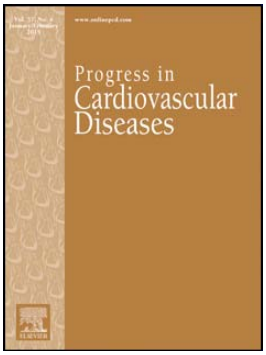

Technology for Diagnosis, Treatment, and Prevention of Cardiometabolic Disease in India

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Title: Technology for Diagnosis, Treatment, and Prevention of Cardiometabolic Disease in India

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Abbreviations

AMNET	Americas' Network for Chronic Disease Surveillance
BM-DCEP	Bone Marrow–derived Circulating Endothelial Progenitors
BP	Blood Pressure
BRFSS	Behavioural Risk Factors Surveillance System
CARRS	Cardiometabolic Risk Reduction in South Asia
CAS	Carotid Artery Stenting
CHW	Community health workers
CDC	Centre for Disease Control
CMD	Cardiometabolic diseases
CTA	Computed Tomography Angiography
CV	Cardiovascular
CVD	Cardiovascular Diseases
DM	Diabetes mellitus
DSS	Decision Support Systems
ECG	Electro cardio graph
EHR	Electronic Health Records
GIS	Geographical Information Systems
GWAS	Genome-wide Association Studies
HC	Health Care
HRIDAY	Health Related Information Dissemination Amongst Youth
IIP	Implantable Insulin Pump
ISRO	Indian Space Research Organization
IT	Imaging Technologies
LAVD	Left Ventricular Assist Device
LMICs	Low and Middle Income Countries
MBPN	Multilayer Back Propagation Network
MDM	Medical Decision-Making
MDS	Million Deaths Study
MMS	Multimedia Messaging Service
mPE	Metallocene polyethylene
NDSS	National Diabetes Surveillance System
PAD	Peripheral Artery Disease
SAARC	South Asian Association for Regional Cooperation
SMART	Self-Management Supported by Assistive, Rehabilitation and Telecare Technologies
SMS	Short Message Service
T2DM	Type 2 diabetes mellitus
WARFS	World Alliance for Risk Factor Surveillance
VDR	Virtual Diabetes Registry System

Abstract

Cardiometabolic diseases (CMD) are a major cause of mortality, morbidity and disability worldwide. Among Indians, CMD onset is at a much younger age and is prevalent in all sections of the society. Prevention, control and management of CMD and its risk factors is a major public health challenge, and alternative approaches need to be explored and integrated into public health programs. Advancements in the fields of computers, electronics, telecommunication and medicine have resulted in the rapid development of health-related technology. In this paper we provide an overview of the major technological advances in diagnosis, treatment and prevention within the field of CMD in the last few decades. This non-exhaustive review focuses on the most promising technologies that the authors feel might be of relevance in the Indian context. Some of the techniques detailed include advances in imaging and mobile phone technology, surgical techniques, electronic health records, Nano medicine, telemedicine and decision support systems.

Key words

CMD, Cardio-metabolic Diseases, India, Technology, mhealth, CVD, Diabetes, DSS

Cardiometabolic diseases (CMD) (i.e. diabetes mellitus/DM, cardiovascular disease/CVD, and kidney disease) were responsible for approximately 33% (17.6 million) of deaths in the years 2010.[1] This enormous burden of CMD morbidity and mortality has increased in parallel to the prevalence of the major risk factors (i.e. high body mass index, high blood pressure/BP, high blood glucose, tobacco use and physical inactivity).[2] In order to slow down the progression of this epidemic, it is important to detect and manage CMDs at a nascent stage, wherein technology can play a significant role. Modern technology has played a significant part in transforming health care (HC) across the globe. Some of these technologies have played an important role in prevention, surveillance, diagnosis and treatment to reduce CMD burden in the last few years.[3]

Technology can act as an interface between physicians and patients, physicians among themselves, and physicians of varying levels of expertise. It can also be seen as a tool for collating and analysing data and helps in chalking out appropriate management plans. Substantial evidence exists on the diverse role technology can play in several aspects of delivering HC, saving cost and improving quality of care. This amalgamation of HC and technology continues to improve saving lives across the globe. In this paper we provide an overview of the major technological advances in diagnosis, treatment and prevention in the field of CMD in last few decades. (Figure 1) This non-exhaustive review focuses on the most promising technologies that the authors feel might be relevant in the Indian context.

Role of Technology in CMD Diagnosis

Advances in medical imaging techniques, nanomedicine, computerized decision support systems (DSS), and electronic health records (EHR) are some of the most promising developments in the field of medicine as a whole. The development of genomic and proteomic multiplex technologies have tremendously improved biomarker discovery and application to diagnostic and therapeutic decisions in clinical practice. Technical advances from basic diagnostic tools to high resolution imaging have led to a better understanding of physiology and anatomy of the cardiovascular (CV) system, thereby, helping gain more detailed insights.

Advances in Imaging Technologies (IT)

In India, several improvements in diagnostic methods and a number of new techniques have been developed and tested to aid in the decision making process. The "medical decision-making (MDM) system" has been used for an automated diagnosis and classification of ultrasound carotid artery images. This system provides a computer-based output for HC professionals and radiologists to aid diagnosis in patients. Two types of contour extraction techniques and multilayer back propagation network (MBPN) systems have been developed. This helps the physician to extensively study the characteristics of carotid arteries in a more reliable manner.[4]

Kumar A. et al. discuss the role of three-dimensional computed tomography angiography (3D-CTA) in the management of aneurism. They specifically describe how using 3D-CTA with 64 slice Multi Detector CT has improved the pre-operative assessment of both ruptured and un-ruptured aneurysms.[5] Maheshwary S. et al. introduced a novel approach for detection of discontinuities in the QRS complexes.[6] A less complex 'haar' wavelet was used for low-power consumption which can be used in battery-operated devices (mobile phone, personal digital assistant/pda devices, tablets etc). For ECG-specific applications, they have formulated the postulates for detection of notches and extremes with proposed criteria for identification of various morphologies.[6]

Advances in Nanomedicine

Nanomedicine is an emerging field that utilizes nanotechnology concepts for advanced therapy and diagnostics. This convergent discipline merges research areas such as chemistry, biology, physics, mathematics and engineering. It bridges the gap between molecular and cellular interactions, and has the potential to revolutionize medicine. Nano medicine has tremendous potential for biomedical applications, such as radiological imaging, vascular implants, gene therapy, myocardial infarction and targeted delivery systems.[7] Some specific areas where nanotechnological approaches for CVD diagnosis and therapy have been advocated include nanoparticles for multimodal image contrast and improved treatment of CVD.[8]

Veiseh O et al. discuss the nanotechnology based approach for management of DM. Nanotechnology can be used in continuous glucose monitoring and insulin delivery systems. Glucose nanosensors are being incorporated into implantable devices, providing more accurate tracking of blood glucose levels while also providing the basis for glucose-responsive nanoparticles that better mimic the body's physiological needs for insulin.[9] Godin and colleagues consider the recent development in nanotechnology for improving diagnosis and therapy of CVD. A variety of “nanoparticle drug delivery systems” have been and are still being developed for treatment of CVD and other conditions. This allows local, directed and prolonged delivery of drug into the target cells.[8]

A major application of nanotechnology in CMD diagnosis involves creating images of atherosclerosis, restenosis and other cardiovascular conditions. Identification of biomarkers provides a powerful approach for screening, diagnosis, prognosis and therapeutic monitoring. Prognosis for patients suffering from CVD can be improved by obtaining more sensitive, specific, and faster assessments of diagnostic markers. Nanotechnology helps in improving detection of existing biomarkers and discovery of new biomarkers. A “lab-on-a-chip approach” has been developed in combination with nanotechnology to improve the sensitivity and accuracy of biomarker detection.[10] New generation biosensors have revolutionized CVD diagnosis and prognosis enabling it to be used as rapid screening tools to detect disease biomarkers at the earliest stage. Advances in interdisciplinary research have made biosensors faster, highly accurate, portable and environmentally friendly.

Nano medicine in India is still in the nascent stages with work being carried out for myocardial tissue regeneration in cases of end stage heart failure. Sridhar et al. constructed nanoparticle embedded Nanofibrous scaffolds to differentiate mesenchymal stem cells into cardiac lineage to replace infarcted myocardium. Their experiment revealed that these scaffolds promoted cardio genesis and enhanced production of contractile proteins.[11] Similar work was carried out by Guhathakurta and colleagues to create a myocardial tissue. They specifically harvested human cardiac muscles from a homograft heart retrieval system and coated them with electrospun nanofibers to make them amenable to scaffolding.[12]

Role of Technology in CMD Treatment and Management

Continuous technological advancements in treatment aspects of CMD have proven to be significantly beneficial in reducing morbidity and mortality. Increased innovation in technology development has bolstered CMD treatment modalities in ways that support a better quality of life for patients.

Decision Support Systems

A DSS is an interactive, flexible and adaptable computer-based information system developed specifically to establish solutions to non-structured management problems thereby aiding in the decision making process. In the HC arena, clinical DSSs provide clinicians, other health providers, and patients with knowledge, specific individualized information intelligently filtered and presented at appropriate times to enhance clinical performance and patient outcomes. It encompasses a variety of tools and interventions such as computerized alerts and reminders, clinical guidelines, order sets, patient data reports and dashboards, documentation templates, and diagnostic support.[13]

Numerous systematic reviews have shown that computerized DSSs enhance preventive care, increase clinical performance, and significantly improve the quality of clinical decision making.[14–21] A cluster randomized community trial in Andhra Pradesh state of India was designed to test the effectiveness and cost effectiveness of DSS among Indian hypertensive patients.[22] Another example from India is the SMARTHealth study, which used a Clinical Decision Support tool to assess and manage CVD risk in resource-constrained setting.[23] This tool was part of a mHealth system that was comprised of a mobile application with an evidence-based risk prediction and management algorithm, and a server-side EHR system. The system was field tested with eleven village HC workers and three primary health center physicians, who screened a total of 292 adults aged 40 years and older. With the assistance of the tool, 34% of participants were identified to be at high CVD risk and were further referred to a physician.[23]

The SIMCARD trial was conducted in resource poor settings of villages in India and China. A mobile phone based DSS was an important component of the simplified management programme for high CVD risk patients. Lay community health workers (CHWs) were trained and supported by a smartphone based electronic DSS to deliver the physician prescribed and approved drugs along with a culturally tailored lifestyle intervention. This led to an

increase in patient reported use of anti-hypertensive medication (25.5%, p<0.001) and a significant reduction in systolic BP in the intervention group. It is believed that inclusion of the electronic DSS along with CVD standardized care provided better patient outcomes and reduced CHW training time.[24]

The CARRS (cardiometabolic risk reduction in South Asia) translation trial aimed to address challenges associated with CVD risk factor control among patients with Type 2 DM (T2DM) in South Asia. The study tested the feasibility, effectiveness, and cost-effectiveness of a multi-faceted intervention (physician directed patient case management facilitated by a non-physician care coordinator using EHR and DSS) to reduce CVD risk among people with T2DM, compared to those receiving usual care.[25] A recent systematic review on DSS concluded that the paucity of well-designed studies on patient-related outcomes is a major hindrance that restricts evaluating the role of DSS in secondary prevention.[26] The authors suggested that future studies on DSS should evaluate both physician performance and patient outcomes and integrate them into the routine clinical workflow with a provision for decision support at the point of care.[26]

Another narrative review which looked at the utility of electronic decision support tool for diabetes care in low and middle income countries supports the use of EHR and computerized DSS tools as innovative conduits for structuring and standardizing care processes but highlights setting and selection limitations in the evidence reviewed. In the context of limited resources, individual economic hardships, and lack of structured systems or trained human capital, this review reinforces the need for well-designed investigations evaluating the role and feasibility of technological interventions in clinical decision making for DM care.[27]

Pharmaceutical and Surgical Innovations

One of the most recent surgical interventions includes the robot assisted surgery. This is the least invasive approach for treating mitral valve disease but is associated with a high cost. Mihaljevic et al. investigated the conditions under which benefits of robotic surgery mitigate

the costs and found that in exchange for higher procedural costs, robot assisted mitral valve surgery offers the clinical benefit of least invasive surgery, lowest postoperative cost, and fastest return to work.[28] Cell implantation is another recent approach for the treatment of ischemic cardiomyopathy and improvement of vascularization and quality of life in patients with peripheral arterial disease (PAD).[29,30]

Bruno A. et al. highlight the efficacy of BM-DCEPs (bone marrow–derived circulating endothelial progenitors) implantation for the improvement of the vascularization and quality of life in patients affected by PAD.[30] Advances in continuous flow technology have improved efficiency, size, implantability, extended support and overall patient outcomes. This has led to an extended role of the left ventricular assist device (LVAD) in clinical use and application.[31] The use of "3D printing in cardiology" is in nascent stages. 3D printing is being increasingly used to build replicas of anatomic structures which is of great value in various aspects of medicine such as preoperative planning for complicated CV surgeries.[32]

A number of studies have been conducted in India aimed at improving technical advancement in treatment aspects of CVD. Jaganathan SK et al. investigated the improved blood compatibility of "metallocene polyethylene (mPE)" after modifying its surface using hydrochloric acid. This is an example of the use of polymer biomaterial due to their non-toxic characteristics. The most common limitation associated with the use of polymers is the infection and bio-incompatibility with host tissues. They found that the surface modification of the polymer mPE improves acceptance.[33] Gupta AK et al. investigated the role of carotid artery stenting (CAS) as an alternative to carotid endarterectomy in the treatment of symptomatic carotid artery stenosis. They concluded that CAS is an effective treatment modality for symptomatic carotid artery disease but should be carefully done in high risk groups having severe medical ailments and those having severe bilateral stenosis of the carotid arteries etc.[34]

State of the art technologies bear substantial potential to be able to reform diabetes care with better outcomes. Insulin delivered using the implantable insulin pump (IIP), though common in high income countries, is now being increasingly used in India. IIP measures blood sugar levels and delivers the exact amount of insulin accordingly. This makes it possible to mimic the action of natural insulin delivery to the body. Selam JL et al. observed

the safety, efficacy and feasibility associated with implantable insulin pumps and reported that all implanted pumps have functioned safely with no instance of over delivery or stoppage. Insulin delivery through implantable pumps is effective and safe for periods up to 1.7 yrs. with a decreased risk of severe hypoglycemia than with intensive subcutaneous insulin therapy.[35]

Several wearable devices are being used by patients to have better health outcomes. The Gluco(M) Wristband is a concept medical device which is based on the principle of reverse iontophoresis and collects glucose samples from body fluids and offers three major functions to diabetics: non-invasive and instant glucose reading, storing of previous reading history with averages, and an extremely useful insulin chamber with loaded syringe cartridge for injections.[36]

Telemedicine and Telehealth

The last decade has witnessed swift adoption of computer and smartphone technology, which has spurred interest in and use of telemedicine. Telemedicine, as defined by the Institute of Medicine, is the use of electronic information and communication technologies to provide and support HC when distance separates participants.[37] Telemedicine is often used interchangeably with the term telehealth, which is more broadly defined as the use of technology in general health related-services. Telemedicine comprises asynchronous and synchronous remote monitoring and mobile HC service (mHealth) technologies or an Internet-based system which uses “telecommunication” and “information technologies” so that patients can send/receive data to/from HC providers.[38] It overcomes the distance barrier and improves access to medical care in remote areas as well.[39]

In India, one of the oldest known telecardiology systems for tele-transmissions of ECGs was established using an indigenous technique. This system allows wireless transmission of ECG from distant places such as a moving intensive care unit van traveling from a patient’s home to the hospital. This system also helps in monitoring of patients with pacemakers in remote areas.[40] Telemedicine has been used by the Indian Space Research Organization (ISRO) to meet the needs of remote hospitals. The network was established by ISRO in 2001 and now covers approximately 100 hospitals across the country of which 78 are rural/remote district health centers that are connected to 22 specialty hospitals in major cities, providing

treatment to more than 25000 patients. Telemedicine system in India is also currently used as telestroke. Telestroke is used for diagnosing stroke patients and classifying stroke as ischemic or hemorrhagic so that patients are treated accordingly.[41]

Telemedicine has been tested for use in tertiary care as well. The "Self-Management Supported by Assistive, Rehabilitation and Telecare Technologies (SMART)" program helps in rehabilitation of patients with PAD involving the upper limbs. The SMART system has a wireless sensor system that allows for 3D real-time computer feedback. The system incorporates tracking devices worn on the upper arm, wrist and chest to record kinematic data from users when they are performing prescribed exercises. The system tracks and monitors the rehabilitation of upper arms and identifies, analyzes and corrects the motion patterns of patients and therapists.[42] Teleservices have provided people with access to information on CVD risk factors from a number of websites.

Tele-monitoring is being increasingly used in India in the diagnosis and management of disease to people in remote areas. An important facet involves data to be collected without the need for face to face contact with the patients; tele-monitoring facilitates ease of access for management and improves the clinical outcomes.[43] Patients who have suffered a cardiac event need constant monitoring and supervision. Traditional methods restrict patient mobility but ThulasiBai and colleagues have proposed the development of a Wearable Cardiac Telemedicine System that can help the mobility of patients, so as to quickly take them back to routine and thereby improve their psychological well-being.[44]

The All India Institute of Medical Science is taking the lead in carrying out several tele-medicine programs which include PAN—African e-network with 54 countries of the African Union, SAARC Telemedicine Project with 6 SAARC countries, In-house Telemedicine link with Rural Hospital at Ballabhgarh in Haryana, Link with 54 centres in India and also abroad.[45] In West Bengal, two hospitals where telemedicine centres have been established are the First Coronary Care Unit inaugurated in Siliguri District Hospital, Siliguri and Bankura Sammilani Hospital, Bankura, West Bengal in 2001.[46]

Technology in CMD Prevention

Mobile Phones

Mobile phones with their many uses are on the vanguard of CMD prevention. The most common among them being the mobile health applications or mHealth applications as they have access to a large population. Some examples include "LIVESTRONG MyQuit Coach – Dare to Quit Smoking" app that helps individuals create their own smoking cessation plan ultimately supporting cessation.[47] Whittaker R et al. describe a youth-oriented multimedia smoking cessation intervention delivered only through mobile phones. Out of 15 participants who took part in a pilot study, nine (60%) quit smoking during the program. This proves that a multimedia mobile phone smoking cessation program is technically feasible.[48] There are several other apps that are easily available and assist in planning and monitoring physical activity, diet plans, salt intake, etc.[47]

In addition to mobile-based applications another simple tool is text messaging, or texting, a way to send information to and from cellular and smartphone devices. Messages can be sent as text (Short Message Service or SMS), pictures, video, or audio (Multimedia Messaging Service or MMS). A text message can be sent to an individual or multiple mobile phones and devices. Text messaging can be used in many ways for CMD patient management such as:

- Locating local CVD and DM testing centers;
- Responding to questions about CVD and DM;
- Reminding patients of medical appointments by sending text reminders;
- Helping patients adhere to their medication schedules by sending text reminders;
- Encouraging people to get tested for atherosclerosis through peer networks;
- Raising money through a mobile giving/text-to-give campaign; and
- Increasing the levels of self-management practice and self-efficiency in patient CVDs.[49]

The Indian telecom network is the second largest in the world with nearly 900 million wireless telephone connections. This high density of network integration connects the remote areas and can be leveraged to deliver and empower public health services.[50] With inclusion of several in built features the mobile phone extends use beyond making/receiving

calls. The increased storage capacity, camera features allow a multitude of functions for transmission of information. In LMICs such as India they have been put to use for communicable disease or maternal and child care interventions but in developed countries it is being used in tobacco cessation and other lifestyle interventions for CVDs.[51]

Rajan et al. have proposed a wireless bio-signal retrieving system. Mobile phone is an important component of this system as the module detects abnormal interpretations in ECG and heart rate of a patient and gives a self-warning ring to the patient; simultaneously it sends a short message service warning to the doctor's mobile phone through the Global System for Mobile Communication.[52] The results bear great potential on preventing cardiac episodes and reduce mortality. There is potential for mHealth tools to better facilitate adherence to chronic disease management, but the evidence supporting its current effectiveness is mixed.

One of the recent analyses on use of smart phones for management of hypertension reveals that numerous applications are available from app stores but none of the apps employed the use of a BP cuff or had any documentation of validation against a gold standard with only 3% of those being developed by health care institutes/organizations.[53] Further research should focus on understanding and improving how mHealth tools can overcome specific barriers to adherence. The Government of India regulations regarding the safety limits, manufacture, marketing, and mobile use are still in primordial stages. There is a need for stringent guidelines by medical regulatory bodies regarding rules and regulations of phone usage while at class or attending patients. There are known adverse effects of radiofrequency waves generated from mobile phones such as changes in heart rate and BP.[54]

Social Media

Social networking sites such as Facebook, Twitter, WhatsApp, Instagram, etc. are immensely popular across the globe. Fifteen percent of social networking site users have received health-related information on the social networking sites,[55] making this a useful medium for prevention and management of CMDs. People have access to information on CVD and diabetes from these social networking sites and can ask questions related to CVD and DM

with experts on open forums. They can also be used to form social support groups for those living with CMDs who can exchange information.[56]

The World Heart Federation offers advocacy tool kits support to develop social media tools to raise awareness for prevention of CVDs.[57] In India, media campaigns were undertaken by the Government of India to cast spots on television and radio on the adverse effects of tobacco use.[58] HRIDAY (Health Related Information Dissemination Amongst Youth), a New Delhi-based nongovernmental organization through Youth 4 Health uses social media platforms such as Facebook and Twitter to engage young people for multipronged advocacy on tobacco control issues.[59]

Role of Technology in CMD Surveillance

The importance of strengthening public health surveillance for CMDs is necessary to provide early warning and develop actions as needed. Use of computer technologies has had a significant impact on surveillance methods for various purposes such as data collection, data analysis, and public health decision making. In chronic disease surveillance, advances in communication technology have resulted in the emergence of global health surveillance networks. Examples include the World Alliance for Risk Factor Surveillance (WARFS) and Americas' Network for Chronic Disease Surveillance (AMNET) initiated Behavioural Risk Factors Surveillance System (BRFSS) developed by the CDC.[60] Recognizing the benefits, there are several countries that intend to simulate and adopt similar surveillance systems.[60] The National Diabetes Surveillance System (NDSS) is a collaborative network of provincial and territorial diabetes surveillance systems in Canada. Canadian residents, who have used the Canadian HC system were recorded through NDSS.[61] The system links health insurance data from each province with the hospitalization database. Such a system provides long-term monitoring of the cases, their complications and management. It serves as an important tool for framing appropriate policy guidelines.

The Virtual Diabetes Registry System (VDR) in New Zealand keeps track of the number of people diagnosed with diabetes. The VDR has become an important tool for monitoring prevalence, policy-making processes, and supporting clinical quality improvement.[62] In the Indian context, the CARRS surveillance program was launched to develop a model

surveillance system for CMDs and risk factors in south Asian countries (India- Chennai and Delhi, Pakistan-Karachi). This surveillance model will generate data on prevalence and trends, help study the complex life-course patterns of CMDs, and provide a platform for developing and testing interventions and tools for prevention and control of CMDs in South-Asia.[63] The program has a strong technology component including the use of geographical information systems. New technologies will continue to improve surveillance system by improving methods epidemic investigation, data collection, epidemiological and statistical analysis, and information dissemination and use of surveillance information by decision makers.[64]

Electronic Health Records

As per the health information management systems society, the EHR is a longitudinal electronic record of patient's health information generated by one or more encounters in any HC delivery setting. Included in this information are patient demographics, progress notes, problems, medications, vital signs, past medical history, immunizations, laboratory data, and radiology reports. EHR systems automate and streamline the workflow of clinicians and can incorporate clinically useful features such as electronic alerts, guideline reminders, and automatic monitoring of quality of care indicators.[65,66] They are most often cited for their potential to reduce medical errors through decision support such as adverse drug interactions and they also have the potential to provide other benefits such as reducing drug costs and making medical history data available during emergency care.[67–69]

In the Indian context, the million deaths study (MDS) and medical certification of cause of death is worth mentioning. MDS is the largest electronic health-related data collection project in the world and is being done in partnership with the Government of India, which has provided access to its data collectors and data already collected. Aside from collecting fresh data the participating organization is analysing existing data and converting records to electronic form.[70] Deo et al. described a "web-based database management system" which was developed for collecting, managing and analysing information of diabetes patients. It is a menu driven software that allows authorized HC providers to access, enter, update and analyze patient information. The system also allows graphical representation of data using bar/pie charts and provides interactive web interfaces that allow users to query the

database and generate reports and is useful in diagnoses and treatment. Therefore, the web-based data management system has been found to be of significant advantage compared to conventional paper-based systems. [71]

Biomedical Sensors

Using biomedical sensors, health-related information is gathered via body worn wireless sensors and transmitted to caregivers via an information gateway such as a mobile phone. Patel S. et al. discuss how caregivers can use this information to implement interventions as needed. As part of the "BIOTEX project" (which is a wearable bio sensing textile to measure physiological parameters and the chemical composition of body fluids), supported by the European Commission, a series of biochemical sensors incorporated into textiles has been developed which helps in monitoring body fluids. A textile-based fluid collecting system and sensors for in-vitro and in-vivo testing of pH, sodium, and conductivity from body sweat have also been developed within the BIOTEX project. This wearable sensor system contributes to early detection of any changes in patients status that may require clinical intervention.[72]

The "Google contacts" continuously measures glucose levels of a diabetes patient through their tears simplifying the process of diabetes management. This wearable technology is still in its initial stages. It incorporates small wireless chips and glucose sensors sandwiched between two layers of soft contact lens materials and has a small hole that allows tear fluid to enter inside the sensor to measure blood sugar levels every second.[73]

Other Technologies

Several other technological innovations are being used in various aspects to reduce the burden of CMD. These include the Geographical Information Systems (GIS), stem cell therapy, and genetic approaches. The GIS is an integrated set of computerized hardware and software tools designed to capture, store, edit, organize, analyse and display spatially referenced data.[74] Spatial and temporal determinants of CMDs can be studied using modern GIS tools. GIS software can analyse geographic distribution, identify statistically significant spatial clusters or outliers, and assess overall patterns of clustering or dispersion. These

tools can be useful in many ways such as obtaining distribution of cardiac patients among populations and distributing health services in local areas and in populations.

For example, "Migrant clinicians' Network HEART (MCN's HEART/health and environment analysis and resource tool) is an interactive web-based geographic application that provides information to support field clinicians.[75] GIS is an important tool to locate services and understand the distribution of CMD in specific areas and guide policy decisions as per population distribution.[75] GIS can assist primary care physicians in providing guidance for disease control programs and strengthen the health system to improve the health of communities.[76] In India there are several projects using GIS in chronic disease research. The earlier mentioned CARRS surveillance study is an example where GIS is used to study the relationship between built environment, CMD and its risk factors.

On one hand the GIS tools provide an overview of the external or spatial distribution and on the other Genome-wide association studies (GWASs) and whole-genome sequencing help study the fundamental and distinctive unit of the individuals. These studies have led to the discovery of novel genomic determinants of CVDs and reveals the relevance of genetics and genomics for the prevention and treatment of CVDs.[77] Gene therapy may enlighten the path for treating diabetes mellitus. Islet cell transplantation has also shown a way for long term treatment options for patients with long-standing diabetes. This would cut down the external use of insulin, pain associated with insulin delivery, and improves patient outcomes although the bio-compatibility is questionable and is subject to further research.[78]

Conclusion

The last few decades have witnessed enormous growth in the development and application of technology in all spheres of life. Advances mainly in the fields of engineering, computer and biomedical sciences have resulted in technological innovations that have changed and continue to change the diagnosis, treatment and prevention of many diseases and conditions including the way HC is delivered. They have become an indispensable part of patient care with solutions for complex cardio metabolic procedures which has resulted in major reductions in CMD burden in many high income countries. The proliferation of smartphones and Internet connectivity provides us with additional opportunities.

The proliferation of smartphones and Internet connectivity provides us with additional Opportunities. Studies have reported that Life style choices including physical inactivity has been fuelling the CMD epidemic in India.[79,80] Newer technologies could play an important role in the control of these risk factors by improved access to information, risk factor assessment, and individually tailored interventions.

Most technological projects fail to achieve their aims in LMIC settings as they are not giving adequate importance to the underlying infrastructural and human resources needs.[81] Ethical issues relating to privacy and data security also need to be considered. The use of technology as part of a comprehensive package care can provide valuable returns. Cultural and social norms regarding the role and use of technology also need to be explored and the findings incorporated into health research involving technology. Nevertheless, immense advances in technology provide us with an opportunity to tame the beast that is the burden of CMDs in India.

References

1. Global Burden of Metabolic Risk Factors for Chronic Diseases Collaboration T. Cardiovascular disease, chronic kidney disease, and diabetes mortality burden of cardiometabolic risk factors from 1980 to 2010: a comparative risk assessment. LANCET Diabetes Endocrinol. 2014;2:634–47.

2. Yusuf S, Hawken S, Ounpuu S, Dans T, Avezum A, Lanas F, 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.

3. Weisfeldt ML, Zieman SJ. Advances In The Prevention And Treatment Of Cardiovascular Disease. Health Aff. 2007 Jan 1;26(1):25–37.

4. Santhiyakumari N, Rajendran P, Madheswaran M. Medical decision-making system of ultrasound carotid artery intima-media thickness using neural networks. J Digit Imaging. 2011;24(6):1112–25.

5. Kumar A, Kato Y, Motoharu H, Sifang C, Junpei O, Takeya W, et al. An update on three-dimensional ct angiography in aneurysms: a useful modality for a neurosurgeon. Turk Neurosurg. 2013;23(3):304–11.

6. Maheshwari S, Acharyya A, Puddu PE, Mazomenos EB, Leekha G, Maharatna K, et al. An automated algorithm for online detection of fragmented QRS and identification of its various morphologies. J R Soc Interface. 2013 Oct 16;10(89):20130761–20130761.

7. Binsalamah ZM, Paul A, Prakash S, Shum-Tim D. Nanomedicine in cardiovascular therapy: recent advancements. Expert Rev Cardiovasc Ther. 2012 Jun;10(6):805–15.

8. Godin B, Sakamoto JH, Serda RE, Grattoni A, Bouamrani A, Ferrari M. Emerging applications of nanomedicine for the diagnosis and treatment of cardiovascular diseases. Trends Pharmacol Sci. 2010 May;31(5):199–205.

9. Veiseh O, Tang BC, Whitehead KA, Anderson DG, Langer R. Managing diabetes with nanomedicine: challenges and opportunities. Nat Rev Drug Discov. Nature Publishing Group, a division of Macmillan Publishers Limited. All Rights Reserved.; 2014 Nov 28;14(1):45–57.

10. Lab on a chip : Insight : Nature [Internet]. [cited 2015 Nov 5]. Available from: http://www.nature.com/nature/supplements/insights/labonachip/

11. Sridhar S, Venugopal JR, Sridhar R, Ramakrishna S. Cardiogenic differentiation of mesenchymal stem cells with gold nanoparticle loaded functionalized nanofibers. Colloids Surf B Biointerfaces. 2015 Oct 1;134:346–54.

12. Guhathakurta S, Mathapati S, Bishi DK, Rallapalli S, Cherian KM. Nanofiber-reinforced myocardial tissue-construct as ventricular assist device. Asian Cardiovasc Thorac Ann. 2014 Oct;22(8):935–43.

13. Payne TH. Computer Decision Support Systems. CHEST J. American College of Chest Physicians; 2000 Aug 1;118(2_suppl):47S.

14. Kawamoto K, Houlihan CA, Balas EA, Lobach DF. Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. BMJ. 2005 Apr 2;330(7494):765.

15. Balas EA, Austin SM, Mitchell JA, Ewigman BG, Bopp KD, Brown GD. The clinical value of computerized information services. A review of 98 randomized clinical trials. Arch Fam Med. 1996 May;5(5):271–8.

16. Garg AX, Adhikari NKJ, McDonald H, Rosas-Arellano MP, Devereaux PJ, Beyene J, et al. Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: a systematic review. JAMA. American Medical Association; 2005 Mar 9;293(10):1223–38.

17. Hunt DL, Haynes RB, Hanna SE, Smith K. Effects of Computer-Based Clinical Decision Support Systems on Physician Performance and Patient Outcomes. JAMA. 1998 Oct 21;280(15):1339.

18. Hunt JS, Siemienczuk J, Gillanders W, LeBlanc BH, Rozenfeld Y, Bonin K, et al. The impact of a physician-directed health information technology system on diabetes outcomes in primary care: a pre- and post-implementation study. Inform Prim Care. 2009;17(3):165–74.

19. Johnston ME, Langton KB, Haynes RB, Mathieu A. Effects of computer-based clinical decision support systems on clinician performance and patient outcome. A critical appraisal of research. Ann Intern Med. 1994 Jan 15;120(2):135–42.

20. Van Wyk JT, Van Wijk MA, Moorman PW, Mosseveld M, Van Der Lei J. Cholgate - a randomized controlled trial comparing the effect of automated and on-demand decision support on the management of cardiovascular disease factors in primary care. AMIA Annu Symp Proc. 2003 Jan;1040.

21. Bosworth HB, Olsen MK, Dudley T, Orr M, Goldstein MK, Datta SK, et al. Patient education and provider decision support to control blood pressure in primary care: a cluster randomized trial. Am Heart J. 2009 Mar;157(3):450–6.

22. Anchala R, Pant H, Prabhakaran D, Franco OH. "Decision support system (DSS) for prevention of cardiovascular disease (CVD) among hypertensive (HTN) patients in Andhra Pradesh, India"--a cluster randomised community intervention trial. BMC Public Health. 2012;12(1):393.

23. Praveen D, Patel A, McMahon S, Prabhakaran D, Clifford GD, Maulik PK, et al. A multifaceted strategy using mobile technology to assist rural primary healthcare doctors and frontline health workers in cardiovascular disease risk management: protocol for the SMARTHealth India cluster randomised controlled trial. Implement Sci. 2013;8:137.

24. Tian M, Ajay V, Dunzhu D, Hameed S, Li X, Liu Z, et al. A Cluster-Randomized Controlled Trial of a Simplified Multifaceted Management Program for Individuals at High Cardiovascular Risk (SimCard Trial) in Rural Tibet, China, and Haryana, India. Circulation. 2015 Jul 17;

25. Shah S, Singh K, Ali MK, Mohan V, Kadir MM, Unnikrishnan a G, et al. Improving diabetes care: multi-component cardiovascular disease risk reduction strategies for people with diabetes in South Asia--the CARRS multi-center translation trial. Diabetes Res Clin Pract. Elsevier Ireland Ltd; 2012 Nov;98(2):285–94.

26. Anchala R, Pinto MP, Shroufi A, Chowdhury R, Sanderson J, Johnson L, et al. The role of Decision Support System (DSS) in prevention of cardiovascular disease: a systematic review and meta-analysis. PLoS One. 2012 Jan;7(10):e47064.

27. Ali MK, Shah S, Tandon N. Review of electronic decision-support tools for diabetes care: a viable option for low- and middle-income countries? J Diabetes Sci Technol. 2011 May;5(3):553–70.

28. Zeevaart JG, Wang L, Thakur V V, Leung CS, Tirado- J, Bailey CM, et al. NIH Public Access. 2009;130(29):9492–9.

29. Assmann A, Heke M, Kröpil P, Ptok L, Hafner D, Ohmann C, et al. Laser-Supported CD133+ Cell Therapy in Patients with Ischemic Cardiomyopathy: Initial Results from a Prospective Phase I Multicenter Trial. PLoS One. 2014;9(7):e101449.

30. Amato B, Compagna R, Della Corte GA, Martino G, Bianco T, Coretti G, et al. Peripheral blood mono-nuclear cells implantation in patients with peripheral arterial disease: a pilot study for clinical and biochemical outcome of neoangiogenesis. BMC Surg. BioMed Central Ltd; 2012;12(Suppl 1):S1.

31. Wang TS, Hernandez AF, Felker GM, Milano C a., Rogers JG, Patel CB. Valvular heart disease in patients supported with left ventricular assist devices. Circ Hear Fail. 2014;7(1):215–22.

32. Schmauss D, Haeberle S, Hagl C, Sodian R. Three-dimensional printing in cardiac surgery and interventional cardiology: a single-centre experience. Eur J Cardiothorac Surg. 2014;1–9.

33. Jaganathan SK, Mohandas H, Sivakumar G, Kasi P, Sudheer T, Avineri Veetil S, et al. Enhanced Blood Compatibility of Metallocene Polyethylene Subjected to Hydrochloric Acid Treatment for Cardiovascular Implants. Biomed Res Int. Hindawi Publishing Corporation; 2014;2014:1–7.

34. Gupta a K, Purkayastha S, Kapilamoorthy TR, Nair MD, Krishnamoorthy T, Rupa S, et al. Carotid artery stenting: results and long-term follow-up. Neurol India. 2006;54(1):68–72.

35. Selam JL, Micossi P, Dunn FL, Nathan DM. Clinical trial of programmable implantable insulin pump for type I diabetes. Diabetes Care. 1992;15(7):877–85.

36. Gluco(M) Wristband Monitors Your Blood Glucose Levels | Tuvie [Internet]. [cited 2015 Nov 5]. Available from: http://www.tuvie.com/glucom-wristband-monitors-your-blood-glucose-levels/

37. Field M, editor. Telemedicine: A Guide to Assessing Telecommunications for Health Care. National Academies Press; 1996. 257 p.

38. Santamore WP, Homko CJ, Kashem A, McConnell TR, Bove A a. Using a telemedicine system to decrease cardiovascular disease risk in an underserved population: design, use, and interim results. Conf Proc IEEE Eng Med Biol Soc. 2007;2007:3701–4.

39. American Telemedicine Association [Internet]. [cited 2015 Nov 5]. Available from: http://www.americantelemed.org/

40. Daniel H, Sulmasy LS. Policy Recommendations to Guide the Use of Telemedicine in Primary Care Settings: An American College of Physicians Position Paper. Ann Intern Med. 2015 Sep 8;

41. Srivastava P V, Sudhan P, Khurana D, Bhatia R, Kaul S, Sylaja PN, et al. Telestroke a viable option to improve stroke care in India. Int J Stroke. 2014 Oct;9 Suppl A1:133–4.

42. Parker J, Mawson S, Mountain G, Nasr N, Zheng H. Stroke patients' utilisation of extrinsic feedback from computer-based technology in the home: a multiple case study realistic evaluation. BMC Med Inform Decis Mak. 2014;14(1):46.

43. Reddy S, Bahl A, Talwar KK. Congestive heart failure in Indians: how do we improve diagnosis & management? Indian J Med Res. 2010 Nov;132:549–60.

44. Thulasi Bai V, Srivatsa SK. Design of wearable cardiac telemedicine system. Int J Electron Healthc. 2007 Jan;3(3):303–16.

45. Telemedicine Facility [Internet]. [cited 2016 Jan 5]. Available from: http://www.aiims.edu/aiims/telemedicine/telepage.htm

46. Dasgupta A, Deb S. Telemedicine: a new horizon in public health in India. Indian J Community Med. 2008 Jan;33(1):3–8.

47. There s an App for That: Policy and Technological Advances in the Prevention of Cardiovascular Disease - Guest Blog - Scientific American Blog Network [Internet]. [cited 2015 Nov 5]. Available from: http://blogs.scientificamerican.com/guest-blog/theres-an-app-for-that-policy-and-technological-advances-in-the-prevention-of-cardiovascular-disease/

48. Whittaker R, Maddison R, McRobbie H, Bullen C, Denny S, Dorey E, et al. A multimedia mobile phone-based youth smoking cessation intervention: findings from content development and piloting studies. J Med Internet Res. Journal of Medical Internet Research; 2008 Jan 25;10(5):e49.

49. Wu C-JJ, Sung H-C, Chang AM, Atherton J, Kostner K, Courtney M, et al. Protocol for a randomised blocked design study using telephone and text-messaging to support cardiac patients with diabetes: a cross cultural international collaborative project. BMC Health Serv Res. BMC Health Services Research; 2013;13(1):402.

50. Government of India. Department of Telecommunications Ministry of Communications & Information T echnology . Annual Report 2014-15. New Delhi

51. Ajay VS, Praveen PA, Millett C, Kinra S, Prabhakaran D. Role of mobile phone technology in tobacco cessation interventions. Glob Heart. 2012;7(2):167–74.

52. Rajan SP, Rajamony S. Viable investigations and real-time recitation of enhanced ECG-based cardiac telemonitoring system for homecare applications: a systematic evaluation. Telemed J E Health. 2013 Apr;19(4):278–86.

53. Kumar N, Khunger M, Gupta A, Garg N. A content analysis of smartphone-based applications for hypertension management. J Am Soc Hypertens. 2015 Feb;9(2):130–6.

54. Paul B, Saha I, Kumar S, Samim Ferdows SK, Ghose G. Mobile phones: time to rethink and limit usage. Indian J Public Health. Jan;59(1):37–41.

55. The Social Life of Health Information, 2011 | Pew Research Center [Internet]. [cited 2015 Nov 5]. Available from: http://www.pewinternet.org/2011/05/12/the-social-life-of-health-information-2011/

56. New Media Tools [Internet]. [cited 2015 Nov 5]. Available from: https://www.aids.gov/using-new-media/tools/

57. Social media | World Heart Federation [Internet]. [cited 2016 Jan 5]. Available from: http://www.world-heart-federation.org/what-we-do/archives/hearts-of-children/material-and-resources/social-media/

58. Murukutla N, Turk T, Prasad CVS, Saradhi R, Kaur J, Gupta S, et al. Results of a national mass media campaign in India to warn against the dangers of smokeless tobacco consumption. Tob Control. 2012 Jan;21(1):12–7.

59. Shrivastav R, Nazar GP, Stigler MH, Arora M. Health promotion for primordial prevention of tobacco use. Glob Heart. 2012 Jul;7(2):143–50.

60. CDC - BRFSS [Internet]. [cited 2015 Nov 5]. Available from: http://www.cdc.gov/brfss/

61. Public Health Agency of Canada. Report from the National Diabetes Surveillance System: Diabetes in Canada, 2009. Diabetes. 2009;1–26.

62. Jo EC, Drury PL, Jo EC, Drury PL. Development of a Virtual Diabetes Register using Information Technology in New Zealand. 2015;21(1):49–55.

63. Nair M, Ali MK, Ajay VS, Shivashankar R, Mohan V, Pradeepa R, et al. CARRS Surveillance study: design and methods to assess burdens from multiple perspectives. BMC Public Health. BMC Public Health; 2012 Jan;12(1):701.

64. Choi BCK. The Past, Present, and Future of Public Health Surveillance. Scientifica (Cairo). 2012;2012(Table 1):1–26.

65. HIMSS - Healthcare Information and Management Systems Society [Internet]. [cited 2015 Nov 5]. Available from: http://www.himss.org/

66. Bostrom AC, Schafer P, Dontje K, Pohl JM, Nagelkerk J, Cavanagh SJ. Electronic health record: implementation across the Michigan Academic Consortium. Comput Inform Nurs. Jan;24(1):44–52.

67. Chaudhry B, Wang J, Wu S, Maglione M, Mojica W, Roth E, et al. Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. Ann Intern Med. 2006 May 16;144(10):742–52.

68. Schillinger D, Piette J, Grumbach K, Wang F, Wilson C, Daher C, et al. Closing the loop: physician communication with diabetic patients who have low health literacy. Arch Intern Med. 2003 Jan 13;163(1):83–90.

69. Stiell A, Forster AJ, Stiell IG, van Walraven C. Prevalence of information gaps in the emergency department and the effect on patient outcomes. CMAJ. 2003 Nov 11;169(10):1023–8.

70. Jha P, Gajalakshmi V, Gupta PC, Kumar R, Mony P, Dhingra N, et al. Prospective study of one million deaths in India: rationale, design, and validation results. PLoS Med. Public Library of Science; 2006 Feb 20;3(2):e18.

71. Deo SS, Deobagkar DND. Design and development of a web-based application for diabetes patient data management. Inform Prim Care. 2005;13:35–41.

72. Patel S, Park H, Bonato P, Chan L, Rodgers M. A review of wearable sensors and systems with application in rehabilitation. J Neuroeng Rehabil. BioMed Central Ltd; 2012;9(1):21.

73. Doyle M. Google contacts will help diabetics monitor blood sugar via tears. 2014.

74. Foote KE, Lynch M. Geographic Information Systems as an Integrating Technology: Context, Concepts, and Definitions [Internet]. Department of Geography, The University of Colorado at Boulder. 1995. Available from: http://www.colorado.edu/geography/gcraft/notes/intro/intro_f.html

75. Centers for Disease Control. Geographic Information System at CDC. Retrieved at 25, Aug 2015. Available at http://gis.cdc.gov/mcnarcims/default.asp,http://www.cdc.gov/gis/application.htm

76. Geraghty EM, Balsbaugh T, Nuovo J, Tandon S. Using Geographic Information Systems (GIS) to assess outcome disparities in patients with type 2 diabetes and hyperlipidemia. J Am Board Fam Med. Jan;23(1):88–96.

77. Ganesh SK, Arnett DK, Assimes TL, Basson CT, Chakravarti A, Ellinor PT, et al. Genetics and genomics for the prevention and treatment of cardiovascular disease: Update a scientific statement from the american heart association. Circulation. 2013. 2813-2851 p.

78. Onaca N, Naziruddin B, Matsumoto S, Noguchi H, Klintmalm GB, Levy MF. Pancreatic islet cell transplantation: update and new developments. Nutr Clin Pr. 2007;22:485–93.

79. O'Keefe EL, DiNicolantonio JJ, Patil H, Helzberg JH, Lavie CJ. Lifestyle Choices Fuel Epidemics of Diabetes and Cardiovascular Disease Among Asian Indians. Prog Cardiovasc Dis. Elsevier Inc.; 2015;1–9.

80. Pratt M, Perez LG, Goenka S, Brownson RC, Bauman A, Sarmiento OL, et al. Can Population Levels of Physical Activity Be Increased? Global Evidence and Experience. Prog Cardiovasc Dis. Elsevier B.V.; 2015;57(4):356–67.

81. Epic Fail: Tech Tricks Are No Fix for Developing-World Problems - India Real Time - WSJ [Internet]. [cited 2015 Nov 6]. Available from: http://blogs.wsj.com/indiarealtime/2015/09/04/epic-fail-tech-tricks-are-no-fix-for-developing-world-problems/

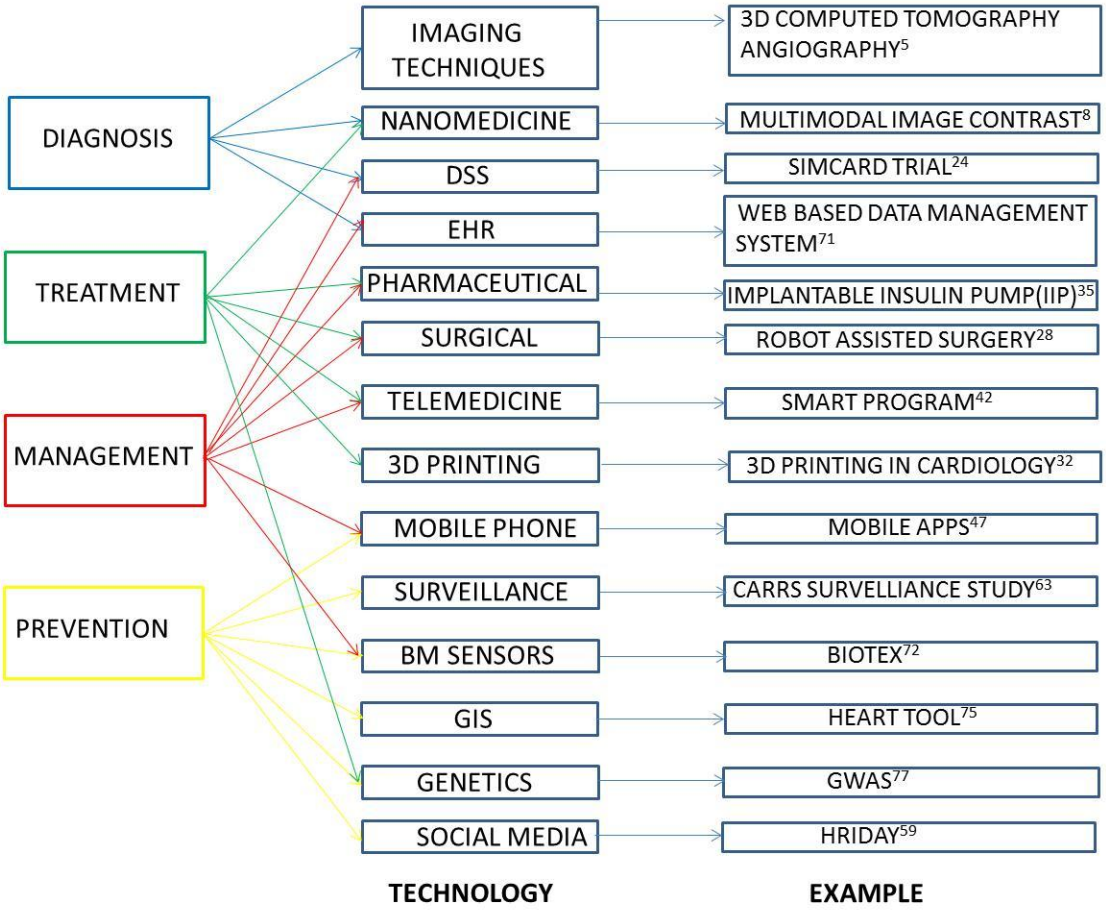

Figure 1: Newer technologies in CMD diagnosis, treatment, management and prevention.