

Mortality Patterns, Disease Burden, and Preventability Classification in Kamrup District, Assam: A Comprehensive Five-Year Epidemiological Analysis (2020–2024)

¹*Dr. Parag Deb Roy, ²Dr. Saumya Shankar Chowdhury, ³Dr. Shashwati Nath, ⁴Dr. Rita Sarkar, ⁵Dr. Geetanjali Bhattacharjee, ⁶Prof. Dr. Hari Kumar Pallathadaka (Guide), ⁷Dr. Shibasish Nath Bhowmik (Co-Guide), ⁸Mr. Akhilesh Lal (Co-Guide)

¹District Surveillance Officer (DSO) cum District Tuberculosis Officer (DTO), Integrated Disease Surveillance Programme (IDSP) & National Tuberculosis Elimination Programme (NTEP), Kamrup, Assam.

²Deputy General Manager (DGM), North Eastern Electric Power Corporation Limited (NEEPCO).

³Assistant Professor, Department of Geography, Saraighat College, Changsari, Assam.

⁴Senior Medical Officer (SMO), Health and Family Welfare Department, Government of Assam.

⁵Consultant, National Viral Hepatitis Control Program (NVHCP) & National Family Planning Program, State Head Quarter National Health Mission (NHM), Assam.

⁶Vice-Chancellor and Professor, Manipur International University (MIU).

⁷Principal Private Secretary (PS) to the Hon'ble Governor of Assam.

⁸Senior Advocate, Gauhati High Court.

ABSTRACT

Background:

Preventable mortality represents a critical measure of healthcare system effectiveness. Globally, the World Health Organization estimates that nearly half of all deaths in low- and middle-income countries are potentially preventable through timely, appropriate healthcare interventions. India is undergoing an epidemiological transition marked by a dual disease burden: persistent infectious and maternal-child health conditions coexisting with rapidly escalating non-communicable diseases (NCDs). Kamrup District, Assam, with its mixed urban-rural population of approximately 1.5 million, provides a compelling setting for comprehensive mortality analysis, given the documented healthcare infrastructure gaps in northeastern India and the paucity of district-level epidemiological evidence from this region.

Objective:

To conduct a comprehensive five-year retrospective analysis of mortality patterns in Kamrup District (2020–2024), encompassing: (i) identification of leading causes of death and their demographic distribution; (ii) systematic classification of deaths by preventability at primary, secondary, and tertiary healthcare levels using evidence-based frameworks; (iii) temporal trend analysis across the COVID-19 pandemic and post-pandemic period; (iv) economic burden estimation of preventable mortality; and (v) generation of targeted, actionable health system strengthening recommendations.

Methods:

A retrospective observational study analyzed 2,578 deaths recorded by the Integrated Disease Surveillance Programme (IDSP) in Kamrup District from January 2020 to December 2024. Causes of death were classified per ICD-10 criteria. A novel three-tier preventability framework was developed, aligned with India's healthcare delivery structure (Primary Health Centres, Community Health Centres/District Hospitals, and Medical College/Tertiary Care). Economic burden was estimated incorporating direct costs (₹50,000/death), productivity loss (15–65 year deaths × 15 years productive life lost × ₹120,000 GDP per capita, Assam), and indirect costs (2.5× direct costs). Descriptive statistics, temporal trend analysis, and comparative analyses were performed.

Results:

Of 2,578 total deaths, cerebrovascular accidents (CVA) constituted the leading cause (n=1,112, 43.1%), followed by sepsis/septic shock (n=445, 17.3%), respiratory failure (n=252, 9.8%), other specified causes (n=207, 8.0%), and cardiac conditions (n=153, 5.9%). Mean age at death was 57.6 years (median 58.0; range 1–110), with males comprising 72.9% (n=1,880). Working-age individuals (15–65 years) constituted 66.6%

(n=1,716) of all deaths. All 2,578 deaths (100%) were classified as potentially preventable: 696 (27.0%) at primary level, 731 (28.4%) at secondary level, and 1,151 (44.6%) at tertiary level. Notable temporal shifts occurred: primary-level preventable deaths increased from 24.5% (2020) to 51.9% (2024), reflecting improving tertiary capacity but persistent preventive care deficits. The total economic burden was ₹354 crores over five years for Kamrup District, with state-level extrapolation yielding ₹8,260 crores, dominated by productivity loss (87.3% of total burden).

Conclusions:

The universal preventability finding and the predominance of cardiovascular and infectious causes of death underscore catastrophic failures in prevention, early detection, and disease management at primary and secondary healthcare levels. An estimated 55.4% of deaths were preventable through strengthening primary and secondary care alone; the most accessible and cost-effective tier. Evidence-based recommendations include universal NCD screening programs, standardized sepsis management protocols, cardiac emergency care with thrombolysis capability, expanded dialysis services, organized trauma systems, and critical tertiary care capacity enhancement. The substantial economic burden provides compelling justification for targeted public health investments.

KEYWORDS: *Preventable mortality; Cerebrovascular accident; Sepsis; Healthcare system gaps; Primary healthcare; IDSP; Economic burden; Assam; Northeast India; ICD-10; Epidemiological transition; Health system strengthening*

1. INTRODUCTION

1.1 Global and Indian Context of Preventable Mortality

Preventable deaths represent the most powerful single indicator of healthcare system performance, encapsulating failures in prevention, early detection, timely treatment, and effective management across all levels of care. The World Health Organization (WHO) estimates that approximately 40–50% of deaths in low- and middle-income countries (LMICs) are potentially preventable through timely access to appropriate healthcare, effective prevention programs, and systemic health system strengthening.¹ These deaths are not merely statistical abstractions - each represents a human life cut short by a failure of the systems designed to protect it, with profound consequences for families, communities, and national economies.

India is experiencing a profound epidemiological transition, characterized by a dual disease burden: on one hand, persistent communicable diseases, maternal mortality, and childhood illnesses that defined the pre-transition era; on the other, rapidly escalating non-communicable diseases (NCDs) including cardiovascular diseases, diabetes, chronic respiratory diseases, and cancer.^{2,3} Cardiovascular diseases now account for approximately 28% of all deaths in India, with this proportion increasing substantially over the past two decades.⁴ The India State-Level Disease Burden Initiative has documented substantial interstate variation in mortality patterns, with stroke emerging as the single leading cause of death and disability-adjusted life years (DALYs) in multiple states.^{5,6}

Northeastern states including Assam face particular challenges: geographic remoteness limiting healthcare access, healthcare workforce shortages at all levels, infrastructure deficits in both physical facilities and medical equipment, poor road connectivity impeding emergency care, cultural and linguistic barriers to healthcare seeking, and historically inadequate public health investment.⁷ Despite improvements under the National Health Mission, these structural disadvantages persist, and district-level epidemiological data that could guide targeted interventions remains critically scarce.

1.2 Preventability Frameworks: Historical Development

The conceptual framework of preventable mortality has undergone substantial evolution since its foundational articulation by Rutstein and colleagues in their seminal 1976 publication introducing 'sentinel health events' - deaths and disabilities that should not occur in the presence of adequate medical care.⁸ This work established the foundational principle that mortality can serve as a quality indicator of healthcare systems, transforming death data from passive vital statistics into active tools for health system evaluation and improvement.

Nolte and McKee subsequently developed and validated comprehensive frameworks for avoidable mortality, constructing rigorously evidence-based lists of conditions preventable through healthcare interventions and distinguishing between conditions amenable to healthcare (treatable through medical care) and conditions

amenable to prevention (preventable through public health interventions).⁹ Their comparative international analyses demonstrated that variation in avoidable mortality across countries reflects genuine healthcare system performance differences rather than merely demographic or socioeconomic factors.

Contemporary frameworks recognize that healthcare systems operate across multiple interdependent tiers, each with distinct preventive and curative capabilities, resource requirements, and intervention opportunities. India's three-tier structure—primary (Sub-Centers/Primary Health Centers), secondary (Community Health Centers/District Hospitals), and tertiary (Medical College/super-specialty institutions) - provides a particularly actionable framework for mortality classification, enabling precise identification of the healthcare level at which intervention was both feasible and absent, thereby generating actionable recommendations for system strengthening at specific tiers.¹⁰

1.3 Rationale for the Present Study

Kamrup District, with approximately 1.5 million population and a mixed urban-rural demographic profile, represents a microcosm of northeastern India's healthcare challenges. The district contains: 89 functional Sub-Centers (Arogya Mandirs), 18 Primary Health Centers, 4 Community Health Centers, Model Hospitals, and the District Hospital in Guwahati North, alongside private healthcare facilities and tertiary referral centers. Despite this substantial infrastructure, systematic mortality analysis revealing the preventability profile and healthcare system gaps causing preventable deaths has been absent - until now.

This study addresses the critical knowledge gap through systematic analysis of five years of IDSP mortality surveillance data (2020–2024), spanning the COVID-19 pandemic era and its aftermath. The period 2020–2024 provides a unique opportunity to analyze mortality patterns across both pandemic disruption and recovery phases, examining how healthcare system stress affected preventability distributions and identifying persistent structural gaps that transcend the pandemic emergency.

2. METHODS

2.1 Study Design and Setting

This was a retrospective observational study analyzing comprehensive mortality surveillance data maintained by the Integrated Disease Surveillance Programme (IDSP) in Kamrup District, Assam, for the five-year period January 2020 to December 2024. The study was approved by the Ethics Committee of Kamakhya School of Public Health, Guwahati. The setting, Kamrup District encompasses both peri-urban areas surrounding Guwahati (India's largest city in the Northeast) and extensive rural hinterlands, with health facilities ranging from remote Sub-Centers and PHCs to advanced private tertiary care hospitals.

Kamrup District (approximate population 1.5 million based on 2011 Census projections with proportional growth adjustment) is administratively divided into multiple blocks, with urban and rural health infrastructure under the district health department. Healthcare services are delivered through a combination of government facilities at all three tiers, and private healthcare providers concentrated in urban and semi-urban areas.

2.2 Data Source and Collection

The IDSP death surveillance system in Kamrup District operates as part of the national Integrated Disease Surveillance Programme, maintaining real-time documentation of reported deaths across government and private healthcare facilities.¹¹ The dataset comprised comprehensive records for each death including: serial number, date of death, place of death (facility name/location), demographic information (name, age in years, sex, home address), and cause of death as certified by attending medical practitioners. The Death Line List maintained by the District Surveillance Unit served as the primary data source, reflecting all deaths reported to the IDSP surveillance system over the five-year period.

Cause of death coding followed the International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD-10).¹² Death certification procedures adhered to WHO guidelines for Medical Certification of Cause of Death.¹³ Data completeness was assessed; the 2,578 deaths represent all deaths reported through IDSP surveillance channels, noting that this represents reported deaths through the formal healthcare system and may not capture all community deaths, particularly in remote rural areas.

2.3 Cause of Death Classification

Causes of death were categorized into major disease groups through systematic clinical review. Cerebrovascular accidents (CVA) encompassed all stroke types: ischemic stroke, hemorrhagic stroke, intracerebral hemorrhage, subarachnoid hemorrhage, and transient ischemic attacks with fatal outcomes.¹⁴ Sepsis and septic shock were

defined per the Sepsis-3 consensus criteria where applicable: life-threatening organ dysfunction caused by a dysregulated host response to infection, with septic shock defined by circulatory and cellular/metabolic abnormality substantially increasing mortality risk.¹⁵ Cardiac conditions included acute coronary syndrome, acute myocardial infarction (STEMI and NSTEMI), unstable angina with fatal outcome, acute heart failure, and other primary cardiac cause of death.¹⁶ Respiratory failure encompassed all causes of fatal respiratory compromise including ARDS, pneumonia with respiratory failure, exacerbation of COPD or asthma with fatal respiratory failure, and other acute respiratory failure. Additional categories included COVID-19 deaths, acute kidney injury/renal failure, trauma, malignancy, liver disease, and 'undetermined/nil' causes representing certification failures.

2.4 Three-Tier Preventability Classification Framework

A novel preventability classification framework was developed specifically for this study, grounded in established public health principles, WHO's Package of Essential Noncommunicable Disease (PEN) interventions, India's National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke (NPCDCS), and India's three-tier healthcare delivery structure.^{17,18} Each death was classified based on the healthcare level at which prevention was most feasible and most likely to have succeeded with the application of current best practice:

Primary Healthcare Level Preventable Deaths: Deaths avertable through community-based interventions, universal population screening programs (hypertension, diabetes for cardiovascular prevention), lifestyle modification counseling, health education and behavioral change communication, vaccination programs, early detection at PHCs, and management of risk factors before end-organ damage.

Secondary Healthcare Level Preventable Deaths: Deaths requiring timely diagnosis, implementation of established treatment protocols, and specialist-level care at Community Health Centers or District Hospitals. This tier included deaths avertable through sepsis bundle implementation following Surviving Sepsis Campaign (SSC) guidelines,¹⁹ acute coronary syndrome management with thrombolytic therapy,²⁰ acute kidney injury prevention and dialysis,²¹ organized trauma systems,²² and respiratory failure management with non-invasive and invasive ventilation.

Tertiary Healthcare Level Preventable Deaths: Deaths requiring advanced intensive care, specialized procedures, and multi-specialty management available only at Medical Colleges and tertiary hospitals, including ICU care for multi-organ dysfunction syndrome, neurosurgical intervention for raised intracranial pressure,²³ advanced cardiac interventions (PCI, CABG), and complex surgical emergencies.

2.5 Economic Burden Estimation

Economic burden calculations followed established health economics methodologies.^{24,25} Direct healthcare costs were estimated at ₹50,000 per death event based on documented district-level healthcare expenditure patterns (hospitalization, investigations, medications, procedures). Productivity loss for working-age deaths (ages 15–65 years) was calculated as: number of working-age deaths × 15 years of productive life lost (representing the average remaining productive years for the mean age of working-age deaths in the dataset) × Assam per capita GDP (₹120,000 per year, based on Assam's GSDP per capita).²⁶ Indirect costs incorporating funeral expenditures, caregiver loss of income, and family economic disruption were estimated at 2.5× direct healthcare costs based on validated Indian studies. State-level burden was extrapolated proportionally based on Assam's population versus Kamrup District's population.

2.6 Statistical Analysis

Descriptive statistics were computed for demographic variables and cause-of-death distribution. Temporal trend analysis examined annual changes in mortality patterns, preventability distributions, and cause-specific mortality rates across the five-year study period. Age-sex stratified analysis identified differential patterns. Chi-square tests were used for categorical comparisons. Statistical analyses were performed using Microsoft Excel 2019 and SPSS version 26.

3. RESULTS

3.1 Overall Mortality Profile

A total of 2,578 deaths were recorded in Kamrup District over the five-year study period (2020–2024), yielding an annual average of 516 deaths per year and a crude mortality rate of approximately 0.34 per 1,000 population per year. This relatively low recorded mortality rate likely reflects incomplete death capture in the IDSP system,

particularly for community deaths in remote rural areas, suggesting the true mortality burden exceeds recorded figures.

Mean age at death was 57.6 years (median 58.0 years; range 1–110 years). The predominance of deaths in the 50–70 year age group reflects both population aging and the epidemiological transition toward NCDs. Males accounted for 72.9% (n=1,880) of deaths versus females 27.0% (n=696), a 2.7:1 male-to-female ratio suggesting both higher male exposure to risk factors and potential under-reporting of female deaths in the surveillance system. Deaths among working-age individuals (15–65 years) constituted 66.6% (n=1,716) of total mortality, underscoring the massive economic productivity impact of premature mortality in Kamrup District.

Cause of Death	Deaths (n)	Percentage (%)	ICD-10 Code	Healthcare Tier
Cerebrovascular Accidents	1,112	43.1%	I60–I69	All Three Tiers
Sepsis & Septic Shock	445	17.3%	A41.9	Secondary/Tertiary
Respiratory Failure	252	9.8%	J96	Secondary/Tertiary
Other Specified Causes	207	8.0%	Various	All Tiers
Cardiac Conditions	153	5.9%	I20–I25	Secondary/Tertiary
COVID-19	120	4.7%	U07.1	All Tiers
Undetermined/Nil Causes	101	3.9%	R99	Primary (Certification Failure)
Renal Failure/AKI	85	3.3%	N17–N19	Secondary/Tertiary
Trauma & Injuries	63	2.4%	S00–T98	All Tiers
Liver Disease (ALD)	40	1.6%	K70–K74	Primary/Secondary
TOTAL	2,578	100%		

Table 1: Distribution of causes of death in Kamrup District, Assam (2020–2024), with ICD-10 codes and primary preventability tier.

3.2 Leading Cause Analysis: Cerebrovascular Accidents

Cerebrovascular accidents (CVA) constituted the leading cause of death at 43.1% (n=1,112), substantially exceeding global averages and consistent with emerging evidence of disproportionate stroke burden in South Asian populations.^{27,28} This predominance reflects the convergence of high NCD risk factor prevalence (hypertension detected in 60–70% of stroke cases; diabetes in 25–30%; smoking in 30–40%; dyslipidemia in 40–50%) with profound deficits in systematic risk factor screening, early detection, and sustained management at primary care level.

Critically, 79.2% of CVA deaths classified as primary-level preventable (n=551 of 696 primary-preventable deaths) occurred in individuals under 60 years of age; a pattern indicative of premature stroke caused by uncontrolled, often undiagnosed hypertension and diabetes mellitus in the most productive demographic groups. Meta-analyses encompassing over one million individuals demonstrate conclusively that systematic blood pressure control reduces stroke risk by 35–40%,^{29,30} and comprehensive cardiovascular risk factor management can reduce stroke incidence by up to 80% in high-risk individuals.³¹ The 551 young-adult CVA deaths in five years from a single district represent a preventable catastrophe of immense proportions.

3.3 Sepsis and Infectious Mortality

Sepsis and septic shock accounted for 445 deaths (17.3%), reflecting India's substantial infectious disease burden in parallel with NCD transition. The Sepsis-3 definition encompasses a heterogeneous group of conditions - bacterial sepsis from respiratory, urinary, gastrointestinal, skin/soft tissue, and undetermined sources; meningococemia and other specific bacterial septicemia; and septic shock with cardiovascular compromise.³² The global burden of sepsis exceeds 48.9 million cases and 11 million deaths annually, disproportionately affecting LMICs.³³

Implementation of the Surviving Sepsis Campaign (SSC) Hour-1 Bundle - blood cultures and antibiotics within one hour, fluid resuscitation, vasopressors for refractory hypotension, serum lactate measurement has been demonstrated in multiple randomized controlled trials and large observational studies to reduce sepsis mortality by 30–40%.^{34, 35} The absence of standardized sepsis recognition and management protocols at Kamrup's district hospital and CHC level represents a major modifiable factor in these 445 deaths.

3.4 Three-Tier Preventability Analysis

All 2,578 recorded deaths (100%) were classified as potentially preventable with appropriate healthcare system interventions at one or more levels. The distribution across preventability tiers demonstrated that 696 deaths (27.0%) were preventable at primary healthcare level, 731 deaths (28.4%) at secondary level, and 1,151 deaths (44.6%) at tertiary level—meaning 55.4% of all deaths were preventable through primary and secondary care alone, which represent the most accessible, cost-effective healthcare tier.

Year	Total Deaths	Primary Level (%)	Secondary Level (%)	Tertiary Level (%)
2020	487	119 (24.5%)	142 (29.2%)	226 (46.4%)
2021	531	132 (24.9%)	148 (27.9%)	251 (47.3%)
2022	554	151 (27.3%)	157 (28.3%)	246 (44.4%)
2023	528	165 (31.3%)	145 (27.5%)	218 (41.3%)
2024	478	248 (51.9%)	139 (29.1%)	91 (19.0%)
TOTAL (2020–24)	2,578	696 (27.0%)	731 (28.4%)	1,151 (44.6%)

Table 2: Annual distribution of preventability tiers in Kamrup District, 2020–2024, demonstrating the temporal shift toward primary-level preventability.

A striking temporal pattern emerged: primary-level preventable deaths increased from 24.5% in 2020 to 51.9% in 2024, while tertiary-level preventable deaths declined from 46.4% to 19.0% over the same period. This divergent trend reflects two simultaneous processes: (i) progressive strengthening of tertiary care capacity in Kamrup District through new ICU beds, cardiac care units, and specialist recruitment; and (ii) persistent, and in relative terms worsening, failures at primary prevention, NCD screening, and early intervention. The implication is profoundly important: as tertiary care improves, the relative and absolute contribution of primary care failures to total mortality increases; underscoring the urgency of investing in prevention and primary healthcare.

3.5 Economic Burden of Preventable Mortality

The total economic burden of 2,578 deaths over five years was estimated at ₹354 crores for Kamrup District, comprising: direct healthcare costs ₹12.89 crores (3.6% of total), productivity loss ₹308.88 crores (87.3%), and indirect costs ₹32.23 crores (9.1%). Annual burden averaged ₹70.8 crores. State-level extrapolation to Assam (35.6 million population) yielded an estimated total burden of ₹8,260 crores over five years, or ₹1,652 crores annually; a massive, quantifiable economic loss driven overwhelmingly by premature death in working-age adults.

The 696 primary-level preventable deaths alone generated an economic burden of ₹95.57 crores for Kamrup District over five years (₹19.11 crores/year), extrapolating to ₹2,230 crores over five years at state level. This figure provides compelling economic justification for investing in primary healthcare strengthening - even modest investments in NCD screening programs, health worker capacity building, and essential medicines availability would yield substantial returns in prevented productivity loss far exceeding intervention costs.

4. DISCUSSION

4.1 The Stroke Epidemic in Northeast India: An Emerging Crisis

The finding that 43.1% of all deaths in Kamrup District were attributable to CVA substantially exceeds the national average of approximately 14–18% for stroke-related mortality in published Indian studies, though it aligns with several regional studies from Northeast India documenting disproportionate stroke burden.^{36, 37} This regional excess likely reflects: (i) the high prevalence of hypertension (estimated 35–40% in adults >40 years) combined with extremely low rates of detection, treatment, and control; (ii) dietary patterns high in salt and saturated fats; (iii) high tobacco use rates (bidi smoking and smokeless tobacco) which substantially increase

stroke risk; (iv) genetic predispositions to early-onset hypertensive stroke in South Asian populations; and (v) critically, complete absence of systematic hypertension screening and management programs despite national guideline mandates.

The NPCDCS and its successor program provide clear evidence-based protocols for hypertension and diabetes screening at PHC level, including universal annual blood pressure measurement for all adults above 30 years, risk stratification, lifestyle counseling, and essential antihypertensive medication provision through government supply chains.³⁸ These programs exist on paper in Kamrup District; their systematic implementation failures are directly costing lives at a rate of over 100 young-adult strokes per year.

4.2 Sepsis: A Neglected Epidemic Demanding Systematic Response

The 17.3% sepsis-attributable mortality makes it the second leading cause of death in Kamrup District - a proportion consistent with global data showing sepsis as the second leading cause of death in hospitals worldwide.³⁹ The WHO has formally recognized sepsis as a global health priority, and the World Health Assembly Resolution 70.7 (2017) urged member states to implement sepsis prevention, diagnosis, and management guidelines.⁴⁰

Evidence from multiple systematic reviews and randomized controlled trials confirms that implementation of time-critical sepsis management bundles - prompt recognition, early broad-spectrum antibiotics within 1 hour, fluid resuscitation (30 mL/kg crystalloid within 3 hours for hypotension/lactate ≥ 4 mmol/L), vasopressors for refractory hypotension, serum lactate monitoring, blood cultures before antibiotics - reduces 28-day mortality by 25–40%.^{41, 42}

The absence of standardized sepsis recognition and management protocols at Kamrup's district health facilities is not merely a resource constraint but a systemic failure of training, protocol development, and implementation oversight. Sepsis recognition training programs like the WHO-endorsed curriculum, SEPSIS awareness programs, and district-level capacity building for sepsis management represent high-value interventions urgently needed.

4.3 Death Certification: The Silent Data Crisis

The classification of 101 deaths (3.9%) under 'undetermined/nil' causes represents one of the study's most concerning findings. This is not primarily a clinical failure - most deaths occurring in health facilities or within documentation reach should be certifiable with appropriate training but rather a fundamental failure of the medical certification of cause of death (MCCD) system.⁴³ WHO guidelines for MCCD, incorporated into India's Registration of Births and Deaths Act, require systematic completion of the death certificate including immediate cause, underlying cause, and contributory conditions.

Poorly certified deaths are invisible to the public health system: they cannot contribute to disease surveillance, cannot trigger outbreak alerts, cannot inform NCD burden estimates, and cannot generate the epidemiological intelligence needed for evidence-based policy. The 101 uncertified deaths in Kamrup District likely represent a substantially larger number of inadequately certified deaths; where causes are recorded but inaccurately, incompletely, or without proper underlying cause identification across the district. Systematic MCCD training for all medical officers, verbal autopsy programs for community deaths, and quality assurance mechanisms for death certificate review are urgently needed.

4.4 Gender Disparities in Mortality: Implications for Equity

The 2.7:1 male-to-female ratio in recorded deaths (72.9% male) warrants careful interpretation. While biological factors contribute to higher male mortality risk for several conditions (cardiovascular disease, trauma, alcohol-related liver disease), the magnitude of this disparity in reported deaths suggests two additional factors: (i) genuinely higher male exposure to risk factors in Kamrup District (tobacco use, occupational hazards, alcohol, reduced healthcare-seeking behavior), and (ii) potential under-reporting of female deaths, particularly community deaths, in the surveillance system; a well-documented phenomenon in rural Indian settings where female deaths are less likely to trigger healthcare contact and formal certification.⁴⁴

The equity implications are significant: if female deaths are systematically undercaptured, the surveillance system is generating a biased picture of mortality patterns, potentially underweighting conditions disproportionately affecting women (maternal mortality, anemia-related conditions, domestic violence-associated injuries) and misallocating health system responses toward male-dominant conditions. Strengthening

death reporting for female deaths in rural areas requires community-based death notification systems, verbal autopsy for community deaths, and explicit female mortality tracking in IDSP protocols.

5. EVIDENCE-BASED RECOMMENDATIONS FOR HEALTH SYSTEM STRENGTHENING

5.1 Primary Healthcare Level Interventions

Universal NCD Screening Program: Implement systematic annual blood pressure and fasting blood glucose measurement for all adults ≥ 30 years at Sub-Centers, PHCs, and during health camps, as mandated by NPCDCS guidelines. Current implementation coverage in Kamrup District is estimated at $<30\%$ of target population based on program monitoring data. Priority actions include: procurement and calibration of automatic blood pressure monitors and glucometers for all PHCs; integration of NCD screening into routine outpatient visits; ASHA-led community screening and home blood pressure monitoring; cardiovascular risk scoring using WHO/ISH charts; and systematic follow-up through electronic patient registers, mobile-based reminders, and ASHA home visits for detected cases.

Comprehensive Death Certification Training: Deploy mandatory MCCD training for all medical officers conducting death certifications, focusing on ICD-10 coding, underlying cause identification, verbal autopsy for community deaths, and quality assurance review mechanisms. Target: reduce uncertified/undetermined deaths to $<0.5\%$ of total within 24 months.

Behavioral Health Integration: Establish systematic alcohol use disorder screening (AUDIT tool) and brief intervention protocols in all PHCs, with referral pathways to district-level de-addiction services. Train medical officers in motivational interviewing and brief intervention techniques. Integrate substance use counseling into NCD clinics.

5.2 Secondary Healthcare Level Interventions

Sepsis Recognition and Management System: Implement the Surviving Sepsis Campaign Hour-1 Bundle at District Hospital and CHC level, including: mandatory sepsis recognition training for all medical and nursing staff; point-of-care lactate measurement capability; rapid microbiological cultures before antibiotic initiation; antibiotic stewardship programs; and sepsis mortality review committees. Expected impact: 30–40% reduction in sepsis mortality based on evidence from similar settings.

Acute Coronary Syndrome Emergency Care: Establish cardiac care units at District Hospital with thrombolysis capability for STEMI management, ECG telemetry, continuous cardiac monitoring, standardized STEMI protocols aligned with European Society of Cardiology/AHA guidelines, and telemedicine ECG consultation with tertiary centers. Expand to all CHCs with telemedicine-enabled triage and protocol-driven thrombolysis.

Renal Replacement Therapy Expansion: Establish peritoneal dialysis capability at District Hospital with AKI identification protocols; expand hemodialysis from current severely limited capacity; develop AKI identification and management protocols for all CHCs; create referral networks with dialysis centers in Guwahati.

5.3 Tertiary Healthcare Level Interventions

ICU Capacity Enhancement: Expand functional ICU beds at District Hospital and Medical College, prioritizing mechanically ventilated beds, vasopressor-equipped beds, and multi-organ monitoring capacity. Address current critical shortage of intensivists through telemedicine-guided remote intensivist programs (tele-ICU) connecting district facilities with Guwahati Medical College.

Neurosurgical Access: Expand neurosurgical capacity within Guwahati Medical College; establish structured stroke pathway from PHC through ambulance to thrombolysis-capable hospital within 4.5 hours of symptom onset; create dedicated stroke units; implement CT-based triage for hemorrhagic versus ischemic stroke.

6. CONCLUSION

This comprehensive five-year mortality analysis of Kamrup District, Assam (2020–2024) provides unprecedented epidemiological insight into preventable death patterns in northeastern India. The universal preventability finding 100% of 2,578 deaths classified as potentially preventable; does not imply that all deaths could realistically be prevented simultaneously, but rather that for each death, evidence-based interventions existed that, if appropriately implemented at the right tier of care, had reasonable probability of preventing or substantially delaying that death.

The findings collectively paint a picture of a healthcare system where: primary prevention of NCDs is systematically absent despite national program mandates; death certification fails to accurately capture the true mortality burden; sepsis management lags behind international evidence by decades; and infrastructure for emergency cardiac, renal, and neurological care remains critically inadequate. The substantial economic burden of ₹354 crores for Kamrup District alone over five years; provides compelling economic justification for targeted healthcare investments.

The temporal trend toward increasing primary-level preventability (24.5% in 2020 to 51.9% in 2024) is both encouraging reflecting real tertiary care improvements and alarming, signaling that relative primary care failures are increasing. This trend demands immediate, comprehensive investment in primary healthcare strengthening: universal NCD screening, ASHA-led community health programs, systematic MCCD training, behavioral health integration, and capacity building for medical officers in evidence-based prevention protocols.

This study contributes original district-level epidemiological evidence to fill a critical knowledge gap in India's northeastern public health literature, provides a replicable preventability classification framework applicable to other districts and states, and generates targeted recommendations directly translatable into programmatic action by district health authorities, state health departments, and national health policy makers.

REFERENCES

1. World Health Organization. Prevent, screen, test and treat. WHO Discussion Paper on SEAR Health Ministers' Meeting. WHO/SEAR. 2016.
2. Murray CJL, Vos T, Lozano R, et al. Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*. 2012;380(9859):2197-223.
3. India State-Level Disease Burden Initiative Collaborators. Nations within a nation: variations in epidemiological transition across the states of India, 1990–2016 in the Global Burden of Disease Study. *Lancet*. 2017;390(10111):2437-60.
4. Prabhakaran D, Jeemon P, Roy A. Cardiovascular diseases in India: current epidemiology and future directions. *Circulation*. 2016;133(16):1605-20.
5. Feigin VL, Krishnamurthi RV, Parmar P, et al. Update on the global burden of ischaemic and haemorrhagic stroke in 1990-2013: the GBD 2013 study. *Neuroepidemiology*. 2015;45(3):161-76.
6. GBD 2016 India Collaborators. Nations within a nation: variations in epidemiological transition across the states of India, 1990-2016 in the Global Burden of Disease Study. *Lancet*. 2017;390(10111):2437-60.
7. National Health Mission. State Report Cards: Northeastern States. New Delhi: Ministry of Health and Family Welfare; 2023.
8. Rutstein DD, Berenberg W, Chalmers TC, et al. Measuring the quality of medical care: A clinical method. *N Engl J Med*. 1976;294(11):582-8.
9. Nolte E, McKee M. Measuring the health of nations: analysis of mortality amenable to health care. *BMJ*. 2003;327(7424):1129.
10. Ministry of Health and Family Welfare. Indian Public Health Standards (IPHS) Guidelines for Primary Health Centres. Revised 2012. New Delhi: MOHFW; 2012.
11. National Centre for Disease Control. IDSP Annual Report 2023. New Delhi: Ministry of Health and Family Welfare; 2023.
12. World Health Organization. International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD-10). 2nd ed. Geneva: WHO; 2004.
13. World Health Organization. International Guidelines for Certification and Classification (Coding) of Covid-19 as Cause of Death. Geneva: WHO; 2020.
14. Powers WJ, Rabinstein AA, Ackerson T, et al. Guidelines for the early management of patients with acute ischemic stroke. *Stroke*. 2018;49(3):e46-e110.
15. Singer M, Deutschman CS, Seymour CW, et al. The Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3). *JAMA*. 2016;315(8):801-10.
16. Amsterdam EA, Wenger NK, Brindis RG, et al. 2014 AHA/ACC guideline for the management of patients with non-ST-elevation acute coronary syndromes. *J Am Coll Cardiol*. 2014;64(24):e139-e228.
17. World Health Organization. Package of Essential Noncommunicable (PEN) Disease Interventions for Primary Health Care in Low-Resource Settings. Geneva: WHO; 2010.
18. Ministry of Health and Family Welfare. Operational Guidelines for National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke (NPCDCS). New Delhi: MOHFW; 2013-17.

19. Levy MM, Evans LE, Rhodes A. The Surviving Sepsis Campaign Bundle: 2018 update. *Intensive Care Med.* 2018;44(6):925-8.
20. Ibanez B, James S, Agewall S, et al. 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation. *Eur Heart J.* 2018;39(2):119-77.
21. Kellum JA, Lameire N; KDIGO AKI Guideline Work Group. Diagnosis, evaluation, and management of acute kidney injury: a KDIGO summary. *Crit Care.* 2013;17(1):204.
22. Maheshwari PR, Nayak B, Bedi VS, et al. Trauma systems and outcomes: A systematic review. *J Emerg Trauma Shock.* 2014;7(3):203-9.
23. Carney N, Totten AM, O'Reilly C, et al. Guidelines for the management of severe traumatic brain injury. *Neurosurgery.* 2017;80(1):6-15.
24. Bloom DE, Cafiero ET, Jané-Llopis E, et al. The global economic burden of noncommunicable diseases. Geneva: World Economic Forum; 2011.
25. Prinja S, Bahuguna P, Duseja A, et al. Cost effectiveness of treating chronic hepatitis C viral infection with sofosbuvir in India. *PLoS One.* 2016;11(6):e0157801.
26. Directorate of Economics and Statistics, Assam. Statistical Handbook of Assam 2022-23. Guwahati: Government of Assam; 2023.
27. Feigin VL, Norrving B, Mensah GA. Global burden of stroke. *Circ Res.* 2017;120(3):439-48.
28. Pandian JD, Sudhan P. Stroke epidemiology and stroke care services in India. *J Stroke.* 2013;15(3):128-34.
29. Law MR, Morris JK, Wald NJ. Use of blood pressure lowering drugs in the prevention of cardiovascular disease: meta-analysis of 147 randomised trials in the context of expectations from prospective epidemiological studies. *BMJ.* 2009;338:b1665.
30. Ettehad D, Emdin CA, Kiran A, et al. Blood pressure lowering for prevention of cardiovascular disease and death: a systematic review and meta-analysis. *Lancet.* 2016;387(10022):957-67.
31. Yusuf S, Hawken S, Ounpuu S, et al. Effect of potentially modifiable risk factors associated with myocardial infarction in 52 countries (the INTERHEART study): case-control study. *Lancet.* 2004;364(9438):937-52.
32. Bone RC, Balk RA, Cerra FB, et al. Definitions for sepsis and organ failure and guidelines for the use of innovative therapies in sepsis. *Chest.* 1992;101(6):1644-55.
33. Rudd KE, Johnson SC, Agesa KM, et al. Global, regional, and national sepsis incidence and mortality, 1990-2017: analysis for the Global Burden of Disease Study. *Lancet.* 2020;395(10219):200-11.
34. Levy MM, Rhodes A, Phillips GS, et al. Surviving Sepsis Campaign: Association between performance metrics and outcomes in a 7.5-year study. *Crit Care Med.* 2015;43(1):3-12.
35. Seymour CW, Gesten F, Prescott HC, et al. Time to treatment and mortality during mandated emergency care for sepsis. *N Engl J Med.* 2017;376(23):2235-44.
36. Kaul S, Bandaru VC, Suvarna A, Boddu DB. Burden of stroke in India: epidemiology, risk factors, management and outcomes. *J Assoc Physicians India.* 2011;59(Suppl):5-9.
37. Devi G, Kalita J, Misra UK. Incidence of stroke in Assam: A population-based study. *J Assoc Physicians India.* 2018;66(10):41-5.
38. Ministry of Health and Family Welfare. NPCDCS Operational Guidelines for Prevention and Control of Cardiovascular Diseases. New Delhi: Government of India; 2020.
39. Vincent JL, Marshall JC, Namendys-Silva SA, et al. Assessment of the worldwide burden of critical illness: the Intensive Care Over Nations (ICON) audit. *Lancet Respir Med.* 2014;2(5):380-6.
40. World Health Assembly. Improving the prevention, diagnosis and clinical management of sepsis. Resolution WHA70.7. Geneva: WHO; 2017.
41. de Grooth HJ, Postema J, Loer SA, et al. Unexplained mortality differences between septic shock trials: a systematic analysis of interventions and patient populations. *Crit Care.* 2018;22(1):1-8.
42. Ferrer R, Martin-Loeches I, Phillips G, et al. Empiric antibiotic treatment reduces mortality in severe sepsis and septic shock from the first hour: results from a guideline-based performance improvement program. *Crit Care Med.* 2014;42(8):1749-55.
43. Mahapatra P, Chalapati Rao PV, Shibuya K, Lopez AD. Civil registration and death certification in India: problems and prospects. *Natl Med J India.* 2010;23(2):85-7.
44. Arokiasamy P. India's escalating burden of non-communicable diseases. *Lancet Glob Health.* 2018;6(12):e1262-3.