International Journal of Research in Medical Sciences
Singh K et al. Int J Res Med Sci. 2024 Apr;12(4):1321-1326
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012
DOI: https://dx.doi.org/10.18203/2320-6012.ijrms20240865

Review Article

Exploring the viability of newer technologies in care and management of tribal diabetes and metabolic syndrome in India

Kritika Singh, Tapas Chakma, Suman Ray, Neha Vaidh, Suyesh Shrivastava*

Indian Council of Medical Research, National Institute of Research in Tribal Health, Jabalpur, Madhya Pradesh, India

Received: 19 January 2024
Revised: 14 February 2024
Accepted: 01 March 2024

***Correspondence:**
Dr. Suyesh Shrivastava,
E-mail: dr.ssuyesh@gmail.com

ABSTRACT

With the advancements of digitalization technology in health sector, diabetes care and management have also experienced modifications and betterment. Various newer technologies cater to the individual conditions and needs and provide a personalized treatment. Device based technologies such as continuous glucose monitoring (CGM) linked to closed loop insulin delivery system, insulin pumps, wearable devices linked with mobile apps have made the self-management of diabetes possible on regular basis. In its contrast, the technologies are yet to reach the tribal settings of India, and also very challenging to implement. Studies have shown that the scenario of diabetes prevalence in Indian tribal population is as crucial as urban population. Also, land alienation, lack of health management infrastructure, low connectivity, technological challenges add up to their condition. While various technologies are challenging to implement due to electricity, network connectivity, infrastructure and storage facilities, some technologies can be implemented easily with the joint approach of primary health care staff, governmental and non-governmental organizations and people with diabetes themselves. Digitization of data is needed as it will give a clearer picture of the prevalence, provide easy access for the follow ups and easier to implement intervention-based technologies. The situation demands a tailored multifaceted approach for implementing the technological based remedies in tribal settings of India as it will increase the quality of life in these areas.

Keywords: Newer technology, Diabetes management, Tribe, India, Metabolic syndrome

INTRODUCTION

Over the past three decades, the world has experienced a dramatic shift towards non-communicable diseases (NCDs), particularly diabetes. Diabetes (both type I and type II) is emerging as a prominent contributor to both morbidities and mortalities in the world and India. According to Mohan 2007, India leads the world with the largest number of diabetic subjects earning the dubious distinction of being termed the "diabetes capital of the world".[1] The number of people with diabetes in India currently is around 40.9 million and is expected to rise to 69.9 million by 2025 unless urgent preventive steps are taken.[2] The prevalence in the recent report by Indian Council of Medical Research- India Diabetes (ICMR-INDIAB) study was observed to be 11.4%.[3] The scenario in the tribal population of India is more or less similar as the diabetes prevalence in tribal areas was observed to be from 0.7-10.1% which is an alarming figure, but still, a systematic tribe-wise prevalence data is meager.[4] Moreover, the tribal population has high prevalence of undiagnosed diabetes. The management of diabetes is a crucial part and poor management can lead to micro and macrovascular complications such as retinopathy, nephropathy, neuropathy, coronary heart disease, and diabetic foot ulcers, also it can be fatal as the World Health Organization (WHO) estimates diabetes to be the 9th leading cause of death worldwide.[5] Type 1 diabetes in India is different in genomic level, as it is associated with different type of human leukocyte antigen (HLA) and most surprisingly it tends to be infrequently associated with positive titers of autoantibodies to beta cells of

pancreas and hence classified as idiopathic diabetes mellitus.[6] Today's world is a technological world and the management of diabetes is also impacted a lot by the digital influence in the health sector. Over a span of just a few years, research and technological breakthroughs in diabetes have led to remarkable progress in its treatment and management. These innovations are still limited to the urban population and are yet to reach the tribal population of India and are also very challenging to implement.

Newer technologies in diabetes management

Informatics device-based technologies

Recent advancements, in the field of diabetes care and management have introduced technologies that can store data provide lifestyle and wellness suggestions and assist with treatment. The emergence of technologies in diabetes management is reshaping how we control glucose levels and care for patients. Continuous glucose monitoring (CGM) systems offer time information on glucose levels giving patients and healthcare providers valuable insights into patterns and trends.[7] Closed loop insulin delivery systems, commonly referred to as artificial pancreas use CGM data to adjust insulin delivery improving precision in glycemic control while reducing the risk of hypoglycaemia.[8] Mobile applications and wearable devices like insulin pumps and patch pumps powered by biosensors, data analytics, artificial intelligence (AI) and machine learning (ML) empower patients not only to monitor their glucose levels but also to actively manage their health through medication adherence and personalized therapy adjustments.[9] These advancements hold promise in improving the quality of life for individuals, with diabetes while also optimizing term glycaemic outcomes and reducing the occurrence of diabetes related complications. As technology continues to advance the future of diabetes management is moving toward solutions that are user centred and effective. Meanwhile, clinical decision support systems have become a vital tool for improving diabetes care. It uses data analytics and computational power to determine relevant patterns from patients' medication history and glycemic records.[10] Then create personalized prescription strategies for their individual needs (Table 1).

Table 1: Device based technology in diabetes control: mechanism, merits and demerits.

Device based technology	Launch year	Mechanism	Merits	De-merits
Insulin pump	1976	The insulin reservoir is connected to the infusion set and a catheter to continuously deliver insulin	Les puncture, less risk of diabetes related complications	No insulin storage facilities in tribal settings, introduction and removal will be challenging.
Insulin pen	1985	"One-click per unit" dosing of Insulin as installed by the recipient need	Accurate, simple and convenient insulin delivery	Lack of training to use in a tribal setting
Insulin jet injectors	1990	Sends a fine insulin spray through the skin by utilizing a high-pressure air current over needle.	Faster absorption of insulin, painless	Expensive
Continuous glucose monitoring	1999	Downloads the readings after they have been collected in the span of 24 hours, similar to a 24-hour cardiac rhythm.	Provides accurate picture of glucose levels throughout the day	Technological issues, expensive
Insulin inhaler	2006	Use compressed air to deliver dry insulin or dissolved rapid-acting insulin to inhale, which directly enters the bloodstream	Rapid action	Expensive and no training of usage
Smart pens	2007	Incorporated with a memory function that allows to store the date, time, and amount of the previous doses of insulin.	Less painful and accurate	Difficulty in applying a mixture of hormones
Patch pump	2011	These infusion pumps free of infusion sets, small, lightweight, and attached to the skin through an adhesive.	Maximized adherence, compact and travel friendly	Expensive to introduce in a tribal setting
Closed loop insulin delivery system	2013	Engage automation delivery of insulin to obtain glycemic targets. Also termed as 'artificial pancreas'	Precise and continuous delivery of insulin	Expensive, mechanical problems

Moreover, initiatives like 'diabetes care at doorstep' which are mobile vans dedicated exclusively for diabetes management and sufficient to scan the micro and macro vascular complications of diabetes can be beneficial to diabetes care [11]. The vans not only include glucometer, stadiometer, sphygmomanometer but also DMSA scan, DTPA scan for nephropathy, fundoscopy to scan retinopathy, mobile ECG to detect myocardial infarction (MI), mini-CT scan to detect cardiovascular diseases for people who smokes and drinks frequently, as well as, TrueNat TB test and hand-held X ray machines to detect tuberculosis.

Intervention based technologies

In the sphere of diabetes management, telemedicine has emerged as a crucial element, especially for areas that are medically underserved and geographically dispersed.[12] This technology enables healthcare workers to oversee and administer glycemic control remotely. It offers counsel and guidance for lifestyle changes, insulin titration, and real-time consultations. In diabetes management, a novel idea is the rise of the "social vaccine", which includes community-based interventions to raise awareness, provide diabetes education, and foster supportive social environments.[13] This new paradigm is in addition to the recent advancements. By fully considering the medical dimension as well as the social contextual determinants of health, this construct embodies a profound fusion of technological advancements and community-led efforts to improve the quality of care and overall well-being of people with diabetes and improve the health of people with diabetes. Additionally, virtual group assessment (VGA) has also proven itself a compatible tool in diabetes management in which people with diabetes can form a group and can be provided with virtual assessment form the experts in anywhere in the world.[14]

Molecular assessment-based technologies

As the recent molecular advances prevails, the diabetes management is also positively affected by it. The PCR based diagnosis of monogenic and multigenic or maturity onset diabetes of the young (MODY) diabetes using next generation sequencing (NGS) can help in onsetting the precision medicine according to the unique genetic makeup of the patient.[15-17] The genome editing nucleases like CRISPR/Cas9 and ZFN-TALEN can be useful for developing suitable models drug testing, locating genetic defects underlying disease pathogenesis, restoring gene function by altering genetic mutations and optimizing patient specific diabetes treatment.[18,19] The major challenge with these are their complicated designs and costly set ups. Adding to the technological approach, the use of nanotechnology in insulin delivery is a potential option, as they are safe, cost effective and allows direct delivery of insulin the blood stream. It uses polymeric biodegradable nanoparticles, polymeric micelles, ceramic nanoparticles, liposomes, dendrimer nanoparticles and efficient over intravenous administration methods.[20] Moreover, Human serum metabolomic analysis can detect the possible pathogenesis of diabetes with other morbidities, which can be beneficial to administer early precautionary measures.[21]

Challenges in implementing the technologies in tribal settings

The implementation of new technologies in diabetes management in tribal settings presents unique and daunting challenges. These areas often face severe infrastructure deficiencies, including unreliable electricity and internet access and storage facilities (insulin storage), which are critical to the operation of advanced diabetes technologies, such as systems for continuous glucose monitoring (CGM) platforms. Additionally, the limited availability of trained medical professionals in tribal areas may hamper the adoption of these technologies, as they often require expertise to properly set up, maintain, and troubleshoot. The primary health care workers have insufficient knowledge and training in these newer forms of treatment procedures.[22] Language and cultural barriers can also be significant barriers, as technology may be unfamiliar or culturally mismatched, requiring extensive education and community engagement. Additionally, the high cost of many advanced diabetes technologies may make them economically inaccessible to resource-limited individuals in tribal communities. Environmental factors such as extreme weather conditions can further complicate the use and durability of these devices. Given these multifaceted challenges, a holistic and culturally sensitive approach, taking into account the unique needs and circumstances of tribal areas, is imperative to ensure the successful integration of new diabetes management technologies

Other challenges include that the data for the compliance of drugs and complications of diabetes among the tribal population is lacking.[23] The problem for the tribal communities is either they don't know about their condition or if they know also, the medication is either not available to them because of their secluded and alienated habitats. Also, they are much more interested in their traditional remedies and have less faith in allopathic medication. It is important that we should have an actual record and a team of experts which should treat and follow up the patients of the tribal communities so that the occurrence of complications among these under privileged tribal population can be minimized. If a systematic data is obtained in digital format in a dashboard, it will be easier to assess the patients for the policy making concerned authorities. Most of the tribal population lives in secluded and far-flung areas, and diabetic patients from these areas cannot visit health centers frequently. These patients cannot control their blood sugar and they are also unaware of micro and macro vascular complication of diabetes. Unawareness, negligence and poor compliance or poor health seeking behaviour adds on to their condition.

Adding to the challenging part, approximately 90% of all the health care center visits in India are made by people living in rural area and most of them may have to travel 100 km to reach the nearest health facility.[24] Apart from all these hurdles, knowledge of diabetes and its complication is also very poor in India. In some studies, it is found that less than only 20% of population knew that diabetes could cause any complications.[25] Unfortunately, literacy status (especially female literacy) which is considered important for child health, is poor in tribal/rural India.[26,27] These poor levels of parent's literacy may also hamper the better control of hyperglycemia of type-1 diabetes affected children as management of type-1 diabetes put extra stress on children and parents due to daily insulin injections, frequent monitoring of blood glucose levels, screening for and managing chronic complications and most importantly handling of hypoglycemic episodes.

Newer technologies of diabetes management feasible in tribal settings

Although the tribal setting has technological, infrastructural, connectivity and literacy challenges in implementing the newer technologies for diabetes management, but some technologies like cognitive behavioural therapy (CBT), telemonitoring, VGA, diabetes dashboard, clinical decision support system (CDSS), 'social vaccine' and some mobile applications can be helpful in tribal settings. Within tribal communities, CBT can provide significant aid in managing diabetes. It also targets mental and behavioural barriers to diabetes management, improving one's psychological state and reducing stress levels.[28] Also, it is particularly effective as it takes the unique cultural practices and beliefs of tribal populations into account, making it a more appropriate option that fits their lifestyle. It imparts individuals with the necessary skills for self-care and enables them to gain control over the condition, which can be crucial in areas with limited resources. In tribal areas, better diabetes outcomes and improved overall health can be achieved through reduced healthcare disparities and prevention promotion with CBT with help of family members and primary health care workers like accredited social health activists (ASHA) and Anganwadi workers (AWW).

Maintaining a detailed record of people with diabetes in the primary health centers in the form of diabetes dashboard can be beneficial for the follow ups of the patients to track their conditions. A detailed record of diabetes in tribal population will provide clinical decision support system, if needed for their conditions accordingly, as done for NCDs.[29] The digitization of the data will help to reveal the actual condition of the disease scenario.[30]

Adding up the approach, if developing country like India will implement VGA approach, where rural and tribal population are living far flung to main health care facilities and doctor population ratio is also very poor (in comparison to WHO minimum threshold of 22.8 per 10 000 population) it will be fruitful to type 1 DM patients, his or her parents and to the health system, but at the same time before starting VGA, there is strong need to sensitization of the type 1 diabetic patient (or parents of children if age is less than 18 years) and strengthening of awareness regarding disease and its complication.[31,32] In a sensitization, awareness and VGA model approach via real time instant messaging in local languages will definitely help these tribal patients in better control of hyperglycemia, less incidences of ketoacidosis, hyperglycemic coma, combating depression and anxiety related to type 1 diabetes and less chances of development of micro and macro vascular complications in later life. Real time VGA approach will definitely improve quality of life (both physical and mental) of children/people having type 1 diabetes in India; however, it will give utmost benefit if delivered in local languages of tribal settings.

Moreover, social vaccines play a critical role in addressing the various determinants of diabetes in tribal communities as it increases the health literacy, and diabetes equally depends on the lifestyle changes which can be administer by being knowledgeable about the condition.[33] In addition, with telemedicine, those living in geographically isolated areas can access healthcare expertise and receive remote monitoring. Clinical decision support systems offer additional support to healthcare providers. The combination of these three elements is essential in effectively managing diabetes within tribal settings that may be underserved. Community-based interventions foster awareness, education, and support networks, which address both medical and socio-cultural factors contributing to diabetes. Powered by data analytics and AI, clinical decision support systems are uniquely positioned to offer personalized treatment strategies, empowering tribal communities to effectively combat diabetes and promote prevention. By addressing healthcare disparities and utilizing a comprehensive approach, these systems can optimize care and improve long-term health outcomes.

DISCUSSION

The disease management in tribal areas is challenging owing to the land alienation, illiteracy, poor connectivity, poor health seeking behaviour, low doctor-patient ratio, but the integration of new technologies promises to improve diabetes management. Telemedicine bridges geographic barriers and provides expert care and advice.[34] Clinical decision support systems analyse patient data to optimize treatment. Mobile apps enable self-monitoring and lifestyle changes. When adapted to cultural contexts, these technologies enable tribal communities to actively participate in health care, improve blood sugar control, and reduce health care inequalities. However, challenges such as limited resources and infrastructure must be addressed to ensure equitable access and maximize the benefits of these tribal diabetes care innovations. The developing country like India can be well benefitted with these technologies not only in urban areas but also in rural and

tribal settings if the technologies can be administered with well planning and managed according to the point of care. The present situation demands the digitization of the data as it presents the clearer picture of the scenario so that the policy makers can act accordingly and the people can be benefitted. Use of molecular based assessment tools including next generation sequencing and genome editing nucleases will be rather challenging in the tribal settings as it involves a complex design and advanced laboratory settings which is next to impossible to set in a tribal setting owing to the connectivity issues. Also, continuous glucose monitoring powered with closed loop insulin delivery system will face the challenge of insulin storage and set up as the health care workers in these settings does not have proper training.[35]

CONCLUSION

The implementation of new technologies for diabetes management is a challenging task in the tribal population. Despite of all the challenges, if proper training and maintenance is provided the people with diabetes and metabolic syndrome in tribal settings can be benefitted largely if these methods are administered, which will surely increase the quality of life of the populations which constitutes a significant figure in India.

ACKNOWLEDGEMENTS

Authors would like to thank Dr. Aparup Das, Director of ICMR-NIRTH, Jabalpur, for his continuous encouragement and valuable guidance throughout the course of manuscript preparation.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: Not required

REFERENCES

1. Mohan V, Sandeep S, Deepa R, Shah B, Varghese C. Epidemiology of type 2 diabetes: Indian scenario. Indian J Med Res. 2007;125(3):217-30.
2. Pradeepa R, Mohan V. Epidemiology of type 2 diabetes in India. Indian J Ophthalmol. 2021;69(11):2932-8.
3. Anjana RM, Unnikrishnan R, Deepa M, Pradeepa R, Tandon N, Das AK, et al. Metabolic non-communicable disease health report of India: the ICMR-INDIAB national cross-sectional study (ICMR-INDIAB-17). Lancet Diabetes Endocrinol. 2023;11(7):474-89.
4. Shriraam V, Mahadevan S, Arumugam P. Prevalence and Risk Factors of Diabetes, Hypertension and Other Non-Communicable Diseases in a Tribal Population in South India. Indian J Endocrinol Metab. 2021;25(4):313-9.
5. World Health Organization. WHO factsheet on diabetes. Available at: https://www.who.int/newsroom/factsheets/detail/diabetes#:~:text=Key%20facts,stroke%20and%20lower%20limb%20amputation.Accessed on 12 December 2023.
6. Unnikrishnan R, Anjana RM, Mohan V. Diabetes mellitus and its complications in India. Nat Rev Endocrinol. 2016;12(6):357-70.
7. Sherwood JS, Russell SJ, Putman MS. New and Emerging Technologies in Type 1 Diabetes. Endocrinol Metab Clin North Am. 2020;49(4):667-78.
8. Templer S. Closed-Loop Insulin Delivery Systems: Past, Present, and Future Directions. Front Endocrinol. 2022;13:919942.
9. Kesavadev J, Krishnan G, Mohan V. Digital health and diabetes: experience from India. Ther Adv Endocrinol Metab. 2021;12:20420188211054676.
10. Pichardo-Lowden A, Umpierrez G, Lehman EB, Bolton MD, DeFlitch CJ, Chinchilli VM, et al. Clinical decision support to improve management of diabetes and dysglycemia in the hospital: a path to optimizing practice and outcomes. BMJ Open Diabetes Res Care. 2021;9(1):e001557.
11. Gopalan HS, Haque I, Ahmad S, Gaur A, Misra A. "Diabetes care at doorsteps": A customised mobile van for the prevention, screening, detection and management of diabetes in the urban underprivileged populations of Delhi. Diabetes Metab Syndr. 2019;13(6):3105-12.
12. Shrivastava S. Can Telemedicine Be a Game Changer for Diabetes Management Among Tribal Populations? J Diabetes Sci Technol. 2021;15(5):1192-4.
13. Okan O, Messer M, Levin-Zamir D, Paakkari L, Sørensen K. Health literacy as a social vaccine in the COVID-19 pandemic. Health Promot Int. 2023;38(4):daab197.
14. Sarveswaran G, Rangamani S, Ghosh A, Bhansali A, Dharmalingam M, Unnikrishnan AG, et al. Management of diabetes mellitus through teleconsultation during COVID-19 and similar scenarios - Guidelines from Indian Council of Medical Research (ICMR) expert group. Diabetes Metab Syndr. 2021;15(5):102242.
15. Bonnefond A, Philippe J, Durand E, Muller J, Saeed S, Arslan M, et al. Highly sensitive diagnosis of 43 monogenic forms of diabetes or obesity through one-step PCR-based enrichment in combination with next-generation sequencing. Diabetes Care. 2014;37(2):460-7.
16. Franceschi R. Precision Medicine in Diabetes, Current Research and Future Perspectives. J Personalized Med. 2022;12(8).
17. Maltoni G, Franceschi R, Di Natale V, Al-Qaisi R, Greco V, Bertorelli R, De Sanctis V, Quattrone A, Mantovani V, Cauvin V, Zucchini S. Next Generation Sequencing Analysis of MODY-X Patients: A Case Report Series. J Pers Med. 2022;12(10):1613.
18. Cheng Y, Wang H, Li M. The promise of CRISPR/Cas9 technology in diabetes mellitus

therapy: How gene editing is revolutionizing diabetes research and treatment. J Diabetes Complications. 2023;37(8):108524.
19. Li H, Yang Y, Hong W, Huang M, Wu M, Zhao X. Applications of genome editing technology in the targeted therapy of human diseases: mechanisms, advances, and prospects. Signal Transduction Targeted Therap. 2021;5(1):1.
20. DiSanto RM, Subramanian V, Gu Z. Recent advances in nanotechnology for diabetes treatment. Wiley Interdisciplinary Rev Nanomed Nanobiotechnol. 2015;7(4):548-64.
21. Zhang Y, Zhao H, Liu B, Shu H, Zhang L, Bao M, et al. Human serum metabolomic analysis reveals progression for high blood pressure in type 2 diabetes mellitus. BMJ Open Diabetes Res Care. 2021;9(1):e002337.
22. Basu S, Sharma N. Diabetes self-care in primary health facilities in India - challenges and the way forward. World J Diabetes. 2019;10(6):341-9.
23. Venkatesan M, Dongre AR, Ganapathy K. A Community-Based Study on Diabetes Medication Nonadherence and its Risk Factors in Rural Tamil Nadu. Indian J Community Med. 2018;43(2):72-6.
24. Rural Health Statistics. 2015. Available at: http://wcd.nic.in/sites/default/files/RHS_1.pdf. Accessed on 24 May 2023.
25. Mohan D, Raj D, Shanthirani CS, Datta M, Unwin NC, Kapur A, Mohan V. Awareness and knowledge of diabetes in Chennai--the Chennai Urban Rural Epidemiology Study [CURES-9]. J Assoc Physicians India. 2005;53:283-7.
26. Census. Literacy in India. https://www.census2011.co.in/literacy.php. Accessed on 24 May 2023.
27. Sandiford P, Cassel J, Montenegro M, Sanchez G. The Impact of Women's Literacy on Child Health and Its Interaction with Access to Health Services. Population Studies. 1995;49(1):5-17.
28. Abbas Q, Latif S, Ayaz Habib H, Shahzad S, Sarwar U, Shahzadi M, et al. Cognitive behavior therapy for diabetes distress, depression, health anxiety, quality of life and treatment adherence among patients with type-II diabetes mellitus: a randomized control trial. BMC Psychiatry. 2023;23(1):86.
29. Jindal D, Sharma H, Gupta Y, Ajay VS, Roy A, Sharma R, et al. Improving care for hypertension and diabetes in India by addition of clinical decision support system and task shifting in the national NCD program: I-TREC model of care. BMC Health Services Res. 2022;22(1):688.
30. Shrivastva S, Chakma T, Das A, Verma AK. Digitisation and realtime sharing of unified surveillance tool and clinicopathological data for efficient management of disease outbreaks. Int J Health Plann Manage. 2021;36(4):1352-4.
31. Karan A, Negandhi H, Nair R, Sharma A, Tiwari R, Zodpey S. Size, composition and distribution of human resource for health in India: new estimates using National Sample Survey and Registry data. BMJ Open. 2019;9(4):e025979.
32. Singh K, Chakma T, Shrivastava S. Type 1 Diabetes Management Among Tribes: How Virtual Group Appointments Approach May Be Beneficial. J Diabetes Sci Technol. 2023;17(4):1121-2.
33. Galaviz KI, Narayan KMV, Lobelo F, Weber MB. Lifestyle and the Prevention of Type 2 Diabetes: A Status Report. Am J Lifestyle Med. 2015;12(1):4-20.
34. Kesavadev J, Mohan V. Reducing the Cost of Diabetes Care with Telemedicine, Smartphone, and Home Monitoring. J Indian Inst Sci. 2023;103:231-42.
35. Sherr JL, Heinemann L, Fleming GA, Bergenstal RM, Bruttomesso D, Hanaire H, et al. Automated insulin delivery: benefits, challenges, and recommendations. A Consensus Report of the Joint Diabetes Technology Working Group of the European Association for the Study of Diabetes and the American Diabetes Association. Diabetologia. 2023;66(1):3-22.

Cite this article as: Singh K, Chakma T, Ray S, Vaidh N, Shrivastava S. Exploring the viability of newer technologies in care and management of tribal diabetes and metabolic syndrome in India. Int J Res Med Sci 2024;12:1321-6.