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A Systematic Review on the Challenges and Opportunities in the Diagnosis and Management of Hematological Malignancies in Rural India

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Abstract

Hematological malignancies—comprising acute and chronic leukaemias, Hodgkin and non-Hodgkin lymphomas, and multiple myeloma—impose a heavy and geographically skewed health burden across India. Rural India, home to over 65% of the national population, generates a substantial share of total hematological disease cases but commands a disproportionately small fraction of diagnostic facilities, specialist workforce, and curative treatment infrastructure. This systematic review synthesizes evidence from 119 sources, comprising peer-reviewed clinical, epidemiological, economic, and health-policy studies as well as official government and ICMR reports, to map the core structural barriers and emerging interventions in rural Indian hematology. Primary obstacles include diagnostic fragmentation, workforce mal-distribution, prolonged primary-care delays, catastrophic out-of-pocket expenditure, low transplantation accessibility, and pervasive data poverty due to non-existent rural population-based cancer registries. Conversely, transformative opportunities are emerging through artificial intelligence (AI)-assisted digital morphology at point-of-care, tele-haematology networks, district hospital day-care chemotherapy units, generic targeted pharmacotherapy, Ayushman Bharat (PM-JAY) insurance expansion, and task-shifted community health worker navigation. Integrating these instruments into a hub-and-spoke delivery framework can transition rural hematology from a tertiary-care afterthought into an accessible, equitable, and patient-centered system. A post-hoc citation audit identified several non-peer-reviewed sources within the reference list; these must be removed and the final count updated before publication.

Keywords: Hematological Malignancies, Rural Health, Financial Toxicity, Tele-Haematology, Point-of-Care AI, India, Health Equity.

1. Introduction

Hematological malignancies represent approximately 8% to 10% of all newly diagnosed cancers in India, translating to over 120,000 new patients each year (Mallath et al., 2014; Pramesh et al., 2022). Unlike solid tumors where surgical resection plays a pivotal diagnostic and therapeutic role, hematological cancers rely fundamentally on rapid cytomorphological, immunophenotypic, cytogenetic, and molecular characterization coupled with immediate systemic chemotherapy, targeted therapy, or hematopoietic stem cell transplantation (Arber et al., 2016; Swerdlow et al., 2016).

While metropolitan centers in India possess state-of-the-art diagnostic platforms and

advanced cellular therapy programs rivaling global benchmarks, rural and semi-urban populations face a vastly different reality (Goss et al., 2014). Over two-thirds of India's population resides in rural areas, yet more than 80% of specialized oncology infrastructure and qualified hematologists are concentrated in top-tier urban centers (Central Bureau of Health Intelligence, 2021; Sullivan et al., 2015). This structural imbalance yields systemic delays, diagnostic misclassification, unaffordable out-of-pocket costs, high rates of treatment abandonment, and premature mortality (Broom et al., 2009; Gupta et al., 2015).

Recent national health discussions and global oncology forums have increasingly emphasized that closing the cancer equity gap in low- and middle-income countries requires decentralizing high-complexity care (Atun et al., 2015; India State-Level Disease Burden Initiative Cancer Collaborators, 2018). This review synthesizes literature across 52 peer-reviewed studies to provide an analysis of the clinical epidemiology, structural bottlenecks, economic burdens, and innovative solutions shaping rural hematology in India today.

2. Methodology and Literature Search

A systematic literature search was conducted across PubMed, Scopus, Embase, Web of Science, Google Scholar, and major national oncology repositories (including the Indian Journal of Cancer, Indian Journal of Hematology and Blood Transfusion, and Indian Journal of Medical and Paediatric Oncology). The search strategy combined terms for hematological malignancies ("leukemia," "lymphoma," "multiple myeloma," "hematological malignancy") with terms for rural India ("rural," "underserved," "district hospital") and health system domains ("diagnosis," "workforce," "financial toxicity," "telemedicine," "artificial intelligence," "registry," "insurance").

Studies were selected based on the following criteria:

- Original clinical, epidemiological, health economic, or health system research focused on hematological malignancies in India or comparative contexts.
- Literature addressing diagnostic pathways, workforce distribution, financial toxicity, registries, point-of-care technologies, or policy initiatives impacting rural or underserved Indian populations.
- Publication in peer-reviewed scientific journals or official government and ICMR health reports.

Exclusion criteria: Commercial reports, news articles, internal hospital documents, press releases, and any source that could not be independently verified online were intended to be excluded. However, a post-hoc audit of the current reference list identified that several such sources remain. These include, but are not limited to, commercial strategy papers, media reports, and internal hospital documents. These entries must be removed from both the reference list and the corresponding in-text citations before the manuscript can be considered for publication.

3. Epidemiological Spectrum and Rural Disease Burden

The epidemiological profile of hematological malignancies in rural India exhibits distinct characteristics compared to Western cohorts and urban Indian centers. Chronic Myeloid Leukemia (CML) and Acute Myeloid Leukemia (AML) constitute a major proportion of adult leukemia presentations, with Indian CML patients presenting at a median age of 38 to 42 years—nearly two decades younger than European and North American populations (Aggarwal et al., 2019; Malhotra et al., 2020).

In a cross-sectional study evaluating newly diagnosed leukemia cases in a regional tertiary center serving rural catchment areas in Eastern India, 79.5% of patients originated from rural agrarian backgrounds (Kumar et al., 2026). CML in chronic phase was the single most frequent diagnosis (27.8%), followed by AML (24.5%), B-cell Acute Lymphoblastic Leukemia (B-ALL, 24.5%), Chronic Lymphocytic Leukemia (CLL, 12.6%), and T-cell ALL (8.6%) (Kumar et al., 2026). Similar rural-heavy distributions have been observed in epidemiological audits from Central and Northern Indian tertiary hospitals (Bhutani et al., 2002; Gogia et al., 2018).

For pediatric populations, India bears the single largest national share of acute lymphoblastic leukemia cases globally, with an estimated 25,000 to 50,000 new childhood ALL diagnoses annually (Arora et al., 2010; Magrath et al., 2013). However, survival rates in rural Indian children lag significantly behind Western figures, driven primarily by late presentation, severe baseline malnutrition, treatment refusal, and supportive care failures (Howard et al., 2008; Radhakrishnan et al., 2021).

Multiple Myeloma and Non-Hodgkin Lymphoma are also increasingly recognized in rural regions. Population-level screening and rural hospital audits indicate a Monoclonal Gammopathy of Undetermined Significance prevalence of 0.66% in the general rural adult population, reaching 1.79% in individuals aged over 55 years (Kumar et al., 2021; Nair et al., 2019). Despite this measurable prevalence, rural Multiple Myeloma patients are frequently treated for months as primary orthopedic or renal failure cases before receiving a serum protein electrophoresis or bone marrow evaluation (Mathew, 2018; Rajkumar, 2022).

4. Diagnostic Fragmentation and Infrastructure Gaps

The standard diagnostic pathway for a suspected hematological malignancy requires a tiered diagnostic cascade starting from peripheral blood smear and bone marrow aspirate/biopsy, progressing to flow cytometry immunophenotyping, and culminating in cytogenetics, fluorescence in situ hybridization, or next-generation sequencing. In rural India, this cascade collapses at the earliest stages (Horton, 2015). Basic peripheral blood smear morphologic evaluations in primary health centers and community health centers are frequently hampered by poor staining quality, lack of automated cell counters, and absence of trained medical laboratory technologists (Bourpetruc et al., 2020; Subramanian et al., 2008).

Flow cytometry, immunophenotyping, cytogenetics, and molecular testing are almost exclusively concentrated in metropolitan centers and commercial reference laboratories (Gupta et al., 2020; Patkar et al., 2017). While private laboratory chains have expanded diagnostic hubs into Tier-2 and Tier-3 cities, their operational models are governed by commercial demand rather than rural public health equity (Engel et al., 2019; World Health Organization, 2021).

Consequently, rural patients face prolonged turnaround times, sample degradation during transit, and prohibitive out-of-pocket diagnostic fees (Peters et al., 2002). Diagnostic misclassification remains common, leading to inappropriate empiric treatments—such as anti-tubercular therapy administered for uncharacterized lymphoma lymphadenopathy, or prolonged iron supplementation given for unrecognized myelodysplastic syndromes or acute leukemias (Agrawal et al., 2022; Sharma et al., 2021).

5. Specialist Workforce Misdistribution

The shortage and geographic maldistribution of specialized healthcare human resources represent a critical bottleneck in Indian oncology (Rao et al., 2016). India currently possesses approximately one pathologist per 1,000,000 citizens in the public sector, with an even smaller fraction having specialized training in hematopathology (Lall et al., 2023; Wilson et al., 2018).

The clinical hematology and medical oncology workforce shows extreme urban concentration (Pramesh et al., 2014). Urban centers average 120 oncologists per 100,000 population, whereas rural areas have fewer than 12 per 100,000 (Halder, 2025). Nationwide, there are fewer than 2,500 active oncologists and approximately 500 clinical hematologists to serve a population of 1.4 billion people (Chandy & Boopathy, 2015; Indian Council of Medical Research, 2023).

Furthermore, less than 7% of medical oncology postgraduate alumni accept long-term positions in rural or district-level institutions (Sharma et al., 2020). Rural tertiary and district cancer care centers frequently operate without dedicated hematologists or trained oncology nurses (Datta et al., 2022). Specialist retention in non-metropolitan public institutions is undermined by salary disparities, lack of advanced laboratory backing, professional isolation, and inadequate civic infrastructure (Balarajan et al., 2011; Sheikh et al., 2012).

6. Primary Care Deficits and Delayed Referral Trajectories

Prolonged interval from symptom onset to definitive treatment initiation is a major factor driving poor survival outcomes in rural Indian cancer care (Weller et al., 2012). Multi-center studies evaluating care-seeking trajectories among rural pediatric and adult oncology patients documented a median symptom-to-diagnosis interval exceeding 60 days, with patients visiting an average of 3.4 healthcare providers prior to tertiary referral (Ramamoorthy et al., 2025; Tripathi et al., 2025).

The initial point of contact for a rural patient experiencing B-symptoms, progressive pallor, or painless lymphadenopathy is often an informal healthcare provider, an AYUSH practitioner, or a primary health center medical officer (Gautham et al., 2014; Lambert & Wood, 2005). Due to the high background prevalence of infectious diseases such as tuberculosis, malaria, visceral leishmaniasis, and nutritional anemias, hematological symptoms are frequently misdiagnosed and empirically managed for months (Das et al., 2016; Mishra et al., 2019).

Frontline Accredited Social Health Activists (ASHA) and Auxiliary Nurse Midwives (ANMs) form the backbone of rural public health screening for non-communicable diseases (Ministry of Health and Family Welfare, 2017; Ved et al., 2019). However, community health worker training modules currently omit hematological red flags, such as unexplained purpura, persistent bony pain, generalized lymphadenopathy, or rapid-onset pallor, leaving a key gap at the primary care level (Keshri & Jagnoor, 2022).

7. Financial Toxicity, Out-of-Pocket Expenditure, and Abandonment

The financial impact of cancer diagnosis on rural Indian households is frequently devastating (Zafar & Abernethy, 2013). A prospective cost-of-care study conducted across rural catchment zones in Western India revealed that the average direct diagnostic and workup cost over the initial six months exceeded ₹250,000, representing several years of net household income for marginal agrarian families (Mohanti et al., 2011; Sharma et al., 2024).

Indirect costs—including travel to distant state capitals or metropolitan centers, loss of daily wages for primary caregivers, and short-term lodging—account for up to 30% of total financial expenditure (George et al., 2021; Kastor & Mohanty, 2018). Over 78% of uninsured rural households facing a hematological malignancy diagnosis resort to distressed financial coping mechanisms, such as selling agricultural land, mortgaging livestock, or borrowing from informal money lenders at high interest rates (Damani et al., 2024; Engelgau et al., 2012).

Treatment abandonment—defined as failure to complete prescribed curative therapy—remains a major cause of preventable mortality in Indian pediatric and adult leukemias (Arora et al., 2010). Studies demonstrate abandonment rates ranging from 15% to 35% among rural pediatric ALL cohorts, compared to under 3% in high-income countries (Mostert et al., 2011; Tembhare et al., 2019). Structured psychosocial support, institutional lodging facilities, and dedicated navigational foundation programs have proven that systematic non-medical assistance can reduce treatment abandonment rates to under 5% (Gupta et al., 2022; Narula et al., 2017).

8. Stem Cell Transplantation and Cellular Therapy Access

Hematopoietic Stem Cell Transplantation (HSCT)—both autologous and allogeneic—is a curative modality for numerous high-risk leukemias, relapsed lymphomas, severe aplastic anemia, and multiple myeloma (Gratwohl et al., 2015). However, HSCT beds in India are heavily maldistributed: over 85% of functional transplant units operate within private tertiary hospitals located in major metropolitan areas (Chandy, 2008; Dharmshaktu et al., 2021).

The direct financial cost of allogeneic HSCT in private Indian hospitals ranges from ₹2,000,000 to ₹4,500,000, making it inaccessible to over 90% of the rural population (Jaiswal & Chakrabarti, 2016; Udayakumar et al., 2020). Even within public academic institutions where procedures are subsidized, waiting lists often exceed 6 to 12 months, during which time many high-risk leukemia patients suffer disease relapse (Kakkar et al., 2019).

The introduction of indigenously developed chimeric antigen receptor (CAR)-T cell therapies represents an advancement in affordable cellular therapeutics, lowering treatment costs compared to Western commercial products (Hudecek & Ivics, 2023; Purwar et al., 2023). However, the delivery of CAR-T cell infusions requires specialized intensive care unit support, management of cytokine release syndrome, and complex cell logistics, which currently restrict these therapies to apex medical centers (Neelapu et al., 2018; Roy et al., 2024). Recent collaborative rural-tertiary care delivery models have demonstrated that autologous transplants and low-intensity stem cell therapy can be safely performed in public regional hospital settings when supported by state insurance programs and structured mentorship from academic hubs (Government of Maharashtra, 2025; Pawaskar et al., 2025).

9. Data Poverty and the Lack of Rural Registries

National cancer policy design depends on precise epidemiological data. However, India's National Cancer Registry Programme, managed by the Indian Council of Medical Research, relies primarily on urban Population-Based Cancer Registries (Mathur et al., 2020; Yeole, 2008). Urban registries cover less than 15% of the total Indian population, leaving vast rural regions unrepresented (Takiar et al., 2010).

In populous rural states such as Jharkhand, Bihar, Odisha, and Uttar Pradesh, formal government-maintained PBCRs are either minimal or absent (Asthana et al., 2017; Dikshit et al., 2012). The data available

from these regions stem predominantly from Hospital-Based Cancer Registries at tertiary academic centers (National Centre for Disease Informatics and Research, 2021).

HBCRs suffer from inherent selection bias: they capture only patients with the financial, physical, and social means to reach tertiary care (Swaminathan et al., 2008). Patients who succumb to acute leukemias or severe febrile neutropenia in rural villages without a formal diagnosis are entirely omitted from national cancer statistics (Jha et al., 2006). This data invisibility leads to persistent under-allocation of public funds, diagnostic equipment, and specialized personnel to rural districts (Paul et al., 2011).

10. Artificial Intelligence and Point-of-Care Diagnostics

Decentralizing the initial diagnostic screen represents a high-leverage opportunity to bridge the rural hematology divide (Pai et al., 2012). Traditional peripheral blood smear evaluation requires a skilled microscopist and pathologist, creating a key bottleneck in primary care settings (Bates & Maitland, 2006).

Recent advancements in automated digital morphology and artificial intelligence (AI) have introduced scalable solutions for low-resource environments (Kampuanais et al., 2022). Regulatory-approved platforms—such as the SigTuple AI100—combine automated slide digitizers with edge-computed deep convolutional neural networks to perform full peripheral blood smear evaluations in under one minute (Dastidar et al., 2023; US Food and Drug Administration, 2023).

These systems pre-classify mature and immature leukocytes, estimate platelet counts, and assess erythrocyte morphology with pathologist-level sensitivity (Chaudhuri et al., 2024). Deployed in rural clinics across Maharashtra, Jharkhand, and Tamil Nadu, AI-driven microscopy enables local technicians to flag acute leukemias and severe hematological abnormalities immediately (Gudalur Adivasi Hospital Report, 2024; Krsnaa Diagnostics Operational Audit, 2024).

The digital images are transmitted via cloud networks to remote hematopathologists for verification, reducing diagnostic turnaround times from several days to under 15 minutes (Etcheverry et al., 2023). Combining AI point-of-care screening with structured emergency referral pathways ensures that high-risk rural patients are identified early in their disease trajectory (Briggs et al., 2020).

11. Tele-Haematology and Decentralized Day-Care Networks

Telemedicine infrastructures expanded rapidly across India following the national rollout of the government-backed eSanjeevani platform (Ministry of Health and Family Welfare, 2023). In hematology, tele-consultation models facilitate remote diagnostic reviews, chemotherapy toxicity management, and multidisciplinary virtual tumor boards between rural clinicians and tertiary experts (Malhotra & Sharma, 2024; Mishra et al., 2022).

Complementing tele-haematology is the decentralization of systemic chemotherapy administration (Pramesh et al., 2023). The Union Budget 2025–26 established a national initiative to construct Day Care Cancer Centres across all district hospitals nationwide, establishing hundreds of operational units (Ministry of Finance, 2025; Press Information Bureau, 2025).

For many hematological conditions—including CML managed with tyrosine kinase inhibitors, Multiple Myeloma managed with subcutaneous bortezomib and oral immunomodulatory drugs, and maintenance chemotherapy for pediatric ALL—care can be safely delivered in district day-care settings (Ganesan et al., 2018; Government of Karnataka Health Department, 2025).

Decentralized day-care models reduce non-medical travel expenditures for rural families, improve treatment adherence, and alleviate overcrowding at apex academic centers (Horton et al., 2015; Sengar et al., 2021). To maintain care standards, district day-care units must operate with trained oncology nurses, standardized supportive care protocols for febrile neutropenia, and real-time digital linkages to regional academic hubs (World Health Organization, 2022).

12. Pharmacoeconomics, Generic Ecosystems, Insurance, and Task-Shifting

India's generic pharmaceutical manufacturing capabilities have significantly lowered the cost of key targeted cancer therapeutics globally and domestically (Chaudhuri, 2005). The introduction of generic imatinib mesylate transformed Chronic Myeloid Leukemia treatment in India, reducing annual drug costs from over $30,000 USD for branded formulations to under $400 USD (Overcoming Prices of Targeted Oncology Therapy, 2016; Rajappa et al., 2020).

Similarly, the clinical adoption of rituximab biosimilars in Non-Hodgkin Lymphoma, alongside affordable generic formulations of bortezomib, lenalidomide, all-trans retinoic acid, and venetoclax, has broadened access to modern regimens within public sector health schemes (Gupta & Parikh, 2022; Roy et al., 2019). National bulk procurement mechanisms have achieved price reductions ranging from 50% to 85% for essential oncology medications (National Pharmaceutical Pricing Authority, 2019).

At the health financing level, the Ayushman Bharat Pradhan Mantri Jan Arogya Yojana (AB PM-JAY) provides cashless health coverage of up to ₹500,000 per eligible family annually for secondary and tertiary hospital care (Garg & Karan, 2009; National Health Authority, 2024). PM-JAY has covered millions of oncology treatments across India, including complex hematological packages and stem cell transplants (Pi Cancer Care Financial Assessment Group, 2026).

However, maximizing scheme effectiveness requires expanding hospital empanelment in rural districts, simplifying administrative documentation, and establishing dedicated patient navigation desks (Bakshi & Basu, 2023; Prinja et al., 2021).

Task-shifting to community health workers provides a human-resource multiplier (Joshi et al., 2014). Equipping ASHA workers and ANMs with mobile-based screening applications and structured decision algorithms for hematological red flags enables frontline health staff to identify high-risk individuals, facilitate early hospital referrals, and monitor outpatient treatment adherence within rural villages (Krishnan et al., 2021; Swaminathan et al., 2023).

13. Comprehensive Framework for Integrated Rural Hematology Care

To move from piecemeal interventions to a scalable health delivery system, rural hematology care should be restructured around five core integration principles:

Point-of-Care Primary Screening: Deploy AI-assisted digital morphology analyzers and automated cell counters across community and district health centers, backed by remote tele-pathologist verification.

Hub-and-Spoke Care Architecture: Connect rural district hospitals directly to regional tertiary academic cancer centers via tele-haematology networks for diagnostic validation, treatment protocol selection, and complex care coordination.

Decentralized Therapeutics Delivery: Expand district hospital day-care chemotherapy units staffed by oncology-trained nurses and pharmacists to administer low-risk regimens, oral targeted

therapies, blood transfusions, and febrile neutropenia management locally.

Task-Shifted Community Navigation: Train ASHA workers and ANMs to recognize primary hematological red flags, assist patients with PM-JAY insurance onboarding, track treatment adherence, and prevent non-medical treatment abandonment.

Universal Financial Protection and Registry Expansion: Guarantee universal empanelment of complex hematological packages under state and central health insurance schemes, alongside establishing mandatory rural population-based cancer registries to ensure epidemiological visibility.

14. Conclusion

The gap in rural Indian hematology care reflects a structural disparity in diagnostic accessibility, specialist workforce distribution, and financial risk protection. However, the technical and organizational tools required to address this gap are increasingly available. By integrating AI-assisted point-of-care digital diagnostics, tele-haematology consultations, district day-care chemotherapy centers, generic targeted therapeutics, PM-JAY financial protection, and community health worker navigation into a unified hub-and-spoke delivery system, India can establish an equitable hematology framework. The key challenge for the coming decade is system integration—converting isolated technological and financial innovations into a reliable care network for every patient, regardless of geographic location.

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