Strategic Opportunities for Leveraging Low-cost, High-impact Technological Innovations to Promote Cardiovascular Health in India

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Accelerated epidemiological transition in India over the last 40 years has resulted in a dramatic increase in the burden of cardiovascular diseases and the related risk factors of diabetes and hypertension. This increase in disease burden has been accompanied by pervasive health disparities associated with low disease detection rates, inadequate awareness, poor use of evidence-based interventions, and low adherence rates among patients in rural regions in India and those with low socioeconomic status.

Several research groups in India have developed innovative technologies and care-delivery models for screening, diagnosis, clinical management, remote-monitoring, self-management, and rehabilitation for a range of chronic conditions. These innovations can leverage advances in sensor technology, genomic tools, artificial intelligence, big-data analytics, and so on, for improving access to and delivering quality and affordable personalized medicine in primary care. In addition, several health technology start-ups are entering this booming market that is set to grow rapidly. Innovations outside biomedical space (eg, protection of traditional wisdom in diet, lifestyle, yoga) are equally important and are part of a comprehensive solution.

Such low-cost, culturally tailored, robust innovations to promote health and reduce disparities require partnership among multi-sectors including academia, industry, civil society, and health systems operating in a conducive policy environment that fosters adequate public and private investments.

In this article, we present the unique opportunity for India to use culturally tailored, low-cost, high-impact technological innovations and strategies to ameliorate the perennial challenges of social, policy, and environmental challenges including poverty, low educational attainment, culture, and other socioeconomic factors to promote cardiovascular health and advance health equity. *Ethn Dis.* 2019;29(Suppl 1):145-152; doi:10.18865/ed.29.S1.145.

Keywords: Innovations; Technology; Cardiovascular Diseases; Diabetes; Policy; Multi-disciplinary; India

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Introduction

Cardiovascular diseases (CVD) and diabetes are leading health challenges in India.[1] Research evidence suggests that, irrespective of geography and ethnicities, population attributable risk of myocardial infarction and stroke can be explained by nine conventional risk factors.[2,3] However, large population groups, which undergo rapid economic and health transitions in India, are faced with a hostile cardiovascular environment, characterized by changes in dietary pattern, sedentary life, tobacco use, and socioeconomic constraints at both the national and personal level.[4] In addition, these populations experience exposure to potential novel risk factors and possibly a genetic or programmed fetal vulnerability to CVD in later life.[4] These perennial challenges in India lead to health inequities and disparities in cardiovascular health in various population groups.[5] Disparities in CVD risk factors have been reported to be increasing across various states in India.[1,6] Risk factors such as tobacco use and low fruit/vegetable intake, are more prevalent in low-education and less wealthy strata, whereas prevalence of hypertension, overweight/obesity, diabetes and hypercholesterolemia are more prevalent among the affluent.[5] A large proportion of individuals remain unaware and undiagnosed of hypertension and diabetes; and among those who receive treatment, many (>60%) fail to achieve the recommended control targets.[7–9] Even more worrying is the disparities in access to health care and inadequate manpower in the public health system to offer high-quality services.[10,11]

Recent scientific and technological innovations have profound effects on the quality and longevity of human life. There is a unique opportunity for India to use culturally tailored, low-cost, high-impact technological innovations and strategies to promote cardiovascular health and advance health equity. The High-Level Expert Group on Universal Health Coverage for India has advocated for innovative strategies to promote health and reduce disparities in CVDs/diabetes.[12] Innovations in CVDs/diabetes care could fall briefly into four domains: prevention; diagnostics; management and rehabilitation; and promising technologies for CVD/diabetes practice. In this review, we summarize these innovations that have potential to strengthen primary care and reduce health inequities. We also discuss the challenges and potential solutions.

Prevention of CVDs and Diabetes

DISHA Intervention for Community-based CVD Prevention

The vast rural populace in India has relatively poor access to CVD/diabetes care compared with urban areas. Shortage of trained manpower is a major barrier to delivering CVD prevention and promotive services in the rural communities. Task shifting/sharing involving frontline health workers in CVD interventions has been debated as a solution to this barrier. Delivery of a multi-pronged intervention, DISHA, through trained frontline health workers has been attempted in selected communities in India through the Anganwadi Centres and Sub-centres.[13] These grassroot-level institutions have been the first contact point between the communities and the Integrated Child Development Service Scheme (ICDS) and the formal Public Health System. The ICDS targets children (0-6 years) and pregnant women and offers supplementary nutrition, health and nutrition education, pre-school education, and immunization at the community level. Anganwadi Centres are managed by an Anganwadi worker, who is chosen from the community and has been trained in health, nutrition and childcare. Similarly, ASHAs are voluntary health workers selected from their communities by the public health system and are attached to Sub-centres. ASHAs support the delivery of maternal and child health services and other national health programs in their communities.

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The DISHA project investigated the effectiveness of task shifting/sharing approach of involving Anganwadi workers and ASHAs in imparting lifestyle interventions at the individual, family and community level. The evaluation was completed recently through an 18-month, prospective, parallel-group, cluster randomized controlled trial across 10 states in India. A cluster was defined as a village with 250–300 households and well-defined geographical boundaries. Such 120 clusters were randomized into control and intervention groups enrolling approximately 18,000 participants in each group. The intervention clusters received: individual level (eg, individual counselling), household level (eg, household visits by frontline health workers) and community level interventions (eg, display of posters, community-level activities and competitions). The intervention focused on: 1) information on healthy diets including low-salt, low-fat, low-trans-fat and high-fiber intake; 2) increasing physical activity of vigorous intensity for at least 30-60 minutes; and 3) quitting of tobacco and alcohol (Figure 1 and Figure 2).[13] The results from this intervention are pending.

Text Messaging for Supporting Behavior Change in Prevention

The Indian SMS diabetes study investigated whether mobile phone messaging that encouraged lifestyle change could reduce incident type 2 diabetes in men with impaired glucose tolerance, through a two-year, prospective, parallel-group, randomized controlled trial.[14,15] The men, aged 35-55 years, were employed in industrial units located in Chennai

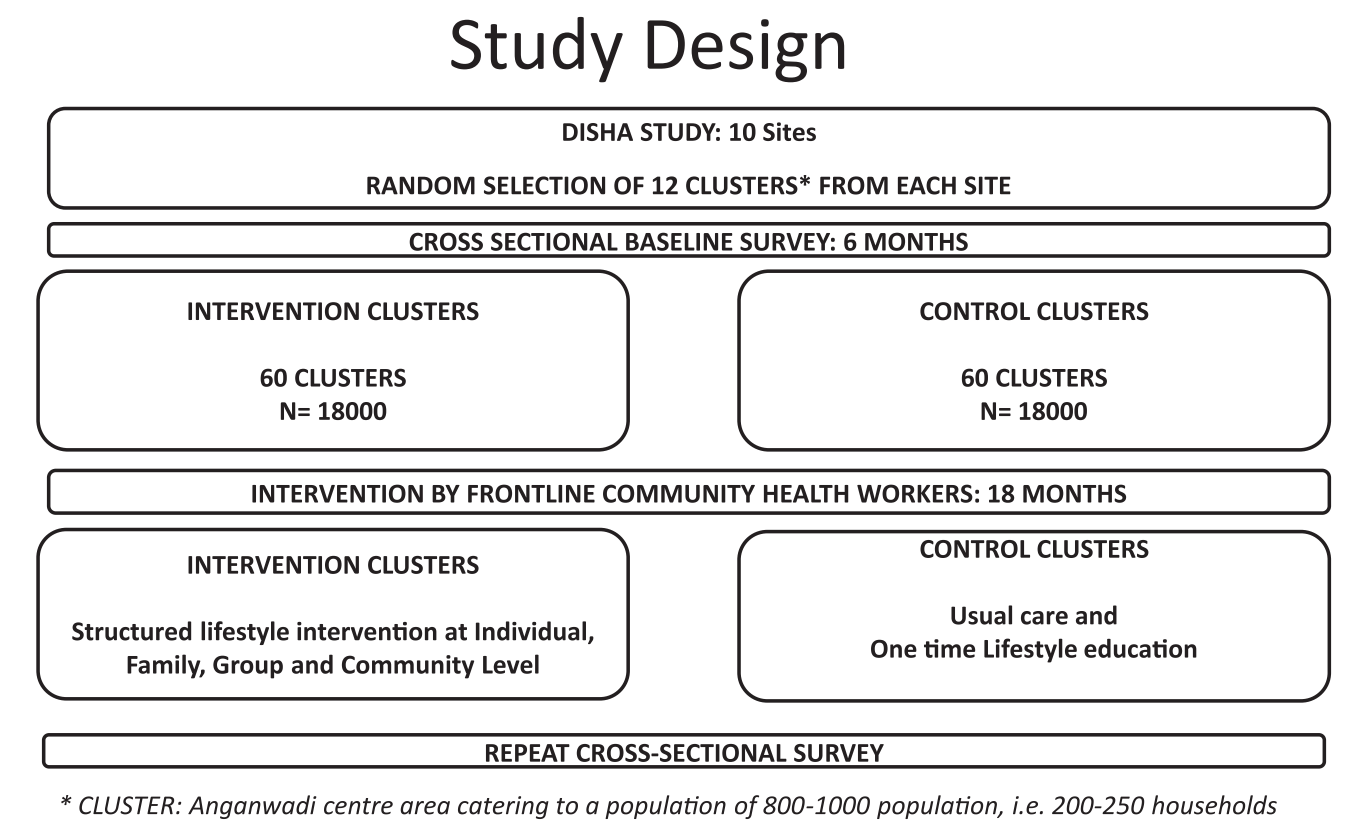

Figure 1. Study design of DISHA intervention

and Visakhapatnam, South India. Of the 537 participants randomized, the intervention group (n=271) received frequent mobile phone messages compared with controls who received standard lifestyle modification advice at baseline only. The frequency, time and number(s) of messages were tailored according to participants' requirements. At the end of the study, the cumulative incidence of type 2 diabetes was lower (18% vs 27%) in the intervention group. Additional three years follow-up, even after withdrawal of the active intervention, also showed beneficial effects of the intervention on diabetes prevention.

The Ministry of Health and Family Welfare, Government of India, along with the WHO-India and other partners, have launched SMS-based initiatives for tobacco cessation (mCessastion Programme), and prevention and care of diabetes (mDiabetes Programme). Potential beneficiaries are encouraged to register their mobile numbers online (https://www.nhp.gov.in/QUIT-tobacco and http://mdiabetes.nhp.gov.in/) to receive messages to support behavior change to quit tobacco use and prevention/self-management of diabetes respectively.[16,17] Reports on large scale evaluation of these efforts are yet to be available.

The above innovations for CVD/diabetes prevention might also have limitations. For example, the DISHA intervention would require well-functioning grassroot institutions, adequate manpower and other resources. In addition, task-shifting/sharing for CVD care might face resistance in resource-constrained settings because of the fear of diluting maternal and child health services, and infectious disease care. SMS-based interventions also have limitations. Literacy and ownership of mobile phones are essential for involving beneficiaries in such interventions thereby limiting the access to a section of the society.

Diagnostics for CVDs and Diabetes

The health technology ecosystem is rapidly evolving in India with a host of startups trying to solve several

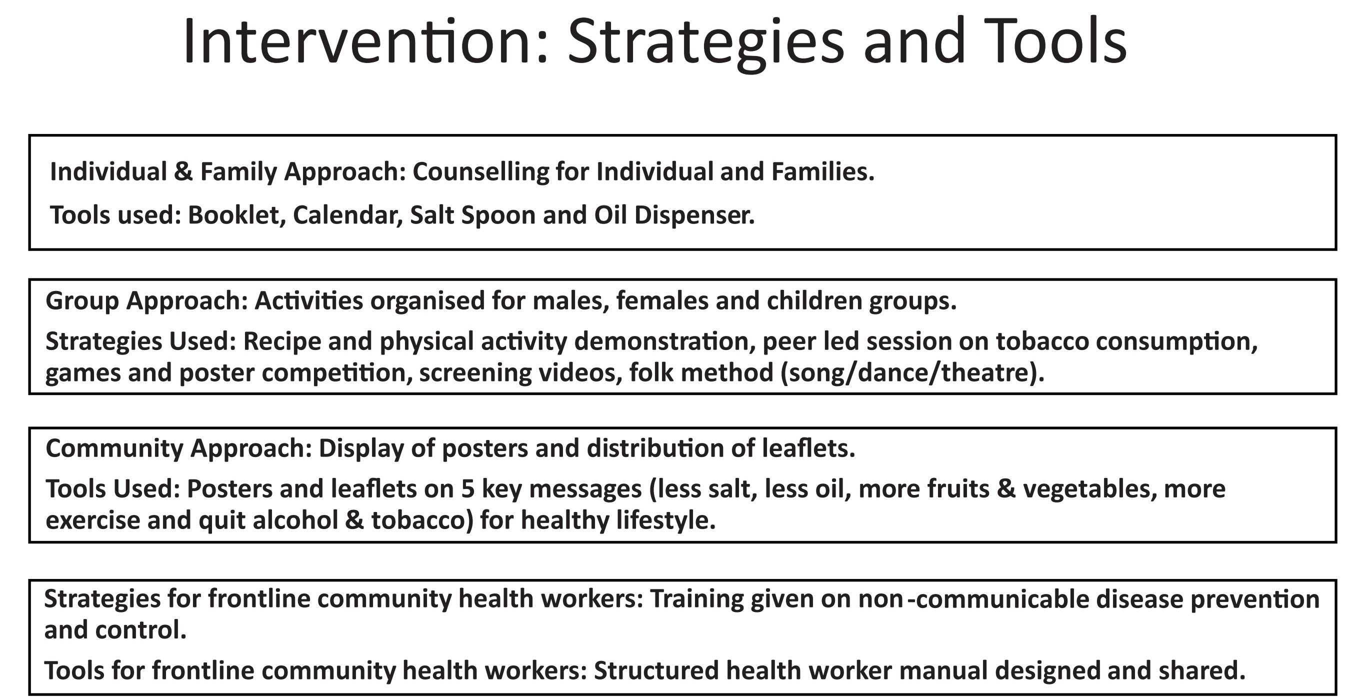

Figure 2. Strategies and tools adopted for DISHA intervention in the communities

health challenges through innovative ways. To support chronic disease screening and management, some of the startups have developed point-of-care devices for measuring glycated hemoglobin (HbA1c), glucose, total cholesterol and triglycerides using a single drop of blood (www.janacare.com). Creatinine, NT-proBNP are being added to cover kidney diseases and heart failure. Similarly, another start-up has integrated multiple point-of-care devices (eg, ear thermometer, 12 lead ECG, blood pressure monitor, spirometer, electronic stethoscope, pulse oximeter, and an optical reader for biochemical investigations) into a portable platform (www.neurosynaptic.com). These providers offer their services at a fractional cost of the conventional methods, thereby improving access to care. These portable devices can be attached to computers, mobile phones and tablets for use in primary care, expanding the coverage of CVD/diabetes care even in resource poor setting.

Some of the startups offer cloud-based ECG machine and services from a team of doctors located in a central hub. Health care personnel at any remote location can use the machine, and send the ECG patient data to the central hub for reading and providing prompt feedback. Startups with machine-learning solutions offer services for detection of abnormalities and trends using clinical and biochemical data for disease diagnosis. Following aggregator business models, some of the startups offer Internet-based platforms for connecting patients with health care providers, local pharmacies, and phlebotomists for scheduling sample collection service for diagnostic tests. Similar platforms for wellness services are connecting patients with nutritionists, food technologists, counselors, and wellness product supply chains. Though such technology solutions can reach out to masses, barriers such as literacy, access to Internet and smartphones, need to be addressed to enable the poor to access such services.

Management and Rehabilitation of CVDs and Diabetes

Although hypertension and diabetes can be effectively managed in primary care, inferior quality of primary care services results in huge burden of undiagnosed and under-treated cases of hypertension and diabetes. Similarly, cardiac rehabilitation programs are often neglected even in high-end tertiary care settings owing to its prohibitive cost. In order to address such critical gaps, the All India Institute of Medical Sciences (AIIMS), the New Delhi-based Centre for Chronic Disease Control (CCDC) and Public Health Foundation of India (PHFI), Atlanta-based Emory University, and the London School of Hygiene & Tropical Medicine (LSHTM), have been individually and collaboratively developing multiple care delivery models that can be integrated into routine care. These models were designed to facilitate task-shifting/sharing with the use of mHealth/e-Health based digital clinical decision support software (DSS) tools for standardizing and improving quality and access to chronic disease care at various levels in diverse settings. Some of these innovations are described below.

CARRS Diabetes Care Delivery Model for Tertiary Care Facilities

Achievement of diabetes care goals is suboptimal even in the tertiary care setting. PHFI, AIIMS, Emory University and CCDC designed a tertiary care level, specialist clinic-based, multicomponent, quality improvement strategy named CARRS diabetes care delivery model. The model, targeting patients with poorly controlled diabetes, comprises guidelines-based treatment, DSS integrated electronic health records (EHR) and a non-physician diabetes care delivery system. Evaluation of this innovative strategy was carried out in a clinical trial involving 10 hospitals in India and Pakistan. The trial recruited 1,146 patients with type 2 diabetes and poor cardiometabolic profiles. During a 28-month period, a greater percentage of intervention participants (18.2% vs 8.1%) achieved multiple CVD control targets along with target HbA1c levels in comparison with control arm participants.[18] The CARRS intervention demonstrated the importance of low-cost strategies such as task shifting/sharing and use of DSS to improve quality of diabetes care even in tertiary care setting.

mPOWER Heart Non-Communicable Disease (NCD) Care Delivery Model for Primary Care Facilities

The AIIMS and CCDC have developed an mHealth-enabled, nurse-delivered NCD care delivery model for primary care. This real-world intervention involved five Government Community Health Centres (CHCs) and the District Hospital in Solan, Himachal Pradesh, India. A mobile app, known as mPower Heart mHealth System comprising DSS and EHR, was used primarily by nurses in the out-patient clinics. The DSS had the following features: 1) Computing clinical risk score for screening patients at risk of diabetes and CVDs; 2) Computing clinical management plan for diabetes and hypertension using standard treatment protocol algorithms; 3) Suggesting optimal drugs, dosages, and contraindications; and 4) Storing patient data electronically to generate serial data to provide continuity of care during follow-up visits.

In a pre-post evaluation, this innovative technology-enabled care delivery model was found to achieve: detecting 100% more people with either diabetes or hypertension during opportunistic screening; significant reduction in mean systolic blood pressure (14 mm Hg), diastolic blood pressure (7 mm Hg), and fasting glucose level (50 mg/dL); and sustaining these levels over 18 months of follow-up. This model has provided the basis for replication of mHealth-based DSS for NCD care in India; the model was adopted for state-wide implementation in 56 health facilities throughout the Indian states of Tripura and Mizoram. So far, more than 45,000 individuals have been treated for hypertension/diabetes from these health facilities using the DSS. The process of integrating the DSS module with an electronic case record form (eCRF) platform will soon be launched throughout the public health system covering the entire county.

Simplified Multifaceted Management for Individuals at High Cardiovascular Risk (SimCard) Care Delivery Model for Rural Communities

The SimCard model was jointly developed by PHFI, George Institute for Global Health (China), Emory University, AIIMS, and CCDC for reaching out to rural communities in India and China. The "2+2" simplified cardiovascular management model comprised two lifestyle recommendations (dietary salt reduction and smoking cessation) and prescription of two accessible, effective, and low-cost drugs (aspirin and a diuretic or calcium channel blocker). It was delivered by community health workers (CHWs) in their communities, with the aid of a smartphone-based DSS. The SimCard model was evaluated in a year long, prospective, parallel group, cluster-randomized controlled trial. From 47 rural village clusters (27 in China and 20 in India), trained CHWs identified 2086 people with high-risk of CVDs (aged 40 years or older with self-reported history of coronary heart disease, stroke, diabetes, and/or measured systolic blood pressure ≥160 mm Hg). During evaluation, participants in the intervention villages were managed by CHWs using an Android DSS App that focused on use of two CVD medications and two lifestyle modifications. Compared with the control villages, the intervention villages had a 25.5% higher net increase in the proportion of patient-reported anti-hypertensive medication use at 12 months of follow-up. There were also significant differences in secondary outcomes such as aspirin use (17.1%, $P<.001$) and systolic blood pressure (-2.7 mm Hg, $P=.04$).[19] The absolute changes observed in the intervention villages were: 32.1% increase in the proportion of patient reported anti-hypertension medication; 14.6% increase in aspirin use; and mean reduction of 11.8 mm Hg in systolic blood pressure. The SimCard model demonstrated that the DSS-enabled, CHW-led CVD care delivery model improved quality of primary care in resource-poor communities in China and India.

Yoga CaRe: A Low-Cost Cardiac Rehabilitation Intervention

Cardiac rehabilitation (CR), a standard treatment for secondary prevention of acute myocardial infarction (AMI), is inaccessible to most patients in India due to prohibitive costs and skills required for multidisciplinary CR teams. CCDC and the LSHTM have jointly developed an innovative, low-cost, scalable CR program based on the culturally acceptable practice of yoga (Yoga-CaRe) for people following an AMI. Yoga-CaRe comprises 13 in-hospital sessions supervised by an instructor with encouragement to practice regularly at home. The exercise-cum-education sessions involve a combination of exercises related to general physical fitness, stress and relaxation (eg, asana, meditation, breathing practices), and exercises believed to be of cardio-protective benefit. The lifestyle and other educational components are informed by Yoga wisdom but moderated by established scientific evidence. Currently the Yoga-CaRe is being evaluated in a prospective, parallel-group, randomized control trial including 3959 participants who had an AMI; the evaluation will assess the program's effectiveness on quality of life and time to occurrence of a first major cardiovascular event at 12 weeks. The results from this trial are awaited.

Promising Technologies for Expanding Access and Quality of CVD/Diabetes Practice

Medical decision making is often complex. Disruptive technologies, eg, medical device sensors, wearable devices, and point-of-care microfluidic lab-on-a chip, are making medical decision-making less complex. Application of these technologies in medicine also create a vast amount of data, opening opportunities for application of artificial intelligence (AI) to synthesize medical decision aids for physicians who traditionally relied on his/her knowledge, experience and judgement. AI application in CVD/diabetes practice falls into three major categories: image recognition; deep learning; and precision medicine using a variety of techniques.[20] Machine learning algorithms are increasingly being used to analyze medical images to detect abnormalities. Research groups from India have used AI-based automated software for detection of diabetic retinopathy (DR) and sight-threatening DR by fundus photography taken using a smartphone-based device (Figure 3).[21] This innovation helps in digital DR screening programs in the community with minimal cost. Similar methods are being developed for analyzing ECG outputs from Holter monitor or smartwatches for remote monitoring of heart failure.

Figure 3. Fundus photography taken using a smartphone-based device showing retinopathy

Deep learning, a recent sophisticated method of machine learning, is capable of automatically discovering representations needed for feature detection or classification from raw data. For example, scientists have used deep learning to model temporal relations among events recorded in the EHR of 3,884 incident heart failure cases and 28,903 controls to predict initial diagnosis of heart failure.[20]

Scientists are also developing precision medicine (PM) for risk prediction by combining new types of metrics with big medical datasets to create prediction models for prevention, diagnosis, and specific therapy of chronic diseases.[22] However, integration of PM into clinical practice requires the reengineering of the health care infrastructure by incorporating newer tools for data collection and analysis, interpretation of the results, as well as to facilitate treatment choices based on new understanding of biological pathways.[22] The potential benefits of using PM are: 1) possibilities for physicians to use genomics, proteomics, metabolomics, and other "omics" in routine clinical practice; 2) better understanding of the pathogenesis and epidemiology; 3) a revised approach to prevention, diagnosis, and treatment; and 4) better integration of EHR as well as data from sensors and software applications in an interactive network of knowledge aimed at improving the modelling and testing of therapeutic and preventative strategies, stimulating further research.[22] However, there are genuine concerns on the impact of PM on health equity.[23,24] Though cost of PM investigations is falling, it is likely that this technology may not be accessible to the poor in the near term.[23]

Partnerships for Promoting Innovations

Many of the health innovations described herein embrace new knowledge and possess the potential to revolutionize the management of CVD and diabetes. To ensure equitable outcomes, the design and implementation of innovations need to respect ethical principles and local values.[25] Decision on the use of innovative technologies should be made by local users, and implementation needs long-term commitment and local ownership.[26] In a nutshell, promoting innovations to reduce disparities in health requires a wider partnership involving multi-disciplinary academia, industry, civil society and the health system operating in a conducive policy environment that also fosters optimal public and private investments in research and development (R&D).

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Challenges

Research and development are critical to affordable innovations to tackle disparities in cardiovascular health. There are several challenges to India's innovation capability such as multiplicity of regulations, stagnant R&D findings, mismatch in R&D priorities and investments, poor access to capital, shortfall of scientific talent, low patent filing and so on.[26] Therefore, India must focus on fiscal incentives, policy support, financing mechanisms, investing in human capital and best-in-class infrastructure to promote R&D and innovations in cardiovascular health.

Conclusion

Several new innovations, both inside and outside biomedical field, are being evaluated in India with mixed success. Many of these innovations, if harnessed intelligently and pragmatically, can address the enormous inequities in health care in India. The challenges of scale, reach and sustainability must be surmounted to address the high CVD and diabetes burden in India in an equitable manner.

Conflict of Interest

No conflicts of interest to report.

Author Contributions

Research concept and design: Prabhakaran, Ajay, Tandon; Acquisition of data:

Tandon; Data analysis and interpretation: Prabhakaran, Ajay, Tandon; Manuscript draft: Prabhakaran, Ajay, Tandon; Administrative: Prabhakaran, Ajay, Tandon; Supervision: Prabhakaran, Ajay, Tandon

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