Technologies for Healthcare Sector in India

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FOREWORD

Indian National Academy of Engineering (INAE) has conducted a comprehensive and exhaustive Research Study on "Technologies for Healthcare Sector in India". India in the context of adequate and quality health care to both rural and urban population is emerging as a country with a daunting challenge and unparallel opportunity.

The INAE study on healthcare provides an in-depth status on the current Healthcare scenario in India. The report investigates both the existing and emerging technologies in the healthcare sector. The broad topics covered in the report include key factors leading to the growth of healthcare sector in India, India's healthcare System, technologies for the healthcare sector, a comprehensive perspective on challenges that lie ahead and global medical and an outlook on equipment market.

In the decade 2010-2020, India shall see a paradigm change with improvements in healthcare. For this objective to be realized capacity to generate and translate scientific and technological advancements into healthcare products and processes is essential. In the context of health care, Translational Science is the overall process of converting the main scientific discoveries and advances in the laboratories into innovative and cost-effective medical products and treatments that are beneficial to human health. Successful translation requires a variety of scientific, medical, technological and business capacities combined with innovations in a synergetic manner with interdisciplinary team efforts.

The research study emphasis need for scalable and cost-effective pervasive technologies for healthcare. With the convergence of telecom and healthcare sectors, mHealth is becoming an extremely important paradigm in India Today. Cell phones have become a common utility device cutting across the income groups, traditions and geographies. The authors of the study visualize emergence of new services and applications on the basis of mobile phones and associated innovations in healthcare targeting the masses in the interior regions of the country. The marriage of telecom and healthcare sectors is bound to yield major dividends for the country in the coming years. This is one area where authors expect huge investments from multinationals, private sector and venture capitalists in India. Cost-effective equipment and instruments for screening and diagnosis at the 'Point of Care' is recognized as other essential component of healthcare delivery system.

Healthcare in semi-urban and rural areas in India needs significant improvements w.r.t. doctors, trained paramedical staff. Robust management system is currently poor and the problem is exacerbated by the lack of Doctors/Specialists in semi-rural and rural areas. We need to overcome this challenge by increasing our capacity in education of doctors and paramedical personnel through attractive career options, policy interventions and motivation.

There are no simple answers to the challenges above. The authors believe that the country needs to have comprehensive road map, a way forward and high leverage of ICT technologies to improve the state of healthcare in rural and semi-rural areas along with the other essential components for achieving inspiring results.

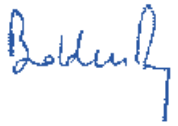
The Government needs to provide major incentives for specialists and Doctors so that they consider service in rural and semi-urban areas of the country. This is an essential and nontrivial requirement, which requires efforts, policies and motivation.

Medical Insurance to all citizens is a critical step. The country needs to invest huge amount of efforts to decide on the policies and allocate money to ensure that citizens who cannot afford treatment and medicines, are provided health insurance by the state.

Venture capitalists and angel investors to be successful need incubation centres to generate success stories in the healthcare sector. Though the last few years have witnessed a surging interest in healthcare by the private sector in India, a lot more remains to be done. This is possible through good policies and examples of success.

The Academy is grateful to the dedicated efforts of INAE team lead by Dr. Rajeev Shorey, Coordinator and Dr. M. J. Zarabi as member. The combined wisdom and experience of the team coupled with the contributions made by a large number of experts, medical practitioners and researchers have enhanced the quality and usefulness of the study.

It is my sincere hope that the detailed study will serve a useful purpose to researchers and practitioners in India and abroad and encourage new investigations, innovations and effective policies in the healthcare sector, thus making India a healthy and happy country with a capacity to emerge as one of the exemplary sustainable conscious and performing super-economies of the world.



(Baldev Raj)

PREFACE

Healthcare is one of India's largest sectors, in terms of revenue and employment, and the sector is expanding rapidly. The sector has seen tremendous growth over the last decade and the current development and pace will trigger the market to reach the estimated market size. The healthcare market in India has opened up for new entrants that hitherto consisted of mainly importers dominating the market.

The population increase in India is due in part to a decline in infant mortality, the result of better healthcare facilities and the government's emphasis on eradicating diseases such as hepatitis and polio among infants. In addition, life expectancy is rapidly approaching the levels of the western world. By 2025, an estimated 189 million Indians will be at least 60 years of age—triple the number in 2004, thanks to greater affluence and better hygiene. The growing elderly population will place an enormous burden on India's healthcare infrastructure.

Engineering will play a major role towards a better and deeper understanding of the technical challenges that surround the healthcare sector in India. Engineers can develop, adapt, and help implement the technological enablers of continuous innovations in health care.

The objective of this report is to gain a deeper understanding of the healthcare sector with a major focus on India. The report investigates in detail both existing and emerging technologies in the healthcare sector. More specifically, the broad topics covered in the report include key factors leading to the growth of healthcare sector in India, India's healthcare System, technologies for the healthcare sector, technical challenges that lie ahead and global medical and equipment market. The report ends with our findings and core recommendations.

A great deal of effort has been made in obtaining information that is already available – from technologies, applications, standards to compilation of key players and their role in the healthcare sector. The report should be considered as an in-depth survey of the healthcare sector in India with an emphasis on 'technologies' and how technologies can help in improving the healthcare sector. It is hoped that the report will serve as an actionable document for thought leaders in the Government, Industry and Academia, in India and abroad, and will spawn a lot more research, innovation and incubation in the healthcare sector in the years to come.

Dr. Rajeev Shorey

Dr. M J Zarabi

5 April, 2011

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India Health Statistics 2008 (Source: WHO [39])

- Total population: 1,151,751,000
- Gross national income per capita (PPP international $): 2,460
- Life expectancy at birth m/f (years): 62/64
- Healthy life expectancy at birth m/f (years, 2003): 53/54
- Probability of dying under five (per 1 000 live births): 76
- Probability of dying between 15 and 60 years m/f (per 1 000 population): 276/203
- Total expenditure on health per capita (Intl $, 2006): 109
- Total expenditure on health as % of GDP (2006): 4.9

1. INTRODUCTION

India's healthcare sector has been growing rapidly and is estimated to be worth US$ 40 billion by 2012, according to Pricewaterhouse Coopers in its report, 'Healthcare in India: Emerging market report 2007' [26]. Revenues from the healthcare sector account for 5.2 per cent of the GDP, making it the third largest growth segment in India. According to [13], the Indian healthcare industry is expected to become a US$ 280 billion industry by 2022.

The sector's growth will be driven by the country's growing middle class, which can afford quality healthcare. Over 150 million Indians have annual incomes of more than US$ 1,000, and many who work in the business services sector earn as much as US$ 20,000 a year. Today at least 50 million Indians can afford to buy Western medicines - a market only 20 per cent smaller than that of the UK [26].

If the economy continues to grow faster than the economies of the developed world, and the literacy rate keeps rising, much of western and southern India will be middle class by 2020.

To meet this surging demand, the country needs US$ 50 billion annually for the next 20 years, says a CII study. India needs to add 2 million beds to the existing 1.1 million by 2027, and requires immediate investments of US$ 82 billion.

Funds in the sector have been largely private. In fact, it is believed that the private sector provides 60 per cent of all outpatient care in India and as much as 40 per cent of all in-patient care. It is estimated that nearly 70 per cent of all hospitals and 40 per cent of hospital beds in the country are in the private sector, says PWC [26].

Let us take a peek at the investments in the healthcare sector and the market for medical equipment in India in order to better understand the overall growth of this sector in India.

Investments

The opportunities presented by the healthcare sector have made it a major draw for potential investors. The healthcare sector attracted US$ 379 million in 2006 - 6.3 per cent of the total private equity (PE) investment of US$ 5.93 billion. The PE deals that the sector attracted in 2006 were as large as inputs into the automotive sector.

Let us see some of the statistics related to the investments in the healthcare sector in India.

- Medical care services provider Apollo Hospitals group will invest about US$ 235.69 million in the next 18 months to set up 15 hospitals in tier-II and tier-III cities in India.
- The Indian government plans to invest US$ 177.22 million across the golden quadrilateral (GQ) project, to develop nearly 140 trauma care centres on the 6,500 km long north-south and east-west corridors.
- Fortis Healthcare Ltd will add 28 hospitals to its 12-hospital chain by 2012.
- George Soros's fund Quantum and BlueRidge bought 10 per cent in Fortis Healthcare.
- Manipal Health Systems raised over US$ 20 million equity from IDFC Private Equity Fund.

- Bangalore-based HealthCare Global Enterprises raised over US$ 10 million in equity from IDFC.
- Metropolis Health Services, a diagnostic chain, raised over US$ 8 million in equity from ICICI Venture.
- Investment firms Apax Partners, IFC and Trinity Capital have invested over US$ 200 million in hospital firms.

Medical equipment and IT

With the potential of the healthcare sector being what it is, ancillary industries such as healthcare equipment and information technology in healthcare are also witnessing a spurt.

The soaring growth projections have prompted foreign medical equipment makers to float Indian subsidiaries – 30 of them received import clearances in 2007 alone. Boston Scientific, Abbott, Becton Dickinson, Guidant, Medtronic, B Braun, Johnson & Johnson, DePuy, Advanced Medical Optics and Stryker are among the leading firms, whose Indian subsidiaries received approvals to import medical devices during the year.

Investments into the medical and surgical instruments segment amount to US$ 115.29 million over the period August 1991 to April 2007. A recent FICCI-Ernst & Young study has predicted 15-20 per cent growth for the Indian medical equipment market and estimated market size to be about US$ 5 billion by 2012.

Hospitals have realised that information technology (IT) can be an effective tool towards efficient systems. According to a report by Springboard Research, India has the fastest growing healthcare IT market in Asia, with an expected growth rate of 22 per cent, followed closely by China and Vietnam. In fact, the Indian healthcare technology market is poised to be worth more than US$ 254 million by 2012.

The role of Information Technology in the healthcare sector will be discussed in detail in later sections. We will also discuss the trends in medical equipments in this sector.

2. THE OBJECTIVES AND SCOPE OF THE STUDY

While healthcare sector could broadly be categorized into (i) Medical diagnostics and (ii) Therapeutics, it encompasses testing, treatment, care, procedures and any other service or intervention, nursing, rehabilitative, palliative, convalescent, preventative, and/or other health related purpose or combinations thereof, including reproductive health care and emergency medical treatment, in any system of medicine. Technology for healthcare includes machinery/ equipments/devices or methods for diagnostics as well as for therapeutics that may be used in relation to provision of healthcare services.

Obviously the area of healthcare is vast and no single report can be expected to deal with it comprehensively and exhaustively. The present study relates more to the status of our healthcare sector and deals primarily with the diagnostic side of the healthcare.

Healthcare is among the largest sectors that provides the largest employment. The healthcare industry not only provides better health for the nation but also will make a significant economic impact on the nation. Any spend on Healthcare leads to contribution to GDP from additional employment in Manufacturing, Pharmaceutical and Healthcare.

Changes in lifestyle, high stress in the workplace, deteriorating urban infrastructure, poor and irregular eating habits, and lack of regular exercise are only some of the contributors to health-related disorders in Indian society today. In the past, healthcare and the technologies for healthcare sector have not got the attention that they deserve. This scenario is now changing rapidly. India is now at the threshold of a major revolution in the healthcare sector. Closely coupled with the healthcare sector is the Information Technology (IT) sector. The huge success and expertise in the IT sector in India is bound to play a major role in influencing the healthcare sector.

We believe that engineering and technology will play a major role towards a better understanding of the technical challenges that surround the healthcare sector in India. Engineers can develop, adapt, and help implement the technological enablers of continuous innovations in health care.

The objective of this report is to gain a deeper understanding of the healthcare sector in India and study in detail both existing and emerging technologies in the sector with a view to make some critical observations and offer some recommendations for improvement in our healthcare sector.

The report specifically attempts to address issues and facts that are critical to the healthcare sector, such as:

- What are the emerging trends in the Healthcare sector in India?
- What are the regulations and the policies environment in the industry?
- What is the future scenario of the Healthcare Market in India?
- Who are the Key players in the Healthcare Market in India?
- What opportunities exist for the Healthcare Market?
- What Challenges are faced by the industry?

- How is the market affected by the other factors prevailing in the economy?
- What are the trends in Indian Medical Tourism Industry?

We would like to point out that the report is a conscious attempt in collating the major developments and trends in the healthcare sector in the world, with an emphasis on India. A great deal of effort has been made in obtaining information that is already available – from technologies, applications, standards to compilation of key players and their role in the healthcare sector. The report should thus be considered as an in-depth survey of the healthcare sector in India with an emphasis on "technologies" and how technologies can help in improving the healthcare sector. It is hoped that the report will serve as an actionable document for the Government, industry and academia, and will spawn a lot more research and incubation in the healthcare sector.

3. KEY FACTORS DETERMINING THE GROWTH OF HEALTHCARE SECTOR IN INDIA

Sampling Research Pvt. Ltd. has conducted a research study on healthcare in India and the perspectives on Intellectual Property Rights in the Pharmaceutical sector. This study was done by conducting in depth interviews of highly placed people (ministers/ directors/ beneficiaries/ NGOs) across all strata of the healthcare system [143]

Not surprisingly most of the respondents rated healthcare in India at an average of a dismal 4 points on a scale of 1-10 (where 1 is lowest and 10 is highest). Many factors contribute to this sorry state of affairs. We will discuss several such factors in this report.

Let us begin by understanding some of the key drivers that are responsible for the phenomenal growth of the healthcare sector in India.

- Growing Population and Economy
- Rising Middle Class
- Rise of Disease
- Deteriorating Infrastructure
- Lack of Insurance

In the following sections, we will discuss each of the above factors in some detail. This will provide the right motivation for the study in this report.

3.1 Growing Population and Economy

Let's start by understanding our crowded world with some staggering statistics.

The United Nations Population Division issued a report (March 13, 2007) stating that "the world population will likely increase by 2.5 billion over the next 43 years, passing from the current 6.7 billion to 9.2 billion in 2050. This increase is equivalent to the total size of the world population by 1950, and it will be absorbed mostly by the less developed regions, whose population is projected to rise from 5.4 billion in 2007 to 7.9 billion in 2050. In contrast, the population of the more developed regions is expected to remain largely unchanged at 1.2 billion, and would have declined, were it not for the projected net migration from developing to developed countries, which is expected to average 2.3 million persons annually." [40].

Here are some additional alarming statistics related to the crowded cities in the world. In 1800, London was the world's largest city with one million people. By 1960, there were 111 cities with more than one million people. By 1995 there were 280, and today there are over 300, according to UN Population Fund statistics. The number of mega cities (with ten million or more inhabitants) in the world has climbed from 5 in 1975 to 14 in 1995 and is expected to reach 26 cities by 2015, according to UN. These exploding populations are rapidly overwhelming infrastructure in these mega cities – nineteen million people in Mumbai alone – as well as driving loss of arable land, deforestation, overfishing, water shortages, and air and water pollution.

It is no surprise therefore that what we are witnessing today – an n-fold increase in diseases, particularly in the developing world – is to a large extent caused by the crowded world that we live in.

"Today, there are 6.7 billion people sharing the planet," said General Hayden in a speech at Kansas State University (April 30, 2008). By mid-century, the best estimates point to a world population of more than 9 billion. That's a 40 to 45 percent increase and most of that growth is almost certain to occur in countries least able to sustain it, and that will create a situation that will likely fuel instability and serious healthcare related issues.

Let's now focus specifically on India. One driver of growth in the healthcare sector is India's booming population, currently 1.1 billion and increasing at a 2% annual rate. By 2030, India is expected to surpass China as the world's most populous nation. By 2050, the population is projected to reach 1.6 billion.

This population increase is due in part to a decline in infant mortality, the result of better healthcare facilities and the government's emphasis on eradicating diseases such as hepatitis and polio among infants. In addition, life expectancy is rapidly approaching the levels of the western world. By 2025, an estimated 189 million Indians will be at least 60 years of age—triple the number in 2004, thanks to greater affluence and better hygiene. The growing elderly population will place an enormous burden on India's healthcare infrastructure. The Indian economy, estimated at roughly $1 trillion, is growing in tandem with the population. Goldman Sachs predicts that the Indian economy will expand by at least 5% annually for the next 45 years, and that it will be the only emerging economy to maintain such a robust pace of growth [26].

3.2 Rising Middle Class

India traditionally has been a rural, agrarian economy. Nearly three quarters of the population still lives in rural areas, and as of 2004, an estimated 27.5% of Indians were living below the national poverty line. Some 300 million people in India live on less than a dollar a day, and more than 50% of all children are malnourished.

However, India's thriving economy is driving urbanization and creating an expanding middle class, with more disposable income to spend on healthcare. While per capita income was $620 in 2005, over 150 million Indians have annual incomes of more than $1,000, and many who work in the business services sector earn as much as $20,000 a year. While this is a fraction of the income that their US peers earn, it is the equivalent of more than $100,000 per year when adjusted for purchasing power parity. More women are entering the workforce as well, further boosting the purchasing power of Indian households. Between 1991 and 2001, the percentage of women increased from 22% to 26% of the workforce, according to the latest Indian government census. Many of these women are highly educated: the ratio of women to men who have a college degree or higher level of education is 40:60. Thanks to rising income, today at least 50 million Indians can afford to buy Western medicines—a market only 20% smaller than that of the UK. If the economy continues to grow faster than the economies of the developed world, and the literacy rate keeps rising, much of western and southern India will be middle class by 2020 [26].

3.3 Rise of Disease

Before we attempt to understand the healthcare sector in India, we first need to get a handle on the statistics related to the causes of deaths in India and some of the killer diseases in India.

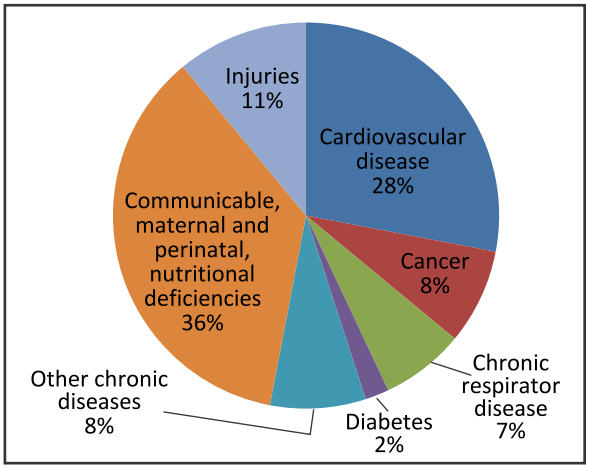

Figure 1 : Projected Deaths by Cause, All Ages, India, 2005 [34]

In India, chronic diseases are projected to account for 53% of all deaths (see Figure 1) [34]. WHO projects that over the next 10 years in India, over 60 million people will die from a chronic disease. The deaths from infectious diseases, maternal and perinatal conditions, and nutritional deficiencies combined will decrease by 15%. Deaths from chronic diseases will increase by 18% - most markedly, deaths from diabetes will increase by 35% [34].

The following are some of the solutions proposed in [34]:

- A least 80% of premature heart disease, stroke and type 2 diabetes, and 40% of cancer could be prevented through healthy diet, regular physical activity and avoidance of tobacco products.
- Cost-effective interventions exist, and have worked in many countries: the most successful strategies have employed a range of population-wide approaches combined with interventions for individuals.
- WHO estimates that an additional 2% annual reduction in national-level chronic disease death rates in India over the next 10 years would result in an economic gain of 15 billion dollars for the country.

We now focus on some of the most common diseases in India, namely, Cardiovascular Disease, Malaria, Tuberculosis, Cancer and Diabetes.

3.3.1 Cardiovascular Disease

One of the most common life threatening disease in India is the Heart disease.

That's been the attitude of most Asians toward heart disease: it's a problem for rich Westerners supersizing themselves to death. Asia's health worries were the age-old problems of infectious disease, famine and malnutrition. But on the road to modernization, a large proportion of Asians are trading healthy traditional diets for fattier foods, physical jobs for deskbound sloth, the relative calm of the countryside for the stressful city. Heart-attack victims are just the first wave of a swelling population of Asians with heart problems.

Here are a few statistics to make our ticker skip a beat: while deaths from heart attacks have declined more than 50% since the 1960s in many industrialized countries, 80% of global Cardiovascular Disease related deaths now occur in low and middle-income nations—which covers most countries in Asia.

In India in the past five decades, rates of coronary disease among urban populations have risen from 4% to 11% [28].

To add to the worries of Indians, an international group of researchers has warned that India may have 60 percent of the world's heart disease patients by 2010. This is so since a study has shown that one in 25 individuals in the country carries a genetic mutation that raises risk of heart disease [27].

Almost 1% of the world's population carries a genetic mutation that leads to heart problems, while in India the mutation reaches a frequency of 4%, say the researchers.

"The mutation leads to the formation of an abnormal protein," Nature quoted lead researcher Kumarasamy Thangaraj from the Centre for Cellular and Molecular Biology, Hyderabad, India as saying. "Young people can degrade the abnormal protein and remain healthy, but as they get older it builds up and eventually results in the symptoms we see," he added.

The mutation, a deletion of 25 letters of genetic code from the heart protein gene MYBPC3, is virtually restricted to people from the Indian subcontinent [27].

"The bad news is that many of these mutation carriers have no warning that they are in danger," says Perundurai S. Dhandapany from Madurai Kamaraj University, Madurai, India, "but the good news is that we now know the impact of this mutation."

People carrying the mutation can be identified at a young age by genetic screening and a healthier lifestyle.

"This is a genetic finding of great importance," says Sir Mark Walport, Director of the Wellcome Trust.

"Heart disease is one of the world's leading killers, but now that researchers have identified this common mutation, carried by one in 25 people of Indian origin, we have hope of reducing the burden that the disease causes.

"This research should lead to better screening to identify those at risk and may ultimately allow the development of new treatments," he added.

3.3.2 Malaria

According to [29], the Malaria Eradication Programme has suffered repeated set-backs due to technical, operational and administrative reasons and the cases have started rising again. Malaria has now staged a dramatic comeback in India after its near eradication in the early and mid sixties.

The estimated economic loss due to malaria in India from 1990-1993 is $506.82 million to $630.82 million. India has spent up to 25% of its health budget on malaria control from 1977-1997, and starting in 1997, India planned to spend $40 million on malaria control, a 60% increase from the previous year. This expenditure is part of a five year program aimed to target 100 districts where 80% of all P. Falciparum cases occur. 70-80% of the malaria control money in India is spent on insecticides [29].

3.3.3 Tuberculosis (TB)

Tuberculosis (TB) is an infectious disease caused by a Bacterium, Mycobacterium tuberculosis. It is spread through the air by a person suffering from TB. A single patient can infect 10 or more people in a year.

Controlling TB in India is a tremendous challenge. The TB burden in India is still staggering. Let us look at the statistics related to TB. Every year, 1.8 million persons develop the disease, of which

about 800,000 are infectious; and, until recently, 370,000 died of it annually — 1,000 every day. The disease is a major barrier to social and economic development. An estimated 100 million workdays are lost due to illness. Society and the country also incur a huge cost due to TB—nearly US$ 3 billion in indirect costs and US$ 300 million in direct costs [30].

In India today, two deaths occur every three minutes from tuberculosis [30]. Can these deaths be prevented? The answer is that with proper care and the right treatment, patients with TB can be cured and the battle against TB can be won.

3.3.4 Cancer

There are an estimated 2.5 million cases of cancer in India at any given time. Nearly 800,000 cases were diagnosed in 2000 and there were 550,000 deaths due to cancer in that same year. Tobacco-related cancers account for almost one-third of all cancers in India—predominantly head and neck, lung, and esophageal cancers. The two most common cancers among Indian women are those of the cervical and breast. What is most disheartening is that many of these cancers can either be prevented altogether or treated effectively if detected early. Worse, yet, more than 70% of all cancers in India are found when the disease is so advanced that treatment is much less effective [31].

3.3.5 Diabetes

India is fast becoming the 'diabetes capital' of the world with an alarming rise in the incidence of the silent killer disease in the country, according to Dr. Sree Kumaran Nair, professor of medicine, Mayo Clinic, USA. Briefing reporters in an international symposium on the disease, Dr. Nair said onslaught of fast food culture, changing lifestyle and lack of exercise were the main reasons for the alarming increase of diabetes in India. By 2025, there would be an increase of 57 per cent in the diabetes cases in the country, he added. Dr. Rober Rizza, Professor of medicine and chairman, Mayo Clinic, USA, said to remain healthy and free of diabetes, exercise, being physically active and ensuring a thin waist-line were essential. If the onset of the disease was delayed by 10 years, several complications can be avoided, he added [32].

The challenge for the engineering profession is to better understand how technologies in the healthcare sector could help detect and prevent killer diseases such as heart attacks, malaria, tuberculosis, cancer, diabetes etc. What India needs is affordable and simple technologies that have the potential to change the landscape of the healthcare sector for a healthy future.

3.4 Deteriorating Infrastructure

The growing demand for quality healthcare and the absence of appropriate infrastructure poses a challenge both to the government and private healthcare delivery providers.

Urbanization is not a side effect of economic growth; it is an integral part of the process. As in most countries, India's urban areas make a major contribution to the country's economy. Although less than 1/3 of India's people live in cities and towns, these areas generate over 2/3 of the country's GDP and account for 90% of government revenues [95].

India's towns and cities have expanded rapidly as increasing numbers migrate to towns and cities in search of economic opportunity. Slums now account for 1/4 of all urban housing. In Mumbai, more than half the population lives in slums, many of which are situated near employment

centers in the heart of town, unlike in most other cities in developing countries [95].

Meeting the needs of India's soaring urban populations is and will continue to be a strategic policy matter. Critical issues that need to be addressed are:

- Poor local governance
- Weak finances
- Inappropriate planning that leads to high costs of housing and office space; in some Indian cities costs are among the highest in the world
- Critical infrastructure shortages and major service deficiencies that include erratic water and power supply, and woefully inadequate transportation systems
- Rapidly deteriorating environment

Some startling facts related to urbanization in India [95] are captured below:

Most Urbanized States: Tamil Nadu 43.9%; Maharashtra 42.4%; Gujarat 37.4%

3 out of world's 21 mega cities: Mumbai (19 million); Delhi (15 million); Kolkata (14 million)

Large Cities: 23 in 1991; 40 in 2001

Urban Population: 25% of 850 million in 1992; 28% of 1,030 million in 2002.

Estimated Urban Population by 2017: 500 million

% of Urban Residents who are Poor: About 25%

Slum Population: About 41 million in 2001

Estimated Slum Population by 2017: 69 million

3.5 Lack of Health Insurance

Health insurance is a matter of life and death, especially for the poor. Although only one in a thousand people may need a serious operation at a hospital, when it does become necessary many households never receive the care they need; Alternatively, they may become deeply indebted in order to pay for the treatment their loved ones require. The first case leads to unnecessary suffering and death while debts may end a family's hope of ever escaping poverty. These tragic outcomes can be avoided through insurance which shares the risk of a major health shock across many households.

Around 24% of all people hospitalized in India in a single year fall below the poverty line due to hospitalization (World Bank, 2002). An analysis of financing of hospitalization shows that large proportion of people; especially those in the bottom four-income quintiles borrow money or sell assets to pay for hospitalization (World Bank, 2002) [94].

In a later section, we will focus on the health insurance market in India in some detail and at the end of the report, we will describe some of the concerns and challenges in this area.

3.5.1 Health Insurance Market in India (where is this section placed?)

Health insurance in a narrow sense would be 'an individual or group purchasing health care coverage in advance by paying a fee called premium.' In its broader sense, it would be any arrangement that helps to defer, delay, reduce or altogether

avoid payment for health care incurred by individuals and households.

The health insurance market in India is very limited covering about 10% of the total population. The existing schemes can be categorized as:

(1) Voluntary health insurance schemes or private-for-profit schemes;

(2) Employer-based schemes;

(3) Insurance offered by NGOs / community based health insurance, and

(4) Mandatory health insurance schemes or government run schemes (namely, Employee and State Insurance Scheme (ESIS), Central Government Health Scheme (CGHS)) [94].

Even though the Indian health insurance market grew by 38% in 2006-07, only 1.08% of India's billion plus population has medical insurance [37]. The general perception is that the prospects for growth in this sector of the insurance market are good. One of the most important developments towards providing health insurance to rural households in India has been the *Rashtriya Swasthya Bima Yojana*.

First Recipient of the RSBY Card

Figure 2 : The Use of Smart Cards in Rashtriya Swasthya Bima Yojana Scheme

India's Prime Minister Manmohan Singh announced the creation of a new health insurance scheme – the Rashtriya Swasthya Bima Yojana or RSBY in August 2007. See reference [62] for all details related to RSBY. We will summarize the salient features of this scheme in the paragraphs that follow.

The objective of RSBY is to protect Below Poverty Line (BPL) households from major health shocks that involve hospitalization. Specifically, BPL families are entitled to more than 700 in-patient procedures with a cost of up to 30,000 rupees per annum for a nominal registration fee of 30 rupees. Pre-exisiting conditions are covered and there is no age limit. Coverage extends to the head of household, spouse and up to three dependent children or parents.

Here is how the RSBY scheme works. The majority of the financing, about 75 per cent, is provided by the Government of India (GOI), while the remainder is paid by the respective state government. State governments engage in a competitive bidding process and select a public or private insurance company licensed to provide health insurance by the Insurance Regulatory Development Authority (IRDA).

The operation of the system involves three stages, enrolment, hospital transactions and monitoring. It is to be noted that the Smart Card technology is exploited to its hilt in the successful implementation of RSBY.

The generally optimistic perception for the growth of health insurance is certainly supported by the growth in the number of policy holders, but the profitability of this line of business remains an issue. The health insurance sector had a loss ratio of about 78% in 2003, which deteriorated to 98% in 2004-05. Currently, available

figures suggest that the claims ratio stands at 110% - 120% [37].

Growth in policy holder numbers, more effective third party administration and an effective network of hospitals is expected to see the numbers improve.

Let us now take a look at the Healthcare insurance premium in India in the last few years. It is to be noted that the private sector grew 129% on a YTD basis. This is an important development and augurs well for the country.

Healthcare Insurance Premium
The private sector grew 129 per cent on YTD basis

Figures in Rs Crore

COMPANY	2007	2006	DIFF.	INCREASE%
Reliance	67.69	8.61	59.08	686.18
ICICI Lombard	735.85	274.46	461.39	168.11
HDFC Chubb	10.18	4.55	5.63	123.74
Star Health	11.05	0	11.05	100
Royal Sundaram	97.45	50.59	46.86	92.63
Cholamandalam	38.6	21.11	17.49	82.85
Bajaj Alliance	158.26	97.69	60.57	62
TATA-AIG	45.35	30.62	14.73	48.11
IFFCO Tokio	71.89	51.97	19.92	38.33
Oriental	440.53	359.72	80.81	22.46
United India	434.64	359.26	75.38	20.98
New India	765.29	669.28	96.01	14.35
National	333.12	294.25	38.87	13.12
TOTAL	**3,209.90**	**2,222.11**	**987.79**	**44.45**
Private	1,236.32	539.6	696.72	129.12
Public	1,973.58	1,682.51	291.07	17.3

Source : IRDA

4. UNDERSTANDING THE LOGJAM: A PEEK AT THE HEALTHCARE SECTOR IN SELECT COUNTRIES

Before we take a deeper look at the healthcare sector and the technologies for the healthcare sector in India, it will be useful to understand the scenario in USA and some other select countries such as China, Brazil and Russia. Let us first see how the US health care dollar is spent [19].

4.1 Healthcare Sector in the United States

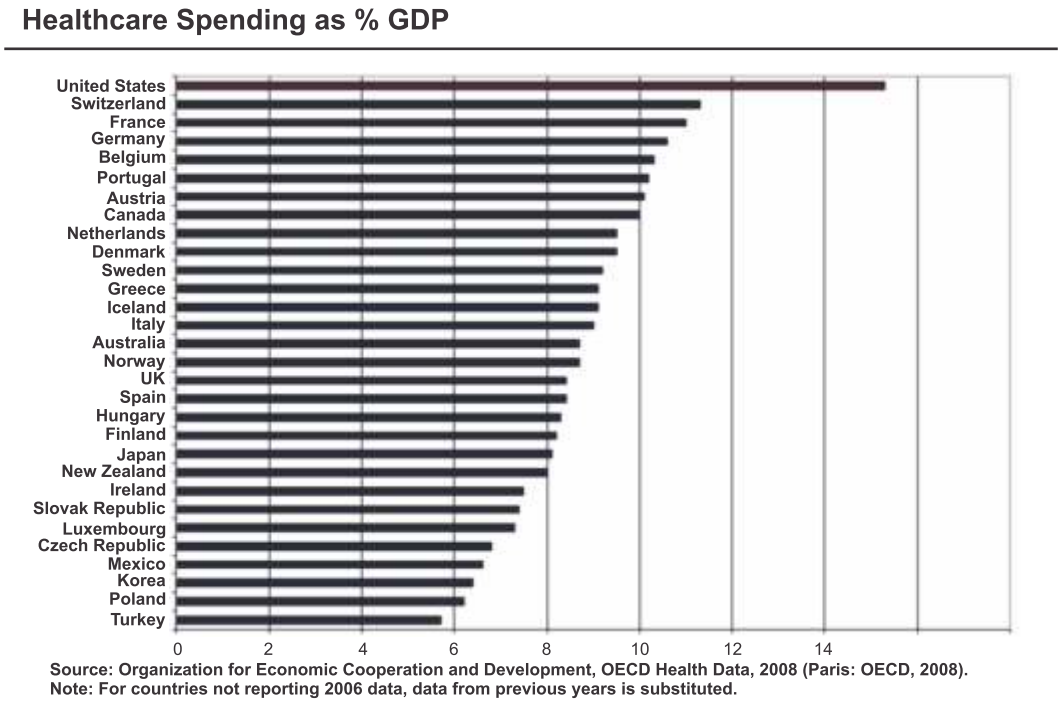

Figure 3 : Healthcare Spending as % of GDP [131]

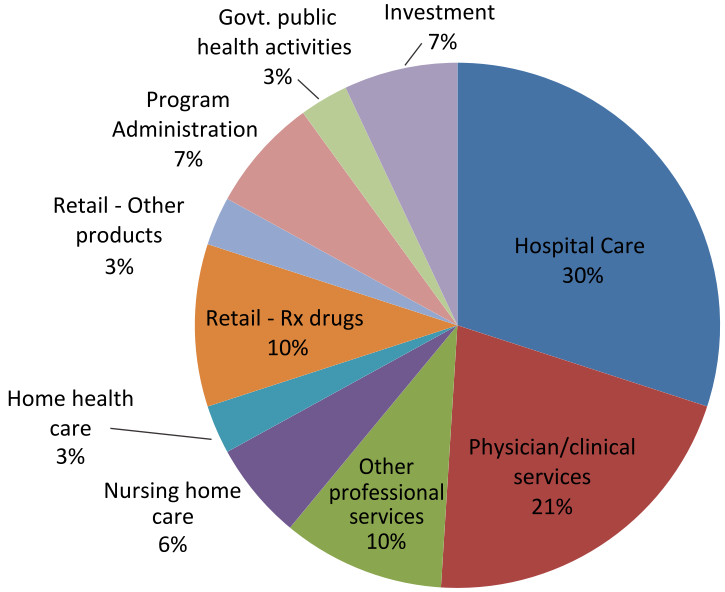

Figure 4 : How US healthcare dollar is spent.

Healthcare spending in the United States currently accounts for more than 16 percent of the country's Gross Domestic Product (GDP), approximately US$2.0 trillion [21]. To put this figure in perspective, as of 2005, only five other countries had GDPs as large as or larger than the United States' healthcare expenditures [22].

As shown in Figure 2, hospital care accounts for the largest share (30%) of health expenditures. Physician services are the next largest items, comprising one-fifth of the national health spending. Prescription drugs, while accounting for only 10% of total expenditures, has been one of the biggest contributors to the growth in spending.

Let us now look at the statistics in some detail. More than 98,000 Americans die and more than one million patients are injured each year as a result of broken health care processes and system failures [14]. In addition, the gulf between the rapidly advancing medical knowledge base and the application of that knowledge to patient care continues to widen.

According to one survey, 75 percent of patients consider the healthcare system to be fragmented and fractured, a "nightmare" to navigate, and plagued by duplications of effort, poor communication, conflicting advice, and tenuous links to the evolving medical evidence base.

The study in [14] concludes that largely because of its cottage-industry structure and dysfunctional reimbursement and regulatory framework, the health care sector has woefully underinvested in Information and Communication Technologies (ICT) – the nervous systems of all information-intensive industries – to support core clinical and administrative business operations. Health care is also underinvested in mathematical/ conceptual tools and techniques for designing, analyzing, and controlling a myriad of complex processes and systems.

In this report, we will attempt to compare and contrast the healthcare sectors in India with that of USA and the other three BRIC (Brazil, Russia, India, China) nations.

US Congress Passes Historic Healthcare Bill

In March 2010, the US Congress passed the historic healthcare bill that extends health care to tens of millions of uninsured Americans and cracks down on insurance company abuses, a climactic chapter in the century-long quest for near universal coverage.

Here is what to expect within the first year of the enactment of the US healthcare bill [130]:

- Insurance companies will be barred from dropping people from coverage when they get sick. Lifetime coverage limits will be eliminated and annual limits are to be restricted.
- Insurers will be barred from excluding children for coverage because of pre-existing conditions.
- Young adults will be able to stay on their parents' health plans until the age of 26. Many health plans currently drop dependents from coverage when they turn 19 or finish college.
- Uninsured adults with pre-existing conditions will be able to obtain health coverage through a new program that will expire once new

insurance exchanges begin operating in 2014.

- A temporary reinsurance program is created to help companies maintain health coverage for early retirees between the ages of 55 and 64. This also expires in 2014.
- Medicare drug beneficiaries who fall into the "doughnut hole" coverage gap will get a $250 rebate. The bill eventually closes that gap which currently begins after $2,700 is spent on drugs. Coverage starts again after $6,154 is spent.
- A tax credit becomes available for some small businesses to help provide coverage for workers.

The two bills together will cost $940 billion over 10 years and cover 32 million uninsured Americans, the Congressional Budget Office estimated [132].

Companies such as health insurer WellPoint Inc. of Indianapolis, medical-device maker Medtronic Inc. of Minneapolis and drugmaker Pfizer Inc. of New York will get millions of new customers with the extension of coverage. Their industries will also face billions of dollars in new fees.

As part of the overhaul, drugmakers agreed to help the elderly more easily afford medicines. Insurers, who opposed the legislation, will have to take all customers, regardless of pre- existing conditions, and face limits on how much revenue can be spent beyond covering medical expenses.

4.2 Healthcare in China

China's economic and social reforms over the past 25 years have met tremendous success. However, the development of the healthcare sector is now far behind its economic development [56]. A review of China's key health indicators makes clear the case for change. Life expectancy and infant mortality trends, for example, illustrate that although China's healthcare system has made progress over the last ten years, improvements have slowed recently. Similarly, indicators such as the reported incidence and mortality rates from infectious diseases have increased in recent years.

Inadequate spending is only part of the problem. Just as serious are the lack of access to affordable healthcare, the inefficient use of healthcare resources and a lack of high-quality patient care.

Without changes to the current system, more than 500 million Chinese will continue to find medical treatment out of their reach, due to the high cost of seeing a doctor. On the bright side, the efficient reallocation of even relatively small amounts of money can go a long way to improving access to affordable healthcare for literally hundreds of millions of Chinese, especially in rural areas.

The healthcare sector in China will need to undergo drastic changes to achieve the government's objectives. The Chinese government clearly understands the magnitude of the problem and has articulated its commitment to closing the significant gaps in the healthcare sector and has emphasized the need for public and private sector cooperation.

Many hospitals are trying to thrive and grow in this environment, with different types of hospitals facing different challenges. As such, different hospitals have adopted different strategies to grow and in some cases, simply to survive. Regardless of the type of hospital, a common theme is the need to improve the quality of care while lowering costs.

The IBM Institute for Business Value in China recently completed a comprehensive study of China's healthcare industry to help answer these questions [56]. The study identified the sector's key challenges, their root causes and potential solutions to transform China's healthcare system. *For instance, the use of technology, such as establishing a national health information network, and using innovative clinical solutions, such as electronic medical records, can help to improve effectiveness of health services in China*.

Looking forward to 2010, the report envisions a healthcare system that provides equitable, affordable and high-quality patient care to China's citizens. Achieving this vision hinges upon – above all – government-led initiatives that will drive concerted change by players across the healthcare system.

4.3 Healthcare Sector in Russia

Russian health care has not been seriously reformed since the collapse of the former Soviet Union in 1991. But in early 2006, the Russian government launched a so-called national projects plan that aims to improve health care [72].

In the last decade, the health of the average Russian has grown significantly worse. Overall life expectancy has fallen from 70 years to 65, with Russian men at particular risk. On average, a Russian man lives 13 years less than his female contemporaries the widest gender gap in the world.

The three major causes of illness among Russians are respiratory disease, circulatory disorders, and alcohol-related injury and poisoning. Russia also has sky-rocketing HIV/AIDS infection rates and growing problems with multi-resistant strains of tuberculosis.

Let's see some statistics related to the health of Russia's population [74]. Heart diseases account for 56.7% of total deaths, with about 30% involving people still of working age. About 16 million Russians suffer from cardiovascular diseases, placing Russia second in the world, after Ukraine, in this respect. Death rates from homicide, suicide and cancer are also especially high. According to a 2007 survey by Romir Monitoring, 52% of men and 15% of women smoke. More than 260,000 lives are lost each year as a result of tobacco use. HIV/AIDS, virtually non-existent in the Soviet era, rapidly spread following the collapse, mainly through the explosive growth of intravenous drug use. According to official statistics, there are currently more than 364,000 people in Russia registered with HIV, but independent experts place the number significantly higher. In increasing efforts to combat the disease, the government increased spending on HIV control measures 20-fold in 2006, and the 2007 budget doubled that of 2006. Since the Soviet collapse, there has also been a dramatic rise in both cases of and deaths from tuberculosis, with the disease being particularly widespread amongst prison inmates [74].

Yet, despite these alarming trends, public health has not been high on the government's agenda. For years, only about three percent of Russia's Gross Domestic Product was spent on health care.

Beginning 2006, the Russian government had approved an additional $3.2 billion in spending on health care as part of its so-called national priority projects. The funds, mostly drawn from Russia's oil revenues, are expected to cover salary hikes for

doctors and nurses, the purchase of new equipment for clinics, and the construction of eight high-tech medical centers in Russia's vast, outlying regions.

One of the more controversial elements of the health reform plan calls for a major shift in emphasis on quality of treatment, rather than Soviet-style obsession with the number of people treated.

The plan also reportedly calls for doing away with tens of thousands of specialists - the idea being to encourage more doctors to become general practitioners or front-line, first responders.

Russian media say that means about 300,000 doctors and health care workers or about half the nation's total could be laid off, and scores of hospitals shut down in the next few years.

This promotion of general practitioners over specialists has many in the medical field worried, including Dr. Olga Golubkova. She is the head of a private clinic in Moscow called Spectra. She told VOA that, in her view, the plan will see Russian health care slide backwards by about twenty years.

Golubkova says a general practitioner, by nature, is not supposed to be curing all kinds of illness. She says there are a limited number of routine medical problems that a general practitioner is competent to treat. She says a general practitioner's job should be to identify and classify an illness and then send the patient to the appropriate specialist.

Now, she says, we will see GPs being forced to be all things to all people, including surgeons, with results one can only imagine.

Russias Deputy Health Minister downplays these concerns. Victor Starodubov told a recent health conference in Moscow that the shift in focus will lead to increased prestige for general practitioners. Starodubov says physicians will soon face less specialist competition, greater wages, and more opportunity to practice streamlined care. He says the result for patients will also be better.

The minister says many of Russia's doctors appeared inadequately prepared or not interested enough in their work to deliver the necessary care. All our efforts must be placed on first-line doctors, he says, because, for any patient, they are often the first and only doctor a patient will see.

Sergei Smirnov says the reforms sound good on the surface. But, as the head of Russia's Institute of Social Policies and Social-Economic programs, he says there are few plans he has not heard or seen tried.

Smirnov also told VOA he has serious concerns about how this major overhaul of Russia's health care system will turn out. How is it possible, he asks, that a national health care project is managed not by the health ministry, but by the presidential administration?

Criticism aside, most agree reform of Russia's health care system is urgently needed. But the question on the minds of many is whether this is really the plan to improve things, or will the Russian people be forced to pay the highest price with their health?

4.4 Healthcare Sector in Brazil

According to the Brazilian Government, the most serious health problems are [73]:

- Childhood mortality: about 2.51% of childhood mortality, reaching 3.77% in the northeast region.

- Motherhood mortality: about 73.1 deaths per 100,000 born children in 2002.
- Mortality by non-transmissible illness: 151.7 deaths per 100,000 habitants caused by heart and circulatory diseases, along with 72.7 deaths per 100,000 habitants caused by cancer.
- Mortality caused by external causes (transportation, violence and suicide): 71.7 deaths per 100,000 habitants (14.9% of all deaths in the country), reaching 82.3 deaths in the southeast region.

In 2002, Brazil accounted for 40% of malaria cases in Americas. Nearly 99% are concentrated in the Legal Amazon Region, which is home to not more than 12% of the population.

The Brazilian health system is composed of a large public, government managed system, the SUS (Sistema Único de Saúde) , which serves the majority of the population, and a private sector, managed by health insurance funds and private entrepreneurs.

The public health system, SUS, was established in 1988 by the Brazilian Constitution, and sits on 3 basic principles of universality, comprehensiveness and equity. Universality states that all citizens must have access to health care services, without any form of discrimination, regarding skin color, income, social status, gender or any other variable.

Government standards state that citizen's health is the result of multiple variables, including employment, income, access to land, sanitation services, access and quality of health services, education, psychic, social and family conditions, and are entitled to full and complete health care, comprising prevention, treatment and rehabilitation. Equity states that health policies should be oriented towards the reduction of inequalities between population groups and individuals, being the most needed the ones for whom policies should be first directed.

SUS has also guidelines for its implementation, the most peculiar being popular participation, which defines that all policies are to be planned and supervised directly by the population, through local, city, state and national health councils en conferences. This is regarded as a very advanced form of direct democracy and has established the guidelines for many similar initiatives in sectors other than health all over Brazilian society.

The public system is still grossly under funded and lacking quality, though that's been improving greatly in the last few years. Important legal issues, such as the regulation of Constitutional Amendment 29, are expected to minimize some of those problems.

Private Health Insurance is widely available in Brazil and may be purchased on an individual-basis or obtained as a work benefit (major employers usually offer private health insurance benefits). Public health care is still accessible for those who choose to obtain private health insurance. As of March, 2007, more than 37 million Brazilians had some sort of private health insurance.

5. INDIA'S HEALTHCARE SYSTEM

Healthcare Statistics

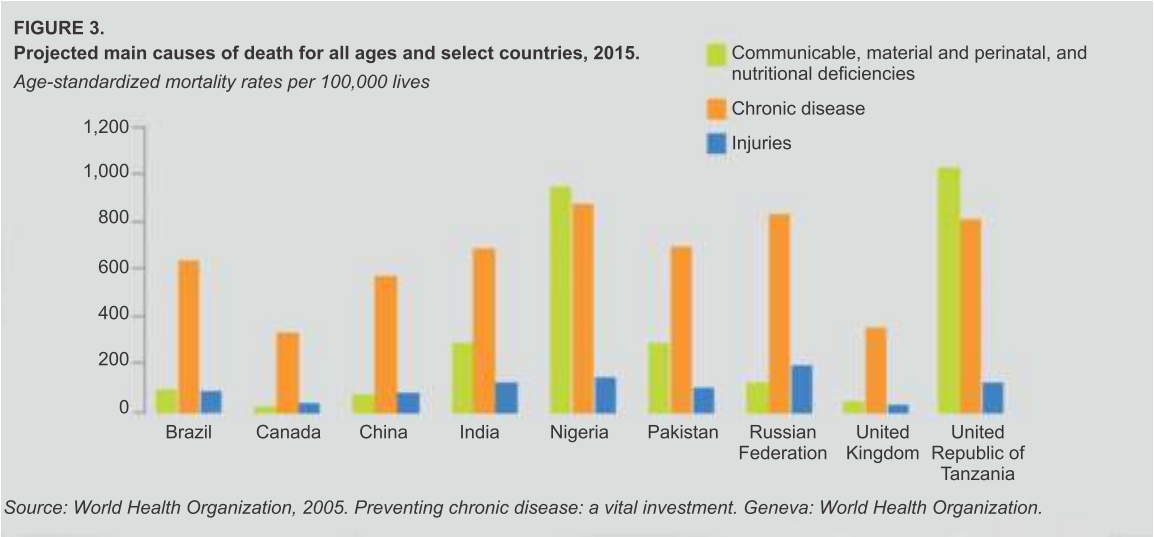

Figure 5 : Projected Main Causes of Death for all Ages and Select Countries, 2015 [23].

The statistics below will serve useful to the reader before we attempt to address the merits and limitations of the healthcare sector in India.

- India has 5,03,900 doctors, 7,37,000 nurses, 162 medical colleges, 143 pharmacy colleges and 3,50,000 chemists [25]
- There are 15,097 hospitals accounting for 8,70,161 hospital beds in India
- There is an extensive three-tiered government healthcare infrastructure comprising 23,000 Primary Health Centres (PHC) and 1,37,000 sub-centres serving the semi-urban and rural areas and 3000 Community Health Centres (CHC) (Source: OPPI 2000 Estimates)
- India's health expenditure is only 5.6 per cent of GDP, whereas most established market economies spend 7-10 per cent of GDP on health. USA spends over 14 per cent.
- USA has 2,340 doctors as compared to India's 143 doctors for very 10,000 people
- On an average, 80 out of every 1,000 children die. This figure is just 9 in the US and 30 for every 1,000 in Thailand.
- Life Expectancy in India is amongst the lowest at 55.5 years compared to US at 75.5 years and 66.5 years for Thailand.
- Compared to Brazil's 4300 beds, India has only 1,600 beds.
- 35% of population of India is below $1 a day (1994-2004) [24]
- 2% of central government expenditure is (1994-2004) allocated to health as against

13% that is allocated to defence [24].

State of Public Health

Let us first look at some startling facts related to the state of public health in India [63].

- Public health expenditure in India has declined from 1.3% of GDP in 1990 to 0.9% of GDP in 1999. The Union Budgetary allocation for health is 1.3% while the State's budgetary allocation is 5.5%.
- Union Government contribution to public health expenditure is 15% while States contribution about 85%
- Vertical Health and Family Welfare Programmes have limited synergisation at operational levels
- Lack of community ownership of public health programmes impacts levels of efficiency, accountability and effectiveness
- Lack of integration of sanitation, hygiene, nutrition and drinking water issues
- There are striking regional inequalities
- Population Stabilization is still a challenge, especially in States with weak demographic indicators
- Curative services favour the non-poor: for every Re.1 spent on the poorest

  20% population, Rs. 3 is spent on the richest quintile
- Only 10% Indians have some form of health insurance, mostly inadequate
- Hospitalized Indians spend on an average 58% of their total annual expenditure
- Over 40% of hospitalized Indians borrow heavily or sell assets to cover expenses
- Over 25% of hospitalized Indians fall below poverty line because of hospital expenses

5.1 Existing Efforts in India in Health Care

The IBM report titled "Improving India's Healthcare System through Information Technology" [11] takes the position that the adoption of advanced, but well-established Information Technology (IT) can significantly assist in improving the state of healthcare in India. The report suggests that India should set its sights on developing an information-based healthcare system, within which transparent, cost-effective, high-quality solutions can be developed for specific problems. The report recommends that the three pieces – a reliable data network, electronic records and standards – will form the foundations of an information-based healthcare system. The framework for an information-based health system has been shown in Figure 4 [11].

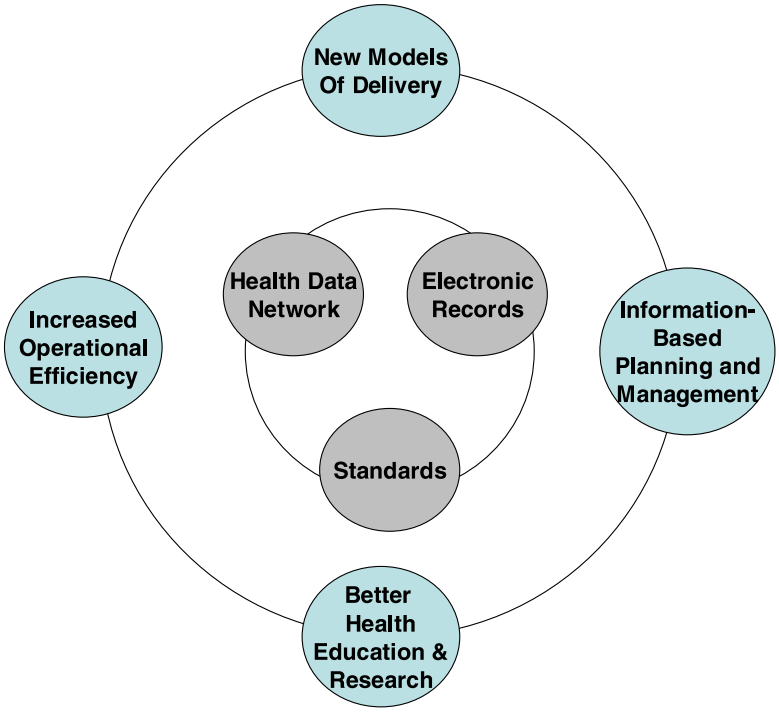

Figure 6 : Framework for an Information-based health system. The inner circle consists of recommendations from the IBM study [11]. The outer circle consists of the benefits that are expected to follow.

The findings in [11] suggest that the following four areas in Indian healthcare sector would benefit significantly from an increased reliance on IT:

(i) Operational efficiency

(ii) Healthcare planning and management

(iii) Healthcare delivery

(iv) Health research and education

Health care for Rural and Tribal People

SEARCH (Society for Education, Action and Research in Community Health) is a non-government organization registered as a public trust and charitable society in India. It was founded in 1985 by a doctor couple, Abhay Bang and Rani Bang. Inspired by the life and philosophy of Mahatma Gandhi, their dream was to develop an institution of community health which provided health care to the local population, and generated knowledge for the global community by way of research. "Think globally, act locally!" [5].

HOSMAC Foundation

HOSMAC Foundation is a non-profit organization, registered in 2005, affiliated to HOSMAC India Pvt Ltd, a healthcare consultancy firm [57]. The vision of the Foundation is to building a networked and sustainable healthcare community by providing innovative solutions to address critical issues in the domain of healthcare. HOSMAC Foundation overtly focuses on improving the healthcare delivery system by making pertinent contributions in the domain of capacity building, knowledge sharing and community empowerment.

An excellent analysis of the hospital industry in India titled "Indian Healthcare Review: Analysis of Hospital Industry" is presented in [58].

5.2 Key Players in the Healthcare Sector in India

A summary of the top private healthcare providers in India is below [119]. A brief description of each of the key players follows.

Player	FY07 Revenues (US $ Million)	Number of Hospitals (2010)
Fortis Healthcare	31	46
Apollo Hospitals	225	49
Manipal Group	NA	19

Healthcare solution vendors

- Philips
- GE healthcare
- Cardinal Health

Multinational IT Vendors

- IBM
- EDS
- Accenture
- HP
- Oracle
- Intel

5.2.1 Philips

Historically, Philips was among the top three players in the healthcare equipment market and continues to enjoy this position in India today.

Philips in India employs around 4000 employees of which 281 employees are from the healthcare sector.

Philips Healthcare in India operates in the diagnostic imaging segment including CT, MRI, X-rays, cardiovascular system, nuclear medicine, PET-CT, and ultrasound imaging systems, and is also a significant player in patient monitoring. Outstanding image quality and reliability, backed by an excellent application and customer support network, has made Philips Healthcare a preferred choice of clinicians and one of the leading suppliers of diagnostic imaging systems. Philips is a leader in cathlabs segment with the most comprehensive range of innovative cardiology solutions in India.

Philips Healthcare in India grew by 21% in 2007. Philips has supplied the MRI, CT scan and Cardiovascular systems as well as the latest Patient Monitoring Systems and Ultrasound to a number of renowned private and public hospitals throughout the country.

The Philips HeartStart Defibrillator has been sold to major governmental institutions, leading domestic airlines and private companies for installation in their premises.

Philips revolutionized the medical systems industry with the introduction of the 256-slice Brilliance iCT scanner. Its introduction has benefited not only patients, but radiologists and administrators as well as physicians in terms of results analysis, time savings and hassle-free usage.

In India, the first Ambient Experience for 1.5 Tesla MRI was installed at Apollo Hospitals, Hyderabad in 2007

Philips is collaborating with Artemis Health Institute, Gurgaon, India in its worldwide research and development efforts. This

collaboration will allow Philips to get real time scientific data from India, which can be used for the product development and upgrade in various imaging modalities like PET CT, MR and Cardiac CT.

Philips also has a R&D centre, Philips Innovation Campus (PIC) at Bangalore where a team of about 1000 engineers and researchers work on healthcare technologies for emerging markets, especially India.

Philips has introduced the SureSigns VM3 patient monitor and the cost-effective Ultrasound HD15 system in India; products specifically designed for India and catered to meet the demands of the various small to mid-sized clinics across the country.

Philip already enjoys leadership position in India's cardiovascular market .With the acquisition of Alpha X-rays Technologies, Philips will now enter the economy /value segment and this will further reinforce leadership position in this important business segment. This acquisition also establishes Philips India's Industrial footprint in Healthcare.

According to Mr. Anjan Bose, Senior Director & Business Head, Philips Healthcare, Philips Electronics India Limited, "The future of healthcare is one of the most pressing global issues of our time. It's clear we face tough challenges. This reality presents Philips with an enormous responsibility and also a great opportunity for the future. Philips' vision is to bring better and earlier screening and diagnosis, more effective patient treatment and an improved ability to manage chronic diseases at home. We want to help shorten hospital stays, reduce costs and improve the quality of people's lives."

"Philips is a top player in the healthcare market in India and is the leader in patient monitoring, echocardiography and Cardiovascular X-ray market. Our healthcare sector in India has been growing faster than the industry and grew at 21% in 2007. Philips' high-end MRI, CT scanner, Ultrasound and Cardiac vascular X-ray systems are found in leading hospitals and medical centres around the country. Our value segment offerings in India are designed with a sharp focus on emerging markets and we are committed to leverage Philips' global expertise to introduce technologically-advanced solutions tailored to the Indian market."

5.2.2 GE Healthcare

GE Healthcare is a $14 billion unit of GE that provides transformational medical technologies that are shaping a new age of patient care. GE Healthcare's expertise in medical imaging and information technologies, medical diagnostics, patient monitoring systems, disease research, drug discovery and biopharmaceuticals is dedicated to detecting disease earlier and tailoring treatment for individual patients. GE Healthcare offers a broad range of services to improve productivity in healthcare and enable healthcare providers to better diagnose, treat and manage patients with conditions such as cancer, Alzheimer's and cardiovascular diseases [88].

GE Healthcare in India

Wipro GE Healthcare is a joint venture between GE and Wipro Corporation; its business activities include:

- Design and manufacture of ultrasound scanners, cardiology products like ECG and fetal monitors
- Sales and service of the full line of medical imaging and information technology products offered by GE Healthcare
- Parts and service logistics

- Software services and technology solutions for GE products
- Applications support and customer training at leading centers through Training-in-Partnership (TiP) programs

Other divisions specialize in the design, sourcing and manufacture of diagnostic imaging systems such as X-ray, CT (computed tomography) and MRI (magnetic resonance imaging).

5.2.3 Apollo Hospitals Enterprise Limited

With 8500 beds across 49 hospitals in India and overseas, neighbourhood diagnostic clinics, an extensive chain of Apollo Pharmacies, medical BPO as well as health insurance services and clinical research divisions working on the cutting edge of medical science, Apollo Hospitals is a healthcare powerhouse in India [122].

The Apollo hospitals are multi specialty tertiary care facilities with centres-of-excellence in medical disciplines including cardiology, cardio-thoracic surgery, gastroenterology, orthopedics & joint replacement surgery, neurology, critical care medicine, nephrology, oncology, hand & micro surgery and reproductive medicine.

5.2.4 Fortis Healthcare Network

The Fortis Group's principal activity is to provide medical and healthcare services. The services include medical treatment, providing infrastructure facilities like, beds, operating theaters, intensive care units, nursing services, pharmaceutical services, laboratory and diagnostic centers and a central sterile and supply department and other related facilities. The Group provides tertiary and quaternary healthcare services such as cardiac care, orthopedics, neuro-sciences, oncology, renal care, gastroenterology and mother and child care.

The Fortis Healthcare network encompasses 46 running hospitals (including 13 satellite/heart command centres) with several more already in the pipeline [120].

5.2.5 Manipal Healthcare

The Manipal healthcare group manages 11 hospitals, including 8 teaching hospitals. Manipal healthcare is one of Asia's largest healthcare management group with multi-stream facilities covering the entire spectrum from secondary to super-specialty care [121].

5.3 Indian Government's Role in Healthcare Sector

5.3.1 National Rural Health Mission

Recognizing the importance of Health in the process of economic and social development and improving the quality of life of our citizens, the Government of India has resolved to launch the National Rural Health Mission [63] to carry out necessary architectural correction in the basic health care delivery system. The Mission adopts a synergistic approach by relating health to determinants of good health viz. segments of nutrition, sanitation, hygiene and safe drinking water. It also aims at mainstreaming the Indian systems of medicine to facilitate health care.

The Plan of Action includes increasing public expenditure on health, reducing regional imbalance in health infrastructure, pooling resources, integration of organizational structures, optimization of health manpower, decentralization and district management of health programmes,

community participation and ownership of assets, induction of management and financial personnel into district health system, and operationalizing community health centers into functional hospitals meeting Indian Public Health Standards in each Block of the Country. The Goal of the Mission is to improve the availability of and access to quality health care by people, especially for those residing in rural areas, the poor, women and children.

5.3.2 National Urban Health Mission

In the first quarter of 2008, India's Health Minister announced that the country would launch a National Urban Health Mission at a cost of Rs. 8,000 crore [84] [85]. This will be the second largest health programme that will fill the lacunae created after the implementation of the National Rural Health Mission (NRHM) and take care of the unmet needs in the fast urbanisation process.

The mission would cover all cities and towns with more than a hundred thousand population. To begin with, it would be launched in about 450 cities and towns. It would focus on 5.5 crore slum dwellers. The government itself would pay the health insurance premium for slum dwellers. The private sector as well as non-governmental organizations (NGOs) would be involved in the effort to reach out to the masses under the programme, which would work in synergy with the earlier rural health mission. Urban local bodies would monitor implementation in their jurisdiction.

An Urban Social Health Activist would be appointed for every 200 population. An urban health centre would also be set up for every 50,000 population. Self-help groups of women, Mahila Arogya Samitis, would be formed for every 100 households to monitor health issues at the grass roots. The Centre would provide them seed money of about Rs 2,500.

Besides, the initiative would seek to ensure that ambulances were available within 7-15 minutes of a telephone call anywhere in the country by 2010. A national programme on emergency and trauma care would soon be launched to ensure this and also improve highway safety at an initial cost of Rs 760 crore.

Ambulances would be available on every 50-km stretch on the highways, trauma centres set up on every 100 km and speciality centres located every 150 km. A telephone facility would be provided on every 5-km stretch [84].

India's Health Minister noted a very alarming trend in India – that road accidents alone were claiming nearly one lakh lives every year and costing the country nearly Rs. 55,000 crore, amounting to three per cent of the GDP [84].

According to the Government of India, the country's healthcare sector would grow faster than what has been the case so far [9]. New avenues of opportunity within healthcare itself could open up as the sector emerges as a significant growth driver.

During 2002, India's health care industry contributed 5 per cent of the GDP. By 2012 the share would go up to 8.5 per cent. Health care spending in the country will also double over the next 10 years [9].

In the last five years, the number of patients visiting India for medical treatment rose from 10,000 to about 120,000.

With an annual growth rate of 30 per cent, India is already inching closer to Singapore, an established medical-care hub that attracts 150,000 medical tourists a year.

Telemedicine is one sector that is expected to experience a boom in the near future, Indian government officials say. With a rural population nearing 700 million, the country will benefit enormously from digital data transmission related to healthcare.

Both public and private entities are aggressively pursuing the use of telemedicine to hasten diagnostics and treatment of a variety of diseases.

The Indian government has already slashed the import tariffs on infrastructure equipment needed for telemedicine. At the 14th summit of the heads of the nations of the South Asian Association for Regional Corporation (SAARC), the member countries had committed themselves to a tele-medicine project.

IT in Health has far reaching results. HOSMAC Foundation, a not-for-profit organisation, focused on the healthcare sector, brought together a group of eminent domain experts and policy-makers to discuss the 'Emerging Role of Information Technology in Healthcare' at a conference in the New Delhi [123]. Aimed at highlighting the need for integrating IT with Healthcare, the HOSMAC Foundation Conference emphasized the imperative need for innovative assimilation of IT through applications such as Telemedicine, Health Information Management Systems (HMIS) and Geographical Information System (GIS) to maximize the reach of healthcare services in India. Also to charter a way forward for practicing IT in Healthcare and look beyond IT's role in administrative management.

The conference was inaugurated by Prof. M.S. Swaminathan, M.P. and Chairman MSSRF. During his speech he emphasised the need for latest IT technologies in healthcare sector that are available to the urban population to be made accessible to the rural areas of India as well. He said, "The Government is committed to expanding rural connectivity through a slew of measures so that rural users can access information of value and transact business. This will include connecting block headquarters with fiber optic network, using wireless technology to achieve last mile connectivity and operating information kiosks through a partnership of citizens, panchayats, civil society organizations, the private sector and Government." He expressed a need for similar initiatives to be made available to Rural India in the field of health information technology as well.

The Conference [123] focused, among related subjects, on the effectiveness of Telemedicine for 'Delivery of Healthcare Systems to the rural and Remote Populations of India', on leveraging Information and Communication Technology for 'Providing Healthcare to Rural India in an Affordable Manner', using GIS mapping for 'Integrated Disease Vector Surveillance'.

Dr. Vivek Desai, Managing Trustee of HOSMAC Foundation felt that "This conference is a platform where industry experts congregate to address the dismal state of expenditure and coverage if IT in Public Health System in India and look at possible solutions".

India would also need to adapt and upscale innovations that take place in the Health sector and look at larger

outreach to promote better health practices, disseminate information, provide solution exchanges, professional support, in short a clarion call to invest on IT for better healthcare systems to make the world a better place to live in.

The panel discussion at the end of the day had Dr. J.P. Steinmann from GTZ Health Sector Support aptly concluding by saying that "we need to see IT as an effective tool that will add momentum to the healthcare delivery system and bridge the gap between the supply of services and its demand, that is, requirement of the people."

5.4 Right to Health Bill: First-of-a-Kind in India

We are currently witnessing the rise of socio-economic rights in India. Some examples of these rights are the Right to Work [126], Right to Information (RTI) [127], Right to Health and Well-Being [124], [125].

The right to work is closely related to other basic rights such as the right to life, the right to food and the right to education. In a country where millions of people are deprived of any economic assets other than labour power, gainful employment is essential for these rights to be fulfilled. Indeed, unemployment is the main cause of widespread poverty and hunger in India. The right to work states that everyone should be given the opportunity to work for a basic living wage [126].

According to [127], the Right to Information is an act to provide for setting out the practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, the constitution of a Central Information Commission and State Information Commissions and for matters connected therewith or incidental thereto.

A major milestone in India in healthcare has been the passage of The National Health Bill 2009 [128]. The National Health Bill is a bill to provide for protection and fulfilment of rights in relation to health and wellbeing, health equity and justice, including those related to all the underlying determinants of health as well as health care; and for achieving the goal of health for all; and for matters connected therewith or incidental thereto [128].

A quiet revolution to create a healthier India has kicked off in the east with Assam becoming the first state in the country to introduce a bill guaranteeing the right to health and well-being [124], [125].

The state government tabled the landmark Assam Public Health Bill, 2010, in the assembly. The bill proposes path-breaking provisions for health equity and justice to achieve the goal of health for all.

The bill makes it mandatory for all new development projects to carry out a health impact assessment. It also proposes to make it compulsory for both government and private hospitals to provide free healthcare services and maintain appropriate protocol of treatment for the first 24 hours to an emergency patient.

“Health does not mean just doctors and hospitals, but everything that influences the well-being of a human being. This is a historic bill and we are the pioneers in the country after the Centre requested all states to bring a law on the right to

health," said Assam Health Minister Himanta Biswa Sarma [124], [125].

After tabling the bill, the Assam Health Minister said that the statute sought to bind the state health and family welfare department legally to meet its obligations — coordination with other departments concerned and providing people with minimum nutritionally adequate essential food, adequate supply of safe drinking water, sanitation through appropriate and effective sewage and drainage systems and access to basic housing facilities.

The Minister added that the bill provides for the health and family welfare department to take appropriate legal steps for fixing responsibility and accountability of departments and agencies concerned in case of repeated outbreaks or recurrence of communicable, viral and water-borne diseases, which are found in a particular area and proved to have taken place because of the failure to improve sanitation and safe drinking water facilities. “Every citizen will have the right to health. In case government hospitals fail to provide medical care because of absence of doctors, the patient will be entitled to remedial measures to be prescribed by the department,’’ he said.

5.5 IP Policy on Healthcare in India

In the increasingly globalized world, Intellectual Property (IP) is here to stay and it is for the world to channelize the intellectual assets for global pubic good through appropriate policy initiatives addressing the incentives to the inventors, innovators and other partners in the innovation cycle.

About 97% of all patents are filed by the industrialized countries of which 90 percent of product patents and technology are owned by the global multinational corporations.

India needs to step up efforts in IP as a whole. This is also true in the healthcare sector where a large fraction of IP is currently coming from Multinational companies and Private sector in India. The Figure [158] shows the total number of patent filings in 2005 by various countries including India. That India is far behind the developed countries is evident from the chart.

The Government of India has put in place a series of policy initiatives that have energized and focused R&D on generating new knowledge that could lead to new products and processes of public health importance. The role of IP has been duly acknowledged in one way or other in various health related policies. Some major policy initiatives include: (i) Drug Policy (2002); (ii) National Health policy (2002); (iii) National Policy on Indian Systems of Medicine and Homoeopathy (2002); (vi) The Science and Technology Policy (2003); (v) National Biotech Policy (2005); (vi) National Pharmaceutical Policy (2006); (vii) Protection and Utilization of Public Funded Intellectual Property Bill (2008); and (viii) National Health Research Policy (2010) [156].

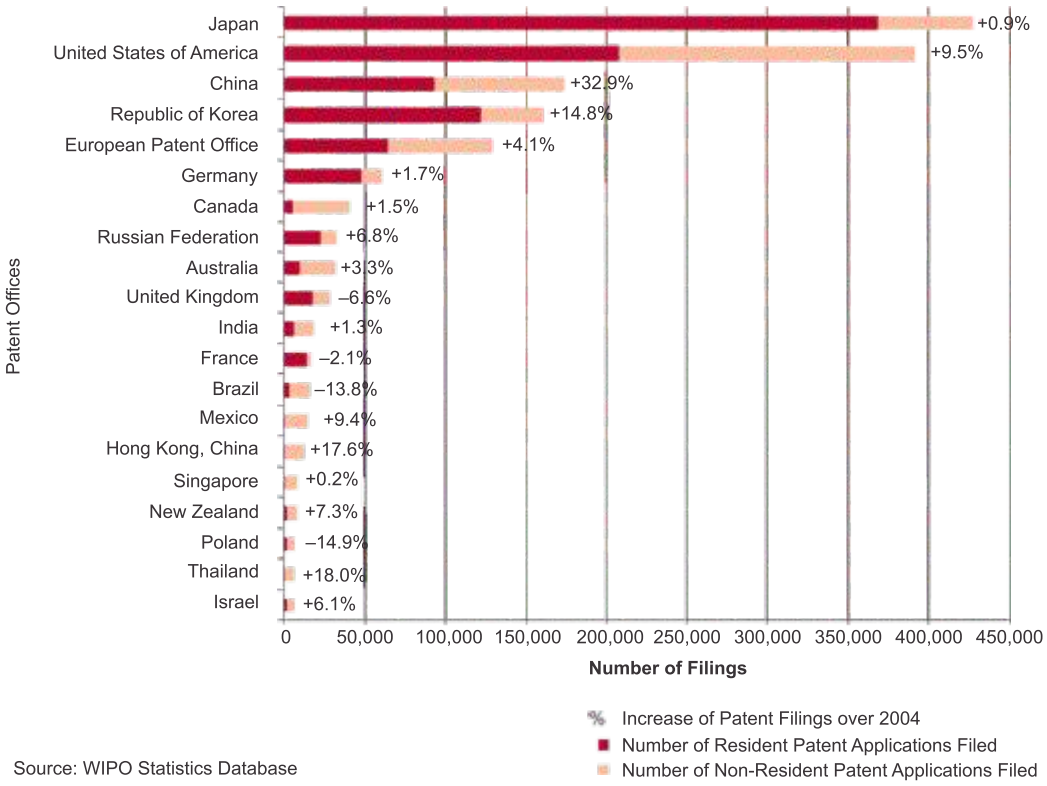

Figure 7 : Top 20 patent offices according to the total number of patent filings in 2005 [158]

5.6 Private Investments in the Healthcare Sector in India

The last few years have witnessed a surging interest in healthcare by the private sector in India. One such example is Helion Venture Partners [159] – a stage independent, India-focused venture fund, investing in high growth technology powered businesses and consumer services. Helion Venture Partners is an early to mid-stage fund, with investments in the range of $2-5 Million. The new areas of focus of the company are healthcare services, businesses that service hospitals and tech applications for hospitals. This is a clear indication that private players in the country are now seeing the benefits of investing in the healthcare sector. With a huge demand-supply gap in the country, the private players are now seeing a return on their investments.

In our view, India will continue to see new players each year willing to invest in the healthcare sector.

6. TECHNOLOGIES FOR THE HEALTHCARE SECTOR

"Technology is to healthcare what nervous system is to human body".

Technology is growing at an exponential pace. Hi-tech gadgets are not just restricted to office but also find a place in hospitals and medical research. In the next section, we discuss a very interesting trend and that is the convergence of hi-tech consumer products such as the cell phone with medical devices. We believe that this trend will open up a Pandora's box and will spawn new research areas and technologies that will benefit the country tremendously. The marriage of consumer products with healthcare products has a tremendous potential and it will likely enable new paradigms, applications and business models. What we are witnessing in this area is only a tip of the iceberg.

6.1 Convergence of Consumer Products with Healthcare Products

Today, a device that fits snugly onto a patient's body or clothing, without being a hindrance to his daily activities, is a preferred choice. A design can influence how the patient deals with her disease. As demand for these tools is growing, device makers are seeking to converge consumer products with healthcare products. The goal is to come up with more intuitive user interfaces that will help patients manage their diseases effectively [33].

"Cell phone is going to become a health management and monitoring device. You will be able to store all your medication, x-rays, blood information and doctor's prescriptions securely and conduct various health-related transactions from anywhere, any time over the air at minimum cost with great deal of flexibility and convenience," says Sam Pitroda, chairman, National Knowledge Commission, India, and chairman, WorldTel.

Researchers at IIT, Bombay, have developed an ECG monitor that can be worn on the body and communicate the patient's data to a doctor through a cell phone interface. Japan's NTT Docomo has unveiled Wellness Navigator cell phone, which measures body fat content and pulse rate. The Korean Institute of Bioscience and Biotechnology has developed a liver checking sensor, which hooks into your cell phone and checks on two enzymes in your blood.

The hi-tech devices will play a pivotal role for chronic disease management, especially circulatory disorders. This not only will reduce human intervention to the minimum, but also the chances of error in administering medical care to individuals and drive down cost of the treatment," says Rajendra Pratap Gupta, vice-chairman, Heartline Telemedical Services Pte Ltd, Singapore.

Now you can wear two sleek gadgets strapped to your belt. One is an iPod and the other an insulin pump and glucose monitor called the MiniMed Paradigm real-time system made by Medtronic. It features user-friendly control buttons and a screen that displays one's glucose levels, giving better information than those daily fingerstick readings provide.

Milind Shah, MD, India Medtronic, says, "In order to manage diabetes properly, patients must understand what affects their glucose patterns and take action to

regain control as quickly as possible. This may help them maintain healthy glucose levels in order to delay or prevent diabetes-related complications."

HealthPia America has come up with a GlucoPhone, a glucose meter that can be attached to select LG and Motorola mobile phones. To use it, a diabetic pricks his finger, dabs the blood on a paper strip, and inserts the strip in a special slot in the phone attachment. An internal reader analyses the sample in nine seconds, the phone displays the results, and – if the patient wishes – sends the data to a medical professional.

Exmovere's web-based Bluetooth-enabled biosensor wristwatch offers automated reports on the elderly individuals' vital signs, including pulse, heart rate and motion. It runs on Windows, Windows Mobile, and/or Windows Pocket PC software. It collects information on the wearer every 30 minutes and alerts caregivers of any abnormal activity. Data is transmitted wirelessly via home PC, GSM Bluetooth-enabled cell phone or GPS car kit, which keeps tabs on the wearer's location and vehicle speed. One can also opt to receive alerts via e-mail, SMS or instant message.

"Convergence of hi-tech and medical devices has helped hearing impaired patients to hear with devices such as the digital hearing aids. The technology used in these devices is based somewhat on the speech processing technology of cell phones. With advances in cell phone technology, there will be better speech processing strategies for hearing devices," feels Dr Gauri Mankekar, an ENT consultant.

"Technology is growing at an exponential pace. Hi-tech gadgets are not just restricted to office but also find a place in hospitals and medical research. Doctors need to update and familiarise themselves with the latest technology to help provide the best healthcare to mankind," concludes Dr Khusrav Bajan, consultant, critical care and internal medicine, PD Hinduja Hospital, Mumbai.

6.2 Miniaturization of Medical Devices

Rapid advances in hardware and electronics have resulted in miniaturization of medical devices. In fact, the parallels with the cell phone industry and the healthcare sector are remarkable and we will have a chance to describe this similarity in later sections.

We are seeing the emergence of tiny devices such as Pulse Oxymeter, Handheld ECG Monitors etc. In Medical Fair India 2009 [], the authors of this report witnessed a large number of small devices that help in the early diagnosis of diseases.

We will discuss some representative examples of medical devices in this section.

Pulse Oxymeter

(a)

(b)

Figure 8 : (a) Finger Pulse Oxymeter;
(b) A Portable/Handheld Pulse Oxymeter

In today's environment, definition of high quality healthcare is evolving as hospitals and clinics react and respond to ongoing changes in the healthcare delivery systems. In a quest to provide better healthcare, hospitals are opting for comprehensive telemetry based systems, especially in its emergency departments and Intensive Care Units. As an example, for patients at risk of respiratory failure, it is important to monitor efficiency of gas exchange in the lungs, i.e., how well the arterial blood is oxygenated as opposed to whether or not air is going in and out of the lungs. These requirements are met using non-invasive medical devices. One such non-invasive medical device is a Pulse Oxymeter [50].

The technique has become a standard clinical method for monitoring patient's blood oxygen saturation and heart rate. Figure shows a typical pulse oxymeters – both Portable/Handheld and Finger Pulse Oxymeters.

There are many types of pulse oxymeters. The most commonly used ones are the Finger Pulse Oxymeter and Handheld Pulse Oxymeter.

The Finger Pulse Oxymeter is a self-contained fingertip pulse oxymeter that incorporates electronics and sensors into one unit. The digital pulse oxymeter provides clinicians with quick, accurate readings of oxygen saturation, pulse rate and pulse strength assessment.

With healthcare facility consolidation and increasing standardization, market for pulse oxymeters seems to be favourably poised. In the near future, pulse oxymeters market is set to exceed $438 million [50].

Handheld ECG

Figure 9 : ReadMyHeart: Handheld ECG

Monitoring our heart's health condition is one of the vital steps towards a long and healthy life. The ReadMyHeart Handheld ECG machine [53] is a device with which we can record our heart's electrical activity in just 25 seconds, view the key parameters on the LCD screen, and later print the trends in heart activity to help our physician detect CardioVascular Diseases.

Monitoring heart's rhythm is made easy, as it is a palm-sized device which can take measurements at any time, in any place, whether it's while eating in a restaurant, after exercising in a fitness center, or after taking a specific drug.

Let us understand how ReadMyHeart works. Electrical waves travel through the heart chambers to charge and trigger heartbeats. If the heart's chambers are not synchronized, the blood will not circulate effectively, which can be a symptom or cause of CardioVascular disease. With ReadMyHeart, we can measure and record our heart's electrical signals as they are emitted through our body. When our thumbs are in contact with the dry electrodes, the palm-sized device is able to trace and record the micro-current our heart generates during heartbeats, generating the related heart function parameters (PR, QRS, ST). ReadMyHeart is hassle-free: the LCD displays our key heart parameters (QRS, ST), blinks if they are out of range and stores up to 30 records.

6.3 The Role of Information Technology (IT) in Healthcare

IT is being used by hundreds of millions of users worldwide today. This includes applications from computer games to social networking and now also applications serving the health of humans such as Telemedicine.

Telemedicine will soon connect experts and make diagnostic results available to all physicians. Important data such as Blood pressure and pulse can be measured at home by the patient and be transferred right onto the doctor's PC in practice. In the case of irregularities or signs of danger, the doctor can intervene straight away.

The vision of computer scientist Reiner Wichert is that one day sensors and systems will give seniors a helping hand in their own home by measuring, monitoring and raising alarms if necessary. With the help of these systems, we will be informed when a flat's inhabitant fell down and helplessly lies on the floor.

Several problems need to be solved before this vision becomes a reality. First is the cost associated with these complex systems. Second would be some kind of standardization of devices and systems.

6.3.1 The Role of Software in Healthcare

Let's take a peek at the role of software in healthcare sector. In the coming years, we are going to witness an explosion of medical devices – from small handheld devices such as pulse oximeter, glucose monitors to large systems such as CAT scanners and Ultrasound systems. Software will increasingly play a crucial role in the healthcare sector.

Companies that have traditionally been strong in Computer Science and Electrical Engineering are expected to increase their investment in the exciting Healthcare sector. We are also likely to see an emergence of collaboration between technology-based and healthcare-based companies. The description in the next paragraph is just one example of such collaborations.

Collaboration between IBM, Google, and the Continua Health Alliance, will enable personal medical devices to automatically stream data results into a patient's Google Health account or other Personal Health Record (PHR). This will extend the value of Personal Health Records to consumers and help ensure

that such records are current and accurate at all times. IBM software will connect personal medical devices to Google Health and other health record systems to allow patients to exchange vital health information with their doctors and other health services professionals in real-time.

6.3.2 Trends in Medical Simulation

Figure 10 : Medical Simulation

Simply put, Medical Simulation is a 'Tool'. The tool has a potential for altering the culture of healthcare.

More specifically, simulation is a training and feedback method in which learners practice tasks and processes in lifelike circumstances using models or virtual reality, with feedback from observers, peers, actor-patients, and video cameras to assist improvement in skills.

Computer-based medical simulation provides a realistic and economical set of tools to improve and maintain the skills of health care providers adding a valuable dimension to medical training. This is similar to professional training in aviation, defense, maritime, nuclear energy and other areas. Medical simulators allow individuals to review and practice procedures as often as required to reach proficiency without harming the patient [152].

Simulation-based Medical Education (SBME) includes several tools and approaches:

- A full environment simulator is similar to flight simulators used to train pilots. The pilot is immersed in a complete replica of the cockpit environment. In medicine, sophisticated mannequins, known as patient simulators provides health care professionals with a computer-based patient that breathes, responds to drugs, talks, and drives all the clinical monitors in the operating room, e.g., blood pressure and pulse rate.
- Task trainers provide a simulated subset of functionality, such as how to give a smallpox inoculation or how to insert a chest tube.
- Computer-based training provides software programs that train and assess clinical knowledge and decision-making skills.
- Simulated/standardized patients allow students to interact with actors trained to act as patients providing students with valuable

feedback on, among other things, bedside manner.

Medical simulation is a cross-disciplinary effort that brings together providers, including nurses, physicians, and allied health professionals across a variety of disciplines with computer scientists, researchers, educators, and human factors engineers [152].

There are several centers of excellence in Medical Simulation world-wide. Some of the highly successful global centers are [153], [154].

Figure 11 : Medical Simulation Center at Manipal University [155]

In India, Manipal University became the first University to have a Medical Simulation Centre [155]. Its acquisition of a variety of manikins (anatomical models of the human body, used in teaching art or medicine) to establish the Medical Simulation Centre has created quite a buzz. Simulation technology which has made its name in areas like aviation, war strategy, architecture or even gaming made its mark in medical education more than a decade ago. What started as tools for skills labs are today full size computer programmed 'dummy' patients that can mimic emergency medical situations and diseased conditions.

Simulation in medical education and research in USA has led to medical professional's credentialing and patient safety issues becoming a norm. Its introduction in India certainly holds a promising and exciting learning experience for young medical professionals.

6.4 RFID Technology in Healthcare

Figure 12 : Radio Frequency Identification Tags

Radio Frequency Identification Tags (RFID) is used for everything from tracking cows and pets to triggering equipment down oil wells. It may sound trite, but the applications are limited only by people's imagination. RFID is also used for security (including controlling access to buildings and networks) and payment systems that let customers pay for items without using cash. The most common applications are tracking goods in the supply chain, containers, high value tools and other assets, and parts moving to a manufacturing production line.

Healthcare is a field where small mistakes can cost huge financial and personal losses. Improving operational efficiency is the prime target for hospitals and healthcare systems. Maintaining effectiveness and keeping a check on every patient, is a tough task. No doubt, doctors and nurses work day and night for the betterment of the patient, but what if human effort is complemented with an excellent technology?

Applications of RFID in Healthcare

There are various RFID applications in healthcare. Though initially, RFID found a negative response in healthcare sector, with changing trends, RFID technology is becoming an important part of healthcare [136], [137].

- **Drug Faking**: Every year, the World Health Organization reports indicate an increase in the illicit trade of medicines. Pharmaceutical companies lose billions of dollars every year due to illicit trade and many people lose their lives on account of wrong medication. All these threats can be averted by using RFID technology. RFID tags are put on medicines, which gives them a unique code and identity. In case of illegal distribution, the fake medicines can be easily distinguished. Expired medicines can also be kept under check by using RFID tags.
- **Inventorying and Stocktaking**: Supply chain management of the medicines and drugs is essential in delivering orders and maintaining an extra stock of medicines. RFID tags can help distributors keep an eye on the availability of medicines, so that they have stocks piled up for emergency requirements. This will also save time and improve the efficiency of the suppliers and distributors.
- **Instrument Safety**: It is mandatory to sterilize medical equipments before reusing them. Infections and contagious diseases spread due to unclean instruments. How can RFID tags prove to be useful here? Medical devices can be provided with RFID tags and RFID readers can be set up at the entrance of storing chambers so that they give information about the status (cleaned/sterilized/unsterilized) of such devices. This helps eliminate disastrous errors that may occur on using unclean instruments. The RFID tags can also give the exact location of the medical devices inside the rooms/chambers that helps to save time.
- **Packaging Problems**: Often the seal and packaging of medicines may be doubtful. Read/write RFID tags can be very useful in solving these problems. Information regarding the seal time, packaging date etc. can be put on the RFID read/write tags that can be checked whenever necessary. Even when the medicines are exported to different countries, the exporters can keep an eye on their materials. This is of great help to pharmaceutical companies.
- **Accountability and Product Safety**: An important part in the process of drug approval is the clinical testing and

authentication of medicines. Using RFID technology, the authorities can make the product more reliable and moreover, the companies will also be accountable to government rules and regulations.

- Patient Tracking and Information: Data management about the patient's health (report tests, medicines etc.) can be maintained on a database and that too, automated directly by the RFID tags. RFID tags can also convey information about the health status of the patients by monitoring and recording blood pressures and heart beat rates. This can facilitate faster recovery of the patient and also help the nurses/caretakers to have a better check on the patient's health.

RFID technology can be made an integral part of healthcare. RFID in healthcare reduces risk factors of human error in the healthcare industry. As RFID technology gets less expensive, healthcare industries will surely employ RFID technology in their hospitals and benefit from it.

6.5 Emerging Paradigms in Technologies for the Healthcare Sector

Figure 13 : Stamp-Sized Patches

Thanks to the exponential growth in IT, Software and Technologies for the Healthcare sector – we are witnessing newer methods that will make life easy for the patient and the doctor. An example of a cheap and simple way to ensure that patients pop their pills merits attention [51].

Taking medicine even for a week is a drag. Taking it every day for six months is a real nuisance. Yet that is what is asked of those being treated for Tuberculosis. TB patients need to pop their pills for half a year if they are to eliminate the bacteria that cause the infection and combat the emergence of antibiotic-resistant strains. Worse, from the point of view of compliance, the actual symptoms of infection tend to go away after just two months of taking the medicine, so the incentive to carry on is negligible. But worse than that, the drugs themselves produce unpleasant symptoms, including nausea, diarrhoea, headaches and insomnia. Indeed, one common anti-TB drug, rifampicin, also has the unnerving side effect of turning people's tears, sweat and urine a shade of reddish orange.

Every cloud, though, has a silver lining, for it was this strange, if harmless, side effect that gave a team of researchers at the Massachusetts Institute of Technology (MIT) their crucial idea: stamp-sized patches, much like litmus paper, that change colour when exposed to the urine of people with traces of medicine in their systems (see Figure 9). The crucial trick of XoutTB [52], as the system built around these patches is known, is that the change in colour reveals a code that a patient can text-message to a service which rewards him with free airtime minutes on his mobile phone. Patients thus have a daily incentive to take their terrible pills.

The XoutTB project began in the spring of 2007, with the launch of the Yunus Challenge, a now-annual contest at MIT to promote development in poor countries. Muhammad Yunus, after whom the challenge is named, is a Nobel Prize-winning pioneer of microfinance—the idea that loans too small for traditional banks to handle are nevertheless crucial in enabling businesses to flourish in the poorer parts of the world.

The winner of that year's challenge was Jose Gomez-Marquez, a medical engineer at MIT. His original idea, inspired by Dr. Yunus's work, was to involve local banks (in this case in Nicaragua) in a scheme that would give TB patients micro-loans in exchange for evidence that they had been taking their medication. That plan fell by the wayside because the banks did not want to get involved. But phone companies were willing to give it a try, and brought with them the bonus of an established infrastructure for distributing the rewards. The resulting trial, which involved 30 people with tuberculosis, was a success, and a second is about to be carried out in Pakistan, where a batch of 400 XoutTB patches is arriving soon.

If XoutTB does work, the team has ambitions to extend it. Other drugs, too, can be a nuisance to remember. The anti-retrovirals used to combat AIDS, for example, have to be taken for the rest of a patient's life. And taking medicines for non-infectious conditions such as diabetes, blood pressure and cardiac related problems is also a chore. Find the right "litmus test", though, and what is now being done with TB drugs could succeed with any of these as well.

Taking our medicine could, at last, become a truly rewarding experience, thanks to the emerging services in the healthcare sector.

6.6 A Sensor for the Skin

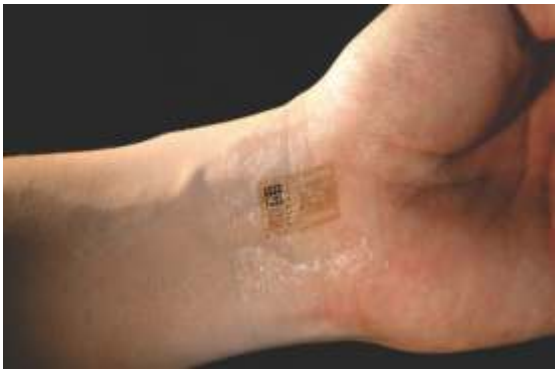

Figure: An Electronic Patch that Attaches to the Skin

Microchips and sensors that can be unobtrusively and painlessly worn on the skin are no longer a stretch of the imagination [163].

A team of American, Chinese and Singaporean scientists have created peelable, extensible, adhesive patches—akin to temporary tattoos—that can host a diverse array of electronics. As of today, these adhesions, the subject of an article in Science [164], have been tested to monitor heart, brain and muscle activity, but they can be modified to work in a range of futuristic applications from electronic bandages to Wi-Fi-receptive ports.

Underlying it all is a technology that allows electronic wires and circuits to be stretched, almost like rubber bands. "Our goal was to develop an electronic technology that could integrate with the skin in a way that is mechanically and physiologically invisible to the user," says John Rogers, one of the authors and a professor in the materials science and engineering department at the

University of Illinois at Urbana-Champaign. “It’s a technology that blurs the distinction between electronics and biology.”

Rogers and his colleagues from the University of Illinois at Urbana-Champaign, Northwestern University, Tufts University, the Institute of High Performance Computing in Singapore and Dalian University of Technology in China reported their findings in the article.

Roger’s group has previously reported examples of stretchable electronic polymers that can be wrapped around curved surfaces as well as human tissue. Last year, the group developed rubbery heart implants that could be patched onto the muscle’s tissue and monitor its activity. This, however, is the first evidence of materials that don’t need to be implanted and can directly be strapped onto the skin.

Flexible electronics, as this emerging field is called, essentially involves creating extremely thin layers of silicon circuits—which are normally obdurate—that can then be made pliant to a variety of shapes. Better techniques to create such slices have made possible ultra-thin TV displays as well as flexible solar cell arrays.

Other international research groups have developed so-called “electronic skins” that employ organic materials, instead of silicon semiconductors, that are more malleable, but less efficient as processors. However, skin poses multiple levels of engineering challenges with its unique adhesive properties and necessary precautions against toxicity.

G. Ananthakrishna, a senior materials science professor at the Indian Institute of Science, said that the work was significant. “Skin is a highly deformable surface. Being able to design electronics that don’t lose their conductive properties when they are themselves twisted and folded onto skin, is quite remarkable and has several practical applications,” he said.

While existing technologies such as electroencephalographs accurately measure a number of physiological activities, epidermal electronic systems, as these devices are called, have almost no weight, no external wires and require negligible power.

Moreover, because of their small power requirements, they can draw power from stray (or transmitted) electromagnetic radiation through the process of induction and also harvest a portion of their energy requirements from miniature solar collectors.

The electronic tattoos are less than 50 microns thick—thinner than a human hair—which are integrated onto polyester-backed surfaces.

Their microscopic breadth means they don’t need glue and are held onto the skin surface by Van der Waals forces, which magnify and weld surfaces at the molecular level.

Regions of the body that previously proved difficult to fit with sensors may now be monitored, including the throat, which the researchers studied to observe muscle activity during speech. The recent study demonstrated device lifetimes of up to 24 hours, and didn’t pose skin irritation, according to the authors.

The throat experiment yielded enough precision for the research team to differentiate words in vocabulary and even control a voice-activated video game interface with greater than 90% accuracy.

“This type of device might provide utility for those who suffer from certain diseases of the larynx,” Rogers said. “This work is really just beginning. On the technology side, our focus is on wireless communication and improved solutions for power—such as batteries, storage capacitors and mechanical energy harvesters—to complement the inductive and solar concepts that we demonstrate in the present paper.”

Monitoring in a natural environment during normal activity is especially beneficial for continuous observation of health and wellness, cognitive state or behavioural patterns.

The researchers used simple adaptations of techniques used in the semiconductor industry, so the patches are easily scalable and manufacturable. Device company mc10 Inc. [165], which Rogers co-founded, is already working on commercializing certain versions of the technology.

Next, the researchers are working to integrate the various devices mounted on the platform so that they work together as a system, rather than individually functioning devices, and to add Wi-Fi capability.

“The vision is to exploit these concepts in systems that have self-contained, integrated functionality, perhaps ultimately working in a therapeutic fashion with closed feedback control based on integrated sensors, in a coordinated manner with the body itself,” Rogers said.

7. TECHNICAL CHALLENGES THAT LIE AHEAD

In this very important chapter, we present key technical challenges in the Healthcare sector. Section 7.1 describes some of the technologies for the Early Detection and Diagnosis of Killer Diseases such as Cancer, Cardiovascular diseases, Tuberculosis and Diabetes. This section is followed by a description of a very important area that is attracting a lot of research world-wide – Nanotechnology for healthcare. We then discuss the role of Information Technology in Healthcare followed by the standards for Electronic Healthcare Records. The convergence of ICT technologies (e.g., Mobile Telephony) with Healthcare is of great interest today. The key element in this convergence is Mobile/Wireless Healthcare. We describe a few emerging applications of Mobile/Wireless Healthcare. Waste Management in the Healthcare Sector is a huge concern today that needs to be addressed by all players in the space. The final section in this chapter highlights key efforts in R&D in Healthcare.

7.1 Technologies for the Early Detection and Diagnosis of Killer Diseases

It is to be noted that the word 'Technology' is used here in the broadest sense and includes biology, drugs, software, and devices.

We will begin by focusing on Cancer, one of the most dreaded diseases in the world today.

7.1.1 Cancer

Let us take a look at the statistics related to Cancer in USA [46].

One in three people will contract cancer, and one in four will die from the disease.

Within five years, cancer will surpass heart disease as the leading cause of death, according to the American Hospital Association.

In 1994, 1.2 million new cancer cases were added to the more than eight million people in the U.S. who have already been diagnosed with cancer.

Since 1950, the overall cancer incidence has increased by 44 percent; the incidence of breast cancer and male colon cancer by about 60 percent; testis, prostate and kidney by 100 percent; and other cancers, such as malignant melanoma, multiple myeloma and some lymphomas, by over 100 percent.

The estimated annual cost of cancer to the United States, excluding incalculable psychosocial costs, is $110 billion, approximately 2 percent of the GNP.

An estimated 80 million people have health insurance insufficient to cover the costs of a catastrophic illness such as cancer.

If we are going to get on top of Cancer, we absolutely have to focus more on prevention. With this in mind, we focus on technologies that help us to better detect the killer disease.

Detecting Cancer when it's Barely There: Bio-Detection Chips

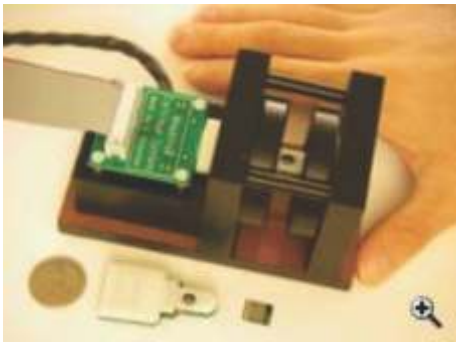

Figure 14 : A Bio-Detection Chip

Scientists from Stanford University have developed a device that can scan blood and find signs of cancer, even at its earliest stages. Early detection will allow early treatment and greatly improve the survival chances of patients [45].

Stanford University scientists have developed a system based on MagArray's biodetection chips that are capable of detecting cancer-associated proteins in a blood serum sample in less than an hour. MagArray is a startup company in the Panorama Institute for Molecular Medicine, a not-for-profit incubator in Sunnyvale, California. The device was created using magnetic nanotechnology and can detect cancer proteins with a far greater sensitivity than that of existing commercial devices. As a result of this enhanced sensitivity, cancer can be detected at a very early stage, while there are relatively few proteins released into the bloodstream.

One of the key researchers in this project is Shan Wang, a Stanford professor of materials science and of electrical engineering. His research group mainly develops magnetic nanotechnology. The new system intends to tag specific cancer-related proteins using magnetic markers. Since there are few magnetic particles in most biological systems, a magnetic mark added to a molecule would create a large signal on a screening of the blood sample. In relation to other detectors which use electrically charged or glowing particles as markers, the magnet based technology can obtain a clearer signal from a small amount of markers in the blood.

The detector contains a silicon chip designed by Sebastian Osterfeld, a Stanford doctoral student in materials science and engineering. The chip contains 64 embedded sensors that monitor magnetic field changes. Attached to these sensors are "capture antibodies" which trap specific cancer-related proteins as they pass through the sensor with the blood. At this point a second portion of antibodies is added to the sample. They attach themselves to both magnetic antibodies and the cancer biomarkers that are already held by the sensor. As a result, the MagArray sensors detect the magnetic nanoparticles together with the cancer markers. The researchers estimate they can detect cancer protein levels 400 times lower than the level required for detection by an existing cancer protein detection technology, known as ELISA [47].

The device can detect more than one protein biomarker during one test. This is important for two main reasons, says Wang. First of all, scientists are still not sure which biomarkers are the best indicators of cancer presence. Second, the more biomarkers are recognized at one time, the easier it is for the doctor to profile the situation, understand exactly what type of cancer the patient has, and suggest the most suitable treatment plan.

It is to be noted that cancer protein detection cannot simply be conducted at home as a means of self-diagnosis. In

order to run the test, a technician must use a centrifuge to separate the serum, which contains the markers, from the blood. Therefore, the device must be located in a hospital or a private diagnostic lab. The detector may have an additional use as a quick test for a heart attack, for patients arriving with chest pain to the emergency room. Heart cell death is also associated with the release of specific biomarker proteins which can be detected by the device. But before any of these ideas come to life, clinical trials must be conducted to gain regulatory approval.

Other means of using a magnet to detect cancer have been reported. One such technique, developed by scientists from Georgia Tech, captures cancer cells with magnets and guides them out of the body. The use of a magnet controlled camera for esophagus imaging which could detect early cancer growths has been developed at the Fraunhofer Institute for Biomedical Engineering in Sankt Ingbert, Germany.

Readers interested in learning more about early detection strategies for cancer should refer to [43] and [44].

7.1.2 Cardiac Related Problems

Cardiovascular disease (CVD) is a major international health problem, which accounts for 38% of all deaths worldwide. It is also estimated that the total cost of CVD in the United States alone is approximately $400 billion and exceeds $1 trillion worldwide [48].

Currently, there are many therapies that can both prevent and effectively treat CVDs. Therefore, strategies to detect CVDs early have great potential to deliver benefits in reducing the burden of disease.

We focus on technologies that aid in the early detection of cardiac related problems. Several such technologies have emerged in the recent past. One example is that of noninvasive heart failure predictive tool developed by Australia-based biotechnology company, HD Medical Group Limited [48].

The company has created groundbreaking patented and patent-pending technology in the area of mechanical heart sound analysis for early detection of cardiac diseases.

In conjunction with Commonwealth Scientific and Industrial Research

Organisation (CSIRO), Australia's largest scientific research organization, the company plans to combine its own core technology with CSIRO's wireless vital signs sensor technology to revolutionize the early detection and management of heart diseases.

These simple noninvasive tests will have immediate application in rural and remote areas and in developing countries, as well as for the general population as a screening tool for use prior to more expensive and/or invasive diagnostic testing. HD Medical is partnering with the Indian government's national network of research laboratories to develop low cost digital medical equipment to be used at primary health care centers throughout India. The project is part of a rural telemedicine program sponsored by the Indian government [48].

7.1.3 Tuberculosis

"Improved diagnostics supports early detection, which translates into early commencement of treatment, one of the

most powerful weapons against diseases such as Tuberculosis (TB)," says Dr. Dave Clark, Aurum's Executive Director [49].

WHO has declared tuberculosis a global health emergency and estimates that over 83 million sputum microscopy tests are performed annually at a cost to the worldwide health system of approximately $2.5 billion2. Of that total cost, 80% of the disease occurs in 22 high-burden countries, including India, China, Indonesia, Nigeria, Pakistan, South Africa, and the Russian Federation. Microscopic sputum analysis is a labor-intensive and tedious process requiring trained technologists to analyze hundreds of glass slide samples per day, in a manual process that is prone to fatigue and human error. Even with these challenges, WHO guidelines clearly state that sputum microscopy is still the preferred field method for diagnosis of TB. With only 40% of TB accurately detected by microscopy, sensitivity improvements are needed to update the methodology while reducing the current analysis costs.

Signature Mapping technology [49] holds the potential to significantly improve the accuracy of diagnosis while lowering the cost and time to diagnose, all of which is critical to the treatment and management of TB."

"TB is an entirely treatable and curable disease, yet every four seconds someone becomes infected with TB and every ten seconds someone dies from TB. The world needs a better technology to quickly, accurately and cost effectively detect TB," states Dr. Clark.

7.1.4 Diabetes

Figure 15 : Glucose Monitors for Diabetes

Diabetes is a disease characterized by elevated blood glucose levels caused either by the body's inability to produce sufficient insulin or by its resistance to insulin's purpose of regulating glucose. About 17 million people in the United States—6.2% of the population—are diagnosed diabetics. This number, along with the discovery of a million new cases yearly, makes diabetes one of the most important health issues in the United States. Worldwide, diabetes rates are increasing even faster, especially in developing countries. The global incidence of diabetes is expected to increase 170% between 1995 and 2025. Causes of this increase are complex and involve poor nutrition, obesity, and more-sedentary lifestyles [55].

The inability to control blood glucose leads to acute and chronic complications. Hypoglycemia, a condition in which blood glucose (glycemia) levels rapidly drop dangerously low, can cause mental confusion, convulsions, and even coma and death. Chronic hyperglycemia (excessive blood sugar) results in a wide range of long-term microvascular and neuropathic complications due to

abnormally high levels of protein glycosylation.

To effectively manage their disease, people with diabetes need to take glucose measurements. At first, the only measurement technology available for home use was the colorimetric urine glucose test strip, which was limited to diagnosing hyperglycemia. Colorimetric test strips developed later used blood obtained from a fingerstick to measure a wider range of glucose levels.

Technology developments in glucose monitoring have been targeted at reducing the pain and inconvenience of acquiring measurements so that glucose can be checked more often daily for better glycemic control. However, the glucose meters use a blood sample and require user intervention to collect and measure that sample. Two new developmental approaches aim at making glucose measurement even easier and less painful than heretofore. *Noninvasive measurement* eliminates the need to violate the skin to acquire a usable sample. And *continuous monitoring*, where measurements are taken repeatedly and automatically over time, creates a long-range glycemic profile from those frequent readings [55].

Although a number of noninvasive and continuous monitoring technologies are in various stages of development, only one device has been approved by FDA so far as an automatic and noninvasive frequent-sampling glucose monitor—the GlucoWatch Biographer (see Figure). Worn on the forearm like a watch, the GlucoWatch Biographer samples glucose through intact skin, quantitates the amount of glucose extracted, and converts that measurement to a glucose-level value.

An excellent description of transdermal glucose monitoring is given in [55].

7.2 Nanotechnology for Healthcare

Nanotechnology has the potential to revolutionise healthcare for the next generation. There are three key areas in which it could do this: Diagnosis, Prevention and Treatment [138].

The vision of the future is of harnessing the qualities of nanotechnology to eventually provide healthcare which operates purely from a preventative state, identifying and stopping potential sources of disease/illness in the body before they even get started.

7.2.1 Prevention

The majority of healthcare is reactive rather than preventative. This is often some time after the initial infection or trauma, which means that tissue damage and suffering has already occurred. In some cases this damage can be irreparable, in others permanent reminders remain (such as loss of function of that body part or scarring).

Therefore, possibly the most important aspect of nanomedicine in the future will be its potential to prevent illness, rather than simply treating it. Nanotechnology will contribute to this through more effective monitoring of individuals' health (allowing diseases to be caught in their infancy) and more sterile hospital environments (limiting the opportunity for bacteria, viruses and other microbes to cause secondary disease). Understanding the genetic make-up of the patient will also allow the doctor to prescribe personalized medicine.

7.2.2 Filters

One of the most important means of preventing disease is preventing

exposure to pathogenic microbes. As well as providing sterile surfaces, this can take the form of filtration of air and liquids that a patient is exposed to during treatment. The trouble is that many viruses are smaller than the pores of these filters and so can penetrate them, making them useless.

New filters have nanoscale pores that are able to remove even the smallest of viruses. Inclusion of active materials, such as silver nanoparticles or titanium dioxide nanoparticles and UV light sources, can enhance this effect by killing the trapped viruses, bacteria and fungi. Such systems are already being employed in the fight against SARS, to prevent the spread of the virus from infected patients to medical staff.

7.2.3 Monitoring

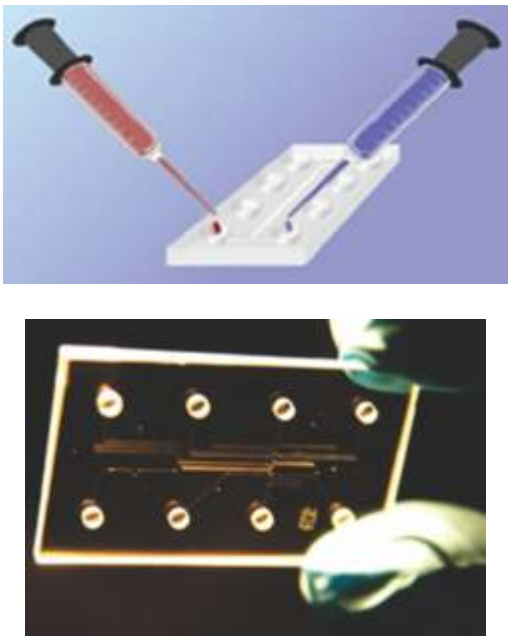

Figure 16 : Lab-On-A-Chip Devices

Monitoring of a patient's health status is important not only for those recovering from operations and treatment, but also for the routine check-up of healthy individuals. Point-of-care (POC) devices offer an unprecedented degree of flexibility through the measurement of many different physiological factors such as blood pressure, blood chemistry (e.g. levels of sugars, hormones, antibodies in the blood), heart rate, and body temperature at the patient's location without the need to send samples off to the lab.

For more complicated tests, POC devices can incorporate Lab-On-A-Chip devices (see Figure) which allow tens or hundreds of different biomolecules to be measured rapidly. By measuring quickly and at the patient's location, doctors avoid the risk of losing samples, waiting days for results to come back from the lab, and misdiagnosing due to samples being stored or treated incorrectly. This allows the correct treatment to be given quickly and gives a portability that allows diagnosis of disease in remote areas (such as HIV infection in developing countries).

In the future such devices may be linked wirelessly to a computer in the doctor's office, allowing patients to monitor themselves from the comfort of their own home and only attend the doctor if a change in treatment is required.

7.2.4 Nanotechnology for Better Healthcare in India

There are around five billion people in the developing world who could benefit from the use of nanotechnology in key sectors such as health. Nanotechnology is already stimulating radical changes in health that promise to both improve existing medical practices and make them more affordable.

In India, for example, researchers have made several advances in nanomedicine, including the development of nano-bioceramics that

repair bone and tissue and an aerosol spray that uses nanoparticles to deliver lung cancer drugs.

Other applications developed in India include a nano-based water filter and the 'iSens' sensor-an affordable and user-friendly nanodiagnostic tool that anticipates heart attacks and is expected to become commercially available soon.

But how effective such advances will be in improving public health will depend on a range of factors beyond the technology itself. These include the existing regulatory framework, funding and infrastructure, and the extent to which the private sector and users participate in technology development [139].

7.2.5 Medical Nanobots

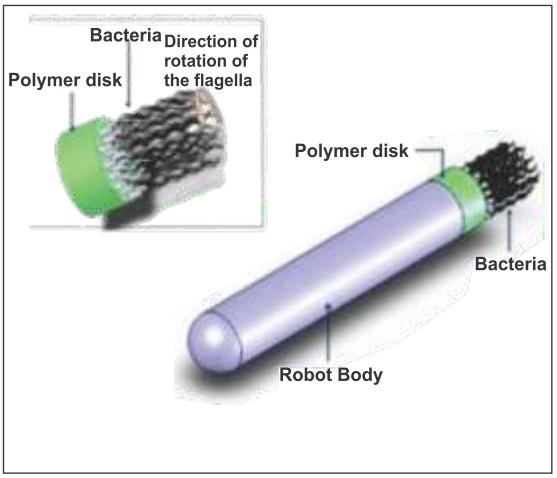

Figure 17 : Medical Nanorobotics

Researchers working in medical nanorobotics are creating technologies that could lead to novel health-care applications, such as new ways of accessing areas of the human body that would otherwise be unreachable without invasive surgery [106].

In the last few years, a vast array of autonomous electromechanical systems have emerged from research labs, making their way onto production lines for industrial tasks, into toy stores for entertainment, and even into homes to perform simple household jobs. While the bulk of robotics research strives to make robots more useful and more capable of even greater levels of autonomy, several labs are attempting to make robotic systems much smaller. One of the most active areas of such research is medical nanorobotics, an emerging field positioned at the intersection of several sciences.

As a discipline, medical nanorobotics remains young for now, but many scientists are already demonstrating new developments they say will form the foundations for the next major breakthroughs in this area. Such breakthroughs could lead to novel applications that offer new ways of accessing small spaces in the human body that would otherwise be unreachable without invasive surgery.

"Nanorobotics can play a major role in medical applications, especially for target interventions into the human body through the vascular network," says Sylvain Martel, director of the nanorobotics laboratory at École Polytechnique de Montréal. "In many types of interventions, medical specialists are lacking appropriate tools to do a good job, and I believe that nanorobotics could bring new methods and tools to these particular applications."

Recent fabrication, actuation, and steering demonstrations of nanoscale robots represent the first crucial steps toward developing real-world applications for targeted drug delivery

and other uses. But researchers say that with many engineering and medical challenges remaining to be met, clinically usable medical nanobots might be viable only after several more years of work in this area. "I believe that the first real application that will have a huge impact is in targeted cancer therapy, such as delivering therapeutic agents directly to the tumor through the vascular network," says Martel.

Currently, Martel and his team are focused on developing a medical application designed to target regions inaccessible to traditional catheterization techniques. The platform they created uses Magnetic Resonance Imaging (MRI) for feeding information to a controller that is responsible for steering the nanobots along blood vessels. The nanobots, which consist of magnetic carriers and flagellated bacteria that can be controlled by computer and loaded with therapeutic and sensing agents, essentially serve as wireless robotic arms that can perform remote tasks.

"Unlike known magnetic targeting methods, the present platform allows us to reach locations deep in the human body using real-time control," Martel says. Still, he predicts it will take three to five years before the system reaches maturity, meaning complete computer-based control of the propulsion and steering mechanisms.

Another researcher designing a similar approach to controlling nanobots is Metin Sitti, director of the nanorobotics lab at Carnegie Mellon University. Sitti and his team are working on building nanobots for drug-delivery applications. In one recent project, he and his team have used bacteria to move nanoscale robots, which use the chemical energy inside the bacteria and in the environment for propulsion. In addition to this propulsion method, Sitti and his team have experimented with optical and magnetic stimuli to coax the bacteria into decelerating, stopping, and moving again.

But as with other similar projects in this area, Sitti and his team are facing several fundamental challenges. "Such bacteria-propelled nanobots are limited by the stochastic nature of cellular motion, and by the relatively brief lifetimes of bacteria," he says. In addition, Sitti says he and his team must develop more effective ways to communicate with nanobots once they are inside a body. "Methods must be found to program and control large numbers of nanobots," Sitti says. "This will be necessary if such devices are to treat large areas of the body, to increase the speed and success of medical operations, and to deliver sufficient amounts of drugs to their targets."

Scientists working in this area say the nanorobotic systems developed by Martel, Sitti, and other researchers could lead to new surgical techniques far more sophisticated and far less invasive than methods currently in use. Such techniques would rely on devices capable of entering the human body through natural orifices or very small incisions to perform diagnostic procedures or repair tissue. "The mechanisms of life operate at the nanoscale," says Aristides Requicha, director of the laboratory for molecular robotics at the University of Southern California. "If we build devices at their scale, we will be able to interact intimately with them."

One goal of Requicha's work in this area is to overturn the basic paradigm of

today's medicine, and to shift from a treatment model to a prevention model through the use of in-body sensors that check for and kill pathogens before the patient has any symptoms. Essentially, Requicha's vision entails rethinking the traditional sequence of patients demonstrating symptoms and then seeking medical care for their ills. "In the long run," he says, "I would like to build artificial and preferably programmable cells." In the meantime, though, one project Requicha and his team are working on is a network of wireless nanosensors capable of operating in biological environments. "This network would give us unprecedented capabilities to study cell biology by being able to acquire data in real time and for extended periods," he says.

7.2.6 Near-Term Applications

Among many projects, Nelson's group is creating artificial flagella designed to mimic natural bacteria in both size and swimming technique and is working on nanobots for retinal surgery. The challenges he and his team face, as with other researchers working in this area, are numerous. Still, Nelson says he remains optimistic, and points to a recent spinoff called FemtoTools [107], in Zürich, Switzerland, that is already marketing micromanipulation products, such as force sensors and microgrippers. "With sufficient resources and energy and the backing of doctors and business people," he says, "retinal therapies using nanobots will be possible within five years."

Nelson's group consists of roboticists, mechanical engineers, electrical engineers, software engineers, computer vision researchers, materials scientists, and chemists. And the team works directly with doctors and biologists. "Trying to understand what all these disciplines are about and how they can work together is a major challenge and, to me, one of the most stimulating aspects of this field," Nelson says. Martel points to a similar experience. "In my office, I can talk about a new imaging algorithm on an MRI machine, and five minutes later have a conversation about microelectronic circuits, antibodies to connect nanoparticles to miniature robots, or genetics to enhance the molecular motor of flagellated bacteria," he says.

In addition to the challenges associated with the interdisciplinary nature of the research, researchers cite safety issues, health concerns, and government regulation as other key issues. Swallowing or injecting miniature robots is not something many patients would readily agree to do without assurances of safety, or at least some demonstrable evidence that the potential benefits outweigh the possible risks. Because human physiology is complex, dynamic, and even different from person to person, reliably producing such evidence likely will remain an engineering challenge for years to come.

Despite the many challenges, researchers say the efforts will yield positive results in the end, with technology that revolutionizes medicine by making health care less expensive and less painful, and enabling medical professionals to target diseases for diagnosis and treatment, precisely and locally.

7.3 Information Technology in Healthcare

Information Technology in Healthcare or Health Information Technology (Health IT) allows comprehensive management of medical information and its secure

exchange between health care consumers and providers [64]. Broad use of health IT has the potential to:

- Improve health care quality
- Prevent medical errors
- Reduce health care costs
- Increase administrative efficiencies
- Decrease paperwork
- Expand access to affordable care

Interoperable health IT will improve individual patient care. It will also bring many public health benefits including:

- Early detection of infectious disease outbreaks around the country
- Improved tracking of chronic disease management
- Evaluation of health care based on value enabled by the collection of de-identified price and quality information that can be compared.

7.3.1 Health IT Tools

A number of tools exist and are also being developed to help health information technology stakeholders plan for, implement, and evaluate health IT. Health IT includes a wide range of capabilities - some as large as the *Nationwide Health Information Network*. Others are smaller in scope and serve to bring health IT to individual stakeholders such as providers, patients, hospitals, pharmacists, and others in this industry. These Health IT tools are examples of specific implementations of health IT that support this industry in specific areas and promote better, more efficient healthcare through the use of today's technologies.

We expect to see a tremendous growth in tools related to health IT in the years to come. The nascent industry has all the potential to become a multi-billion dollar industry in India. Let us know take a look at some of the challenges in the space of health IT tools.

Some of the important health IT tools are listed below:

- Clinical Decision Support
- Electronic Medical Records
- ePrescribing
- Personal Health Records
- Remote Monitoring
- Secure Messaging
- Telehealth

We will now briefly discuss each of the above health IT tool.

7.3.2 Clinical Decision Support

Clinical Decision Support (CDS) provides clinicians, staff, patients or other individuals with knowledge and person-specific information, intelligently filtered or presented at appropriate times, to enhance health and health care. CDS encompasses computerized alerts and reminders to care providers and patients, clinical guidelines, condition-focused order sets, patient data reports and summaries, documentation templates, diagnostic support, and other tools that enhance decision making in clinical workflow.

While stand-alone CDS systems exist, the majority of CDS applications operate as components of comprehensive

electronic health record systems. Because CDS requires computable biomedical knowledge, person-specific data, and a reasoning or inferencing mechanism that combines knowledge and data to generate "advice" to clinicians, CDS is a sophisticated health information technology component. Challenges such as expressing clinical guidelines in computable form and avoiding disturbances in workflow and patient-provider communications have delayed the adoption of electronic health records with CDS capabilities.

7.3.3 Electronic Medical Records

An EMR (Electronic Medical Record) is a real-time patient health record with access to evidence-based decision support tools that can be used to aid clinicians in decision making. The EMR can automate and streamline a clinician's workflow, ensuring that all clinical information is communicated. It can also prevent delays in response that result in gaps in care. The EMR can also support the collection of data for uses other than clinical care, such as billing, quality management, outcome reporting, and public health disease surveillance and reporting [64].

In general terms, EMRs are clinician-focused in that they enhance or augment the workflow of clinicians or administrators. EMRs are said to be interoperable if they are able to exchange data using standardized data transmission formats.

Implementation of an EMR also creates issues related to identification of stakeholders within a community or region and getting their buy-in, legal issues related to cross-institutional data sharing, security and privacy of shared records over potentially insecure network lines, and patient access to and augmenting their own data in electronic format (using the web, for example) [64].

7.3.4 Electronic Prescribing

According to [64], "E-prescribing is the transmission, using electronic media, of prescription or prescription-related information between a prescriber, dispenser, pharmacy benefit manager, or health plan, either directly or through an intermediary, including an e-prescribing network. E-prescribing includes, but is not limited to, two-way transmissions between the point of care and the dispenser."

7.3.5 Personal Health Record

A Personal Health Record (PHR) is an electronic application through which individuals can maintain and manage their health information (and that of others for whom they are authorized) in a *private, secure, and confidential environment*.

The most salient feature of the PHR, and the one that distinguishes it from the EMR and EHR, is that the information it contains is under the control of the individual. The individual is distinctively the guardian of information stored or accessible within a PHR. Similar to the role of a librarian, a person managing a PHR decides what volumes of information to include, how they are maintained and ordered, and who can read them or "check them out." Standards and policy will need to determine if and how individuals can delete or modify information in a PHR that originated from an EHR and how these modifications are communicated to other providers with whom the data in the PHR are shared.

7.3.6 Remote Monitoring

Remote monitoring is the electronic transmission of health care data either entered directly by a patient (or his/her caregiver) or through a medical device to a clinician's Electronic Health Record (EHR) or a patient's Personal Health Record (PHR). The ability for a clinician to monitor patient information captured remotely in an ambulatory setting, such as physiological, diagnostic, medication tracking, and activities of daily living measurements, may be a key enabler for the management of chronic health problems and initial management of new conditions. Remote monitoring may also be a component of maintaining wellness for the aging population. Remote monitoring could include, but is not limited to, communication of: physiologic measurements (e.g., weight, blood pressure, heart rate and rhythm, pulse oximetry, glucose etc), diagnostic measurements (e.g., transthoracic impedance) medication tracking device information (e.g., medication pumps, infusion devices, electronic pillboxes), and activities of daily living measurements (e.g., biosensors, pedometers, sleep actigraphy etc).

7.3.7 Secure Messaging

Secure messaging is the secure and protected transmission of information between patients and their providers, including clinicians and their support staff. This messaging is similar to traditional email where both patients and clinicians can send and respond to communications without having to be on-line at the same time. Giving patients the ability to compose and send a secure communication to a clinician will, at times, give them access to their clinicians in a more timely, efficient manner than an office visit or a phone call. Similarly, clinicians will benefit from having the ability to respond to or initiate secure communications to facilitate the care process and promote better patient health. This communication will be done in a manner which provides appropriate information to the patient and meets existing needs for clinical documentation. Secure messaging can also serve as a preventive healthcare tool by allowing clinicians to provide clinical reminders to their patients.

7.3.8 TeleHealth

TeleHealth is the use of telecommunications technologies to deliver health-related services and information that support patient care, administrative activates and health education. The technology is a means to improve access to care, while reducing cost of transportation and increasing convenience to patients care.

In the USA, there are more than 200 TeleHealth networks connecting some 2,000 institutions across the country [66].

Some of the TeleHealth applications are listed below:

1. **Live videoconferencing**: Audio and video feeds used to connect two or more geographically dispersed health care facilities to enable patients, physicians to consult in real time.
2. **Store-and-forward systems (S & F)**: Digital images and other clinical data are captured at the point of care; they are temporarily stored and later forwarded to another location.
3. **Remote patient monitoring**: Home-based monitoring devices are used by patients to easily capture and transmit clinical data over the internet (such as BP and glucose levels). This application

is becoming more prominent with the care of chronically ill patients.

4. **E-visits/e-consults**: Evolved from secure – email or phone based encounters e-visits can be offered by health insurers through a secure Web portal.

There are numerous benefits of TeleHealth. Some of the benefits are (i) improved access to care and personal health information, (ii) improved efficiency (most lab results available online within 24 hours), (iii) improved convenience and accessibility for consumers, (iv) decreased use of office visits and physician phone calls, (v) remote patient monitoring, (vi) improved accessibility to specialist care, (vii) enables early, proactive intervention for follow-up care, (viii) reduced wait times, and, (ix) improved access to specialty care and improved training and education of medical interns.

A few of the obstacles to TeleHealth are (i) low consumer awareness, (ii) provider liability concerns, (iii) state-specific licensing and regulatory requirements, (iv) traditional provider reimbursements methods, and, (v) data interoperability and portability.

Example: AFHCAN TeleHealth Solution

An example of a highly successful effort in TeleHealth is AFHCAN [65]. AFHCAN is part of the Alaska Native Tribal Health Consortium, Anchorage, Alaska. AFHCAN began as the Alaska Federal Health Care Access Network, an initiative of the Alaska Federal Health Care Partnership (AFHCP) back in 1998. The first author has had a chance to visit AFHCAN in 2003 in Anchorage, Alaska and was impressed by the tools, technology and expertise that exist there.

AFHCAN designs and develops complete TeleHealth solutions for the changing world of health care delivery. The combination of an award-winning store-and-forward system and highly-successful TeleHealth programs has made AFHCAN an authority in the telemedicine world [65].

AFHCAN offers a diagnostic store-and-forward TeleHealth platform with the ability to create a telemedicine case containing textual information and data from biomedical peripherals, and send the case for consultation. Health care professionals are able to view the data and respond to the case using a standard PC workstation.

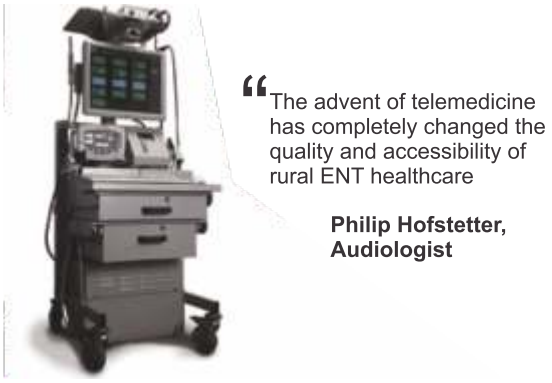

Figure 18: An AFHCAN Telemedicine Cart

Alaska's unique environment has proven to be a great challenge to AFHCAN design efforts - a challenge that has inspired an even greater solution. Development efforts have focused on creating products that will work with poor connectivity, in harsh climates, and for a wide variety of users.

AFHCAN's success should be a wake-up call to healthcare efforts in India. If a TeleHealth solution could work well in a hostile environment characterized by poor connectivity and harsh climate, then there is no reason why India cannot emulate the efforts of AFHCAN.

Some of the other emerging areas that are likely to play an important role in healthcare are described below.

Healthcare Ontologies and Knowledge Management Systems: This area will include annotation, health care ontologies, coding standards, communication standards, quality tagging and quality of service, distribution issues, coding systems and ontology mapping, search, user customization and alert agents.

E-learning, Educational Games and the Impact of Information Delivery to Patients and Professionals: This will include the use of digital libraries in building online communities, moderated discussion groups, qualitative and quantitative evaluation studies, user attitudes towards the knowledge, studies of changes of user attitude with respect to digital libraries.

Web 2.0 in Healthcare and Online Communities of Practice:

"Web 2.0" refers to a perceived second generation of web development and design, that facilitates communication, secure information sharing, interoperability, and collaboration on the World Wide Web. Web 2.0 concepts have led to the development and evolution of web-based communities, hosted services, and applications; such as social-networking sites, video-sharing sites, wikis, blogs, and folksonomies [67].

That Web 2.0 has the potential to enable numerous services related to healthcare is therefore not a surprise. Some of these services include online support for healthy lifestyles, wellbeing and public interventions etc.

It is clear that Information and Communication Technologies (ICT) will play an increasingly important role with each passing year in enabling health related services and solutions.

We believe that the engineering community in India can contribute tremendously in enabling new, smart and affordable technologies in the healthcare sector. Healthcare sector is a classic example of a convergence of various disciplines such as computer science, electrical engineering, software engineering, instrumentation, bio-technology and of course the medical profession. The country needs to exhibit a lot of vision if we are to excel in the healthcare sector.

There are several ways by which we could achieve this:

- Encourage and fund start-ups in the country in the healthcare sector
- Commence new engineering curriculum in healthcare sector with an emphasis on technologies

In the next section, we focus on a very important area in the healthcare sector - standards for Electronic Healthcare Records.

7.4 Standards for Electronic Healthcare Records

Medical information systems today store clinical information about patients in all kinds of proprietary formats. To address the resulting interoperability problems, several Electronic Healthcare Record (EHR) standards that structure the clinical content for the purpose of exchange are currently under development. In this section, we describe the most relevant Electronic Healthcare Record standards. An excellent survey of EHR standards is given in [75]. The reader wishing to get more detailed information in this area is encouraged to refer [75].

The Electronic Healthcare Record (EHR, also called Electronic Health Record),

which has been a key research field in medical informatics for many years, is de-fined as “digitally stored health care information about an individual's lifetime with the purpose of supporting continuity of care, education and research, and ensuring confidentiality at all times". The EHR includes information such as observations, laboratory tests, diagnostic imaging reports, treatments, therapies, drugs administered, patient identifying information, legal permissions, and allergies. Currently, this information is stored in all kinds of proprietary formats through a multitude of medical information systems available on the market. Typical formats include relational database tables; structured document-based storage in various formats and unstructured document storage such as digitized hardcopies maintained in a classical document management system. This results in a severe interoperability problem in the healthcare informatics domain.

Making EHRs interoperable will contribute to more effective and efficient patient care by facilitating the retrieval and processing of clinical information about a patient from different sites. Transferring patient information automatically between care sites will speed delivery and reduce duplicate testing and prescribing. Automatic reminders will reduce errors, improve productivity, and benefit patient care. Furthermore, one of the prominent research directions in the medical field is about using genomics data for improving health knowledge and processes for prevention, diagnosis, treatment of diseases and personalization of health care. This also necessitates the interoperability of biomedical information and the EHRs [75].

In the following sections, we present a brief overview of the seven EHR standards that exist today.

7.4.1 CEN/TC 251 AND ENV/EN 13606 EHRCOM

CEN/TC 251 [CEN/TC 251] is the technical committee on Health Informatics of the European Committee for Standardization. Its mission is to achieve compatibility and interoperability between independent health systems and to enable modularity by means of standardization. This includes requirements on health information structure to support clinical and administrative procedures, technical methods to support interoperable systems as well as requirements regarding safety, security and quality.

The CEN Pre-standard ENV 13606:2000 Electronic Healthcare Record Communication [CEN ENV 13606 2000] is a message-based standard for the exchange of electronic healthcare records. The standard defines an EHR information model, called the extended architecture since it is an extension of the earlier pre-standard ENV 12265 [CEN ENV 12265]. It also defines a list of machine-readable domain terms that can be used to structure EHR content, a method of specifying distribution rules, that is, rules under which certain EHR content may be shared with other systems and, finally, request and response messages that allow systems to exchange subsets of an EHR. ENV 13606 does not attempt to specify a complete EHR system; instead it focuses on the interfaces relevant for a communication between EHR systems.

In 2001, CEN/TC 251 decided to revise ENV 13606 into a full European Standard, taking into account the existing implementation experience and

to adopt the openEHR archetype methodology. EN 13606, called EHRcom, will be a five-part standard consisting of the following:

- The Reference Model,
- Archetype Interchange Specification,
- Reference Archetypes and Term Lists,
- Security Features, and
- Exchange Models.

Figure 19 shows the logical building blocks of EHR content. The top level is a directory of possibly nested folders for a patient, allowing for a high-level organization of the EHR, for example, per episode or per clinical specialty. Folders contain zero or more compositions by reference. A composition (which roughly corresponds to one clinical document) may contain sections with section headers and entries which consist of elements or clusters of elements. Each element has a single value of a single data type. Content in the EHR extract is always added or replaced as a complete composition – versioning, ownership and audit trail in EHRcom are based on the composition.

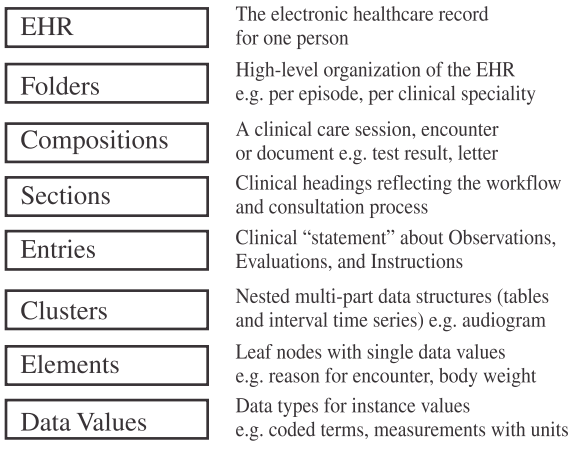

Figure 19 : Logical Building Blocks of EHRcom

7.4.2 HL7 Standard

Founded in 1987, HL7 (Health Level Seven) [HL7] is a non-profit, ANSI accredited Standards Developing Organization that provides standards for the exchange, management and integration of data that supports clinical patient care and the management, delivery and evaluation of healthcare services.

The HL7 standard is developed with the assumption that an event in the health-care world, called the trigger event, causes the exchange of messages between a pair of applications. When an event occurs in an HL7 compliant system, an HL7 message is prepared by collecting the necessary data from the underlying application systems and it is passed to the requestor, usually as an EDI (Electronic Data Interchange) message.

HL7 is developing Version 3 which is based on an object-oriented data model, called Reference Information Model (RIM). Up to the current Version 2.5, the scope of the HL7 standard was limited to the exchange of messages between medical information systems. Starting with Version 3.0, a document markup standard, called the Clinical Document Architecture (CDA) has been proposed. CDA documents are encoded in Extensible Markup Language (XML).

7.4.3 Digital Imaging and Communications in Medicine (DICOM)

DICOM (Digital Imaging and Communications in Medicine) is known as the de-facto standard for medical image communication. The standard defines data structures and services for the vendor independent exchange of medical images and related information.

It is being developed by medical industry and medical professional organizations under the umbrella of the National Electrical Manufacturers Association (NEMA) [79].

DICOM uses a binary encoding with hierarchical lists of data elements identified by numerical tags and a complex DICOM-specific application level network protocol. Two DICOM based EHR standards have been defined, namely, Web Access to DICOM Persistent Objects (WADO) and DICOM Structured Reporting.

The WADO standard defines a Web-based service that can be used to retrieve DICOM objects (images, waveforms and reports) via HTTP or HTTPS from a Web server.

7.4.4 Integrating The Healthcare Enterprise (IHE)

Integrating the Healthcare Enterprise (IHE) not-for-profit initiative was founded in 1998 in the USA by the Radiological Society of North America (RSNA) [80] and the Healthcare Information and Management Systems Society (HIMSS) [81]. The goal of the initiative is to stimulate integration of healthcare information resources.

While IHE does not develop standards as such, it selects and recommends appropriate standards for specific use cases and also develops restrictions, that is, application profiles for these standards that allow for a simplified system integration. The result of this technical work, a fully implementable set of specifications, is published as the IHE Technical Framework and revised annually. IHE is strongly supported by the industry.

Medical Markup Language (MML)

The Medical Markup Language (MML) has been developed since the mid 1990s by the Electronic Health Record Research Group of the Japanese Ministry of Health and Welfare. Its purpose is to provide a standardized way to exchange medical documents and other clinical data. The first version of this specification was based on SGML (Standard Generalized Markup Language) but later XML (Extensible Markup Language) was chosen.

Market Relevance of EHR Standards

Table 1 : Market Relevance of EHR Standards [75]

	CEN EHRcom	HL7 CDA R2	ISO WADO	DICOM SR	IHE RID	IHE XDS	MML
Final specification available	No	Yes	Yes	Yes	Yes	Yes	Yes
Implemented	No	Yes	Yes	Yes	Yes	Yes	Yes
Commercial products available	No	Yes	Yes	Yes	Yes	Yes	Yes
Intended for international market	Yes	Yes	Yes	Yes	Yes	Yes	No
Focussed on medical imaging sector	No	No	Yes	Yes	No	No	No

Table 1 summarizes the market relevance of the EHR standards. It shows whether or not the standards are available as a final specification, whether implementations of the standard are known and whether or not implementations of the standard are available in off-the-shelf commercial products for the medical market. The final specifications are not yet available for EHRcom. All other standards are finalized, although many XDS add-on services and content profiles are still under development. Both prototype or project-based and commercial product implementations are known to exist for all standards except EHRcom [75].

In summary, the evaluation of the various EHR standards reveals no clear "winner". The content format standards are surprisingly similar in concept and capabilities, using a two-level modeling approach with a simple reference model and constraint rules (archetypes, templates) for mapping clinical data onto the model. The EHR standards differ in the progress achieved in the standardization process. Each of the content formats seems to be suitable for implementing electronic healthcare records.

7.5 Mobile/Wireless Healthcare

There are major developments going on in the field of Mobile/Wireless healthcare. This section gives a brief overview of some of the developments going on in the area [104].

Let us first understand the motivation behind a mobile based healthcare system. The key to minimising long-term complications is to empower patients to take more responsibility for the management of their condition. A lot of time of healthcare professionals and bed space in the hospitals are wasted for the routine procedures that can be avoided by remote monitoring of the patients. The economic driver is reduction in unplanned hospital admissions.

Figure 20 : Personalised Feedback Screens

Vodafone has been field-testing neurosurgical telemedicine applications using third generation (3G) technology in Germany. Scientists in Denmark have successfully used text messaging to collect diary data from asthma patients in a pilot study to determine whether increased remote support improves clinical outcomes. Previous studies using home PCs to send the same diary information proved disappointing, with users rejecting the application after a short while.

Researchers from the Norwegian Centre for Telemedicine in Tromso studied parent-child interaction using a mobile and wireless system for blood glucose monitoring, and concluded that, whether or not the health outcome is improved as a result, the peace of mind provided by such a system may make it a commercial proposition.

In Finland, Medixine has been promoting home care by integrating diagnostics

and patient diaries before sending results via a PC based web-link to health professionals. The company is now offering the same functionality using hand-held mobile PCs.

Researchers in the UK have, however stolen a march. When scientists from Oxford University set out to determine whether a system based on automated transfer of data, real time analysis and immediate feedback to the patient could improve glycaemic control for young adults with type 1 diabetes, they adopted the mobile approach.

For the first time, the use of mobile telephone technology was proved to have a significantly beneficial effect and resulted in demonstrably improved clinical outcomes.

The system involved in the trials, which has subsequently been made commercially available under the "t+ diabetes" brand, uses a glucose meter linked by Bluetooth to a GPRS-enabled mobile telephone. (GPRS allows a handset to communicate with a remote server without the user having to dial in manually).

After the patient has taken a reading in accordance with the advice he or she has been given by a GP or practice nurse, they spend around 10 seconds adding essential diary information about diet, exercise and general health via the telephone's keypad. The system is intuitive and easy to use.

The information, together with the reading, is sent by the handset to a central computer which responds within seconds, providing patients with personalised feedback in easy-to-read graphical format delivered to their mobile's display.

The number crunching done by the remote computer uses sophisticated algorithms to help negate the effects of occasional rogue readings and deliver a consistently meaningful result to the patient's mobile.

7.5.1 Mobile Healthcare: Security and Privacy

We expect that wearable, portable, and even embeddable medical sensors will enable long-term continuous medical monitoring for many purposes: for patients with chronic medical conditions (such as blood-sugar sensors for diabetics), for people seeking to change behavior (such as losing weight or quitting smoking), or for athletes wishing to monitor their condition and performance. The resulting data may be used directly by the person, or shared with others: with a physician for treatment, with an insurance company for coverage, or by a trainer or coach. Such systems have huge potential benefit to the quality of healthcare and quality of life for many people. Since the sensor data may be gathered through a patient's mobile device (such as a mobile phone), a wireless network, and the Internet (see Figure 21), there are many opportunities for the sensor data to be tampered or otherwise inaccurate [102].

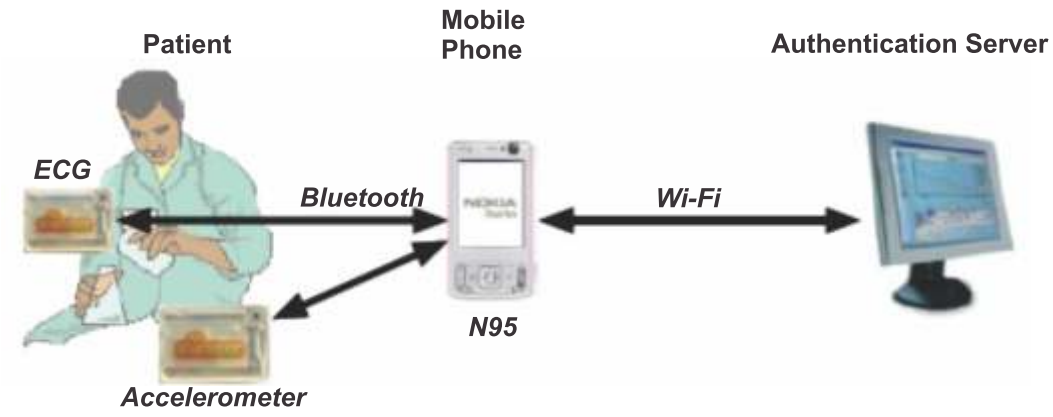

Figure 21 : Remote Health Monitoring: Typical Architecture [102]

In the Trustworthy Information Systems for Healthcare (TISH) project [103], researchers seek to develop novel protocols and systems that can support the collection of medically-relevant sensor data on small handheld devices, notably smart phones, with an emphasis on data security and patient privacy.

We describe the TISH project [103] in brief in the next section.

7.5.2 Trustworthy Information Systems for Healthcare

Healthcare in the 21st century requires secure and effective information technology systems to meet two of its most significant challenges: improving the quality of care while also controlling the costs of care. Yet developing, deploying and using information technology that is both secure and genuinely effective in the complex clinical, organizational and economic environment of healthcare is a significant challenge in its own right.

This is a multidisciplinary area where research will drive innovation in information-sharing technology that ensures security and privacy while addressing the pragmatic needs of patients, clinical staff, and healthcare organizations to deliver efficient, high-quality care.

There is a dire need to address fundamental challenges in current and emerging areas of information security, as identified by its healthcare partners. These challenges are (i) protecting the security of clinical information, while ensuring that clinicians can access information they need, when and where they need it, with technology that clinicians can actually use and healthcare enterprises can actually manage, and (ii) securing the collection of sensor data through personal sensor devices to enable monitoring of patient outcomes while giving patients usable control over their privacy. To be effective, such technologies must consider the economic, organizational and sociological dynamics that are critical to creating and implementing IT that is secure as well as usable and effective.

The objectives described above will lead the researchers to tackle many challenges. For example, what authentication (and de-authentication) mechanisms are practical in a clinical setting, a fast-paced environment with diverse staff roles and physical

constraints on technology? For patients sent home with mobile devices that measure their health and monitor their activity, what abstractions and interfaces allow them to easily control their privacy? What are the risks to operating continuity and efficiency from widespread security-related IT disruptions within a healthcare organization? How do security and privacy perceptions and practices vary across stakeholder groups and organizational settings? There is a need to approach these challenges from the user perspective, grounding solutions on the needs of real users (patients, providers, and provider organizations) - gained in part by embedding researchers into a clinical practice.

7.6 Wireless Health Care: The Convergence of Mobile Telephony and Health Care

The evidence of m-health's usefulness is at last starting to trickle in [144]. A study in the *Lancet*, a medical journal, shows that something as simple as sending text messages to remind Kenyan patients to take their HIV drugs properly improved adherence to the therapy by 12%. WellDoc [145], an American firm, found in a recent trial that an m-health scheme that relies on behavioural psychology to give diabetics advice on managing their ailment has more effect than putting them on the leading diabetes drug.

Another reason to think that m-health has a promising future is the flurry of business interest in it. One push comes from the rise of cloud computing (providing data storage and processing over the internet), which Peter Neupert of Microsoft argues will be "transformative" for wireless health. UltraLinq, an American start-up [146], uses the cloud to offer medical imaging on the software-as-a-service model. AT&T, a telecoms giant that already collects revenues of $4 billion a year from health care, has just created a division devoted to pursuing wireless health-care business using cloud computing.

A second push will come from American policy, which will dispense more than $30 billion in subsidies over the next few years to encourage doctors and hospitals to adopt electronic medical records. The digitization of America's paper-based health system will, argues Todd Park of the Department of Health, inevitably boost m-health [144].

A further impetus is likely to be provided by ideas bubbling up from developing countries. Victoria Hausman of Dalberg, a development consultancy, has surveyed dozens of m-health business models in Haiti, India and Kenya in work for the World Bank. She predicts that mobile banking, which has already taken off in Kenya, will be a great enabler of m-health. Firms are coming up with ways for patients to pay doctors, receive subsidy vouchers and so on, using their phones.

Substituting technology for labour (such as the absent doctor at the government clinic) is another trend. Healthpoint Services, a start-up, is establishing for-profit centres in rural Punjab, in India, that provide health services, as well as clean water. Its health workers roam with backpacks carrying diagnostic equipment; a mobile phone captures and interprets the data, which can then be used for paid telemedicine consultations. Procter & Gamble, an American consumer-products giant, has announced a commercial partnership with Healthpoint.

Though there is some skepticism about m-health, however, given the growing evidence of its usefulness and the new business models from emerging markets, there is reason for hope. As Bill Gates pointed out at the 'm-health conference' in Washington, DC, USA [147], "Middle-income countries are where most innovation in health care is going to come from."

For a detailed description on emerging Wireless Technologies for E-Healthcare, the interested reader is encouraged to go through [162]. The reference describes important services/ applications that run on wireless Body Sensor Networks (BSNs) or wireless Personal Area Networks (PANs). Several challenging issues related to wireless technologies in e-healthcare systems are discussed in [162].

7.7 Emerging Applications of Mobile/ Wireless Healthcare

Wireless medical technologies have made huge strides in the last few years and continue to gain pace. While they provide increased comfort and mobility to patients, wireless medical devices also allow healthcare organizations to manage resources more effectively and help improve medical efficiency and practices. The medical services include ambulatory vital signs monitoring, wireless cardiogram sensors, Radio Frequency Identification technology (RFID) with real time presence, Internet Protocol (IP) over WLAN-based communications systems, to name a few.

New technologies for health information transfer enables patients and caregivers to connect with ease, ultimately improving the quality and efficiency of care. In healthcare, safety, accuracy and speed are vital. Using technology to improve the precision and efficiency of patient care can reduce liability and save lives.

Wireless technology can connect physicians' offices with doctors, patients with nurses, and medical supplies can be made readily available. The result is increased safety while limiting risk without adding costly resources. Wireless information technology has the potential to save healthcare providers significant time in accomplishing routine administrative and healthcare-related tasks. Wireless information technology includes mobile computing that in turn involves use of a portable wireless device (e.g., a laptop or handheld computer or personal digital assistant [PDA]) to access a wireless local area network or the Internet.

Healthcare is increasingly becoming digitized and there is growing need to develop and deploy sophisticated information systems. However, the wireless technology that is transforming various areas of business currently is yet to be fully explored by the healthcare industry to support quality maintenance and improved efficiency. The popularity of mobile handheld devices in the healthcare arena is poised to increase against a backdrop of technology savvy patients and the evident benefits of mobility and flexibility. The drive to reduce costs and improve efficiency without compromising patient safety and service quality should have a positive impact on the impact of wireless technology in the healthcare sector.

7.7.1 Nokia's new technology helps fight cholera in Africa

A post that appeared on Nokia's blog highlights how near-field communication (NFC) is helping a not-for-profit organisation fight cholera in Haiti. [148],

[149] The situation in Haiti remains dire, more than a year after a deadly earthquake hit the country. Among the challenges is providing safe drinking water to Haiti's poverty-stricken population, the vast majority of whom don't have running water in their homes, according to a Feb. 18 Scientific American article that inspired the Nokia blog post. According to Nokia, the organization – Deep Springs International (DSI), has provided 35,000 Haitian households with chlorination systems in 5-gallon buckets equipped with RFID chips. The chips are activated whenever a health worker toting an NFC-enabled Nokia 6212 phone visits and passes the phone within a few centimeters of a bucket. The SMS questionnaire replaces paper forms that often take days to reach DSI headquarters. According to Scientific American, DSI picked the 6212, a model that has been around since 2008; since the phone has a long battery life but lacks a touch screen or other advanced features that would make it attractive to would-be thieves.

7.7.2 SMS to check authenticity of drug

Figure 22 : Packages with unique codes and private virtual phone number

Figure 23 : Instant authentication message in response

First some startling facts. Nine to 12% of all drugs sold in India are either substandard or fake. We now don't need to fret since help is at hand. A new technology claims it can check the authenticity of the drugs we are consuming. The technology can tag the drugs we buy and confirm its standard by a simple SMS [150]. [151].

While the World Health Organization (WHO) says 20% of Indian drugs are substandard or illegal, the Indian government recognises 9% of Indian drugs as substandard. The fact of the matter is there's no way a consumer can know whether the medicine he or she buys are fake or substandard.

A company called Pharmasecure in India [151] plans to tackle the fake drug racket using an ingenious method – by tagging the drugs with a unique code and feeding that into a database. This way, consumers can send an SMS to confirm if it's authentic. Pharmasecure says several Indian pharma companies are interested in the technology and the first one on board is Hyderabad-based MSN Labs.

"Anything with SMS is very catchy in India. So this is very compelling and we wanted to try this technology end to end," Bharat Reddy, MD of MSN Labs, said.

Two of their drugs, Floxsafe, an antibiotic, and Vitasafe, a multivitamin, now bear unique codes on each pack.

7.7.3 Platform that allows Medical Devices to Communicate Wirelessly

Figure 24 : US $10 platform lets consumers effortlessly monitor health at home [160]

Cambridge Consultants has announced the first demonstration of the emerging industry standards for medical device interoperability [160]. The 'Vena' platform is a breakthrough software solution on a single chip that allows medical devices such as blood pressure monitors to transmit data wirelessly. The development gives consumers, especially those with chronic conditions, the ability to monitor their own health accurately, systematically and independently. The platform uses low-cost wireless technology and will allow devices to deliver medical readings to a central monitor located at home, or even to an online health record such as Google Health or Microsoft Health Vault. The Vena software solution can be added to a medical device using hardware with a potential cost of less than US $10 at the appropriate volumes.

Online health services allow a consumer to manage their own health and fitness data securely. Controlling when and with whom the data is shared offers the potential to improve the understanding and management of their health.

"Due to both an increasingly independent mindset and time-poor healthcare providers, consumers are taking an increasingly active part in monitoring and managing their health," says Paul Williamson, Head of Wireless Medical, Cambridge Consultants. "This first successful demonstration of the platform, combined with its affordability, and compatibility, opens up a whole vista of possibilities in the way health is monitored and treated. This platform takes us one step closer to all the possibilities of *next-generation healthcare*."

For the first time, the Vena platform embeds both the emerging IEEE11073 standard [161], which ensures compatibility of data exchanged between different types of devices, and the emerging Bluetooth Medical Device Profile, optimised for the secure transport of medical data, onto the single chip. Successfully concept tested with a pulse oxymeter and weighing scales, the platform will be expanded to include other types of devices including blood pressure monitors. The platform is also capable of delivering a complete display, which means that device manufacturers now simply need to add their sensor of choice and the device is wireless-ready.

The Vena platform can be used with multiple devices providing a connection to online records through a monitoring station, home PC or set top box. In addition to Bluetooth, the platform incorporates complete support for a range of other connections. Full TCP (Transmission Control Protocol) implementation allows Wi-Fi or Ethernet connections. Cable connections via UART (Universal Asynchronous Receiver/Transmitter) or USB can also be added. The platform can even be used to transmit data via mobile phone

for health and fitness applications on the move.

"The Vena platform can be easily built into devices at any stage of the design or production process," said Paul Williamson.

7.7.4 Mobile Health Device Links Patients and Healthcare Professionals

Figure 25 : Cambridge Consultants' Minder, powered by Vena, arms patients with a pocket-sized 'smart' device that can reduce recovery times and hospital visits [160]

Cambridge Consultants [160] announced a new product concept based on its low-cost Continua-compliant 'Vena' platform. The 'Minder', powered by Vena, enables continuous, real-time medical data collection and transmission via cellular networks. Increasing the accuracy and frequency of patient data reporting, the Minder demonstrates a new technology solution that can lower the cost of healthcare by improving the quality of patient care. Doubling as a pocket-sized digital patient checklist, Minder is a sophisticated gateway that captures wireless medical data and transmits it to a patient's online health record, creating higher volume and higher quality data for Electronic Medical Records (EMR). Moreover, Minder can receive real time updates to the checklist thereby enabling two way communications with healthcare professionals or caregivers, enabling more meaningful use of e-health records.

Usually, a hospital visit is required in order to record data, such as ECG or blood pressure readings, into a patient's EMR. However, as wireless-enabled medical devices continue to grow in number, the novel Minder device showcases a viable pathway for such readings to be acquired and transmitted remotely. For physicians and hospitals, this would provide access to more accurate data to work with, while increasing efficiency and decreasing unnecessary and expensive hospital visits. For patients, the Minder takes the stress out of the often complex daily medication and monitoring regimen.

With the goal of increasing compliance via user engagement, the Minder displays an interactive timed to-do list that can be customized for individual patients. For instance, the recovering heart attack victim can now transmit their blood pressure readings from home to their EMR in real-time. If the reading is high, the Minder could instantly alert a care provider who could have the patient carry out necessary steps by sending tasks back to the Minder. If the reading is on target, it could prevent an unnecessary hospital visit.

7.7.5 Ubiquitous Health Monitoring

"The rollout of *ubiquitous health monitoring* is gaining traction. The question is not 'if' but 'which' technologies will take hold. Between the proliferation of countless health apps for smart phones and even the first Continua Certified smart phone, we are seeing an opportunity to drive a new market and lower health care costs via connected health solutions," said Vaishali Kamat, Group Manager, Medical

Technology, Cambridge Consultants. "The other big question going forward will be: 'How do I design a product in a smart way so that I can get it to market without regulatory hiccups?' We believe the answer lies in standards-based technology such as Vena, which can provide reliable platforms for dedicated health devices. In the end, the companies that clear regulatory hurdles first will most likely dominate the market."

The Vena technology used in Minder, leverages Cambridge Consultants experience with CSR's BlueCore and Qualcomm's Wearable Mobile Device (WMD) hardware and implements Continua Health Alliance standards for Personal Area Network (PAN) and Wide Area Network (WAN) interfaces. Devices based on Vena can receive data via Bluetooth or USB from any Continua Certified devices and transmit this data via HL7 over cellular networks, thus empowering users to manage health and wellness anytime, anywhere. The Vena wireless healthcare software stack, embeds the Bluetooth™ Health Device Profile (HDP) optimized for the secure transport of medical data and the IEEE 11073 standards [161] for compatible exchange of information between devices. Vena has been at the heart of Cambridge Consultants' Vena family of devices – an inhaler, the VenaHub USB gateway, and core technology for A&D Medical's wireless blood pressure cuff and weight scale. The Qualcomm WMD supports a variety of 3G networks and provides integrated GPS, and accelerometer and Bluetooth technologies.

With the ability to customize for different target populations – whether it's individuals with chronic diseases, seniors living independently or those trying to fight obesity – the Vena platform can support various device sizes, types, and complexities. Nevertheless, the Minder is a classic example of how a small gateway with a simple user interface can serve as a powerful and engaging tool for health management.

7.8 Waste Management in the Healthcare Sector

Health Care Wastes (HCWs) are all wastes generated by health care and health research facilities and associated laboratories. They include both (a) "communal waste," such as paper and bottles that can be dealt with through the local solid waste management system; and (b) potentially dangerous "biomedical wastes", such as sharps (needles, scalpels, knives, blades, broken glass) and wastes with infectious, hazardous, radioactive, and genotoxic properties that endanger human health and the environment. Managing HCWs safely is essential, however, quite a challenge [100].

Health-care waste management in India is receiving greater attention due to recent regulations (the Biomedical Wastes (Management & Handling) Rules, 1998). The prevailing situation needs to be analysed covering various issues such as quantities and proportion of different constituents of wastes, handling, treatment and disposal methods in various health-care units (HCUs).

The waste generation rate ranges between 0·5 and 2·0 kg per bed per day. It is estimated that annually about 0·33 million tonnes of waste are generated in India. The solid waste from the hospitals consists of bandages, linen and other infectious waste (30–35%), plastics (7–10%), disposable syringes (0·3–0·5%), glass (3–5%) and other general wastes

including food (40–45%). In general, the wastes are collected in a mixed form, transported and disposed of along with municipal solid wastes. At many places, authorities are failing to install appropriate systems for a variety of reasons, such as non-availability of appropriate technologies, inadequate financial resources and absence of professional training on waste management [101].

7.8.1 Healthcare Waste Management Technologies

Figure 26

Healthcare waste management technologies aren't just limited to the treatment step along the healthcare waste stream.

Use of appropriate containers into which waste is segregated is very important both to ensure further safe handling (internal transport, storage and eventual external transport to the waste treatment and/or disposal facility) as well as for identification purposes.

Making sure that protective equipment is provided to waste handlers is an extra measure that must be taken to minimize risks of injury and infection.

Transport vehicles both for on and off-site transportation need to comply with a set of minimum requirements.

At the level of treatment and final disposal technical options, the choice will be dependent on quite a number of parameters amongst which the setting (urban or rural), population density as well as transport issues that will typically be determinant in the choice between a centralized or decentralized system.

Considering the fact that a universal treatment solution has yet to be invented, the final choice of the best available alternative is strongly dependent on local conditions rather than a global policy as the parameters to be taken into consideration show.

7.8.2 Containerization

Figure 27

The recipients used for the different categories of HCW must not only be sufficiently robust to minimize accidental spillages (example of a plastic bag containing infectious waste that tears open), but have also the appropriate colour coding and labelling for clear and univocal identification.

7.8.3 Handling

Figure 28

Sanitary staff and cleaners should always wear protective clothing including, as a minimum, boots or robust working shoes and heavy duty gloves.

The internal transport of HCW requires the use of dedicated wheelie bins, trolleys or carts. Internal transport should follow specific routes through the HCF to reduce the passage of loaded carts through wards and other clean areas. The carts should be (i) easy to load and unload, (ii) have no sharp edges that could damage waste bags or containers and (iii) easy to clean.

7.8.4 Transportation

Figure 29

The external (off-site) transportation of HCW is required when hazardous HCW is treated outside the HCF. The waste producer is then responsible for the proper packaging and labelling of the containers that are transported.

The transportation should always be properly documented and all vehicles should carry a consignment note from the point of collection to the treatment facility. Furthermore, the vehicles used for the collection of hazardous HCW should not be used for any other purpose. They shall be free of sharp edges, easy to load and unload as well as to clean and fully enclosed to prevent any spillage.

7.8.5 Treatment

Large HCFs are particular in that they usually produce a sufficient amount of waste to justify the purchase of a relatively sophisticated HCW treatment unit but on the other hand, due to their localization within densely populated urban settings, can be confronted with a lack of space as well as oppositions from the surrounding community depending on the technology chosen.

The final choice between an on or off-site treatment option will depend on a number of parameters.

It is to be noted that one can use technologies such as Radio-Frequency Identification (RFID) tags for improving the efficiency of Containerization and that of Transportation.

7.9 Efforts in R&D in Healthcare

Lab on a Chip: Point-of-Care Devices

Point-of-care diagnostic kits help doctors move from trial and error in the early stages of infection to a focused treatment schedule.

Figure 30 : BigTec's point-of-care diagnostic kit [91]

Remember the last time you fell ill, and in the absence of an accurate diagnosis, your doctor continued with his prescription for viral fever—only for laboratory tests to prove later that the high fever was due to the dengue or typhoid virus? In order to give patients focused treatment right at the start of an illness; an increasing number of doctors are depending on point-of-care devices that can identify the exact strain of a virus within hours of a test.

"In the initial stages, many diseases exhibit common symptoms. For instance, low-grade fever and general malaise are also initial symptoms of jaundice. But they are rarely diagnosed as such until the yellowness spreads," says Ashutosh Shukla, head, internal medicine, Artemis Health Institute, Gurgaon. It is problems such as these that point-of-care diagnostic kits expect to resolve, allowing physicians to move from trial and error in the early stages of infection to a focused treatment schedule.

It is for such treatments that point-of-care-devices are gaining popularity. BigTec Pvt. Ltd, a Bangalore-based biotechnology start-up [91], is planning to launch a diagnostic kit to detect Hepatitis B infection using DNA recognition technology. The kit can detect the pattern of the virus and provide an exact result within 15–20 minutes of a test. "Primarily this kit will use a blood sample from the patient," says Chandrasekhar Nair, co-founder, BigTec [91]. The start-up, according to its medical director B.K. Iyer, is working towards developing similar kits for other infectious diseases, such as chikungunya, malaria and dengue.

Malaysia-based Geneflux Biosciences Pvt. Ltd [92] is planning to launch MyDenKit [92], which uses molecular diagnostics technology to check for all strains of dengue virus in a single test within a time span of 5 hours. The company also plans to launch another diagnostic kit, MursaFlux, which can detect the presence of MRSA (Methicillin-resistant Staphylococcus aureus) bacterium in the blood. With just a single test, the results of which will be ready in 4-5 hours, the kit can detect three types of bacteria. If untreated, MRSA infection can lead to pneumonia, bone and joint infection, endocarditis or toxic shock syndrome, according to Prashanth G. Bagali, director and vice-president, science and technology, Geneflux Biosciences.

Medical practitioners say these kits, also referred to as "lab-on-a-chip", can redefine diagnosis and treatment techniques. "These kits work well in conditions with low signal-to-noise ratio. It means they can detect diseases even before (the) symptoms are full-blown," says Dr Shukla. He, however, cautions that these kits cannot be the sole basis for prescriptive treatment. "The human body is not an arithmetic model. Results of these tests have to be used in tandem with patient history and clinical examination."

Figure 31 : ViScope100: A Cardiac Anomaly Indicator

Apart from being useful in the treatment of infectious diseases, point-of-care-devices have many other benefits. For instance, the ViScope100, a cardiac anomaly indicator for physicians and cardiac specialists which was launched in India in 2008 [93] (see Figure 13), gives an audio and visual display of the heart's activity in real time and helps physicians screen for cardiac abnormalities and diseases such as valvular defects, septal defects and heart murmurs during regular consultation. "These devices provide complementary information in an audio-visual format and when such information confirms clinical findings, it is very reassuring", says Srikanth Raghavan, consultant and director of paediatric cardiac services, Manipal Health Systems, which is promoted by the Manipal Education and Medical Group (MEMG), one of India's leading providers of medical and education services.

Glucometers that help patients monitor their own blood glucose levels are another example of point-of-care devices. "Using a glucometer at home can result in a variation of between 10–15% in readings at times, but what it does very well is flag off a concern that a patient can then follow up by visiting a regular hospital", says Suman R., consultant diabetologist, Madhu Neha Diabetic Centre, Bangalore. Later this year, Geneflux Biosciences will launch a third diagnostic kit, HaemFlux, to test for type 2 diabetes. "This kit is under validation in the laboratory in Malaysia using blood samples of 250 diabetes (type 2) patients, from three ethnic races, Chinese, Malays and Indians. We expect to launch this product by the end of 2009," says Dr. Bagali.

Inexpensive, Fast and Accurate Point-of-care Diagnostics Using Microfluidic Chips

For the vast majority of Indians living in villages, high tech medical tests are out of their reach. But inexpensive, fast and accurate point-of-care diagnostics that doctors can use anywhere could soon be a reality, thanks to the work of Dhananjay Dendukuri, CEO and co-founder of Bangalore-based Achira Labs [108].

A PhD in chemical engineering from Massachusetts Institute of Technology, Dendukuri has developed a novel platform that allows samples of blood, urine, saliva, or other body fluids to be loaded directly on to a plastic microfluidic chip and tested for the presence of multiple analytes in a few minutes. The focus is on immunoassays (protein tests).

"This automated testing platform consists of a fluorescence-based, portable reader and reagent-loaded microfludic chips. The miniaturized assays allow for reduction in the volumes of expensive reagents used and hence their cost," says Dendukuri.

"The low development cost of the platform coupled with the sensitivity and reliability of expensive tests will enable a large number of people to have access to health-care tests in under-developed parts of India and other countries," he adds.

"Such an expansion of the 'reach' of diagnostics could have enormous long term health-care benefits in these underserved societies and markets," believes Suri Venkatachalam, founder and CEO, Connexios Life Sciences and co-founder and chairman, Achira Labs.

For changing the paradigm of centralized testing, and democratizing medical diagnostics, Dendukuri has bagged Technology Review India's "Humanitarian of the Year" title, says Narayanan Suresh, group Editor of Technology Review India.

For long, microfluidics has promised to be a solution for point-of-care diagnostics but one of the key challenges that has prevented the widespread entry of microfluidic products into the market is the lack of reliable manufacturing schemes that can transfer the technology from the lab to the market.

Moreover, the development of multiple tests on a chip platform has been held back by the lack of reliable methods to efficiently and rapidly load multiple reagents on the chip.

Dendukuri along with his team has developed a technology to manufacture the microfluidic chips to circumvent the problems of loading reagent for multiplexed assays. Dhananjaya has innovated around microfluidics, focusing on lab-on-a-chip (LOC) for point of care in the diagnostics space which was a carry over from his doctoral dissertation at MIT. He has manufactured the LOC such that samples from multiple patients and multiple tests per patient could be done. Given that in emerging markets, such as India, this testing is not available (with a reasonable turn around time and at a reasonable cost), it would go a long way in democratization of diagnostics [108].

7.9.1 Telemonitoring Solution for Diabetes: smarthealth.in

Figure 32 : Telemonitoring Solution for Measuring Blood Pressure

A telemonitoring solution called smarthealth.in has been developed at Aundh, Pune, India for diabetic patients. Diabetes is a common condition and India is the leading country in terms of the number of diabetic patients [109], [110].

With this device, patients can measure their blood pressure and blood glucose level at home. The readings are then sent to doctors through telephone for analysis. Doctors can view blood pressure and blood glucose readings of their patients on the internet anytime, anywhere. Once monitoring is done, the doctor can send an automatic SMS alert to his patients informing whether the blood pressure and blood glucose level have crossed the alert range.

The easy availability of readings on the internet reduces the need for the patient to visit the doctor. Thus, smarthealth.in encourages the patient for self healthcare. Moreover, it is a tool for doctors to analyse and effectively diagnose large number of patients at a time.

The world is moving towards easy-to-use high-tech and cost-effective solutions. Looking at today's lifestyle, smarthealth.in aims to provide smart healthcare. It helps in considerable cost and time saving. Further, the patients can monitor their health from home with the help of doctor's advice and system alerts. The doctors are able to manage large number patients in less time with a single click of mouse.

The upcoming enhancements in this device includes the addition of parameters such as weight and activity monitoring (calories calculation) and electrocardiography. Smarthealth.in supports different business models, hospitals, pharmacies, general physicians, nurse and fitness and wellness centres. It is a customized solution to best suit the needs of the customers.

Currently, smarthealth.in is working on the development of Electronic Medical Records (EMR). The EMR would manage the health records of the patients with vital details such as storing patient's information, clinical chart, medical images and report generation, with the capability to automate the daily tasks with comprehensive functionality.

It would also have a unique capability of customizing template for almost any medical specialty. Further, it has developed web application for diet control and management in which customers can pose their diet-related queries to associated dieticians and obtain online consultation [109], [110].

7.9.2 Silicon Locket for Cardiac Monitoring

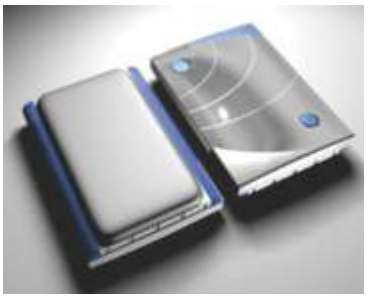

Figure 33 : Silicon Locket for Cardiac Monitoring

The Microelectronics group of IIT Bombay in collaboration with the School of Biosciences and Bioengineering has developed a Silicon Locket as part of a complete suite for cardiac monitoring and diagnosis. Three versions of the locket have been designed with appropriate hardware and software interfaces for downloading to a PC. The locket, which allows continuous monitoring of various heart parameters, has inbuilt algorithms for arrhythmia detection. At its occurrence, the locket automatically transmits through SMS the last few seconds of the ECG data to a central server using a mobile phone interface. The locket also has an integrated motion artifact detection software and interference cancellation scheme. An elegant SU8 based accelerometer has been designed, fabricated and tested for detecting motion artifact. A low-power version of the silicon locket is also under development, and a three-lead ECG chip has been designed and tested. Tata

Consultancy Services, which has funded the programme, has demonstrated the Silicon Locket at a number of venues; currently field trials are underway at hospitals [135].

8.0 THE GLOBAL MEDICAL DEVICES AND EQUIPMENT MARKET

We will begin with an understanding of the global medical devices and equipment market. We will then describe the Indian market scenario followed by market trends, growth drivers and the key issues and challenges as far as the Indian market is concerned. The interested reader is recommended to go through the detailed up-to-date report [99].

The global medical devices and equipment market is estimated at US $215.2 billion in 2008, growing at a CAGR of 4.5% during 2004-08. The significant growth in pharmaceutical and healthcare sectors in the recent years brightens the future prospects of the medical devices and equipments industry [99].

Indian medical equipment and supplies market is estimated at US $2.75 billion (approximately Rs.123.75 billion at the rate of Rs. 45 per dollar) in 2008 with a growth of 14% over the previous year.

It is to be noted that the market in India for medical supplies and disposables is dominated by the domestic manufacturers, whereas the costly and high-end medical equipments are mostly imported. We will present the Indian market scenario in detail in a later section.

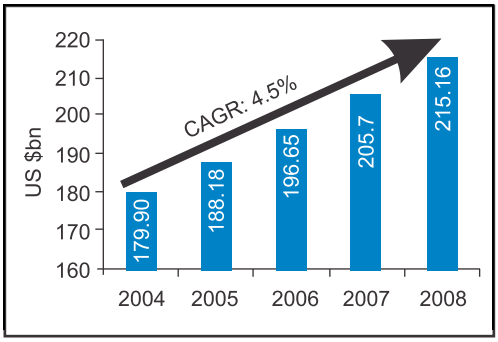

Figure 33 : Global Medical Devices and Equipment Market

The global medical devices and equipment market was estimated at US $215 billion in 2008 (see Figure 33). The market has grown at a CAGR of 4.5% during the five year period 2004-08.

New technological innovation in the treatment and diagnosis front, growing aging population and shifting disease pattern which needs long term medical care and diagnosis, are some of the major factors that drive the growth of global medical devices market.

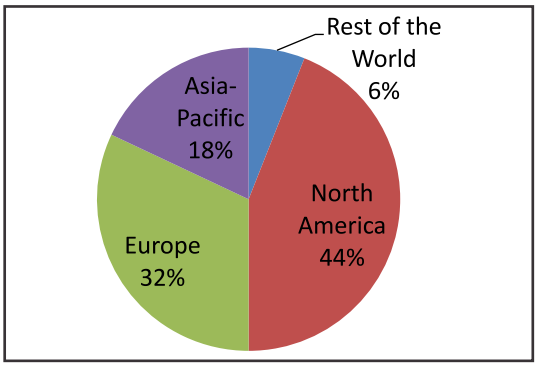

Figure 34 : Segmentation of Global Medical Devices & Equipment Market – By Geography

North America, which includes the US and Canada accounted for nearly 44% of the global medical devices and equipment market in 2008 (Figure 34). The US alone accounts for 40% of the total market. European market, which includes Germany, France, Italy, the UK, Spain, and the Netherlands, accounts for 32% of the total market. Germany alone accounts for 14% of the total European market. Asia-Pacific market, which includes India, China, Japan, Singapore and Taiwan accounts for 18% of the total market. Japan alone accounts for about 10% of the total market. The rest of the world, which includes Brazil and Russia accounts for 6% of the total market.

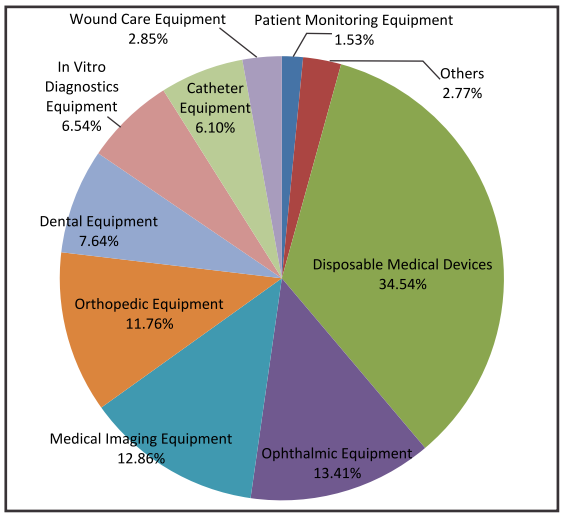

Figure 35 : Segmentation of Global Medical Devices & Equipment Market – By Applications

Globally, medical equipment, which includes ophthalmic, medical imaging, orthopedic, dental, In Vitro, catheter, patient monitoring and wound care equipment accounts for about 63% of the total market in 2008. The ophthalmic equipment segment leads the market with a share of 13.4%, followed by the medical imaging equipment, which accounts for 12.9% (Figure 35). While medical disposables comprise 34.5% of the global medical devices market, other equipment/ devices account for 2.8%.

8.1 The Market for Medical Devices in Brazil, Russia, India and China (BRIC)

The leading emerging and rapidly-growing economies of the BRIC countries represented a total market of 2.76 billion people and a combined GDP of US$6.1 trillion in 2007 [86]. But where do commercial opportunities exist for medical device manufacturers companies now, and what are the future prospects?

The BRIC countries' medical device and equipment markets are currently valued at US$9.5 billion [86]. This is a large sum of money, but is collectively much lower than found in leading markets such as the USA and Japan. Growth rates, up to 10.9% in China for example, are impressive, but the low starting point – along with a range of other operational issues – means companies must be targeted in the opportunities they pursue.

There are, of course, wide regional differences in expenditure levels within the BRIC countries, far more so than in developed countries where health systems have evolved to provide a more uniform level of coverage. All four countries have a relatively wealthy urban population with a far greater spending power than their respective national average. In the case of China and India, these urban populations have grown rapidly, and number hundreds of millions. The challenge for these countries is to extend this level of wealth to the rest of the population, in order that better levels of healthcare become affordable.

The change in BRIC countries will be incremental. Short-term opportunities exist in meeting the health demands of the burgeoning middle classes, and future prospects are bright, where steady growth in BRIC markets will erode commercial differences with the established markets in North America, Japan and Europe.

Espicom, the leading provider of medical market intelligence has come out with an excellent report titled "The Market for Medical Devices in Brazil, Russia, India & China 2008". The interested reader is encouraged to read the report [86].

8.2 Indian Market for Medical Equipment and Devices

The medical devices and equipment industry plays a crucial role in healthcare system. Several devices and equipment are used for diagnosis, therapy and patient monitoring. Apart from the pharmaceutical sector, the medical devices and equipment are set for a vibrant growth. Medical equipment and supplies market in India is estimated at US $ 2.75 billion (approximately Rs. 123.75 billion @ Rs 45 per US $) in 2008 with a growth of 14% over the previous year (Figure 36). Market for medical supplies and disposables is dominated by the domestic manufacturers, particularly those in the unorganized market. The high-end medical equipment market (e.g., imaging devices, patient monitoring systems) is dominated by the MNCs.

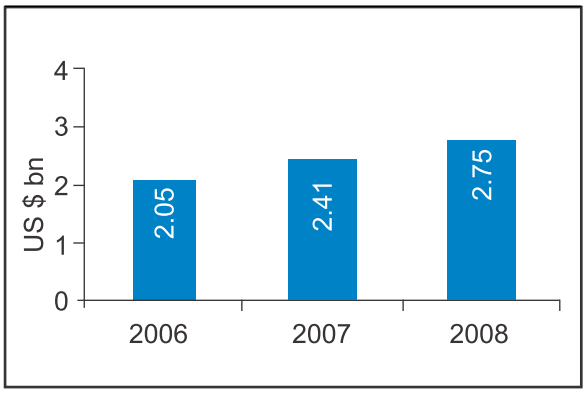

Figure 36(a) : Medical Devices and Equipment Market in India

Majority of the Indian medical devices and equipment market is dominated by the medical instruments and appliances used in specialties such as ophthalmic, dental and other physiological classes. This segment accounts for 25% of the total market, followed by orthopedic/prosthetic goods segment accounting for 20% of the total market (Figure 36). Syringes, needles and catheters together constitute 12.4% of the total market. The high-end specialty electro medical equipment accounted for 10.2% and X-ray apparatus 9.4% of the total market.

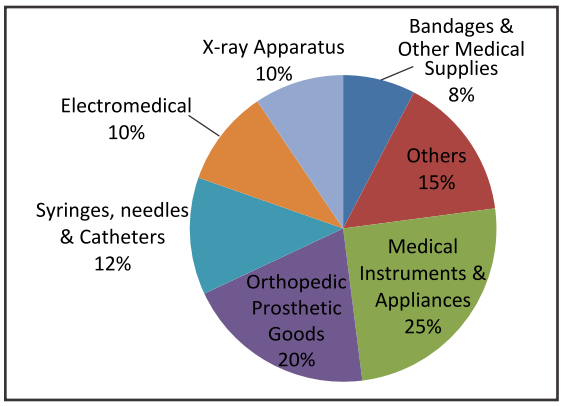

Figure 36(b) : Segmentation of Indian Medical Devices & Equipment Market - by Application (Others include endoscopy equipment, cardiovascular control equipment and Healthcare IT equipment etc.,

Source : Cygnus Research [99])

S. No.	Major Suppliers
1	Roche Diagnostics
2	Transasia
3	Bayer Diagnostics
4	Span Diagnostics
5	Nicholas Piramal
6	Orchid
7	Tulip Diagnostics
8	Zephyr Biomedical
9	Biorad
10	Liliac

Figure 36(c) : Key Players in Indian Diagnostic Kits Market

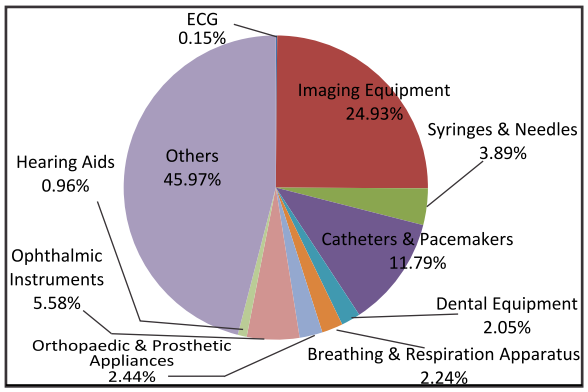

Figure 37 : Medical Devices & Equipment Imports by Category (Others include massage apparatus, X-ray tubes and other instruments for medical, surgical and veterinary uses Source: DGFT & Cygnus Research [99]).

Imports constitute over 50% of the market. Most imported products have high gross margins; however, the market is becoming increasingly competitive due to low entry barriers (for MNCs), an increasing number of players and an expanding consumer base. Currently, the high value imported products include Imaging Equipment, Catheters & Pacemakers, Orthopedic & Prosthetic Appliances, Breathing & Respiration Apparatus, and Dental Equipment. Figure gives category wise distribution of medical device imports during 2008.

Cygnus report [99] predicts a continued demand for the following medical devices - ECG and EEG monitors; DC defibrillators; patient monitoring systems; radiography equipment; therapy equipment; surgical diathermy units; apnea/respiratory monitors; colour Doppler ultrasound scanners; CT and MRI systems; digital subtraction angiography systems; laser and fibre optic devices such as endoscopes, colonoscopies, laparoscopes, laser lithotripters etc; linear accelerators; X-ray equipment, including dental and general purpose mobile C-Arm; ophthalmology equipment; radiotherapy equipment; simulators and treatment planning systems.

The value of imports in 2008 was estimated at around US$1,274 million with a CAGR of 23.3% during the period 2004-08. The Medical device suppliers seeking to enter India's market typically enter into joint ventures or licensing agreements to manufacture their products within India, or employ local agents to distribute them. The Indian government encourages all these options. Several factors such as price, quality and service are driving imports in the market.

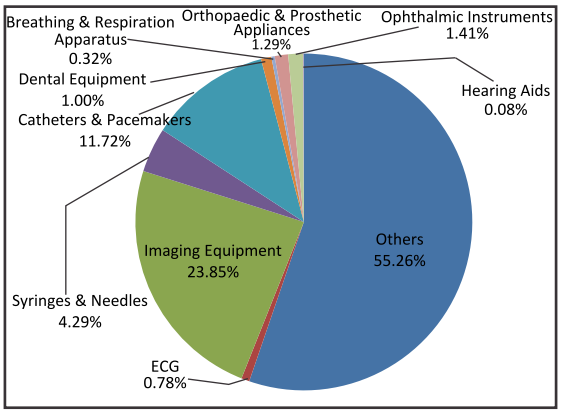

Figure 38 : Medical Devices & Equipment Exports by Category (Others include massage apparatus, X-ray tubes and other instruments for medical, surgical and veterinary uses Source: DGFT & Cygnus Research [99]).

With the growing demand for medical facilities across the country, the market for medical equipment in India is fast expanding. The medical devices market for exports in India is estimated around US $ 447.4 million in 2007-08 with a CAGR of 11.3% over the period 2004-08. The exports mainly consist of dental instruments, surgical items and other laboratory equipment (see Figure 38). Indian manufacturers of good quality mid tech products struggle with a stigma for unreliability.

The reader is encouraged to see [129] for an excellent and detailed report on the Medical Devices in India. Several important recommendations have been provided in the report [129].

8.3 Indian Medical Devices and Diagnostic Industry: Growth Drivers

The growth of Indian medical devices and diagnostics industry is driven by a host of factors. Some of these factors are described below.

- Booming Economy
- Increasing Healthcare Expenditure
- Changing Demographic Profile
- Increasing Incidence of Lifestyle Diseases
- Increasing Number of Medical Tourists
- Proliferation of Hospitals

We have already described some of the above factors in previous sections.

8.4 Indian Pharmaceuticals Market: Current Status and Growth

India has already gained prominence in the international generics market due to the globalization efforts of its drug manufacturers. More recently, as part of joining the WTO, the country has begun honoring intellectual property rights. In addition, global pharmaceutical manufacturers have been taking advantage of lower costs in India and have been outsourcing significant percentages of their clinical trial and manufacturing work to India.

Apart from these broad trends, Indian companies and consumers have been experiencing a phenomenal increase in wealth and purchasing power due to the high GDP, relative political stability, a government that has focused on privatization of many industries that were previously largely government controlled, and the meteoric rise in the stock markets over the past 4 years.

These events are changing the face of the global pharmaceutical development market and have created a new opportunity for growth within the Indian domestic market. The following are other trends impacting the healthcare space:

Drugs

- Indian pharmaceutical companies have been raising a significant amount of capital to fund acquisitions in International markets
- Greater resources are being devoted to R&D efforts, in some cases (e.g., Sun Pharmaceuticals, Dr. Reddy's) evidenced by a spin out of R&D divisions into a separate company
- An emerging discovery and development sector, with startups investing in biology and chemistry based approaches
- The growing importance of bio-generics manufacturing capabilities as biological drugs go off patent

Services

- Increasing access to health insurance by the middle class
- Increasing hospitals and specialty hospitals servicing the medical tourism industry in which international patients come to

India for surgeries and diagnostic tests where quality care is delivered at a fraction of the cost

- Clinical lab chains such as Metropolis Health gaining importance due to standardization of tests – making them attractive as outsourcing opportunities for the US and European hospitals

The reader is encouraged to refer the position paper [87] which is part of an effort by McKinsey & Company's Pharmaceutical and Medical Products (PMP) practice to identify "Opportunities to Spur Innovation by Leveraging Emerging Markets".

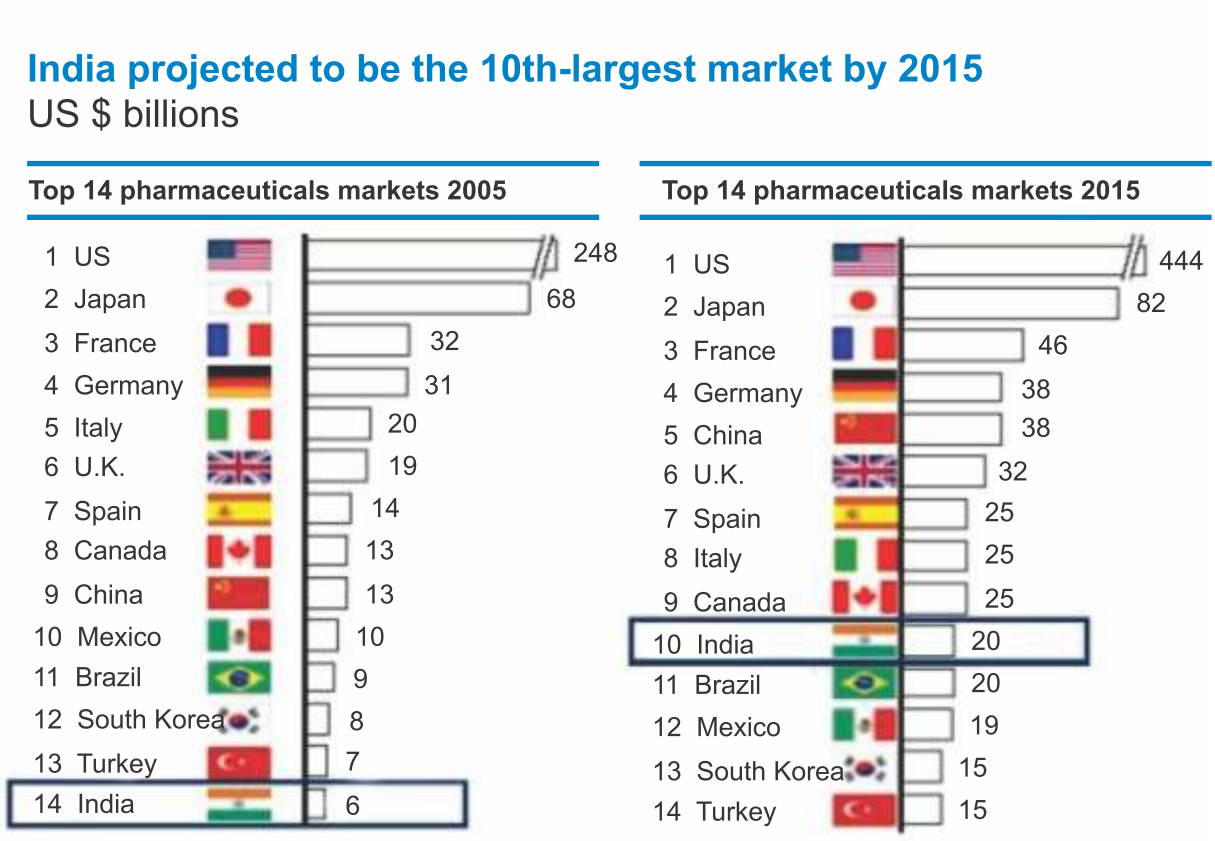

Figure 39 : India Projected to be the 10th Largest Market by 2015.
Source : IMS Midas; "India Pharma 2015: Unlocking the Potential of the Indian Pharmaceuticals Market" McKinsey Report.

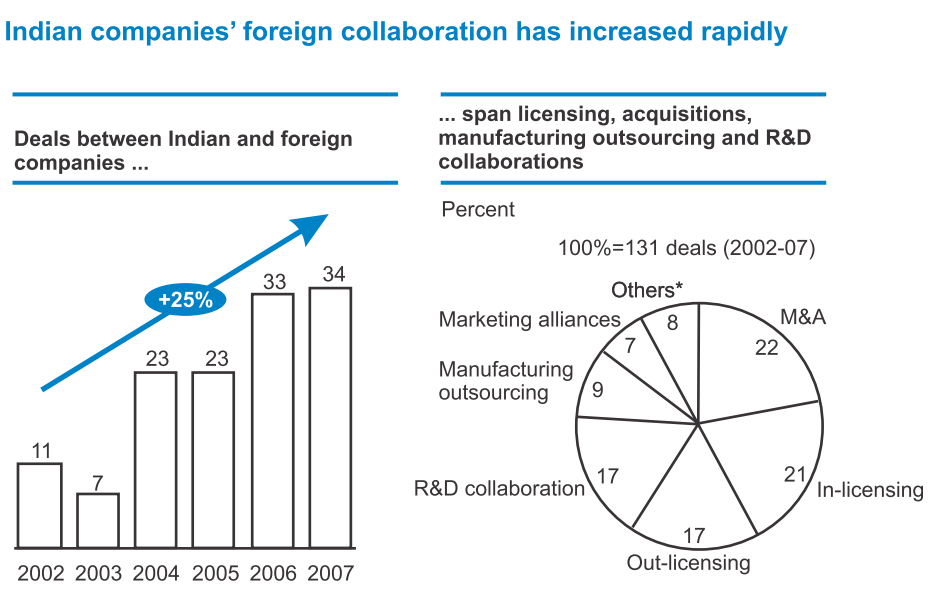

Figure 40 : Indian Companies' Foreign Collaboration has increased rapidly

9. FINDINGS AND CORE RECOMMENDATIONS

9.1 Discussions with Thought Leaders in India

The investigators have had several meetings with thought leaders in the past one year to discuss the technologies for the health care sector in India and the challenges in the sector. We have attended several conferences and workshops in the healthcare sector and have had meaningful discussions with doctors, investors and practitioners in the area.

The objectives of our meetings have been (i) to arrive at an actionable document and (ii) to list the priority areas for the health care sector in India.

The experts have pointed out several gaps and challenges in the health care sector in India. Some of the pain-points have been described in the following sections.

9.1.1 Healthcare Sector in India: Limitations and Gaps

Mr. Jaideep Gupta, CEO of Apollo Hospital in New Delhi, pointed out that high quality medical grade equipment does not exist in India [3]. India needs high quality medical grade equipment in all categories including Hospital Beds, Switches, Plug Points etc and these are not indigenously manufactured. Mr. Gupta mentioned that even hospital air-conditioning is rudimentary in India. We need to focus on low cost air-conditioning equipment for hospitals and particularly the government.

Manufacturing of low tech medical equipment (e.g., Sterilizers, Catheters) in India needs to be addressed.

The number of hospital beds are woefully inadequate in India. The current hospital bed density is 0.86 per 1,000 population, estimates an Ernst & Young-FICCI projection [117].

There exists a good engineering support in India. We are in a reasonably good shape as far as engineering support services is concerned.

The use of IT in Health Care is poor in India. We need affordable, efficient and quality health care. There is a clear need for standardization (e.g., HIPAA standards [4]) in this sector. A brief description of the HIPAA standards is provided below.

9.1.2 HIPAA Standards [4]

The Health Insurance Portability and Accountability Act of 1996 (HIPAA) established new standards for the movement and uses of health care information.

There are three types of standards created by HIPAA: privacy, security and administrative simplification (e.g., transaction standards). Taken together, these regulations have a major impact on the day-to-day functioning of the hospitals and affect virtually every department of every entity that provides or pays for health care.

According to experts in AIIMS [2], India needs to focus on two main areas. These are Infective diseases (e.g., Tuberculosis, Malaria, Hepatitis) and Non-Communicable diseases (e.g., Cancer).

The experts in AIIMS (see Acknowledgement Section) have identified areas where the costs are exorbitant. For example, antibodies are very expensive in India. Kits for Hepatitis-B are expensive. As an example, the approximate cost of a single chip for Real Time Polymerase Chain Reaction used for Leukemia is Rs. 7000. There is a dire need for such kits to be designed in India, according to the AIIMS doctors.

Another sector where the costs are extremely high is Biological Markers. Hospitals such as AIIMS import biological markers that are extremely expensive and unaffordable for the majority of Indian patients. As an example, the typical cost per antibody is Rs. 15,000 and the hospital needs at least 3 to 4 antibodies for complete testing. This results in approximate total costs of Rs. 50,000 – a huge amount for patients in India.

Several instruments and equipments in the health care sector in India are imported. The high cost of these instruments is almost always borne by the patient.

The experts in AIIMS have reiterated the need for (i) the design of new diagnostic equipment in India and (ii) reduction of healthcare cost.

9.2 Medical Technology Industry: Impediments to Growth - How they can be overcome

The Third Medical Technology Conference 2010 held in New Delhi on 9 July 2010 [141] focused on the measures that can be undertaken by the industry in India to generate demand and simultaneously build supply capacity and capability. The experts pointed out that the current spend on medical technology is $2 per capita and we need to move to $10 per capita.

The key inhibitors for increasing demand are (i) low purchasing power in tier 2/tier 3 cities and rural areas, (ii) inadequate healthcare infrastructure, (iii) competition from lost cost/low quality imports, (iv) lack of trained operators/users, (v) issues in maintenance/after sales service.

According to D. Raghavan from Siemens Ltd, the generic factors that impede growth of medical technology are accessibility of healthcare, lack of awareness and innovation. Healthcare technologies need to be geographically distributed across various regions of the country. Sanjeev Bagai from Batra Hospital and Research Centre mentioned about the lack of Regulation and Standardization in India. As an example of excellence, he mentioned the success of Pittsburgh, USA. According to Anjan Bose, Philips Electronics India Ltd, growth in medical technology will result from the Demand-Supply gap that exists in the country. There is also a dire need for innovative business models in the country. According to Arjun Sarker from Covidien, no one size fits all in the medical technology industry since the market is highly heterogeneous. He also mentioned about the lack of penetration of insurance in the country and the need for training and education of medical practitioners [141].

The experts pointed out the synergy between Telecom and Healthcare sectors in India. The next revolution in India after the Telecom revolution will be the revolution in the Healthcare sector. Several sections in this report have described how the Telecom sector has been and will continue to influence the

Healthcare sector in the years to come. In fact, the parallels between the Telecom sector and the Healthcare sector are remarkable!

The options to increase demand could include focus on cost-effective manufacturing, expansion of target markets, increasing investments through private equity & venture capital, reducing counterfeit or illegal imports and innovations across the spectrum of medical technology value chain.

9.3 Issues and Challenges in the Healthcare Sector in India

Some of the issues and constraints that are found to impact the industry are India's dependency on imports for supply of medical devices, strict industry regulatory environment, low level of healthcare insurance and low levels of healthcare facilities and awareness especially in rural areas. We will now discuss each of the above factors in some detail [99].

9.3.1 Dependency on Imports

Indian medical devices supply is heavily dependant on the imports from other countries such as the US, Japan, UK, France, Germany, etc. Although imports occupy a major chunk of the total Indian market, the proliferation of joint ventures is likely to erode this share slightly. Wipro-GE is an example of a successful joint venture in India. These joint ventures and other business collaboration modes are slowly changing the landscape of the Indian medical devices industry.

Typically, domestic production consists primarily of low technology products (such as surgical textiles and other medical supplies), whereas the demand for high technology devices is met predominantly by imports.

One possible reason for higher dependence on imports can be traced back to low level of R&D spending by Indian medical devices industry. Moreover, import duty exemption for devices and technologies that are not available in India in turn encourages the import rather than investing in domestic R&D and manufacturing. Further, domestic manufacturers cannot offer their products at a competitive price against that of the imported products that have the benefit of tax exemption.

9.3.2 Low Levels of Health Insurance Coverage

The health insurance in the country presently covers only 3% of the population. This small number constitutes both public-funded and private medical insurance.

One of the reasons for low penetration of health insurance in India is the lack of regulations in the health sector resulting in an exposure of the beneficiaries to various wrong practices present in the system. It is therefore recommended that any regulation on health insurance should ensure that the patient is provided with the choice of provider and insurer while managing the cost environment.

Some other measures to increase the health insurance coverage in India include permitting FDI in stand-alone health insurance ventures up to 49% and standardization of medical definitions across all health insurance products from different companies. Finally, the government needs to address the low levels of awareness about the essentiality of health insurance in India.

9.3.3 Stringent Regulatory Regime

In March 2006, the Drug Controller General of India (DCGI) issued new guidelines regulating the import and manufacture of medical devices. Under the new medical device regulations, importers of the notified medical devices are responsible for applying for import licenses and filing product registrations with the DCGI, as a pharmaceutical importer would normally do. The re-classified products list includes the sterile devices such as cardiac stents, catheters, intra ocular lenses, I.V. Cannulae, bone cements, heart valves, scalp vein set, orthopaedic implants and internal prosthetic replacements to be considered as drugs that require central clearance prior to import, manufacture or marketing in the country with effect from March 1, 2006 [99].

The cause of concern for the industry is the high cost of obtaining the required documentation for these regulatory submissions. The high fee could become a burden for smaller manufacturers and also affect the available range of products in India as the sales per device are usually quite small. Further, a high registration fee could create a barrier to innovation by local and smaller manufacturers to develop low cost devices suited for the Indian market.

9.3.4 High Import Duties: Escalation in the Cost of Medical Devices

A 4% Special Additional Duty for medical devices and instruments announced in the Union Budget 2006-07 is expected to increase the cost of diagnostic scans and high-end tests. Therefore, after this increase, medical instruments such as CT Scanners, MRI machines, Cathlab and ventilators which were earlier under the 5% Customs duty slab will now attract 9% duty while ultrasound machines, patient monitors, defibrillators and blood cell counters will be charged under the 26.8% Customs duty category. In conjunction with various taxes at the state level, the cost to patient will increase by 10-20% in diagnostics.

Another point of contention is that the duty exemption for diagnostic kits that used to detect life threatening diseases continues to only apply to basic techniques. These basic techniques are increasingly replaced by newer and more precise methods such as the Polymerase Chain Reaction (PCR) test. At present only tests such as the ELISA and CLIA enjoy the duty waiver while the PCR kits attract 37%.

9.3.5 Poor Medical Infrastructure Facilities and Low Levels of Awareness in Rural India

Major medical infrastructural facilities such as hospitals, testing labs and diagnostic centres are concentrated in urban areas in India, whereas the rural areas do not possess such facilities. The doctors and healthcare specialists are neither well acquainted with the new technologies and equipment nor can afford to purchase high cost equipments. The affordability of the rural population of costly healthcare treatments is very limited; hence the scope of establishing and running costly medical infrastructural facilities and equipment is not bright. Considering the fact that 72% of Indian population lives in rural areas, non-availability or under-availability of medical infrastructure in rural areas leads to a missed opportunity and needs to be urgently rectified. Of course, there are ways by which health care could reach the masses in India. Some of these methods

such as Telemedicine have been described earlier in the report.

9.3.6 Accreditation and standardization

Accreditation and standardization are extremely necessary to monitor the quality of the mushrooming of small time equipment manufacturers in India. Today, anybody can start manufacturing equipment, like any other small business, without any permission or license. By the same norm, the quality of equipment sold by the MNCs needs to be filtered. India should not become a dumping ground for other countries. In the US and China, one needs to have FDA and SDA approvals respectively, to sell medical equipment. Similarly, no medical equipment can be installed in the European Union countries, unless it carries the CE mark.

9.3.7 Hurdles Faced by Indigenous Companies in Making High-End Equipment

Let us try to understand the hurdles that the indigenous companies face in making high-end equipment. Some Indian manufacturers often find it difficult to bridge technology gap and need to catch up with the MNCs in research and development. The MNCs have been there for many years, whereas the Indian companies have to find innovative ways to acquire technology and nurture it at a rapidly accelerated pace.

9.3.8 Cultivating an "Export Mindset" by Indigenous Manufacturers

It is necessary to look outwards, adopting a global approach, i.e., an export mindset. Since India represents almost two per cent of the world market in medical equipment, if we make our equipment quality wise and cost wise suitable for the export market, the industry can grow by leaps and bounds.

Medical equipment is inherently low volume, highly intellectual and manual effort requirement business. This is because of stress on design, embedded software capabilities, testing, simulation and clinical trials.

What is needed, however, is to get satisfied with nothing less than the global benchmarking in quality and performance. Once this is done, international quality certifications, both for the manufacturing and service support systems, would go a long way in building export business.

9.3.9 The Indian Market for Medical Equipment

The Indian market for medical equipment and supplies was valued at US$1,505 million in 2006. Despite strong growth rates, the market remains disproportionately small, ranking among the top 20 in the world but with per capita spending of just US$1. High quality products are sought after, particularly in the private sector, and the high-tech end of the medical device market is dominated by multinationals.

Private sector investment in healthcare has been increasing since the mid 1980s and it is expected that future increased demand for medical equipment and supplies will come from private sector hospitals and medical centres. India has a growing middle-class of around 300 million people with disposable incomes and increasing healthcare expectations. Around one third of these can afford to pay for good quality private healthcare and this number is growing [86].

9.4 What the Indian Government Needs to Do?

First and foremost, the Government of India needs to increase the spending in the healthcare sector. Sample this: India ranks 171 out of the 175 countries in the world in public health spending [111].

This is less than some of the sub-Saharan African countries, a World Health Organization (WHO) study of 2007-08 has revealed. This being the status, can we tackle the existing epidemics and new entries like H1N1 flu? [111].

For a country of one billion, India spends 5.2% of the GDP on healthcare. While 4.3% is spent by the private sector, the government continues to spend only 0.9% on public health. When the economic growth index is moving forward, the wellness index is dipping.

''Public health spending as a percentage of GDP is minuscule. Due to this, India is being overly dependent on private sector. With lowest insurance penetration, people are forced to spend out of their resources. In fact, neighbouring China ranks among the leading developing countries in public health spending, almost 6% of the GDP,'' said Vishal Bali, CEO, Wockhardt hospitals.

9.4.1 Healthcare: from a State subject to Centralized subject

Some of the concerns that have been raised by thought leaders in the area are: (i) the lack of co-ordination among states and among center-states, (ii) lack of accountability, (iii) need for checks and balances, e.g., we should not allow import of sub-standard products.

9.4.2 Providing Affordable Healthcare to All

We should look at innovative healthcare models, work on standard definition and working environment for PPP.

One major initiative to provide quality healthcare at affordable cost is by way of Public Private Partnerships (PPP), which will go a long way in bringing efficient and affordable healthcare system to India.

The advantages of PPP are that the core competencies of both the partners can be effectively used for the benefit of each other. Private and public players can leverage the potential lying with local panchayats, NGOs and civil society organizations. PPP will also result into tax benefits for the private healthcare players and hence can deliver the subsidized healthcare services to rural population which is a high on the agenda for the public partner.

9.4.3 Need for a Formal Engineering Education

There is a lack of formal engineering education in Healthcare where technology is improving exponentially. There is a dire need to bridge the gulf between the rapidly advancing medical knowledge base and the application of that knowledge to patient care. This is where new courses in healthcare sector will play a very important role.

9.4.4 Need for Soft Skill Training for Healthcare Personal

With an ever increasing population in urban areas of India and with the mushrooming of clinics, dispensaries and hospitals in the urban centres, there is a dire need for soft skill training for healthcare personal [112].

There is a need to create a new breed of service oriented paramedics in India. With the advent of new technologies and services, healthcare now requires newer specialization. In our view, India has a major role to play in creating new set of services and skill sets pertaining to the healthcare sector.

9.4.5 Greater R&D in the field of Healthcare

There is a critical need for greater R&D institutions in healthcare in India.

Health care is underinvested in mathematical/conceptual tools and techniques for designing, analyzing, and controlling a myriad of complex processes and systems.

Both Public and Private sectors need to increase their investment in R&D in the healthcare space.

9.4.6 Lack of start-ups in Healthcare

Though we are now witnessing the growth of start-ups in the healthcare sector, the numbers are still very few.

Some of the key players in India are Bigtec labs and Achira labs in Bangalore. Considering the fact that the software and services sector in India is growing by the day, there is all the more reason why start-ups in healthcare should excite investors and researchers alike.

9.4.7 Medical Equipment in India

Most of the medical equipments in India are imported and medical devices industry in India has not grown much. The Government of India is working on medical devices legislation, in order to standardize the quality of Indian manufactured medical devices [50].

There is a dire need for companies to either independently or in partnership with the Indian government's national network of research laboratories to develop low cost digital medical equipment that can be used at primary health care centers throughout India.

9.4.8 Increasing Role of Information & Communication Technologies in Healthcare

In a country where both medical infrastructure as well as medical manpower is scarce, the gap between demand and supply can be bridged with technology. Communication technology, particularly telemedicine, can act as a missing link connecting rural and urban India— resulting in more people availing better healthcare services.

The use of technology such as establishing a national health information network, and using innovative clinical solutions, such as electronic medical records, can help to improve effectiveness of health services in India.

What India needs is a high speed, reliable "HealthNet" backbone network that enables exchange of both real-time and non real-time information (e.g., data, voice and video) related to the health of citizens of the country.

The Wide area Quality of Service Network Testbed by Education & Research Network (ERNET) is worth mentioning in this section [113], [114].

The objective of this effort is to provide Quality of Service (QoS) assurances to applications that require assured end-to-end bandwidth, communication privacy, minimal round trip time for packet delivery, regularity of the data flow. This testbed will be interconnected with the

local testbed at other locations in the country. It will serve as a vehicle among other institutions to carry out R&D and distance learning. This testbed will be integrated with ERNET2 (ERNET version of Internet2) [114].

The R&D activity aims to develop QoS sensitive applications and platform for multimedia communication (VoIP, MPEG video), interactive distance learning-virtual class room, digital library, real-time robotic/ process control, and telemedicine, secure & scalable IP multicasting platform.

This QoS enabled Network will be made open to industries, academia for testing their products for distance learning, digital library, and deliver of multimedia communications.

We believe that healthcare related applications will enable the 'HealthNet' backbone in the coming years. This backbone can either be a separate backbone network or co-exist with the QoS network backbone discussed in this section.

9.4.9 Mobile Clinics in India

Figure 41: Sanjeevan Mobile Clinics: Healthcare on Wheels for Remote Regions in India [116].

Mobile clinics are helping to deliver healthcare services to rural parts of India. Although compact, the clinics are equipped with everything medical teams need to provide patients with primary care. One such Mobile clinic has been built by Siemens [116].

If people are unable to visit the doctor, then the doctor has to visit them – that was the idea of the team at Siemens India Healthcare. It developed and designed the Sanjeevan Mobile Clinic, a fitting name, as Sanjeevan is associated with the treatment coming to the patient's doorstep, unlike the patient going to the hospital for treatment. Sanjeevan also means "a life giving herb".

From the outside, the mobile clinic looks much like any other coach, but inside it's kitted out with the best that high tech has to offer: a highly functional doctor's office, complete with an array of modern diagnostic aids, including X-ray, ultrasound, mammography and electrocardiogram equipment. Besides a second examination room, there's also a darkroom for developing X-ray images that doubles up as a viewing room for health education films, and to enable it operate independently, the mobile clinic even has its own power generator. The mobile clinics are customized according to the client's requirements.

The fleet of mobile, fully autonomous clinics and their teams of medical and technical staff are often on the road for many days at a time, carrying out medical examinations and delivering quality treatment to people in remote areas.

Figure 42

Figure 43 : Smile on Wheels - National Level Mobile Hospital Programme

Another project worth noting is the Smile on Wheels. This is a national level mobile hospital programme from Smile Foundation [115], catering to the underprivileged children and women in remote rural areas and urban slums.

Mobile clinics are not just easy to configure and equip in a wide variety of ways, they are also inexpensive to purchase and operate, making the Mobile Clinic an excellent model for structurally underserved regions and developing countries all over the world.

9.4.10 Concerns and Challenges in Health Insurance in India

Some of the concern or barriers towards implementing a social health insurance scheme are enumerated below along with the possible way ahead.

India is a low-income country with 26% population living below the poverty line, and 35% illiterate population with skewed health risks. Insurance is limited to only a small proportion of people in the organized sector covering less than 10% of the total population.

Currently, there is no mechanism or infrastructure for collecting mandatory premium among the large informal sector. Even in terms of the existing schemes, there is insufficient and inadequate information about the various schemes.

Much of the focus of the existing schemes is on hospital expenses. There continues to be lack of awareness among people about health insurance. In spite of existing regulation in some States, the private sector continues to operate in an almost unhindered manner. The growth of health insurance increases the need for licensing and regulating private health providers and developing specific criteria to decide upon appropriate services and fees.

There is also a need to evolve criteria to be used for deciding upon target groups, who would avail of the scheme/s and also to address issues relating to whether indirect costs would be included in health insurance. Health insurance can improve access to good quality health care only if it is able to provide for

health care institutions with adequate facilities and skilled personnel at affordable cost.

9.5 Recommendations

The challenge for Indian policy-makers is to find ways to improve upon the existing situation in the health sector and to make equitable, affordable and quality health care accessible to the population, especially the poor and the vulnerable sections of the society. It is in a way inevitable that the state reforms its public health delivery system and explores other social security options such as health insurance. Implementing regulations would be one mechanism to contain provider behaviour and costs.

There is an urgent need to document global and Indian experiences in social health insurance.

Different financing options would need to be developed for different target groups. The wide differentials in the demographic, epidemiological status and the delivery capacity of health systems are a serious constraint to a nationally mandated health insurance system. Given the heterogeneity of different regions in India and the regional specifications, one would need to undertake pilot projects to gather more information about the population to be targeted under an insurance scheme and then develop options for different population groups.

An important development in India is the recent appointment of Mr. Nandan Nilekani as the chairperson of the Unique Identification Authority (UIA), formed to issue IDs to every citizen in the country. The move to set up the UID Authority of India (UIDAI), under the aegis of the Planning Commission, is aimed at providing a unique identity to the targeted population of the flagship schemes to ensure that the benefits reach them [96].

According to the Government of India (GoI), the Unique Identification Authority shall have the responsibilities to lay down plans and policies to implement the Unique Identification Scheme, shall own and operate the Unique Identification number database and be responsible for its updation and maintenance on an ongoing basis. The flagship schemes of the GoI include the National Rural Employment Guarantee Scheme, Sarva Shiksha Abhiyaan, *National Rural Health Mission* and Bharat Nirman [96].

We believe that the introduction of the unique identification number scheme is a very important step towards providing affordable healthcare and health insurance to the citizens of the country.

The Government should take effective steps to ensure increase in the affordability to the health insurance schemes, especially amongst the rural population. With higher insurance penetration in the country, the accessibility to quality healthcare services would greatly improve.

Government should provide advantages to the private sector in terms of long term tax benefits for establishing hospitals in the rural areas. With the private healthcare providers being incentivized, there will be increase of quality healthcare facilities in rural India. This would act as a great catalyst towards increasing accessibility to quality healthcare for the common man and would make way for entry of private sector in the rural markets.

Some valuable recommendations have been captured in [25]. According to [25],

India needs to create a conducive environment and the following recommendations are given in the report.

9.5.1 Attracting investment

- Granting infrastructure status to the healthcare sector
- Creating fiscal policies, such as providing low interest rate loans, introducing tax holidays for investment in low per capita income states, reducing import/excise duty for medical equipment, et cetera, to promote investment in healthcare services
- Facilitating various clearances and certifications such as medical registration number, etc.

9.5..2 Changing the legislation

- Mandating the employers to buy group or individual medical insurance for their employees to ensure a certain minimum financial coverage
- Mandating the private sector units that take advantage of improved fiscal policies, to commit resources to remote rural/under developed sectors
- Create an autonomous body to standardise on medical messaging, codes and vocabulary, content and format, identification standards and security
- Mandate the healthcare service providers to transmit select patient data to the government for analysis. This data will be analysed to identify trends and evolve policies
- Create a national database of health care providers, their facilities and services. This will create awareness among the population towards quality health care
- Streamline the process of handling patient grievances
- Create a nation-wide agency to deal with patient requests such as ambulance hotline, emergency/first-aid consultation, trauma help-line etc

9.5.3 IT initiatives

- Sharing of patient information between providers, patient and payers.
- Security and privacy services
- Need for standards for messaging, codes and vocabulary, content and format standards

To witness a successful revolution in healthcare, [25] concludes that we need to bring the above set of activities together. If this works for India over the next decade, the vast population living in rural and urban areas will bear the fruit of success

9.5.4 Potential for the Healthcare Sector in India

(1) High-growth in the domestic market will arise from the following factors

- Increasing health awareness: share in total private consumption expected to increase by 10%
- Increasing penetration of health insurance

- Rapid growth in private sector companies owning and managing hospitals

(2) High-growth in medical tourism

- Cost of comparable treatment is on average 1/8th to 1/5th of those in western countries.

(3) Opportunities exist in multiple segments along the value chain

- Service providers: curative and preventive in primary, secondary and tertiary care
- Diagnostics services: imaging and pathology labs
- Infrastructure: hospitals, diagnostic centres
- Health insurance: less than 10% of the population is currently covered by health insurance. The medical insurance premium income is expected to grow to US$3.8 billion by 2012

(4) Emergence of Healthcare BPO: medical billing, disease coding, forms processing and claims adjudication

(5) Training: large opportunity for training doctors, managers, nurses and technicians

9.6. Core Recommendations

What is the way forward for India in the Healthcare sector? What is the right game plan for India in this sector? What are the high priority areas that the country needs to focus on?

We summarize below the areas of high priority in the healthcare sector that need immediate attention in India.

(i) There is a need for scalable, cost-effective pervasive technologies for healthcare. With the convergence of Telecom and Healthcare sectors, mHealth is becoming an extremely important paradigm in India Today. Cell phones have proliferated each and every corner of the country and therefore we expect to see the emergence of new services and applications in healthcare targeting the masses in the interior regions of the country.

In our view, the marriage of Telecom and Healthcare sectors is bound to yield major dividends for the country in the years to come. This is one area where we expect huge investments from Multinationals, Private sector and Venture Capitalists in India.

(ii) There is a dire need for cost-effective equipments and instruments for screening and diagnosis at the 'Point of Care'.

(iii) Healthcare in semi-urban and rural areas in India is in shambles. The state of the hospitals is extremely poor and the problem is exacerbated by the lack of Doctors/Specialists in semi-rural and rural areas. How then do we solve this vexed issue?

There are no simple answers to the challenges above. We believe that the country needs to leverage ICT technologies to improve the state of healthcare in rural and semi-rural areas.

The Government needs to provide major incentives for specialists and Doctors so that they consider spending time in rural areas in the country. One proposed measure is that the Government make it

mandatory for all Doctors and Specialists to spend a fraction of their time in areas that lack medical facilities in the country.

(iv) The country needs to invest in medical education with an emphasis on healthcare and related sectors. There is a need to invest in training centers and polytechniques in healthcare sector so as to attempt to fill the huge demand-supply gap of specialists.

(v) For the country to be healthy and therefore happy, providing Medical Insurance to all citizens is extremely critical. We need to invest huge amount of effort and money and ensure that citizens who cannot afford complex treatment and medicines, are provided health insurance by the state. A healthy country is a happy country!

(vi) Venture capitalists and Angel investors in India need to support incubation centres and start-ups in the healthcare sector. Though the last few years have witnessed a surging interest in healthcare by the private sector in India, a lot more remains to be done.

An interesting example is Helion Venture Partners [159] – a stage independent, India-focused venture fund, investing in high growth technology powered businesses and consumer services. The new areas of focus of Helion Venture Partners are healthcare services, businesses that service hospitals and tech applications for hospitals.

10. CONCLUSION

With global revenues of an estimated $2.8 trillion, the healthcare industry is the world's largest industry. India's high population makes it an important player in this industry. According to the Insurance Regulatory and Development Authority, the Indian healthcare industry has the potential to show the same exponential growth that the software and Healthcare industries have shown in the past decade.

The healthcare sector in India is witnessing a surge of activity and the beginning of what is seen as a rapid phase of growth. Emerging healthcare segments like diagnostic chains, medical device manufactures as well as hospital chains are increasingly attracting investments from a variety of venture capitalists. At a broader level, this trend in healthcare is often seen as a manifestation of the overall surge in private equity and also growing interest among private equity funds for Indian companies.

Healthcare is poised to be a new driver of growth for economy. Given the geographical access required for delivering care and the fact that infrastructure has to be spatially distributed, it has the potential to create pan India job opportunities across a number of towns and villages. It is estimated that each additional bed has the potential to create 5 direct jobs and 25 indirect jobs. This could translate into over 27.5 million jobs by 2017.

The additional employment generated could lift 8-10% of households above the poverty line. Medical value travel could make India the 'Healthcare Destination of the World'. It has the potential to contribute more than US$ 2 billion annually by 2012.

And last but not the least; healthcare could greatly enhance the 'Brand Perception' of the country. No wonder that all prospective stakeholders are excited at the very thought of this market. Clearly, some of the most exciting laps of the healthcare race will be run in India in the coming years [35]. For India to be ahead in the race, new and emerging technologies will play a key role. It is with this in mind that the current report focuses on ‘Technologies for the Healthcare Sector in India’.

As a next step, the authors plan to translate the learning of the last two years into a detailed research proposal that would be submitted to DIT and DST. The funding from such a detailed research proposal would enable the establishment of a centre of excellence in Healthcare.

It is to be noted again that a study of the area of healthcare is vast that no single report can be expected to deal with it comprehensively and exhaustively. The present study relates more to the status of the healthcare sector with an emphasis on India and deals primarily with the diagnostic side of the healthcare.

We sincerely hope that in the years to come, this report will spawn a lot more research and innovation in technologies for the healthcare sector in India and around the world.

This report has resulted in the authors submitting research proposals to the Government of India in the area of 'Mobile/Wireless Healthcare'. We are hopeful that the proposals will be accepted. If that happens, a tangible outcome would have resulted from this theoretical study [166].

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Technologies for the Healthcare Sector in India

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