around data privacy and sovereignty present significant challenges.

The primary objective of this study is to examine how global mobility, international trade, and technological innovation collectively shape health systems and influence public health equity. The study seeks to analyse the impact of migration, medical tourism, and cross-border healthcare on workforce distribution and access to services; assess how trade agreements and pharmaceutical markets affect the affordability and availability of essential medical products; and evaluate the role of digital health technologies in strengthening cross-border health system collaboration.

This study adopts a qualitative methodology based on a comprehensive review of peer-reviewed literature, policy documents, and global health reports. Comparative analysis is used to explore different regional experiences and governance approaches related to health workforce mobility, pharmaceutical trade, and digital health adoption. A health equity lens is applied to assess how benefits and risks are distributed across populations and countries.

The expected outcomes indicate that global mobility, trade, and technology can significantly strengthen health systems when guided by inclusive and coordinated policy frameworks. Potential benefits include improved access to healthcare services, enhanced availability of medical products, and greater integration of health systems through digital platforms. At the same time, the study highlights persistent challenges such as workforce imbalances, unequal access to medicines, supply chain dependence, and digital divides.

The findings underscore the need for ethical health workforce migration policies, equitable trade and intellectual property arrangements, and harmonised digital health governance. Aligning global collaboration with national health priorities is essential to ensure that globalisation contributes to resilient health systems, improved patient outcomes, and greater public health equity worldwide.

Rebalancing Pharmaceutical Policy and Regulation for Equitable Healthcare Accessibility in India

Bhanu Teja Rayala

The healthcare sector in India is situated in a complicated region where pharmaceutical development, regulation, and public access come into play. Though India has made itself a successful pharmaceutical leader in the global arena with affordable medications for not only itself but for the world, public access to healthcare is quite unbalanced. This has arisen with certain questions about healthcare in relation to pharmaceutical regulation.

The role of pharmaceutical policy and regulation in shaping and enhancing accessibility of healthcare in India shall be critically reviewed in this study. Pharmaceutical policies are expected to promote affordability, foster innovations, and ensure health for the people, while the regulation processes are expected to ensure that the pharmaceuticals are safe and of good standards. There are challenges associated with pharmaceutical policies and their regulations, which may result in slow innovations and inaccessibility of health care.

This study adopts a qualitative and conceptual research methodology that combines ideas from various documents like policies, theoretical writings, and public health reports to analyse the current drug management systems. It introduces various major tools of the policy that include the management of drug prices, the promotion of generic drugs, and the procurement system that affect the affordability of healthcare. It also explores the challenges faced in the management of drug approvals and the underutilisation of ideas from academic writing.

The article also delves deeper into the importance of collaboration between industry and academia, as well as technology-driven healthcare solutions, as enablers of accessibility on a strategic level. Research collaborations, in conjunction with health-tech solutions, have the potential to transform the delivery of healthcare into rural and resource-scar areas with the help of adaptive regulatory policies.

It is concluded that equal accessibility to healthcare can only be achieved with a change in the governance paradigm and a blend of regulatory and innovative measures in the governance of pharmaceuticals in India. In today's scenario, a smooth system with fewer gaps needs to be developed to ensure equitable public healthcare in the nation.

The research work helps to shape the debate on aligning pharmaceutical governance with equitable public healthcare in India and aids in formulating a scientific and coherent pharmaceutical system to ensure a hassle-free and equal healthcare system in the nation.

Keywords: Pharmaceutical Policy, Healthcare Regulation, Accessibility, Public Health Governance, Innovation

Synopsis

Healthcare accessibility encompasses a broad range of challenges that may be influenced by a host of variables including government policies, measures put up by legislation, financial ability, and advancement. In India, the pharmaceutical industry plays a crucial role concerning public healthcare; however, inequitable benefits deriving from the pharmaceutical industry expansion remain unconstitutional. Although there has been progress concerning the availability and affordability of medicines, inequities concerning accessibility remain a concern in rural as well as financially vulnerable settings. The synopsis explores the impact of pharmaceutical policies on accessibility and appropriate avenues for improvement.

India's pharma policy strives to ensure that necessary medicines are available at an affordable cost, alongside encouraging innovation. This could be achieved through measures such as price regulatory systems, encouraging generics, or the government procuring medicines. While making medicines affordable through such measures would help contain costs, making innovation in the pharma sector an expensive proposition could discourage private players from innovating in the domain of medicine, thus being hesitant to introduce new medicines in the market.

Regulation is an essential part of the pharmaceutical system and ensures the safety, efficacy, and quality of drugs being marketed. Regulators monitor both clinical trials, drug manufacturing processes, and drug

approval for launch in the market with the intention of safeguarding public health. However, complicated drug approval processes take longer and may hamper access to essential drugs and technologies being brought into the healthcare innovation ecosystem by small companies, startups, and academicians.

Healthcare accessibility in India faces more impediments in terms of infrastructure and socio-economic conditions. The lack of adequate healthcare infrastructure, qualified healthcare professionals, and a substantial proportion of out-of-pocket spending create a huge problem in the healthcare system in rural and less-accessible areas. Even with an expansion in healthcare services through governmental health schemes, there exists a discontinuity in their implementation.

Collaboration between industry and academia is an untapped and immensely important avenue for filling the gaps in policy, innovation, and accessibility. It is the responsibility of academic institutions to produce innovation through their research. On the other hand, the pharma industry can provide scalability with the required regulatory know-how for translating innovative ideas into affordable health solutions. Student/recent faculty members can also be involved to improve this pipeline.

Technology has become an enabling factor in bringing about changes in the delivery of medical services. The digital health platforms or telemedicine services have the capacity to reach underserved populations with extended medical services. On the contrary, technology in medical services needs an enabling framework in medical policies related to issues such as privacy in medical data. Disorganised policies in medical services related to technology may limit the reach of telemedicine services.

Emphasis in this summary is on the need to approach the issue of accessibility in the healthcare sector not in isolation but by embracing systems thinking that brings on board pharmaceutical policy reform, adaptability in regulation, collaborative innovation, and technology. Accessibility in the healthcare sector must be tackled by implementing systems thinking to develop equitable and sustainable public health outcomes in India.

Methodology The proposed research uses a qualitative, conceptual research methodology in its strategy based on literature review, analysis of health policies, scanning of public health frameworks, pharmaceutical regulation, and accessibility of health care. Expected Outcomes: The article is anticipated to make policy-relevant contributions about ensuring a balance between regulation and innovation, enhancing cooperation, and ensuring greater accessibility of healthcare.

How do the Differences in Health Insurance Models Influence Their Effectiveness in Reducing Out-Of-Pocket (OOP) Expenditures? A Comparative Study

Aryanshi Singh, Ayushi Nanda, Siva Nandhana Punnakkal

Universal Health Coverage allows everyone to access essential healthcare services without burning a hole in their pockets. “Despite India's policy-level acceptance of UHC, more than 47% of healthcare spending in the country is still borne by households” (Sivarchaka & Mamgain, 2024). The National Sample Survey (NSS-75th round) report highlights that “only 19.1% of the urban population and 14.1% of the rural population are covered by health protection” (Sivarchaka & Mamgain, 2024). A WHO (2022) report states that approximately 55 million Indians are pushed into poverty every year due to out-of-pocket spending. These figures point to the urgent necessity for systemic reforms that guarantee equal access to healthcare.

This paper aims to deconstruct India’s Pradhan Mantri Jan Aarogya Yojana (PM-JAY) to examine how health insurance policies act as instruments of socioeconomic transformation. Anchored under Sustainable Development Goal 3.8, this study analyses how institutional design, political will and inter-sectoral coordination influence the policy’s effectiveness in reducing out-of-pocket expenditure (OOPE) and promoting social equity. Using a networked institutional framework, the paper explores the dynamic relationship between state, market and society in implementing PM-JAY across the national, state and district levels.

Out-of-pocket spending is not simply a result of inadequate public funding; it points to the current policy's fundamental institutional and implementation shortcomings. Drawing inspiration from Brazil’s *Sistema Único de Saúde* and Indonesia’s *Jaminan Kesehatan Nasional*, the paper concludes that equitable transformation requires structural reforms that enhance inclusion, accountability, and the redistributive capacity of the state.

Keywords: Universal Health Coverage, PM-JAY, Out-of-pocket expenditure, Socio-economic policy, Policy deconstruction

Background and Rationale of the Study

The Sustainable Development Goal (SDG) 3.8 ensures everyone has access to affordable, high-quality healthcare and financial insurance against catastrophic medical expenses, which has been translated into Universal Health Coverage within the global health policy. Despite India's policy-level acceptance of UHC, significant healthcare spending in the country is still borne by households.

"The idea of expanding social protection for health under the presiding BJP first appeared as the pledge of 'Health Assurance to all Indians' in their 2014 Election Manifesto, as a desire to increase access to healthcare and reduce OOPE" (Srivastava et al., 2023). This idea was inspired by the High-Level Expert Group (HLEG) 2010 report on Universal Health Coverage (UHC), an expert group constituted by the erstwhile Planning Commission to provide recommendations on UHC strategies in India.

A significant event to reform the criticised National Health Policy (2002) was "the transfer of Rashtriya Swasthya Bima Yojana **(**RSBY) from the Ministry of Labour and Employment (MoLE) to the Ministry of Health and Family Welfare (MoHFW) on 1 April 2015" (Srivastava et al., 2023). Key actors involved in this phase included "the MoHFW, the Union Cabinet, and, later, the NITI Aayog" (Srivastava et al., 2023). The MoHFW led sporadic inter-ministerial meetings with multiple development partners, such as the Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ), the World Health Organisation (WHO), and the World Bank, to explore the possibilities for a new policy. "Fourteen speciality-wise sub-committees were established to develop an insurance benefits package, with consultation from states having well-functioning schemes" (Srivastava et al., 2023).

The National Health Policy 2017 succeeded the **policy legacy** of RSBY, and state schemes served as a pre-existing institution, influencing the agenda-setting phase. It was proposed that UHC be progressively achieved through health and wellness centres for primary care and insurance for secondary and tertiary care.

In conclusion, the combination of an identified problem of high out-of-pocket expenditure (OOPE) arising from the predecessor policy leaks and strong political will, along with support from the policy entrepreneurial NITI Aayog and the strategic engagement of international development partners effectively capitalised on the favourable political climate following the 2014 elections creating a "**policy window**" (Kalita & Croke, 2023) that enabled advocates to elevate PMJAY onto the public and political agendas.

Policy Concern

Universal Health Coverage allows everyone to access essential healthcare services without burning a hole in their pockets. "Despite India's policy-level acceptance of UHC, more than 47% of healthcare spending in the country is still borne by households" (Sivarchaka & Mamgain, 2024). The National Sample Survey (NSS-75th round) report highlights that "only 19.1% of the urban population and 14.1% of the rural population are covered by health protection" (Sivarchaka & Mamgain, 2024). A WHO (2022) report states that approximately 55 million Indians are pushed into poverty every year due to out-of-pocket spending. These figures point to the urgent necessity for systemic reforms that guarantee equal access to healthcare. Thus, out-of-pocket spending is not simply a result of inadequate public funding; it points to the current policy's fundamental institutional and implementation shortcomings.

Objective of the Study

The primary objective of this comparative study is to analyse how different health insurance models influence their effectiveness in reducing **out-of-pocket (OOP) expenditures**. Specifically, the study focuses on the **Pradhan Mantri Jan Arogya Yojana (PM-JAY)** in India, aiming to:

- Evaluate the effectiveness of PM-JAY's three-tier institutional structure (National, State, and District levels) in reducing financial burdens.
- Assess the interplay between the state, market, and society in delivering healthcare services.
- Measure the impact of various policy instruments on transparency, accessibility, and fraud prevention.

- Compare PM-JAY with international health insurance models in **Brazil and Indonesia** to identify best practices and lessons for reducing OOP expenditures.
- Explore how flexibility in implementation models (assurance, insurance, or hybrid) affects outcomes across different Indian states.

Methodology

The research employs a **comparative and descriptive analytical framework** to assess the policy's impact. The methodology includes the following key components:

- **Institutional Layer Analysis:** The study evaluates the roles and specific policy tools used at the Macro (National Health Authority), Meso (State Health Agencies), and Micro (District Implementation Units) levels.
- **Actor-Network Assessment:** It examines the "State-Market-Society Interplay," analysing the collaboration between government bodies, private sector players (such as empanelled hospitals and insurance companies), and societal actors (such as ASHAs and NGOs).
- **Instrumental Evaluation:** The researchers analyse specific policy instruments, such as **Ayushman Cards**, standardised package pricing, and the **PM-JAY Digital Warehouse**, for their effectiveness in preventing fraud and improving service delivery.
- **Cross-National Benchmarking:** A comparative analysis is conducted between India's PM-JAY, Brazil's SUS, and Indonesia's JKN. This involves comparing funding mechanisms, beneficiary identification systems, and the extent of outpatient coverage across these nations.
- **Performance Metrics:** The study uses data from the **National Health Accounts**, NHA reports, and secondary academic sources to measure the reduction in hospitalisation costs and identify remaining gaps, such as the exclusion of outpatient services and the "missing middle" population.

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Affordable Medicines for All: Policy Challenges and Opportunities in the Indian Pharmaceutical Sector

Shiv Bhan Yadav

Ensuring access to affordable medicines remains a central challenge for India's healthcare system, despite the country's position as a global leader in generic drug manufacturing. Medicines constitute a significant share of out-of-pocket healthcare expenditure in India, making affordability a decisive factor in treatment adherence and health outcomes. Over the years, various policy interventions have been introduced to regulate drug prices, encourage domestic production, and promote equitable access to essential medicines. However, inconsistencies in policy implementation, regulatory bottlenecks, and regional disparities in healthcare delivery continue to restrict the reach of affordable pharmaceutical care.

This paper aims to examine the policy environment shaping medicine affordability in India and to assess how existing pharmaceutical policies influence access, availability, and innovation. The study focuses on identifying key policy challenges that limit equitable access to medicines, while also exploring emerging opportunities for reform within the Indian pharmaceutical sector. Special attention is given to the role of pricing regulations, public procurement mechanisms, and innovation-oriented policies in supporting healthcare as a public good.

The study adopts a descriptive and analytical research approach based on secondary data. Policy documents, regulatory notifications, published academic studies, and reports from governmental and health organisations are systematically reviewed. A policy analysis framework is applied to evaluate the effectiveness of current pharmaceutical regulations in achieving affordability without undermining innovation or industrial growth. The study also considers recent policy initiatives aimed at strengthening domestic manufacturing capacity and improving supply chain efficiency.

The expected outcomes of this research include a clearer understanding of how pharmaceutical policies shape access to affordable medicines in

India. The paper anticipates highlighting critical gaps between policy intent and real-world outcomes, particularly in relation to price control coverage, regulatory efficiency, and healthcare infrastructure. At the same time, it identifies policy-level opportunities such as improved governance, targeted incentives, and stronger public–private collaboration to enhance medicine affordability. By positioning affordable medicines as an essential public good, this study seeks to contribute evidence-based insights for policymakers and stakeholders working towards a more equitable and sustainable healthcare system in India.

Keywords: Affordable medicines; Pharmaceutical policy; Drug pricing; Healthcare equity; Indian pharmaceutical sector

A Critical Public Policy Analysis of the Pharma Sector

Neha Pandey

The global pharmaceutical sector operates under a complex public policy mandate that seeks to promote life-saving innovation while ensuring equitable access to essential medicines. This dual objective has generated persistent policy tensions, as the dominant patent-based intellectual property regime prioritises market exclusivity to incentivise research and development, often at the cost of affordability and access. High drug prices, delayed generic entry, and limited investment in non-profitable public health priorities have intensified health inequities, particularly in low- and middle-income countries such as India. Despite India's position as a leading global supplier of generic medicines, significant gaps remain in domestic access, affordability, and regulatory effectiveness.

This study undertakes a critical public policy analysis of the pharmaceutical sector to examine how existing regulatory frameworks can be reoriented to balance innovation incentives with public health equity. Adopting a mixed-methods research design, the study combines qualitative comparative policy analysis with quantitative secondary data analysis. A systematic comparison of pharmaceutical policy frameworks in India, the United States, and European countries is conducted using the Walt and Gilson health policy analysis framework, focusing on intellectual property laws, pricing mechanisms, and regulatory governance. Quantitative data are drawn from institutional sources, including the World Health Organization, National Pharmaceutical Pricing Authority, Central Drugs Standard Control Organisation, National Family Health Survey, and Indian Patent Office reports. Where available, primary data from medical representatives and retail pharmacies are incorporated to contextualise pricing and access dynamics.

The analysis suggests that persistent gaps between pharmaceutical affordability and health equity stem from structural weaknesses in patent-centric pricing models, pharmaceutical dispensing channels, and

Over-the-Counter (OTC) regulation. Inadequate governance of OTC markets disproportionately affects vulnerable populations, reinforcing incomplete treatment pathways and financial exploitation. At the global level, international medicine surplus redistribution appears to distort healthcare outcomes and deepen socioeconomic inequities. Incorporating affordability and accessibility indicators into existing health measurement frameworks provides a more accurate assessment of treatment outcomes than availability alone. Overall, the findings highlight the necessity of treating essential medicines as public goods within an ethical, welfare-oriented pharmaceutical policy framework.

Keywords: Pharmaceutical policy, access to medicines, intellectual property rights, drug pricing, health equity, public health

Extended Abstract Background

The global pharmaceutical sector operates within a complex public policy mandate: to stimulate continuous medical innovation while simultaneously ensuring affordable and equitable access to essential medicines. The dominant policy architecture governing this sector is anchored in intellectual property rights (IPRs), particularly patent-based monopolies, which are intended to incentivise high-risk pharmaceutical research and development (R&D). While this model has contributed to major therapeutic breakthroughs and extended life expectancy worldwide, it has increasingly been criticised for producing adverse equity outcomes (Schweitzer, 2015). High drug prices, prolonged market exclusivity, and strategic "evergreening" practices have restricted access to essential medicines, especially in low- and middle-income countries (LMICs) and among vulnerable populations in high-income economies (Halliburton, 2009; South Centre, 2018).

In the Indian context, despite being recognised as the "pharmacy of the world," structural gaps persist between low manufacturing costs and affordable retail prices for domestic consumers. Studies indicate that policy instruments such as the Drug Price Control Order (DPCO) have had limited success in reducing out-of-pocket expenditure due to unregulated trade margins and fragmented regulatory enforcement (Singh, Ravi & Dam, 2020). The COVID-19 pandemic further exposed the

limitations of the global patent regime, underscoring the urgency of rethinking pharmaceutical governance in the interest of public health security.

Importance of the Study

This study addresses a critical policy failure: the inability of the prevailing pharmaceutical policy framework to balance innovation incentives with the ethical imperative of universal access to medicines. Existing literature highlights three interlinked failures—the innovation-access gap, regulatory quality failures, and policy fragmentation across jurisdictions (WHO, 2017; Joseph, 2019). While substantial public funds contribute to early-stage drug discovery, there are limited mechanisms to ensure a proportional public return in the form of affordability and access (Fulda, Lyles & Wertheimer, 2011). By foregrounding essential medicines as public goods rather than purely private commodities, this research contributes to policy debates on health equity, regulatory reform, and sustainable pharmaceutical innovation, particularly in India's mixed health system.

Methodology

The study adopts a mixed-methods approach combining qualitative comparative policy analysis with quantitative secondary data analysis. Qualitatively, pharmaceutical policy frameworks in India, the United States, and the European Union are compared using the Walt and Gilson health policy analysis framework, focusing on policy context, content, actors, and processes. Quantitative analysis draws upon secondary data from the World Health Organization (WHO), National Family Health Survey (NFHS), National Pharmaceutical Pricing Authority (NPPA), Central Drugs Standard Control Organisation (CDSCO), and Indian Patent Office annual reports. Where available, primary data from medical representatives and retail pharmacists are incorporated to examine pricing practices and market access dynamics. Additionally, stakeholder analysis of policy documents, legislative testimonies, and official statements from pharmaceutical industry associations, regulators, and patient advocacy groups is conducted to map competing interests and power asymmetries (Seiter, 2010).

Expected Outcomes

The expected outcomes of this research focus on bridging the gap between medical affordability and global health equity through data-driven policy and structural reform.

Policy and Framework Development The primary output will be a Health Equity Model featuring welfare-oriented policy blueprints. These aim to regulate pharmaceutical dispensing channels and reform Over-the-Counter (OTC) regulations to prevent the exploitation of vulnerable populations and ensure that "health restoration" is not a luxury of the wealthy.

Global Equity and Market Analysis The study will deliver a critical assessment of international medicine dumping, documenting how first-world surplus affects global healthcare indices. It will refine the Human Medicine Index by integrating affordability and accessibility metrics, providing a clearer picture of how high pricing skews recovery outcomes across different socio-economic strata.

Treatment Wholeness and Behavioural Insights Finally, the research will produce a comprehensive treatment map that accounts for the "collaterals" of medicine—including the role of supplements and the misuse of medicines as intoxicants. By identifying how patients navigate OTC channels as a workaround for formal care, the study will provide actionable insights to close "poor health concerns" and move toward a more holistic, ethical healthcare delivery system.

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Use of Heterogeneous Catalysis in the Synthesis, Characterization, and Antidiabetic Evaluation of Bioactive Thiazolidine-2,4-Dione Derivatives

Chandrakant Bajpai

Diabetes mellitus is a complex, chronic metabolic disorder characterised by persistent hyperglycaemia resulting from defects in insulin secretion, insulin action, or a combination of both. It represents one of the most significant public health challenges of the twenty-first century due to its rapidly increasing global prevalence, long-term complications, and substantial socioeconomic burden. According to global health estimates, diabetes mellitus affects hundreds of millions of individuals worldwide, with a particularly alarming rise in low- and middle-income countries such as India. The disease is associated with serious microvascular and macrovascular complications, including nephropathy, neuropathy, retinopathy, cardiovascular disease, and stroke, which significantly impair quality of life and increase mortality rates. Despite the availability of multiple classes of antidiabetic agents, effective long-term glycaemic control remains difficult to achieve in many patients due to adverse effects, drug resistance, reduced efficacy over prolonged use, and patient non-compliance.

Current therapeutic strategies for the management of type 2 diabetes mellitus (T2DM) primarily focus on improving insulin sensitivity, enhancing insulin secretion, reducing hepatic glucose production, and delaying carbohydrate absorption from the gastrointestinal tract. However, commonly used oral antidiabetic drugs such as sulfonylureas, biguanides, α-glucosidase inhibitors, and existing thiazolidinediones are often associated with limitations including hypoglycaemia, gastrointestinal disturbances, weight gain, hepatotoxicity, and cardiovascular risks. These drawbacks have intensified the need for the discovery and development of novel antidiabetic agents that exhibit improved efficacy, better safety profiles, and reduced side effects.

Thiazolidinediones (TZDs) constitute an important class of five-membered heterocyclic compounds containing nitrogen and sulphur atoms and are well established as insulin-sensitising agents. The

thiazolidine-2,4-dione nucleus is considered a privileged pharmacophore in antidiabetic drug discovery due to its ability to modulate glucose and lipid metabolism primarily through activation of the peroxisome proliferator-activated receptor gamma (PPAR-γ). In addition to their antidiabetic properties, TZD derivatives have been reported to exhibit a wide range of biological activities, including anti-inflammatory, antioxidant, antimicrobial, anticancer, and cardioprotective effects. Structural modification of the thiazolidinedione core, particularly at the C-5 position, has been shown to significantly influence pharmacological activity, making it an attractive site for molecular optimisation.

In parallel with drug discovery efforts, there has been increasing emphasis on developing environmentally benign and sustainable synthetic methodologies. Heterogeneous catalysis has emerged as a valuable tool in modern organic synthesis due to its numerous advantages, including ease of catalyst separation, reusability, reduced reaction time, operational simplicity, and compatibility with green chemistry principles. The use of heterogeneous catalysts minimises waste generation and avoids harsh reaction conditions, making the synthetic process more efficient and eco-friendlier. In this context, the present study was designed to explore the synthesis of novel thiazolidinedione derivatives using a heterogeneous catalytic approach and to investigate their potential antidiabetic activity through in vitro evaluation.

The primary objective of the present research was to synthesise a series of novel 5-substituted thiazolidine-2,4-dione derivatives, characterise their chemical structures using appropriate analytical techniques, and evaluate their in vitro antidiabetic potential using an α-amylase inhibition assay. α-Amylase plays a critical role in carbohydrate digestion by catalysing the hydrolysis of starch into glucose, thereby contributing to postprandial hyperglycaemia. Inhibition of α-amylase is a clinically validated strategy for controlling postprandial blood glucose levels, and compounds targeting this enzyme are considered effective therapeutic agents for the management of T2DM.

In the present study, thiazolidine-2,4-dione was condensed with a series of substituted aromatic aldehydes to afford a library of ten novel derivatives. The selected substituents included halogenated, nitro, amino, hydroxy, and alkoxy groups, allowing systematic evaluation of electronic and steric effects on biological activity. The reactions were carried out using a heterogeneous catalytic system under optimised conditions, leading to moderate to good yields of the desired products. Reaction progress was monitored by thin-layer chromatography, and the crude products were purified using recrystallisation and column chromatography techniques.

The synthesised compounds were characterised by melting point determination, infrared spectroscopy, proton nuclear magnetic resonance spectroscopy, and mass spectrometry. Following structural characterisation, the compounds were subjected to in vitro antidiabetic evaluation using an α-amylase inhibition assay. Most derivatives exhibited moderate to significant enzyme inhibition. Among them, the fluoro-substituted derivative demonstrated the highest inhibitory activity, suggesting its potential as a lead compound for further development.

In conclusion, this study demonstrates the successful application of heterogeneous catalysis in the synthesis of bioactive thiazolidine-2,4-dione derivatives and highlights their promising antidiabetic potential. The findings support further in vivo and mechanistic studies to establish these compounds as viable candidates for antidiabetic drug development.

An insight into the Synthetic strategy of Chalcone analogues

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Chalcone, an α,β-unsaturated carbonyl compound belonging to the flavonoid family, is obtained from both natural and synthetic sources and has attracted sustained scientific interest due to its broad pharmacological relevance and chemical versatility. Traditionally, chalcones are synthesised via the Claisen–Schmidt condensation involving equimolar quantities of benzaldehyde and acetophenone in the presence of aqueous alkali such as sodium hydroxide or potassium hydroxide. In addition to this classical method, several well-established name reactions have been reported for chalcone synthesis, including Claisen–Schmidt condensation, Suzuki–Miyaura reaction, Wittig reaction, Friedel–Crafts reaction, Julia–Kocienski reaction, Sonogashira isomerisation coupling, carbonylated Heck coupling reaction, Mukaiyama aldol reaction, Meyer–Schuster rearrangement, direct crossed-coupling reactions, ionic liquid catalysed synthesis, and photo-Fries rearrangement, many of which afford chalcone derivatives in high yields. Conventional as well as eco-friendly technologies such as solvent-free synthesis, grinding methods, ultrasound irradiation, microwave-assisted synthesis, and one-pot protocols have been developed to improve efficiency and sustainability. Downey and co-workers reported the synthesis of chalcones through the Mukaiyama aldol reaction using enol silanes generated from acetophenones in the presence of trimethylsilyl triflate and tertiary amine bases. The chalcone scaffold is frequently hybridised with diverse heterocyclic systems such as isoxazoles, thiadiazoles, benzoxazepines, benzodiazepines, pyrrolines, cyclopropanes, 2H-chromenes, thioethers, 2H-quinolines, indanones, isoindolines, pyrylium salts, imidazo[1,2-a]pyridines, spiro-pyrrolidine-indolines, phosphinines, imidazoles, phthalazines, pyrimidines, thiazoles, pyrroles, benzothiazepines, pyrazoles, pyridines, pyrazolines, isothiocyanato ketones, 1,4-thiazephines, isoxazolines, xanthoangelol J, and chalcone epoxides, establishing chalcones as privileged scaffolds with wide therapeutic relevance. Extensive studies have demonstrated that chalcones exhibit a broad spectrum of biological activities including analgesic, antipyretic, antimutagenic, antibacterial, antimalarial,

antihelminthic, amoebicidal, antiulcer, antiviral, insecticidal, antiprotozoal, anticancer, cytotoxic, anti-HIV, antidiabetic, antifibrinogenic, antifungal, anti-gout, antihistaminic, antihyperlipidemic, antihypertensive, anti-inflammatory, anti-invasive, antileishmanial, anti-metastatic, antimicrobial, antineoplastic, antinociceptive, anti-obesity, antioxidant, antiplatelet, antiretroviral, antitrypanosomal, antitubercular, anxiolytic, hypnotic, immunosuppressive, and antiosteogenic activities. Beyond pharmacology, chalcones have found applications as artificial sweeteners, analytical receptors for iron (III) determination, fluorescent polymers, fluorescent whitening agents, insecticides, organic brightening agents, polymerisation catalysts, and scintillators. This abstract presents a comprehensive landscape of chalcones, encompassing their structural features, natural occurrence, synthetic methodologies, eco-friendly approaches, and extensive biological and industrial applications.

Keywords: Chalcones; α,β-Unsubstituted carbonyl compounds; Flavones; Organic synthesis; Catalyst