



MAXIM IN INDIA (A)

SREELATA JONNALAGEDDA AND SRINIVAS PRAKHYA

Sreelata Jonnalagedda, Professor of Marketing, and Srinivas Prakhya, Professor of Marketing, prepared this case for class discussion. This case is not intended to serve as an endorsement, source of primary data, or to show effective or inefficient handling of decision or business processes.

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Maxim, headquartered at San Jose in California, was founded in 1983 by Jack Gifford and other professionals with experience in semiconductor design and sales. The company posted \$2.47 billion in sales in 2011, with 9,300 employees, and 35,000 customers worldwide. Maxim developed expertise in designing and manufacturing highly integrated analog and mixed-signal semiconductors. Maxim set up a technology design center in Bangalore in 2006. The Bangalore center has grown over the years and moved up the value chain in terms of contributing to technology design at Maxim. Gopal Krishna, Head of India operations, had joined Maxim in 2009. In mid-2011, Gopal Krishna was contemplating the new context that Maxim faced in India. India had been a location that contributed to design and engineering activities in Maxim while now India as a market appeared increasingly attractive. As a first step towards exploring this opportunity, Gopal decided to engage with the marketing faculty at Indian Institute of Management Bangalore. Energy, banking security, and medical diagnostics were identified by Gopal as promising sectors. Liberalization of the energy sector in India was underway and participation of the private sector in production and transmission was steadily increasing. The Indian government had embarked on a project of assigning unique identification numbers to all citizens. One of the purposes behind this initiative was to enable direct transfer of benefits to individuals participating in government-funded schemes for poverty alleviation. This would require participation of the banking system which in turn would require enhancing banking security. The healthcare system had been expanding but mostly in secondary and tertiary care. Maxim had extensive product lines in these sectors catering to worldwide demand.

The team decided to initially focus on medical diagnostics for identifying potential value exchange opportunities in primary health care. The size of the medical electronics industry in India was US \$ 850 million and has since been growing at a CAGR of 17% (<http://www.ficci.com/spdocument/20210/FICCI-Deloitte-Thought-paper-on-Medical-Electronics.pdf>). Maxim had an extensive range of solutions for medical diagnostics some of which could be suitable for the Indian market. However, the team's approach instead was to start from scratch and develop an understanding of the primary entities involved in the conception, creation, and delivery of value propositions; customer, company, collaborators, and competition. A delineation of these elements and the overall context would be one way to understand the marketing canvas and identify possible value exchange opportunities. The starting point then would be to study consumer needs and behavior. A group of students interviewed medical professionals including doctors and administrators and observed patients at primary care centers and hospitals.

PRIMARY CARE IN INDIA – MEDICAL DIAGNOSTICS

In interviews (summaries of interviews are presented in **Annexure 1**), medical professionals in primary care centers described the basic equipment they used. These included:

1. Auriscope
2. Calorimeter
3. Doppler machine (hand-held)
4. ECG machine
5. Electrophoresis machine
6. Glucometer

7. Hemogram
8. Ophthalmoscope
9. Oximeter
10. Sphygmomanometers
11. Ultrasound machine

In general, respondents mentioned the need for relatively inexpensive, portable, battery-operated solutions. When discussing calorimeters which are used for blood investigations – determining content of blood sugar, bilirubin, creatinin, cholesterol, uric acid and hemoglobin – processing speed of 20 minutes per sample was mentioned as a major bottleneck. Semi-automatic analyzers that can handle multiple samples would be very useful if they were inexpensive. Portable ECG machines are available but are prohibitively expensive. Portable X-ray machines do not deliver the requisite image quality. Similarly, the portable ultrasound machine has the advantage of being small and truly portable but its resolution is not as good as the standard machine. Hemograms are used to conduct comprehensive blood test but the most commonly required tests are Hemoglobin (Hb), total count (TC), differential count (DC), and platelet count. Hence, if unbundling were possible and led to lower cost, a simpler version of the hemogram equipment would be useful. The power pack in the electrophoresis apparatus which was used for detection of Sick Cell Anemia failed very frequently. Doctors regarded the old mercury sphygmomanometer as the gold standard for measurement of blood pressure. This was because of the inaccuracies associated with using the digital or aneroid sphygmomanometers. They were not very sturdy and their readings were not stable or consistent.

In rural health centers, power supply was a nagging issue. The urban–rural disparity in India has been striking. The relatively expensive equipment prevalent in urban areas translated to expensive diagnostics and treatment. This was not affordable to the population which needed relative solutions. Truly portable solutions were required to increase reach and penetration. A related issue was the lack of reliable power supply and this led to ineffective use of equipment as well as its damage.

The daily wage structure and lack of insurance translates to need for immediate diagnostics as frequent visits were not feasible. Hence, there was need for multi-modal analytics and micro-level investigation for quick diagnosis. Also, rural and semi-urban areas lacked trained experts so that simple and intuitive interfaces even for sophisticated tests would be useful. It is possible that fully digital approaches instead of electro/chemical/mechanical processes would enhance effective health care. Information technology can be very useful in rural areas – telemedicine and development of accessible databases can help partially overcome the need for specialists. Aftersales service was an issue for doctors in rural regions. They faced difficulty in getting instruments repaired as dealers kept changing.

INDUSTRY

Semiconductors have been ubiquitous in the life of the consumer and are at the heart of many consumer electronics products. The global semiconductor industry sales in 2011 were reported at \$299.5 billion with a CAGR of 9% between 1988 and 2008 (www.sia-online.org). Integrated circuits, where a large

number of transistors are integrated on a single chip, were used in almost all electronic equipment. The industry has been research intensive and Moore's law (the number of transistors that can be placed on a processor will double every 2 years) continues to hold. Various business models emerged in semiconductor manufacturing. These include integrated device manufacturers with activities spanning the entire value chain, foundries that only manufacture, fabless companies that focus on research and development and sales using semiconductors manufactured by others, and companies that focus on developing and licensing intellectual property.

Integrated circuits are categorized as belonging to memory, micro, and logic families. Data processing, communications, and consumer electronics have been the leading end-user markets for chips. Other end-user markets include industrial applications, automotive, energy, and medical electronics. In manufacturing chips, the focus is on the yield and in increasing the number of circuits in a chip. Yield is particularly important for standard products relative to customer-specific products. Intel, Samsung, Texas Instruments, and Toshiba have been leading players in the industry. The value chain activities start with silicon extraction from sand. This activity requires significant energy inputs. The next step involves purification and extraction in a mono-crystalline form to produce raw wafers. Wafers, packed into airtight units, are used by chip manufacturers for designing chips. The next step is production of masks or glass plates that are used to copy the chip layout onto the wafer. Individual chips are then cut out of the wafers, enclosed in protective casings, and shipped out. Over the decades, the industry that originated in the United States has spread out across the world. Also, most vertically integrated players have operations dispersed across the world to create efficiencies based on cost. Companies tend to focus on specializing in specific tasks leading to value chains that are more complex. Semiconductors are being used in more and more product categories in consumer and business markets and across the world. As the emerging markets become more important, end product prices can be expected to decrease. The semiconductor along with a few other components typically forms the intelligent core of an end product. In many instances, the end product comes into being as a result of value addition by a network of organizations.

MAXIM IC – MEDICAL DIAGNOSTICS

Maxim, founded in 1983, has been designing and manufacturing analog and mixed signal ICs. The company, with 9,300 employees, catered to 35,000 customers in 2011 and generated \$2.47 billion in revenue. In 2014, Maxim operated globally in 26 countries with 24 sales offices, 40 technology design centers, and 11 wafer fabs and test facilities. Maxim had a broad portfolio of offerings across 29 product categories. One of Maxim's core values was that of innovation with the company generating an average of one new IC design per day and has developed over 500 application-specific ICs in collaboration with customers. It aspired to be a "complete solutions partner" to its customers, providing them with end-to-end solutions for all their operations. Over 30% of sales revenue was ploughed back into R&D efforts, thus underscoring the organization's commitment towards innovation. Maxim has grown its expertise in different areas and has grown in size through several inorganic acquisitions over the years.

The company was headed by the CEO, Tunc Doluca, under whom there were three broad verticals:

1. Technology and Manufacturing: This division was responsible for Technology Development, which includes R&D work. It also took care of the entire manufacturing operations of the company. All the manufacturing was carried out in the United States. India did not have any fabrication facilities as the requirements for the manufacture of chips was highly stringent. The Quality Assurance Group within this division ensured the reliability of all ICs produced in the fabrication units.
2. Business Divisions and Development: This division included the Chief Technology Officer's (CTO's) office, which was responsible for driving innovation in the company. Through this office, the company entered into collaborative ventures with educational institutes such as the IITs. This division also proactively explored avenues that would be attractive for the company to venture into. Maxim was divided into 17 Business Divisions, each responsible for a different family of products. All these divisions belonged to the Business Divisions and Development vertical of Maxim.
3. Sales and Support: This arm of the company included the Sales, Applications and Distribution team, which was the customer-facing department. It also included support functions: Finance, IT, Accounting, Supply Chain Management, Legal, Facilities, HR, and Purchasing.

In medical diagnostics, 6,300 products were listed in Maxim's catalog. Some of its best offerings (see the *Medical Solution Guide* available at <http://www.maximintegrated.com/solutions/nav/medical/>) were in the (1) home medical, (2) medical imaging, and (3) diagnostics, monitoring, and therapy spaces. Home medical solutions included blood glucose meters, insulin pumps, blood pressure monitors, heart-rate/fitness monitors, digital thermometers, and hearing aids. Medical imaging solutions included ultrasound imaging systems, positron emission tomography (PET) imaging, magnetic resonance imaging (MRI), and computed tomography (CT). Diagnostics, monitoring, and therapy solutions included pulse oximeters, recommended solutions table, infusion pumps, dialysis machines, digital stethoscopes, electrocardiographs, spirometers, ventilators, and continuous positive-airway pressure (CPAP) devices. In addition, Maxim offered high performance medical instruments such as blood gas analyzers and flow cytometers.

Benefits provided by the Maxim range across products include reduced system cost, extended battery life, flexible interfaces, flexibility and scalability to reduce design time, stability and reliability, small and compact solutions reducing board space, enhanced portability, high level of integration, reduced heat dissipation, excellent audio and image quality, and precision in signal processing. For instance, in blood glucose meters integrated analog front-ends (AFE) provided accurate and precise glucose measurements while extending battery life, deliver accurate results in a smaller meter. Further, charging could be done directly from a USB port eliminating the need for an AC-DC adapter and sensor measurement errors were reduced using an easy interface.

COMPETITION – MEDICAL DIAGNOSTICS

The imperative to increase penetration of health care in India through improvement in affordability, accessibility, availability, and awareness has brought into focus the need for frugal innovation. There are

a few examples of successful attempts in the industry on this front. GE has adopted India-specific needs as a specific focus area for its healthcare division. Other than collaborating with healthcare providers and NGOs to develop affordable healthcare solutions, it has invested in research for developing new products. One outcome is GE's Mac series of low-cost portable ECG machines developed at GE's technology center in India. These machines were originally priced at a third of imported equivalent machines, were lightweight, battery operated, and made up of commercially available components to ensure easy aftersales service. Development of this product line continued at GE with more inexpensive versions being introduced. The GE MAC 600 was priced at INR 60,000–75,000, which is roughly 80% lower than similar quality products (\$1 = INR 61 approx. in January 2015). The machine was very small in size, easy to hold, easy to operate, and provided instantaneous results. It consisted of proven Marquette 12 SL ECG analysis software, was battery operated with a single charging being sufficient for 250 runs. Medived developed a pacemaker that was less expensive than comparable international products. 3Nethra, a product that pre-screened for eye ailments, was an innovation from Forus. It was an integrated, portable, intelligent, non-invasive, and non-mydratic eye pre-screening device that could detect five major ailments (diabetic retina, cataract, glaucoma, cornea, and refraction). Inbuilt auto detection software generated a pre-screening report on the problem detected within 5 minutes of screening. 3nethra can easily be operated in a rural environment by a minimally trained technician to benefit rural patients. This device talked to an integrated telemedicine and data center that could easily help scale through remote diagnosis and treatment. 3nethra has been developed with the sole aim of enabling mass pre-screening outside the hospital environment, so that doctors spend time on needy patients. Bigtec Labs has developed a miniaturized, stripped down version of a polymerase chain reaction machine (PCR). The machine is portable and available at a price that is less than a tenth of the extant bulky fully loaded versions of PCRs. This product has the potential to significantly reduce time taken to analyze and diagnose. The company continued to work on developing nucleic acid amplification platform using micro-electro-mechanical systems technology. Perfint Healthcare has been an organization with expertise in developing solutions for image-guided interventional procedures in oncology. Their innovative product ROBIO used robotics to make image-guided, soft-tissue biopsies simpler, safer and more accurate and was half as expensive as imported alternatives such as fluoroscopes.

COLLABORATION

Firms operating in the medical diagnostics space in India actively collaborated with research and academic institutions for research and development and in some instances for product realization. Collaboration with healthcare organizations and NGOs was sought for validation and for identifying market needs.

In the semiconductor industry, often a network of entities was involved in creating an offering or product to the end user. Although semiconductor solutions make up the core of many end products in consumer durable and other markets, many other entities could be involved in creating the final product. These could include value-added resellers (VAR), original equipment manufacturers (OEM), independent design houses (IDH), electronic manufacturing services (EMS), and original design manufacturers

(ODM). In many instances, OEMs outsourced the design as well as manufacture of their equipment and add value in branding and marketing. .

For instance, OEMs could outsource the design of medical equipment to IDHs. The IDHs were responsible only for designing equipment according to the specification of the OEMs. Once the design was ready, the actual manufacturing operations were outsourced to EMSs. These EMSs produce the equipment according to the specifications provided to them by the OEMs. Often, all the components to be used in the manufacture were specified by the OEMs; only the execution was carried out by the EMSs. In a few instances (~20%), only the overall design and budget constraints were outlined to the EMSs and the components used in the manufacture were left to their discretion. Another agency in this context is the VAR. VARs worked with chip manufacturers (CMs) and built a solution using the CM's products. Once the VARs designed a solution, they promoted this among the OEMs. If this solution was adopted, then the VARs entered the value chain and an indirect but strong link was established between the CM's product and the OEM's equipment. An emerging entity in this scenario is the ODM. ODMs performed the functions of IDHs and EMSs put together. OEMs outsourced the design as well as the manufacture to ODMs.

WAY FORWARD!

A need gap analysis of the interviews revealed possibilities and Gopal was considering the way forward.

Gopal carefully considered the information and described the following as innovation opportunities.

1. Combination of multiple sensors for multi-mode analytical ability for quicker diagnostics (e.g. BP + glucose + Oxygen + ECG) requiring mixed signal micro and Digital Signal Processing-based analytics.
2. Faster analysis of subset of parameters to reduce equipment cost and increase diagnostic speed (e.g. instant digital analysis Hb + TC + DC + PC in blood or bacterial culture studies) requiring imaging processor and ISP analytics for cell phone platform.
3. Simple, intuitive portable monitors (e.g. portable ECG with built-in analytics and alarms and ability to data log) requiring mixed signal micro, DSP, and radio.
4. Inexpensive imaging/diagnosis equipment for field use (ophthalmoscope, auriscope, ENT investigations) requiring image processor and Image Signal Processing-based analytics for cell phone platform.

While evaluating these options, the team felt that basic questions needed to be revisited.

1. What benefits are being sought by consumers in the medical diagnostics space? Which of these benefits would Maxim focus on to develop a solution?
2. What skills and resources are required to provide these benefits? Who should Maxim collaborate with to garner the required skills and resources?

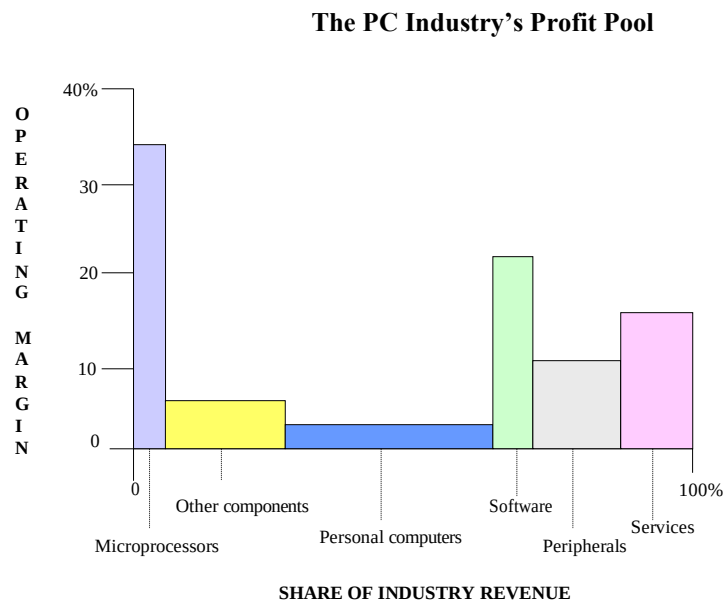
Maxim in India (A)



Answers to these questions could clarify opportunities and point to product development efforts that would be worthwhile investments. The relative importance of benefits and intensity of competition would be likely to vary across segments such as home, primary care physicians, and hospitals. Also, would it be possible to develop a sequential introduction plan with different versions of products? Would a sequential plan enable addressing different markets such as rural, home, and large hospitals?

Once Maxim identifies potential value exchange opportunities, it is faced with a fundamental question – should it focus on developing the semiconductor core for the solution and market this to original equipment manufacturers? Or, should it consider appropriating more value by undertaking other activities in the value chain? **Figure 1** provides a depiction of revenue distribution and variation in operating margins among the players in the PC industry

Figure 1



***Profit Pools: A Fresh look at Strategy - Orit Gadiesh and James L Gilbert**

Source: Orit Gadiesh and James L Gilbert, Profit pools: A fresh look at strategy, *Harvard Business Review*, May-June 1998.

Generally, the team was reflecting on the entire exercise of exploring value exchange opportunities in the Indian medical diagnostics market. Was there any learning that would be applicable to exploring value exchange opportunities in the other promising sectors (energy and banking)?

Exhibit 1

Interviews with physicians

1. Interview with Dr. Anil Agadi

The following is a summary of our interaction with Dr. Anil Agadi on July 20, 2011:

Dr. Agadi is primarily a surgeon and also acts as the CEO of Agadi hospitals. He has been working here for 14 years. Dr. Agadi handles ~50 patients per day. The hospital itself handles ~250 patients per day. These figures are for the day time. There would be approximately 30 to 40 additional patients in the hospital at night.

Equipment used by Dr. Agadi:

- Laboratory equipment: X-ray machine, scanning machine (4D – Toshiba, Siemens)
- Primary: Pulse Oximeter – finds it very handy; compact and useful. Hand-held Doppler machine – to observe blood-flow

In general: it would help if reports of tests were available instantly – with minimum time lost as “processing time”.

The doctor does not feel any dissatisfaction with the equipment that he currently uses.

However, according to him, a potential advancement would be a device which can with the same sample of blood yield results of BP, blood glucose monitoring (including HbA1c), hemoglobin, urea creatinin content in blood, etc. A patient should be able to operate this diagnostic equipment in his/her home.

As far as the equipment that the doctor uses in his day-to-day life is concerned, he does not see any requirement. According to him, “there is only so much that machines can do. You ultimately need a person (doctor) to interpret results of any test.”

Cost and space (space more than cost) are factors that constrain the equipment that the hospital has invested in.

Portable ultrasounds are not very clear. Their resolution is not fine enough to make accurate diagnosis.

Flow meters are not accurate enough to be reliable.

In secondary care, there has been much advancement in medical equipment and care. The same amount of research has not been invested in creating more affordable primary care.

2. Interview with Dr. Parimala

Dr. Parimala is a general practitioner who has been looking after a rural health center for the last 16 years. This is a primary health center visited by all kinds of patients in the village for treatment.

The various kinds of ailments that are treated here include: hypertension, high blood pressure, arrhythmic heart, psychiatric conditions, and skin problems. There are also doctors who specialize in gynecology, obstetrics, pediatric care, and antenatal care.

This health center is located off the Mettupalayam road, approximately 20 kilometers from Coimbatore, Tamil Nadu. This is around 2–3 kilometers from the main road and there are no direct bus facilities here.

Equipment commonly used at this health center are as follows.

1. Blood pressure apparatus
2. Sphygmomanometers (aneroid type as well as mercury meters)
3. Calorimeter
4. Binocular microscope
5. Computerized E.C.G. machine
6. Glucometer

Ultrasonography equipment is not used here. Dr. Parimala does not experience any difficulty with the equipment in this health center.

When asked about the problems faced by the doctors here, Dr. Parimala enumerated certain issues. These can be classified into the following categories.

- i. Inaccessibility of the hospital location and transportation and other facilities
- ii. Erratic supply of electricity
- iii. Cost of the more sophisticated equipment is very high
- iv. Lack of sufficient technical manpower to assist the doctors

Facilities

As the health center is located in a remote area, it is not easy for people to reach the place. Transportation is irregular and infrequent. The nearest place for further care is either Coimbatore or Mettupalayam, both of which are approximately 25 km away.

Health care is completely free in this hospital. If patients are to be referred to other doctors elsewhere, affordability becomes a concern as other hospitals do not follow the model of free health care. At government hospitals, there is a lack of doctors or trained personnel who can treat patients.

In addition, internet connection is very slow and no broadband facility is available in such remote regions.

Power

The supply of power is erratic and voltage fluctuations are very frequent. The hospital has a stabilizer and generator. Equipment got burnt when used without the stabilizer.

Equipment which depend on electricity for their functioning are refrigerator, calorimeter, microscope, E.C.G. machine, sterilizer, and the focusing lamp.

Cost: The E.C.G. equipment is costly. The machine in the hospital is compact and portable, although it is not transported much. The other equipment used in the health center is not expensive.

Apart from the equipment listed earlier, this health center does not use other, more sophisticated equipment. They do not have any automatic analyzers.

The calorimeter that is used is a very simple, inexpensive piece of equipment. It is used for blood investigations – determining content of blood sugar, bilirubin, creatinin, cholesterol, uric acid, and hemoglobin.

If semi-automatic analyzers are made more affordable, the doctor would then want to include them in the hospital. Cost is definitely a factor in the equipment purchases made by the hospital.

The hospital is not self-sufficient in its diagnostic capabilities. Only a few basic investigations can be conducted in their own lab. Often, blood samples are sent outside for further detailed analysis. This is where the presence of semi-automatic analyzers would help the health center. The funding for equipment purchases is handled by the hospital headquarters.

If cost were not a factor, then the additional equipment that Dr. Parimala would like to include in the health center are:

1. **Semi-automatic analyzer** in the Biochemistry Laboratory: This is an upgraded, computerized machine which performs similar functions as a calorimeter. It takes minimal time for processing, and results are immediate. At present, the calorimeter used by the hospital needs 20 minutes to process each sample. A semi-automatic analyzer gives immediate results and 50–60 samples can be loaded at a time onto it. It costs approximately INR 1.5 lakh.
2. **Cold chain refrigerator:** This is an ice-lined refrigerator used to store samples for up to 48 hours even without power.
3. **Ultrasonography equipment:** There is no constant need for this equipment. However, if it were available once a week, it would be useful.

Lack of technical manpower:

If more trained technicians were present at the health center, this would increase doctors' productivity. The time spent by doctors performing peripheral functions could be better allocated toward treating more number of patients.

Telemedicine

There are no further problems with the equipment being used. However, Dr. Parimala would find telemedicine to be a very helpful tool owing to the following reasons.

- A specialist opinion can be sought when required.
- Diagnosis can be made and treatment recommended without having to shift the patients.
- Advanced medical education can be provided to technicians who work in remote areas.

3. Interview with Dr. Deepa C Prabhu

Dr. Deepa is the medical officer at IIM Bangalore. The clinic at IIMB caters to the patients on an out-patient basis. The patients include faculty and their family members, staff and students. Dr. Deepa treats patients on a daily basis and refers emergency patients to Apollo Hospital located opposite to IIMB.

The doctor does not face any problems with the equipment that she uses, as her usage is very limited. She does not really feel an urgent need to have more equipment in her clinic. She is satisfied with the basic equipment required to measure vital statistics of a patient.

Equipment commonly used at this health center are as follows.

1. Blood pressure apparatus
2. Sphygmomanometers
3. Oximeter
4. Glucometer

Regarding additional equipment which might be useful, the doctor said she would require integrated equipment. This would measure temperature, BP, oxygen levels, glucose, and cholesterol. This kit may be used for elderly patients who need all these statistics to be monitored on a daily basis. It could be a disposable kit used on a per-patient basis. Similar equipment is already being used abroad for monitoring patients.

Cost is a factor for using these disposable kits, since costly kits would not be preferred on a daily basis.

Such clinics do not face problems such as procuring more compact instruments. Neither do they face bottlenecks owing to the equipment used. Delay may be caused in obtaining laboratory results from external testing facilities.

Dr. Deepa is hopeful for the future of medical technology with endoscopy employing fiber optics and robotics surgery coming into play.

4. Interview with Dr. Girija Singh

Dr. Girija Singh used to work at St. John's Hospital. She also has a private medical practice at her home where she treats several patients in a day.

Dr. Girija has the most minimal medical equipment at her clinic. There are blood pressure measuring devices: the mercury as well as electronic. However, the doctor prefers to use the mercury measurement device. She considers it as the gold standard for blood pressure measurement. The other device can give error up to 10% in its reading.

The doctor does not face any problems with the equipment she uses, as her usage is very limited. She does not really feel an urgent need to buy more equipment for her clinic.

Upon further probing into what other equipment the doctor might find useful in her clinic, she said she could use an E.C.G. machine and a glucometer. However, she finds it very difficult to actually take readings from these machines. She prefers asking her patients to get the requisite tests done from diagnostic clinics outside and then come back to her for the treatment. (This is where a technician would be of help: one who could help with handling the medical equipment.)

Another reason for not keeping additional equipment in her clinic is the space constraint in her clinic.

5. Interview with Dr. Shenoy

Dr. Shenoy has a private clinic in Mathikere, Bangalore. He has been actively practising medicine for over 40 years. The various equipment used by Dr. Shenoy are as follows.

- Stethoscope
- Thermometer
- Weighing machine
- Storage drum
- Minor surgical instruments
- Auriscope
- Sphygmomanometer
- Ophthalmoscope

General Equipment

Although the thermometer, weighing machine, and storage drum are strictly speaking, not equipment, the rest of the gadgets mentioned here are of interest to this study.

The stethoscope is used to gauge the health of the patients' lungs and heart. The refrigerator is used for storing vaccines and other items that need cold storage. The drum is used for storage of dressing material.

ENT Apparatus

The auriscope is an ear–nose–throat (ENT) instrument. It is used to look into the outer canal of the patient's ear and ear drum, nose, throat, etc.

For measurement of a patients' hearing (quantification of hearing loss), the doctor uses an apparatus akin to a tuning fork.

The ophthalmoscope is used to look into the patient's retina. It uses light from an LED source with which the eye is observed. Before using this equipment, the corneal opening of the patient's eye has to be enlarged. This is usually done by an ophthalmologist, not a general practitioner.

This procedure takes time and it is cumbersome. Patients will have a certain waiting time before examination when their eye is dilated. Often, general practitioners' clinics are not designed to accommodate extra waiting patients.

Sphygmomanometer – Types

Dr. Shenoy has three kinds of sphygmomanometers.

- **Mercury:** For his day-to-day use at the clinic, the doctor relies on the mercury sphygmomanometer. He is very comfortable using this equipment as he has been using it for the last 45 years without any complaints. According to his experience, in the clinic setting, most doctors prefer the use of the mercury sphygmomanometer.
- **Aneroid:** The aneroid type is easily transportable (the mercury meter is bulky and difficult to carry around). The doctor has two meters of the mercury type, both made in the United States.
- **Digital:** In several hospitals, the digital sphygmomanometer is used extensively. However, these have been known to give different readings at different times. They can be used to get an approximate idea of the patient's blood pressure range, but cannot be relied upon for accuracy.

Dr Shenoy recalls his experience with the digital sphygmomanometer. He bought it 15 years ago from a Japanese manufacturer. He was enthusiastic about this new development and bought it eagerly to test its working. However, he found that, with the slightest movement, the readings displayed by the meter changed. This caused him to lose interest in the digital meter.

This indicated that not all doctors are resistant to the adoption of newer technologies. However, in embracing any new development, they expect (quite reasonably) that it should surpass the earlier equipment in functionality. Ease of handling is not as important a concern here as the accuracy and reliability of the machine's output.

Other Blood Testing Equipment

For blood glucose measurement and other blood tests, Dr. Shenoy (similar to Dr. Girija) prefers not to do the testing himself. He generally sends his patients to a nearby laboratory for blood tests. Most of his patients who are diabetic own blood glucose meters, but Dr. Shenoy does not have it in his clinic.

Need for More Equipment

Upon being asked for his suggestions on medical equipment, Dr. Shenoy was of the opinion that big hospitals were a better ground for this kind of study than his basic unit. ICs did not have a big part to play in his kind of work.

The doctor does not feel the need for any new equipment for his practice. He is happy with whatever basic equipment he has. If there is any new advancement in the equipment, he is ready to try it out. However at the moment, he cannot think of any unfulfilled requirement he might have or any additional equipment he might need.

Doctor Shenoy's aim has been to provide economical treatment to his patients. He believes that the many years of his experience help him make the lives of his patients easier.

6. Interview with Dr. Atul Gupta (Delhi)

Dr. Gupta has been serving in the Northern Railway Hospital for more than 12 years. He is a Senior Divisional Medical Officer at Delhi.

The doctor feels that the design and application need to be improved and made more user-friendly. The software should be easy to use with touch screen devices; understanding the patterns which arise in the results should all be explicit. The interface is very important.

Another issue Dr. Gupta pointed out was the convergence issue. Data should be transferred seamlessly from devices to computers and back so that we can talk to the devices in real time. This connectivity can be very helpful in storing all the patients' info at a central location (one single database) and may help in tracking the patient's history easily.

He further explained that it is not important that the machines are integrated; it is actually going to make it more complicated. Rather, the information should be communicable. For example, patients whose ECG and X-ray have been done on separate machines, it may be used in isolation or can be sent to the central database where all the other info of the patient is stored. When one clicks on the patient's name or ID, you can see all the reports.

The doctor says that today, we have different manufacturers for each instrument and they have separate technology for each instrument; it is very difficult to integrate all the information. The future requires

centralization and net-enabled devices so that we may talk to doctors/family members in the United States and discuss the patient's condition via access to his information.

This is similar to telemedicine requirements, where we can use specialist expertise far away from the patient for his/her treatment.

He does not have a problem with how instruments are becoming more portable and compact but feels there is trade-off here. The quality of these instruments is not as good as the bigger instruments, for e.g., the X-ray machine which is portable does not give the same picture quality as the bigger machine. Here again, he feels you can sometimes compromise on quality as you just need results and some tests where diagnosis is either true or false as in the instance of pneumonia, we could settle for lesser quality tests too if it serves our purpose. It entirely depends on your requirement.

Dr. Gupta also mentions that complex instruments require special training for using them. This is becoming difficult these days as we require a separate person to work on each machine. In critical care, you see a patient may have many machines around him, so a ventilator, ECG machine, glucometer, etc. will all be operated by different people, which is not practical. It has to be made simpler to use. It should be automatic as you have other things to worry about than using the machine correctly.

When probed about primary instruments, he said that using a BP monitor may become a bottleneck at times. You need practice and experience to obtain a correct reading. Errors are common as mercury level may drop before result is read.

Now, we have digital BP monitors which are condition dependent and not very robust. If it is tied to the arm correctly, it gives a good reading. The sensors do not work when it is not fastened correctly. These monitors are not very accurate.

Secondly, the glucometers can also yield faulty results because of the quality of the strips. They are dependent on temperature and moisture, which makes it difficult to maintain.

7. Interview with Dr. Maddhu Chadha (Delhi)

Dr. Maddhu has been serving in the Northern Railway Hospital for about 8 years now. She is also a Senior Divisional Medical Officer in the railway hospital at Delhi.

On a daily basis, Dr. Maddhu uses the glucometer, ECG machine, BP instrument, bypass machines, CR machines, incision set, pulse oxymeter, nitro ventilators, etc.

The doctor feels that the general machines are user-friendly and has no difficulty with them. However, some of the machines are very complicated and require engineers to handle them. They should be simplified.

Since the instruments are used by many people around the clock, they should be sturdier. The instruments are light weight, so portability is not a problem.

Cost is variable and differs in range such as the Chinese equipment may be cheaper and the same instrument may be costly if it is made in India.

Availability of instruments is not a problem. However, the aftersales service is very bad. We have difficulty in getting the instrument repaired or for maintenance. Dealers keep changing; hence, aftersales service is a problem.

8. Interview with Doctors of Swami Vivekananda Youth Movement

In order to understand the concerns of doctors working in rural areas, we visited a hospital close to the town of Sargur, Karnataka. This hospital, called as Swami Vivekananda Youth Movement (SVYM) hospital was set up by a group of doctors in 1987 in order to serve tribal people in the region who had been displaced from their original homes. What makes the insights from doctors in this hospital different from those of city doctors is the location of the hospital and the fact that it needs to be self-sufficient as much as possible.

Apart from the main hospital, which we visited, there is another primary care unit located even further away from the town, which caters, almost entirely, to tribal people, even today. Along with establishing healthcare facilities, the SVYM organization has also set up education facilities with some help from local government bodies.

The doctors that we interacted with are as follows.

- **Dr. M. A. Balasubramaniya:** He is the CEO of the hospital and is responsible for overseeing the management of the hospital.
- **Dr. M. R. Seetharam:** He is the President of the Governing Body of SVYM. This body has seven members and is elected annually in order to take important governance-related decisions.
- **Dr. Rajendra Prasad:** He is a general physician at the SVYM hospital.

The objective of this interaction was jointly described in two steps:

1. Arriving at a definition of health care
2. Match Maxim's competence with this definition to see where it can contribute

Healthcare opportunities exist not just in the field of diagnosis, but also in the treatment of patients and in the management of information systems.

All these areas were explored over the course of the interaction with the doctors.

Dr. Balasubramaniya stressed the importance of learning about a patient through listening and interacting with him/her. He rated this very high in importance; in order to diagnose any disease, it is essential to understand what the patient actually is suffering from, not just what he/she complains of.

A major problem faced by doctors at present is the lack of awareness among the people they seek to help. Most people are not aware of what is available and this prevents them from using even existing facilities. An example of this is the water purification tablet called Aquatab which the hospital distributes. This tablet takes 30 minutes to purify 10 liters of water. After this time, the water can be decanted and is pure enough to be used for drinking purposes. This is one of the examples of how increasing awareness can help people better their lives.

Information Dissemination Systems

In order to spread awareness about health, hygiene and preventive care, the hospital has undertaken an information dissemination drive. The media being used by them for communicating to the villagers are:

- **Street plays:** Identify areas where villagers congregate and then educate them.
- **Self-Help Groups:** Target education to members of these groups
- **Community Radio Project**
- **Audio Visual Recordings:** The SVYM group has created specific educational recordings. They see potential in this medium as schools and Gram Panchayats in the area are equipped with computers. Hence, SVYM can disseminate info through this channel by distributing CDs. They are also simultaneously working with the state government to incorporate this education into the school curriculum.

In this context, the doctors also expressed interest in Dr. Gorgaonkar's work, which enables people to use the keyboard to type in Indian languages. The doctors cited the local people's lack of knowledge of the English language as a barrier to their using computers. Such an innovation would spread the benefits of computer usage among the local people.

Vision for the Future

The doctors envision a **Global Data Integration System** in the future. They seek to make **Preventive Care** possible through inputting of data into a larger, global database. This database – yet to be created – will contain records of diseases faced by people along with several details of when they were afflicted, their family details, and the region they belong to. All zones will have their water sources mapped out and their hygiene conditions recorded.

Sorting of data can be done on the basis of any parameter required. This will make demographic mapping of diseases possible, among other possible uses. Doctors would be able to trace problems back to their root cause. This will enable them to potentially create demographic maps of diseases and identify the probability of people being affected by them based on the region they come from.

Once this is done, the next step would be to take preventive action. Doctors could impart targeted knowledge on particular aspects of health and hygiene on a need basis to these regions. If necessary, they could even target health camps at a cluster of villages afflicted by a particular disease.

The inspiration for this thought arose from the doctor's exposure to a Community Information Platform (CIP) developed by the University of Iowa. This is called e-granary and it is a web-based repository of medical and development related issues. Most articles are peer-reviewed and community information is also maintained on this portal.

Medical Equipment-Related Issues

When asked about the medical equipment handled on a daily basis, the following emerged as factors causing discomfort to the doctors where there could potentially be a role for Maxim to bridge the gap:

Pulse Oxymeter

This device is used to measure the pulse of the patient and also the saturation of oxygen in the patient's blood. The device fits onto the finger of the patient in order to be able to make this measurement. The shape of this portion is similar to a clip. The doctors feel that it should be similar to a cap to ensure accuracy of readings.

Hemogram

This machine is used to perform blood tests on patients' blood samples. The Complete Hemogram costs INR 2,00,000. The Complete Hemogram machine is capable of performing a variety of tests on the patient's blood sample. However, the tests most commonly used are for the following:

- Hemoglobin (Hb)
- Total Count (TC)
- Differential Count (DC)
- Platelet Count

Using a machine which is capable of doing just these tests would greatly help the doctors provided the machine could be made available at reduced cost and test results would be immediate.

The reasoning used here follows the Pareto Principle, that is, most of the patients require only the simple tests and only a few require the more advanced ones. However, since the Complete Hemogram is equipped to perform all the tests, costs of testing go up for everyone.

Ophthalmoscope

This equipment used to study the health of patients' eyes is costly for rural doctors. At present, it costs between INR 8,000 and 10,000. This is basic equipment essential for a hospital and reducing its cost would be beneficial.

Electrophoresis Machine

This is used to identify Sick Cell Anemia, which is prevalent among people indigenous to this region. The only other method of detecting this disease is paper chromatography, which is a very costly process.

The problem with electrophoresis equipment is that its power pack is not reliable. It stops functioning within a short span of time. Rectifying this drawback would be of significance to the local regions.

Bacterial Culture

Culturing of either blood or urine samples from patients is performed depending on the type of disease suspected. The time taken to obtain results from this method is very high. As a result, this prolongs the waiting time before which effective care can be provided to the patient after diagnosis.

The process of bacterial culturing, in simple terms is as follows. First, the sample must be incubated in a nourishing medium and 48 hours is provided for bacterial growth, if any. Then, the bacterial sample so formed is tested for drug resistance.

If there is no bacterial growth, then the doctors wait for an additional 24 hours (totaling 72 hours) before declaring the sample to be bacteria-free. In the meanwhile, before the results arrive, the patient is started on a course of medication based on the doctor's assessment.

However, the scope for Maxim to intervene in speeding up this process is relatively low, as it involves accelerating the rate at which bacteria grow, which is dependent on the type of bacteria present.

Blood Glucose Meter

If the measurement of HbA1c could also be incorporated into the conventional blood glucose meter, it would greatly help in assessing diabetic patients' status over 3-month duration. The blood glucose monitor indicates only blood glucose levels in the patient's blood at a given point of time. The HbA1c test is performed using HPLC equipment, which is costly.

Albuminuria

This diagnostic test is used to detect kidney failure and is specifically useful to diabetic patients. There is also a spot test which measures the protein-creatinin ratio in the patient's urine to determine whether the filtration capability of the organ has been compromised. However, this is a cumbersome process.

Macroscopic test is a swifter method, where a simpler stick test is used to determine presence or absence of albumin in the patients' urine. However, the more useful test is the microscopic one as it helps to test for kidney failure. If microscopic albuminuria is made simpler, it would greatly benefit patients.

Neonatal Applications

Medical applications could be very useful in the neonatal field. Two instances of therapeutic interventions in this area were discussed.

- **Temperature Modification:** Hypothermia is a common problem faced in newborn babies. Newborn babies are kept in cribs lined with thermostatic materials in order to keep them warm. There is potential for innovation in this area.
- **Phototherapy:** Treatment of jaundice in children is done by controlling bilirubin levels in their blood. This is done by concentrating UV light using tube lights.

Waste Management

Disposal of equipment in hospitals is also a challenge. Newer, eco-friendly methods for disposal would be of significance.

Inventory Management

The hospital uses Hospital Management System (HMS) software to manage records of patients who have been treated at the hospital.

- However, they are unable to record details of their smaller health center at Kenchenahalli, where immunization shots are given on a weekly basis. Tracking these vaccination shots on a “per-child” basis would be an advancement of their operations.
- The hospital also manages its mobile healthcare service and treats patients in neighboring areas. All records of this mobile-administered service are written by hand.
- The doctors devised a mobile tablet capable of recording patient data which can later be transferred to the master database. This tablet could be carried by the healthcare providers traveling in the van to record data. The tablet can also be used by the staff at Kenchenahalli where HMS is not implemented.
- In addition to these applications, the vital sheets attached to patients' beds in a hospital can be replaced by a nurse carrying a tablet. It can store data of all patients, and this data can later be integrated with the HMS.

The key here is **compatibility**. The various machines used to capture data must be compatible with each other and with the master database system.

Futuristic Possibilities: Nanotechnology can be used to create time release capsules for the controlled release of drugs into patients' bloodstream. This will minimize the number of times a patient has to visit the hospital.

8(a) Interview with Dr. Mohan

Dr. Mohan is a primary healthcare doctor who has been working in the Sargur hospital near Mysore. The doctor attends to about 40–45 patients per day on an outpatient basis and 4–5 patients in the in-patient section.

Equipment commonly used at this health center are as follows:

1. ECG machine
2. Scanning machine
3. X-ray machine
4. Primary incision equipment
5. HB investigation

In the hospital laboratory, the equipment used are as follows.

1. Microscope for investigations
2. Autoclave machine: used for sterilization
3. Suction machine
4. Oxygen cylinder
5. Nebulizer
6. Ophthalmoscope

Except the scanning machine which is used once in a month, all the other machines are used every day such as ECG, X-ray, sonography machine, etc. All equipment required for routine checkups and lab investigations are available; these include the stethoscope, BP apparatus, and thermometer.

They also have **non-electrical equipment** such as different types of Ayurvedic tablets, enema kit, etc. Special **electrical equipment** includes the pulverizer. This is used to powder Ayurvedic medicines, which are then used in the treatment of patients.

Hospital Description

The health center is located in a remote area called Kenchenahalli. It is a small hospital with only 10 beds. This basic hospital is primarily meant for the treatment of tribal patients. All the doctors are specialists in Ayurveda and Allopathic treatment is handled by one doctor who comes from Sargur.

Speciality – Ayurveda

They have an Ayurvedic Department which is called Panchakarma Center. This literally means five types of treatment. Here, after oil massage, the patient is required to take a steam bath. Steam chambers are used for this purpose.

Although Dr. Mohan specializes in Ayurveda, his investigations are still dependent on certain basic tests for Hb levels, blood sugar, etc. Handheld devices are used during emergencies because they provide immediate results, but the accuracy levels are not good. Contamination of the equipment is very easy and hence should be used carefully.

Immunizations and other services

This hospital conducts immunization (for Polio, DPT, etc.) at their healthcare center every Thursday for children. Sonography is performed by the gynecologist to obtain details of fetus health. There are also field workers who collect data about the villagers.

Difficulties faced

When asked about the difficulties caused by the equipment, the following points were raised.

- It is difficult to maintain a temperature which is optimum for the deep freezer.
- Handling of the microscope requires special care. Technicians who work on the microscope need to be trained to take special care of the sensitive parts of the instrument (objective and eye-piece). This is true for all lab instruments as they are handled by more than one person. This may affect the sturdiness of the instruments.
- The hospital has been using solar-powered equipment which sometimes get switched off. Backup is present in the form of charging batteries. The doctor wondered if there was any other way of doing this.
- Formulae for Ayurvedic medicines are provided to apprentices in the form of Excel sheets. The Excel sheets can be locked for editing to prevent changes in formulae.

Unmet needs

There are some instruments which are expensive and are not used frequently. The cell counter is one such example; the cost of using it for less than 10 results at a time cannot be justified.

Binocular microscope is also required here. These are better than normal microscopes for investigations.

There is no ICU here; so, it is not possible to handle patients requiring intensive care in this clinic.

With specific reference to tribal patients, one problem is that they are not ready to stay in the hospital and it is very difficult to persuade them to visit the hospital for any treatment.

Future HMS Usage

If this hospital adopts HMS, they would need to transfer existing records to the system. Every patient has a unique ID which references the village that he/she belongs to and then the individual himself/herself. This would need to be integrated with the new ID allotted to the patient in the new system.

All supplies to this health center are obtained from the hospital at Sargur. Owing to this, Dr. Mohan can procure everything he needs within 2 hours. Thus, Sargur serves as a backup for this health center. The larger concerns of the hospital in general are common with the master hospital at Sargur.

In terms of operational efficiencies, Dr. Mohan is very happy with the condition of this health center. The management of patient-flow is done such that 5 minutes are spent per patient for examination. Within 30 minutes, the patient can ideally finish his/her visit.

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