Non-Communicable Diseases among Tribal Populations: Healthcare Inequalities, Social Challenges, and the Emerging Role of AI-Based Clinical Decision Systems

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Abstract
Non-communicable diseases (NCDs) are now one of the most serious public health problems on a global scale. Non-communicable diseases are now affecting those populations who are mainly urban, but no longer are limited to only urban populations. Tribal groups, historically well known for being affected by infectious diseases or malnutrition, now suffer increasingly from diabetes, hypertension, cardiovascular disease, chronic respiratory disease and cancer (Kaur et al. 250). The introduction of chronic non-communicable diseases has resulted in an epidemiological transition among these tribal populations, which in turn is associated with poverty, social exclusion, nutritional imbalance, the inaccessibility to health care, environmental vulnerability, changing lifestyles and a lack of awareness regarding their health (Sathiyanarayanan et al. 342).
In addition, tribal populations in India experience significant and pervasive systemic inequalities with regard to accessing health care as a result of location (geographical isolation), lack of resources (infrastructure and trained medical personnel), limited transportation and economic marginalization (Mohindra & Labonté). In addition, the development of drought conditions, migration, unemployment, and a lack of rural healthcare systems in places like Rayalaseema within Andhra Pradesh has made tribal individuals even more susceptible to chronic illnesses and has placed increased burdens on them as a result of their status as vulnerable populations.
Through critical assessments, the review article examines how the growing number of NC Diseases affecting tribal populations in India is related to various factors, including societal/cultural, economic/financial and other healthcare practices relative to a variety of NC diseases. The Article also explores how AI-based healthcare systems, predictive analytics, telehealth, and other clinical decision-making support systems can improve outcomes and healthcare management for Indigenous people with NC diseases. Furthermore, the paper argues that while technology can help to reduce healthcare inequalities for tribal people, it requires the integration of culturally competent healthcare practices, community involvement/education, and ethical public policy.

Keywords: Non-communicable diseases, Tribal health, Rayalaseema, Artificial Intelligence, Healthcare inequality, Clinical decision systems, chronic diseases, Inclusive healthcare

INTRODUCTION:

Social development and human health are integral to the development of society. A population that is healthy helps not only with the productivity of the economy, but also

with the stability of a society, as well as its ability to maintain its cultural identity. On the other hand, access to healthcare remains tremendously unbalanced among the different segments of society. In India, tribal people are still among the most disadvantaged groups in terms of healthcare services, access to food, education, social welfare programs, and other services (Mondal). Historically, tribal groups were affected predominantly by communicable diseases such as malaria, tuberculosis, diarrhea, and malnutrition. Because of the isolation of many tribal groups from the cities, most tribal groups tend to have had lower levels of lifestyle associated diseases than do people who live in the cities. However, with the changes in social and economic systems, developments in the natural environment and urban influences have led to the movement of people into and from many tribal groups, and changes in people's diets, the health of many tribal groups is changing (Sathiyanarayanan et al., 343). As a result, the number of non-communicable diseases, such as cancer, obesity, cardiovascular disease, chronic respiratory disease, Type II diabetes, and hypertension, has increased dramatically among tribal populations (Kaur et al., 251).

There has been a change from infectious diseases being the predominant cause of mortality to the increased prevalence of chronic illnesses, which show an epidemiological transition from infectious diseases to non-communicable diseases. With this shift, new health risks have also developed through modernization, such as the consumption of processed foods; a sedentary lifestyle; tobacco use; alcohol consumption; psychological stress; and improper nutrition (Nagwanshi et al.). Unfortunately, many tribal communities have health care systems primarily focused on treating and preventing infectious diseases only, with little availability for chronic disease management. The situation is even more precarious in geographic regions that are vulnerable to climatic extremes, like Rayalaseema (in Andhra Pradesh), where drought conditions, unstable agricultural production, large scale migration, high unemployment rates, social inequities, and poverty are common historical experiences. Populations that are tribal or rural in nature also face great barriers to access to health care services, such as a lack of access to hospitals within reasonable distance, limited number of specialists, poor transportation options, and also a lack of awareness regarding prevention of diseases. The last several years have brought many technological developments that are beginning to transform health care systems across the globe. These technologies include the development of artificial intelligence (AI), advances in machine learning, predictive analytics, electronic health records, and telemedicine are all examples of tools used to aid physicians in diagnosing and treating patients (Bompelli et al.). AI-based health systems have the potential to identify risk factors for diseases at much earlier stages, facilitate clinical decision-making to increase patient-accessible healthcare resources, and provide assistance to health professionals in remote locations.

Understanding Non-Communicable Diseases:

A non-communicable disease (NCD) is an illness that lasts for a long time or develops slowly and is not infectious. NCDs do not pass from one person to another, unlike communicable diseases. The long-term treatment of NCDs is usually done in conjunction with the management of lifestyle changes and ongoing medical supervision. According to the World Health Organisation (WHO), the four types of NCDs are cardiovascular disease, diabetes, chronic respiratory disease, and cancer, with all four types being responsible for a large percentage of global mortality and now representing a major public health crisis in developing nations like India. Many different risk factors can be linked to the occurrence of NCDs. Tobacco use, alcohol use, an unhealthy diet, obesity, lack of physical exercise, stress, environmental toxins, and hereditary factors may all increase the likelihood of developing one or more NCDs (Nagwanshi et al.). In many instances, due to the effects of

poverty, poor nutrition, drug addiction, and limited access to health care, tribal communities are seen as being at a higher risk for developing chronic diseases. Another important aspect of NCDs is that frequently, they go undiagnosed when people first develop them. For instance, both hypertension and diabetes are considered "silent diseases" because very few people will show any of the warning signs associated with them until serious complications arise. For these reasons, it is very important to have early detection of NCDs and access to preventive care to lower mortality rates and improve people's quality of life (World Health Organization).

Epidemiological Transition among Tribal Populations:

For decades, the tribal healthcare discussion in India has focused almost exclusively on the topics of infectious disease, maternal mortality, childhood malnutrition, and anaemia. However, it is now evident from recent research that there is a rapid transition in the epidemiological profile of tribal populations (Sathiyanarayanan et al. 342).

Historically, people living in traditional tribal lifestyle had physically active professions, natural diets, low levels of obesity, and strong social structures in their communities. Globalisation and economic change brought about gradual shifts in these lifestyle patterns. For example, there are many more processed foods, tobacco products, alcoholic beverages, and sedentary jobs available than ever before, which have all contributed to changing behaviours among tribal populations (Nagwanshi et al.).Evidence from research conducted in the tribal regions across India reveals a significant increase in hypertension, obesity, type 2 diabetes, cardiovascular disease, and chronic respiratory disease (Kaur et al. 252). This transition poses a great challenge for tribal health systems that are structurally weak and under-resourced.

Socioeconomic Determinants of Tribal Health:

Social and economic contexts impact health outcomes for any group. Poor social and economic conditions create multidimensional poverty for many tribal peoples. As a result, tribal communities face issues such as poor education, inadequate housing, unemployment, lack of access to adequate sanitation, and lack of access to appropriate levels of health care (Mondal).

Poverty and Nutritional support:

Poverty is one of the primary predictors of health problems within the tribal community today. Many tribal communities do not have access to sufficient amounts of quality nutritiously rich food or to potable drinking water. Additionally, a number of tribal families do not have access to adequate medical facilities to access health care services. Poor nutrition results in weakened immune systems among tribal peoples and increases their susceptibility to long-term diseases (Mohindra and Labonté). Seasonal migration and irregularity of employment result in negative changes to dietary patterns of many tribal communities. Many families have been forced to consume processed foods with low nutritional value because of instability and scarcity of resources; thereby leading to increased incidence of obesity (due to dietary patterns) as well as increasing rates of metabolic syndromes among tribal people.

Health Literacy and Education:

Health literacy provides a pathway to reducing the risk of developing chronic health problems and accessing the resources necessary to manage chronic illnesses. Most tribal communities do not have enough knowledge about what chronic disease symptoms look like, how to prevent themselves from getting them, or why regular health checks are important (Mondal). When a person lacks health literacy skills, they will have difficulty making appropriate decisions about whether or not to seek treatment and therefore may experience late interventions because of their health-related decisions.

Behavioural Risk Factors Associated with Addiction:
The prevalence of tobacco and alcohol abuse among tribal groups is high. The use of tobacco and alcohol, i.e., smoking, chewing and drinking locally produced alcoholic beverages, greatly contributes to the potential of developing cancer, hypertension, liver disease, and cardiovascular conditions (Nagwanshi et al.).

Healthcare Inequalities in Tribal Regions:
Barriers to accessing healthcare are a big issue for many Indian tribes, but healthcare inequality is one of the greatest. Many government programs exist to help provide healthcare resources; however, there are gaps in the implementation of many government healthcare services provided in very remote communities within India (Mohindra & Labonté).

Insufficient Medical Facilities
There are not enough clinics in tribal areas for clients to receive primary care and checkups, diagnostics, and emergency medical services. Most of the clients who live in these remote locations are located leagues from a specialist, so when they do arrive at their specialized offices, they often cannot get the care they need in a timely fashion.(From Kaur et al. 255)

Insufficient number of doctors/ health care professionals:
Many tribal communities in remote areas do not have access to a qualified health care worker. Many doctors may prefer to practice in more urbanized locations because of the lack of basic services such as water, electricity, and transportation. Thus, most Aboriginal People living in rural communities may need to rely on family or unqualified health care providers and/or self-medicate.

Cultural and Linguistic Differences:
Cultural differences between the Aboriginal community and the organizational health care system can lead to mistrust and poor communication. In addition, some health care providers (i.e., nurses and physicians) do not understand the language(s) of the Aboriginal community or do not regard the Aboriginal community's cultural values and beliefs when providing care (Mondal, n.d.).

Artificial Intelligence and Healthcare Transformation:
Artificial Intelligence is hailed as one of the most revolutionary advances in healthcare today. AI (Artificial Intelligence) is defined as the ability of a computer system to analyze data, identify trends, and assist in making decisions (Bompelli et al.).
In the healthcare industry, AI technologies are used more often for such functions as predicting disease, providing medical imaging services, monitoring patients, helping to diagnose conditions, delivering telemedicine, and planning treatment, etc. In underserved

tribal areas with few specialty physicians and no access to diagnostic facilities, use of AI in healthcare can have a large impact on increasing access to healthcare.

AI-Based Clinical Decision Systems:
AI-based clinical decision support systems (CDSs), like any other CDS, help healthcare professionals make better decisions about diagnosing and treating patients by using data-driven approaches to analyze patient data to generate evidence-based recommendations. An example of how an AI-based clinical decision support system may assist in making more informed treatment decisions is to analyze a patient's blood sugar levels, blood pressure, body mass index, family history, personal lifestyle choices, and other behavioural patterns in order to generate recommendations on the likelihood of developing a chronic disease. When used in tribal health systems, CDSSs reduce the time it takes to diagnose a patient, allow for more preventive treatments, improve the accuracy of treatment selection, and facilitate the ability to manage the patient's health using remote communication technologies.

Telemedicine and Remote Healthcare:
Tele health increases access to practice for healthcare providers in both rural and tribal healthcare management. Communication through digital technology allows patients to consult physicians without travelling long distances. Tele health systems with AI will enhance healthcare delivery through improved outreach, reduced costs of treatment, and improved access to routine monitoring and early medical intervention (World Health Organization).
Tele health may greatly enhance access to patient care in tribal communities where there are limited transportation options, thus improving the overall quality of care provided to the patients.

Ethical Challenges in AI-Based Tribal Healthcare:
AI has the Potential to change the way people receive their healthcare and predict their illnesses. However, using AI in tribal healthcare settings raises concerns related to ethics, technology, society, and informatics. Health care technology is not value-neutral; it is influenced by data quality, infrastructure, institutional and social inequities. Therefore, when introducing AI to tribal health-care environments, we must carefully consider the areas of digital access, equity of algorithms used, transparency of algorithms used, cultural sensitivity, and ethical governance.

Digital Divide and Technological Exclusion:
Digital Access to Health Care in Indigenous Communities - One of the main issues for indigenous communities using AI for health care is called the digital divide. The digital divide is where some people have access to technology while others do not (e.g., access to the internet, mobile phones, electric power, etc.). There continue to be areas within tribal communities in India that lack reliable networks, do not have enough electric power, and do not have a way to communicate digitally. Therefore, many indigenous communities in India may not be able to access AI-based healthcare systems, such as telemedicine, electronic health records, or mobile diagnostics.
Digital Illiteracy will further complicate access for tribal communities to health care. Older people and lower-income tribal families may not have the skills necessary to use digital health care systems. As a result of the above circumstances, the use of AI for health care

will likely create a widening gap between the digitally connected population and the data-free population.

Tribal communities could rely on intermediaries to interact with AI-Powered Mobile Health apps due to a lack of digital literacy and language accessibility. This would compromise their autonomy in making healthcare decisions.

AI systems are mostly built in English or Hindi, while most tribal communities primarily communicate in indigenous or regional dialects. The language barrier creates a lack of understanding, trust, and effective communication between the tribal people and the digital healthcare system.

In today's ever-growing world of artificial intelligence (AI) in healthcare, we are collecting larger and larger amounts of data from patients. Patient data is collected via various platforms that continuously gather very sensitive data, such as:

- Health history
- Biometric data
- Behavioural patterns
- Genetic data
- Location information
- Lifestyle information

This presents tribal healthcare providers with unique and significant ethical issues as it relates to privacy, ownership, and patient informed consent. For many members of the tribal population, they may not understand how their medical data is being captured, stored, shared or analyzed via the digital health systems. The lack of health literacy and technology familiarity will hinder tribal members from providing fully informed consent for how their medical data will be used.

Healthcare data obtained from tribal peoples is subjected to potential inappropriate use by businesses like insurance companies, pharmaceutical companies, corporations, etc. (any legal entity) without the tribal community's permission. When healthcare data does get shared or provided without a community's consent, there is a risk of discrimination, social stigma, and exploitation of vulnerable populations.

Digital monitoring (also known as digital surveillance) is another serious issue; for example, artificial intelligence-based systems (many of which are being used; and by different companies) can continuously monitor patients' activities through wearable's or mobile apps and develop a "surveillance state" in which tribes believe they are being monitored rather than getting the care they require. This will contribute negatively to the faith that tribal groups have in healthcare providers, systems, and their healer.

To function ethically, a healthcare system must involve:

- An open and transparent method of managing data.
- Public involvement throughout its development.
- A method for obtaining consent in multiple languages.
- Maintain patient confidentiality through electronic means of protecting the data.
- Create safeguards to protect patient confidentiality through the law.

Algorithmic Discrimination and Data Inequity:

An algorithmic discrimination is a serious informatics-related issue with healthcare systems utilizing AI. AI is trained on massive datasets to allow machines to learn about diseases, behaviour problems, and treatment options. However, if the datasets are primarily composed of urban, wealthy populations or people who do not live on tribal land, these

data will not be able to provide accurate measurements to the tribes that they are intended for.

The majority of the healthcare data used in the development of artificial intelligence comes from urban hospitals, private healthcare facilities and areas with advanced technologies. As a result of insufficient health documentation, a lack of electronic records, and insufficient health care infrastructure, the tribal population is underrepresented in scientific biomedical datasets. Because of this underrepresentation, the AI systems may not be able to identify unique types of diseases, differences in nutritional condition, genetic differences, exposures to environmental factors, or the impact of cultural health practices on the tribal groups.

For instance, algorithms used to predict the risk of diabetes or heart disease may lead to incorrect predictions if tribal dietary patterns, lifestyles at work or environmental stressors of the tribal population are not accurately accounted for in the data inputted into the predictive algorithm. Such misinterpretation of data can have delayed health care treatment, inaccurate prognoses, inappropriate recommendations for treatment, or failure to provide access to health care services.

The potential for algorithmic bias could maintain pre-existing structural inequalities in the healthcare system of your country. If an AI system consistently prioritizes those who have better documented health records, then the AI system may not see the tribal communities in digital health governance.

Therefore, to develop an inclusive approach to health informatics within tribal communities, we need:

- Representative data sets for tribal health
- Collecting region-specific data
- Developing algorithms that consider cultural context
- Using participatory design with local communities and healthcare workers in designing the AI system.

Lack of Healthcare Data Infrastructure

In order to develop reliable Artificial Intelligence systems, a vital necessity would be accurate, regular and systematic healthcare records. Unfortunately, fragmented medical records, inconsistent documentation and a lack of digitised medical records systems is what Tribal healthcare Systems have to deal with.

The majority of Primary Healthcare Centres in Tribal locations continue to use paper records which have diminished the ability of these providers to perform the following:

- Predictive analytics
- Disease tracking
- Automated risk prediction
- Long-term patient monitoring

The availability of extensive health records or a central repository in a wide variety of formats is one of the essential components of building reliable AI or machine learning systems. Large amounts of data are needed to train AI algorithms. The lack of reliable data (incomplete/inconsistent tribal health records) will produce low predictive accuracy with regards to health care and improve health care systems.

As is true throughout Rayalaseema, there are significant gaps in health care technology (Informatics) infrastructure in rural areas.

These gaps are largely due to the lack of coordination and integration between

(1) rural health centres

(2) district hospitals/county health departments and

(3) digital health care systems creating gaps in patient monitoring and the continuity of care.

To strengthen the health care trend systems for tribes, it is important to:

- Digitize all Rural Health Centre Records,
- Create a cloud-based integrated health care record,
- Create standard medical databases; and
- Invest in Rural Health Care Informatics.

The increasing use of automated systems to assist clinicians in diagnosing and formulating treatment plans raises a set of ethical issues surrounding accountability and the use of human judgment.

Automated systems cannot account for all of the emotional, cultural, and social elements that impact healthcare decisions, and as a result, clinicians may rely too heavily on automated systems to make clinical decisions. When working with Tribal populations, it's important for the clinician to be familiar with:

• Local belief systems
• Traditional methods of healing in Indigenous populations
• Relationships within the social context
• Family dynamics
• Cultural perspectives of illness

It is possible that AI systems will not interpret these contextual factors properly. Relying too heavily on the recommendation of machines may diminish the amount of human interaction in providing health care, thus negatively affecting culturally sensitive delivery of care.

Accountability is also an ethical concern when it comes to medical errors. If a machine produces a recommendation for a treatment that was later determined to be harmful to the patient, who is responsible for what happened? For example, is the physician liable for damage, or is the software developer responsible, or is the health care facility liable for the patient's injuries?

There must be a clear ethical and legal framework and regulatory structure governing the use of AI in health care.

Cultural Sensitivity and Community Trust:

The connection between tribal communities and health care institutions is predicated on trust and will therefore influence how tribal citizens view and accept new technology. As tribal citizens are often less familiar with the use of digital tools and may have reservations about the potential for exploitation, they may be hesitant to accept the use of AI-based health care technologies by the health care system. When technology is introduced into tribal communities without due regard for cultural consideration, it is perceived as external interventions being forced upon the tribe. As a result, AI-based health care models designed for tribal communities must be culturally adaptive and community-based.

Community health workers, local leaders, and tribal representatives need to be involved in:

- the design of health care plans,
- collection of data,
- the implementation of technology, and
- The development of programs that create awareness about health care.

The goal of developing and using culturally sensitive artificial intelligence systems is to blend the most innovative technology with indigenous knowledge, local communication patterns, and human-centred health care principles. Culturally sensitive AI use in the

delivery of health care services to tribal citizens must focus on more than just technological efficiency; they must prioritize the dignity, inclusion, equity, cultural appropriateness, and social justice of the health care delivery system.

CONCLUSION

Tribal communities across India are now experiencing the rise of non-communicable diseases as part of their daily life. The rising incidence of illness due to diabetes, high blood pressure, heart disease, lung problems and conditions that develop from metabolism is evidence of a larger change that has taken place in the lives of poorer people. This change is much more than just medical in nature; it is also fundamentally associated with the problems of social inequity, environmental degradation, poverty, homelessness, and the effects of a changing lifestyle, lack of food security, and uneven development.

For many years, discussions of healthcare among tribal peoples in India have mainly focused upon preventing the spread of infectious diseases, maternal deaths, poor nutrition and lack of hygiene. The current state of healthcare demonstrates that there is an ongoing epidemiological transition for tribal peoples since many of them are experiencing both infectious diseases and chronic diseases. The combination of these two burdens puts tremendous strain on the already very weak healthcare systems in rural and isolated areas of tribal communities.

Healthcare access in the Rayalaseema region provides critical insights into different aspects of healthcare disparity. Drought, economic instability, migration, unemployment, societal exclusion, and poor healthcare infrastructure combine to create a complex web that forms the framework of health experiences for tribal communities. Many patients who suffer from chronic illness are unable to receive timely diagnoses because they lack access to regular screening, specialist physicians, and timely transportation, as well as low levels of health knowledge. Access is therefore an issue not solely confined to the medical realm but instead becomes an issue of social justice and human dignity.

The literature clearly indicates that there is substantial evidence for the influence of socioeconomic determinants on increasing the burdens of non-communicable disease in tribal populations. Poverty, illiteracy, substance dependence, poor nutrition, vulnerability within the environment, and exclusion from healthcare services all have negative effects on health outcomes in this population. Tribal communities continue to experience structural inequality, which limits their ability to access timely diagnosis, preventative care, and long-term treatment, leading to chronic diseases becoming a public health/health crisis challenge as well as a challenge to development.

The goal of the study was to explore the use of AI technologies in enhancing access to healthcare services for tribal communities, and this research has shown that while these technologies offer many benefits, including improved access and the elimination of geographical boundaries to the delivery of healthcare services, they will only be effective if the existing social constructs around healthcare are equal and equitable for Indigenous people. As long as these existing social constructs are unequal, AI and other new technologies can enhance healthcare inequity as they compound the existing inequities within the tribal communities; as well as create additional barriers to access, such as the digital divide, poor access to the internet and poor digital literacy. Other issues affecting access to AI technologies, and the ethical dilemmas associated with AI technologies and their use in tribal communities, include: lack of language access to translation services, algorithm bias, and concerns regarding the use of data (and algorithms) without consent

by the tribe, and lack of transparency around the use and collection of data related to the use of AI technologies.

Health technology that is primarily developed for urban areas may overlook the cultural realties, environmental contexts, and lived experiences of indigenous tribes. Thus, the innovation in health care must move beyond technical efficiencies, and instead adopt a more human-centred and culturally-inclusive approach to health care delivery. Indigenous tribes should not be relegated to a mere source of data for the purposes of technical experimentation, but rather be active partners in the planning, implementation and decision-making processes related to health care.

This review points out that there is also a significant research gap in the literature regarding interdisciplinary research in health care. While numerous studies discuss the prevalence of NCDs in tribal populations, there is only a limited body of research that has integrated the use of artificial intelligence, tribal health system management, social inclusion, and regional health care disparities in a single analytical framework. There remains significant opportunity for research in Rayalaseema concerning AI-mediated prognostic models; community-centric health technologies; and culturally-appropriate digital health systems. Ultimately, the future of tribal health depends on creating a single, integrated health-care model composed of:

- medical science
- technology
- public health policy
- social inclusion and
- Moral responsibility.

AI should not be viewed as a substitute for Human/Health Systems; instead, it should serve as a supporting tool to enrich Healthcare Access, support the Healthcare Workforce, and enhance the quality of life of subordinated people.

Ultimately, health care should be viewed as a Human Right rather than a Privilege that is only extended to those who can afford it or are living in advanced technological countries. Inclusive Health Care Systems must reflect the views, cultural identity, and life experience of Tribal Peoples. Sustainable development of healthcare can occur when technology is used responsibly, ethically, fairly, and in collaboration with the people it serves.

With this understanding, AI-enabled systems for Inclusive Health Care Management will make a difference in improving the management and prognosis of Non-Communicable Diseases in Tribal Populations. The success of such systems will not depend solely on their technological sophistication but on their ability to serve all people humanely, fairly, equitably, accessibly, and justly.

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