Matri Seva: a telemedicine software for rural healthcare program of RKMHOS, Varanasi

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***Abstract*—Telemedicine system provides an alternative to patients by facilitating virtual clinical consultations over traditional hospital visits. Healthcare benefits ranging from quality treatment and access to specialist doctors for residents of rural parts at times of need have proven to be beneficial. Additionally, rural patients employed as daily wage workers save time and money, thereby encouraging them to stay connected throughout the year. It is gradually showing the potential to change the healthcare delivery system for the better especially in the rural areas.**

At the Department of Computer Science and Engineering, IIT Kharagpur, a open source telemedicine software, iMediXcare, has been developed. A customized version of this telemedicine software, Matri Seva has been developed and deployed to support the rural healthcare program of Ramakrishna Mission Home of Service (RKMHOS), Luxa, Varanasi through its department, Vivek Sanjivani, An Initiative for Healthcare and Education. Vivek Sanjivani provides free telemedicine services to people in rural parts of Uttar Pradesh and Uttarakhand, India.

***Index Terms*—Rural healthcare, Digital health, Telemedicine, iMediXCare, Matri Seva**

I. Introduction

Telemedicine is a technology that provides medical services and exchanges of medical data among remotely connected healthcare service units [1]. It facilitates remote consultation among doctors and patients. The technology found to be useful in improving the quality of healthcare services with a lower cost, compared to ambulatory healthcare services [2]. It has benefits not only in reducing the cost of treatment but also in saving time and trouble of travel (and stay) to a distant place. According to the economic survey 2022-2023 conducted by the Ministry of Finance [3], 65% of the Indian population resides in rural parts of India. The rural healthcare system may not always have the necessary medical supplies, and it also lacks medical specialities and an adequate number of doctors, nurses, medical technicians, etc [4]. Proper healthcare services and recognized medical professionals are only available in a few urban regions. It creates a disparity between rural and urban populations. In such circumstances, telemedicine services are a viable and feasible solution [5], which reduces the cost of medical service and improves accessibility.

With the advent of digital technology, the practice of telemedicine started around mid-nineties of the last century [6]. But its uses increased in many folds during the years of COVID pandemic and thereafter. The previous versions of telemedicine services involved the usage of low-bandwidth network connections like dial-up connections [7]. Initially, electronic health records (EHR) were maintained as digital records at nodal hospitals [8]. As the network bandwidth has improved over time, telemedicine services with integrated video conferencing and online information exchange [7] have come into existence.

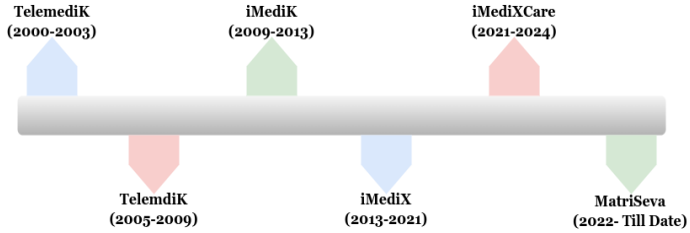

Fig. 1. Different generations of telemedicine software developed at IIT Kharagpur

There are some challenges in telemedicine in terms of software usability and validation. The protocols for performing telemedicine under various context are not yet standardized [4]. It is quite common to see some of the bottlenecks of existing telemedicine system. For example, a patient may perform multiple and redundant registration each time visiting a telemedicine center. It creates difficulty in getting access of patients' prior visit history. In many instances, medical reports or prescriptions are uploaded in the form of scanned images/documents, causing difficulty in running data analytics for various purposes, such as improving and auditing the services. The early internet boom has also introduced many vulnerabilities for systems connected to the internet. The exchange of medical information is very sensitive and needs additional layers of security at system architecture level to ensure consistency and privacy of data. A four-tier architecture proposed in [9] reduces the risk from such vulnerabilities.

At the Indian Institute of Technology (IIT), Kharagpur, the research and development of telemedicine systems have been going on since 1999 and considered to address various issues as mentioned above. In 2009, iMediK, a four-tier telemedicine system [9], [10], has been developed as a centralised telemedicine server to handle electronic health

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records, that included text, images, audio, and video. Later, the system is ported to opensource computing platforms and named iMediX [6], [11]. It was subsequently integrated with a Picture Archiving and Communication System (PACS) that facilitated storing and retrieving radiological data, and with an opensource video conferencing system, JitsiMeet [12]. During the Covid pandemic, the research group developed an open-source telemedicine system named iMediXCare [13],which has a systematic approach in treating patients, staying at their residences through remote consultations by physicians. In Fig. 1 a time line of development of telemedicine systems of different generations at the Institute is shown. In 2021, iMediXCare has been customized to build a telemedicine system , named Matri Seva, for running rural healthcare services, an ongoing program of Ramakrishna Mission Home of Service (RKMHOS), Varanasi, through its department *Vivek Sanjivani*, an initiative of Healthcare and Education. This department focuses on Healthcare, specially rural healthcare, through Telemedicine services. It operates eleven centres with both Stationary Telemedicine Units (STUs) and Mobile Telemedicine Units (MTUs). These units enable remote medical consultations, effectively bridging gaps in healthcare access across geographical boundaries. For example, in the year 2023-24, it provided healthcare to a total of 59,553 beneficiaries across three districts, in Eastern Uttar Pradesh and Uttarakhand. This included serving 32,658 patients through their telemedicine units and conducting Non-communicable Disease Screening (NCDS) for 21,626 beneficiaries.

In Vivek Sanjivani, telemedicine has been running for the past six years. In April 2021, Matri Seva replaced its old telemedicine system, as it is found to be more convenient to operate and useful in coordinating activities. In this paper, we present a study on the impact of the telemedicine software Matri Seva in providing healthcare services from the department of Vivek Sanjivani of RKMHOS, Varanasi.

In the following sections, we first review the features of iMediXCare, the base system, whose customization to develop Matri Seva is discussed next. We also report various statistics related to the services catered through the telemedicine system highlighting features of rural demography and prevalent diseases among them for which medical services need critical attention.

II. iMediXcare

iMediXcare [13] is a free, open-source, web-based, multi-tenant telemedicine system. It models an Out-Patient Department (OPD) workflow of a hospital. It provides teleconsultation to a patient through video conference, sharing of electronic documents, and text chat. It implements several roles of a user, such as of an administrator, a doctor, a data entry operator, a medical technician, and a patient. It has a role-based access control. The administrator has primary control over the system, such as center creation, user management, doctors' availability, etc. A data entry operator registers a patient in the system, uploads medical records, and assigns a doctor for consultation. The technician can upload pathology or radiological data that is advised by the doctor. A distinct feature of this telemedicine system is the provision of the role of a patient, who is capable of making a request for teleconsultation, performing online consultation with a remote doctor using video and data conferencing, and getting access to medical records after consultation. A schematic diagram of the system workflow is shown in Fig. 2.

iMediXcare is built on a three-tier architecture. The system consists of three layers: the presentation layer (PL), the business logic layer (BLL), and the database layer (DL) [14]. It runs on an Apache Tomcat HTTPS server® [15] and uses MySQL^{TM} RDBMS. Users of the system interact with PL using the graphical user interface (GUI) that facilitates users in providing instructions. The objective of PL is to communicate with BLL by imparting instructions received from users and furnishing the results acquired from BLL in an organized fashion, making them interpretable to users. BLL interprets the user instruction and communicates with DL using structured queries, thereby fetching useful information from the database. The desired information is then transmitted back to PL from BLL. BLL acts as an intermediate layer which communicates between PL and DL. Communications between these layers are facilitated by JAVA RMI (Remote Method Invocation), which keeps both database and web servers isolated from database servers, allowing remote connections. The information storage is maintained at DL, which uses the Relational Database Management System (RDBMS) to store data by interfacing with the database server.

III. Matri Seva

iMediXcare, being an open-source telemedicine application, is customized to meet specific needs. The customized software is named *Matri Seva*. Vivek Sanjivani is an initiative for Healthcare and Education of Ramakrishna Mission Home of Service, Luxa, Varanasi. Eleven facilities are used by this department to provide telemedicine services using Matri Seva, which comprises five Stationary Telemedicine Units (STUs) that are static at a location and six Mobile Telemedicine Units (MTUs) which are roaming through places.

One of the primary objectives of Matri Seva is to capture information in a specific format, which enables healthcare professionals properly diagnose the disease, make proper and effective line of treatment, offer patient-specific treatment and evaluate the progress of recovery in each patient. In case of relapse of disease in any patient, doctor can review the earlier treatment and prescribed medicine and formulate the new line of treatment. Sometimes doctor finds new medicine to be initiated for particular patient to enhance the recovery. Monitoring the beneficiaries diagnosed with non-communicable disease (NCD) is one of the prime responsibilities of healthcare professionals. Based on the medical history of beneficiaries in these areas, four major WHO-approved diseases are considered for NCD screening which are hypertension, diabetes mellitus, breast cancer, and oral cancer. Along with these screenings, the system caters to following community outreach programs.

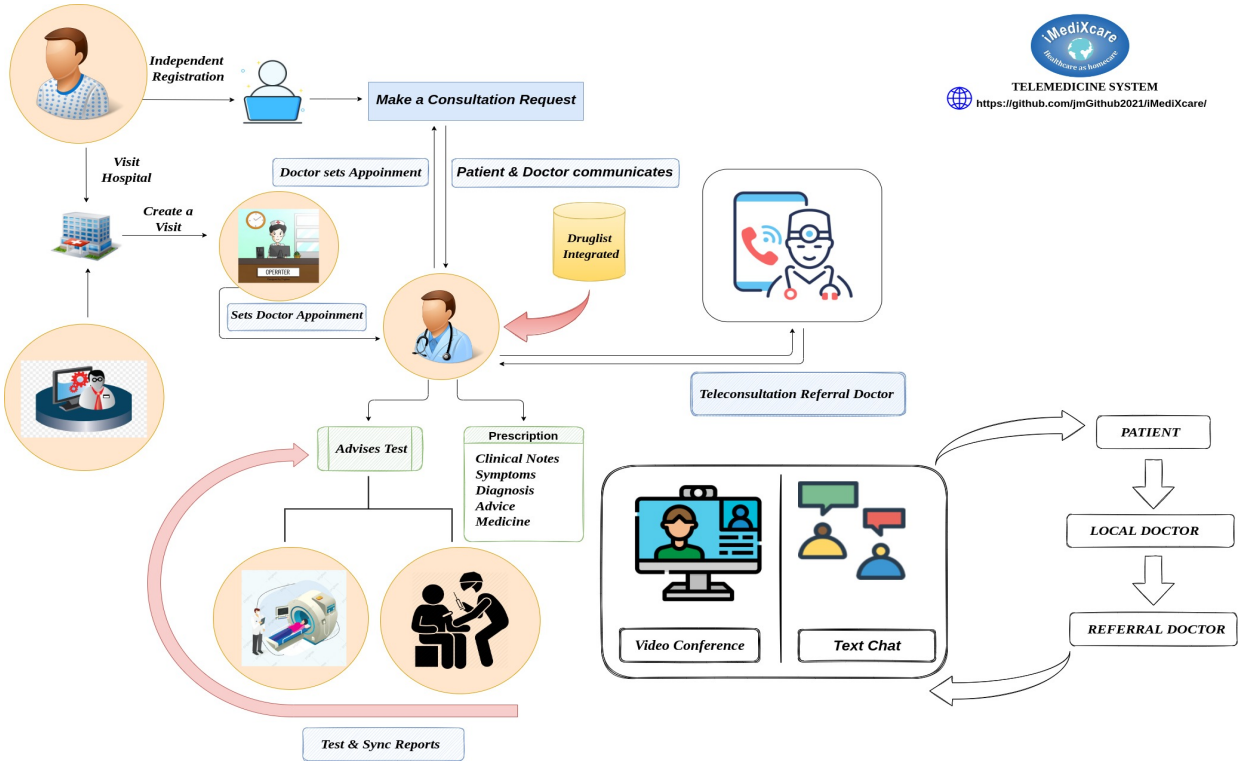

Fig. 2. Workflow of iMediXcare Teleconsultation.

- *Antenatal Care* - Through this service, the health of pregnant women is monitored periodically to ensure the health and wellbeing of both the fetus and the mother.
- *Mansik Soundarya (Mental Health Programme)* - Mental health is an integral part of health. It involves the development of mental potentialities, the avoidance of mental illnesses, therapy, and rehabilitation. In India, the age-adjusted suicide rate is 21.1 per 1,00,000 people, while the burden of mental health issues is 2443 disability-adjusted life years (DALYs) per 1,00,00 population. According to WHO projections, the economic loss resulting from mental health issues between 2012 and 2030 is anticipated to reach Rs. 8 lakh crore (or USD 1.03 trillion). One in seven Indians were affected by mental disorders of varying severity in 2017. The proportional contribution of mental disorders to the total disease burden in India has almost doubled since 1990. To address the huge burden of mental disorders and shortage of qualified professionals in the field of mental health, Vivek Sanjivani has been implementing 'Mansik Soundarya' programme (Community Mental Healthcare Programme) since December 2013.
- *General Movement Assessments (GMA) in Neonates and Infants* - Infants below nine months are considered to be at high risk of developing body movement related difficulties if there is any sign of disability. Regular follow-ups may involve a few non-invasive methods to ensure the health condition of the infant.
- *Gynecare services* - This service focuses on treating females facing gynaecological problems. Educating the beneficiaries in rural areas regarding the cause and remedial measures also falls under this service.
- *Eye care* - Cataract and refractive errors are two major public health problems in the context of ocular health in India. Vivek Sanjivani offers eye care facilities to rural beneficiaries to overcome these problems.

A. Telemedicine network and work flow

The working model of *Matri Seva*, requires primarily three types of users, namely, *doctor*, *centre administrator* and *data entry operator*. *Matri Seva* operates through eleven telemedicine units (TUs), each of them is created as a center in the multi-tenant system. Out of these eleven units, five are Stationary Telemedicine Units (STUs) and six are Mobile Telemedicine Units (MTUs). A STU operates from a fixed location from a building or a prefabricated room, whereas a MTU operates in a moving vehicle at different locations. A list of STUs and MTUs is provided in Table I.

In Matri Seva, the hub of the telemedicine activities also functions as a virtual hospital, to which all the doctors are registered. These doctors are available for remote consultation for any of the Telemedicine Units. The *healthcare workers*, with their roles either as a center administrator or a data entry operator, are equipped with laptops or computers, web cameras, microphones, printers, power back-up, and internet service at STUs and MTUs, thereby mediating the telemedicine service to residents of remote areas. The preliminary vitals,

TABLE I
LIST OF MTUS AND STUS

Mobile Telemedicine Units (MTUs)	Gaura, Manikpur, Patewar, Ramnagar (Devahin), Kanaksarai, Deepnagar
Stationary Telemedicine Units (STUs)	Majhawan, Kalwari, Naugawan, Hinauta, and Bakhpur

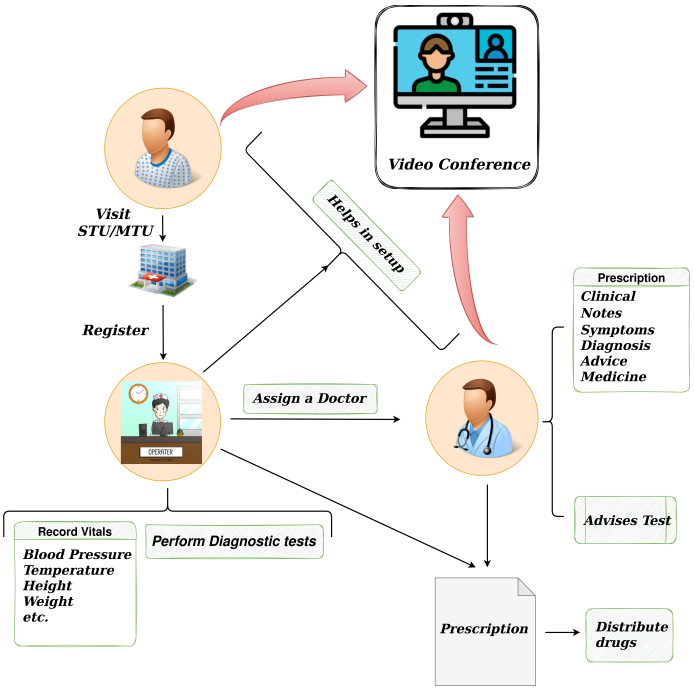

Fig. 3. Workflow of Telemedicine service in which Matri Seva is used.

such as blood pressure, height, weight, etc., are recorded by field workers. The field workers are also responsible for setting up appointments with available doctors. The workflow of *Vivek Sanjivani telemedicine service*, in which the role of *Matri Seva* is illustrated in Fig. 3.

As *a data entry operator* of a centre, a healthcare worker uploads vitals, and medical history of a patient. Then she (he) sets appointments with a doctor, and initiates audio-video consultation between the patient and the remote doctor. Teleconsultation enables doctors from across India and abroad (one doctor from the United Kingdom (UK)) to communicate directly with patients while taking advantage of network bandwidth and audio-visual interfaces. Though it is possible to perform video conferencing (VC) using the interfaces of Matri Seva, it is done using an independent VC system, $WebEx^{TM}$.

Using the system a doctor from her (his) account records observations and diagnoses, advises investigations (both pathological and radiological), and prescribes medicine to patients. The uploaded medical records, along with treatment prescriptions, are accessible to them. Once a prescription is generated by a doctor it enters into a queue for systematic disbursement of medicine to patients. The interface is provided to the role of a data entry operator.

The patients receiving telemedicine service are registered to a single nodal unit/centre where the patient reports on every follow-up. The assigned nodal unit/centre is generally the nearest MTU/STU from their residence. The doctors, however, are registered to a single center (a virtual hospital) acting as the hub of the activities, named *Vivek Sanjivani*. Once the availability of a doctor is communicated to a nodal administrator, the appointments with patients are set at that nodal center. Subsequently remote consultations take place at scheduled time slots.

The customized features added to Matri Seva are listed below:

1) Cross center assignment of a doctor to a patient: A patient may be registered to any nodal center, but she (he) may be assigned to a doctor of the center at hub. In iMediXCare, a patient is assigned only to a doctor registered to her (his) center.
2) Prescription format has been customized to include menu driven lists of various information, such as, medicines, diagnoses categorized with two levels of hierarchy, general instructions and advice, pathological and radiological tests, etc. The two levels of hierarchy of diagnosis include the *basic diagnosis* and the *detailed diagnosis*. The basic diagnosis identifies the broad category of a disease, and the detailed diagnosis more specific to a disease. For example, under *Acute Respiratory Infection (ARI)* as a basic diagnosis, a detailed diagnosis may be any of the following: *Allergic rhinitis*, *Common cold*, *Lower Respiratory Tract Infections (LRTI)*, *Pharyngitis*, *Pneumonia*, *Upper Respiratory Tract Infections (URTI)*, etc.
3) Provision of making a repeat prescription with editable interface.
4) Generation of customized reports and statistics.
5) Interfaces for performing screening of four non-communicable diseases, namely, *Hypertension*, *Diabetes Mellitus*, *Breast Cancer*, and *Oral Cancer*.
6) An interface for systematic disbursement of medicine by a health worker is provided. Using this interface, the prescriptions are logged in a queue for their turn in disbursing medicine to patients.
7) Applications are run using *Docker* containers [16], [17].

With these new features, some examples of added benefits in efficient and effective running of telemedicine, as well as, other health and education services are listed below.

1) The two level hierarchy of diagnosis is found to be very useful in coordinating the health and education programs in the department of Vivek Sanjivani. The basic diagnosis allows to enlist the patients for a specific type of disease as well as for Nutritional Food supplements programmes. The detailed diagnosis provides an ample opportunity to Disease Recovery status for individual

patient as well as a group of patients for a specific range of time. For example, the data allows to understand the severity status of a Bipolar patient. Doctors can also understand the efficacy of any medicine for a type of disease.

2) The gradual observations of medicine for a few consecutive occasions in prescriptions give an opportunity to assess recovery stage of any patient.
3) The patients who came one or a few occasions and later on discontinued are tracked from Patient-wise Diagnosis chart and followed up with phone calls to engage them in the Telemedicine programme.

TABLE II
PATIENT TURNUPS AND NEW PATIENTS

Year	Ratio of Visitwise/Distinct	New patients
2021-2022	1.58	13175
2022-2023	1.54	11347
2023-2024	1.60	11119

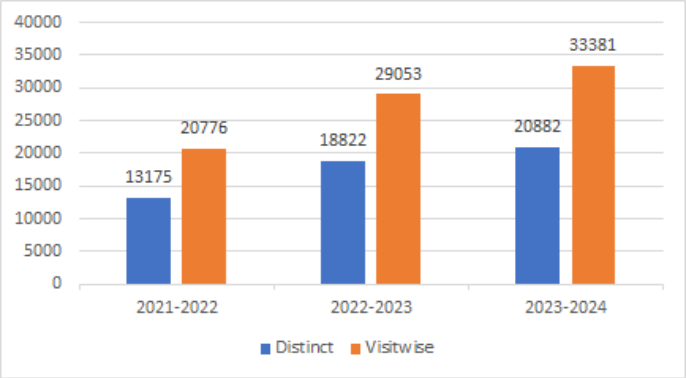

Fig. 4. Distinct vs Visitwise patients

IV. A STUDY ON PATIENTS' DEMOGRAPHY AND PREVALENT DISEASES IN RURAL EASTERN UTTAR PRADESH AND UTTARAKHAND

Matri Seva has been functioning steadily for more than three years starting from 1^{st} May, 2021. The system has been installed in MS AZURE^{TM} cloud sever with 16 GB RAM and 2 TB storage space. The number of patients has shown consistent increase during this period of three years (Fig. 4). In order to monitor the quality and improvement in treatment, patient-wise, diagnosis-wise and visit-wise, studies are conducted. Each patient receives a follow-up date towards the end of a telemedicine session and is expected to appear for another check up. The field workers take proactive measures to bring patients in the follow-up sessions. In Fig. 4, the term *Visitwise* refers to the number of patients, who made multiple visits to the nodal units, and the term *Distinct* signifies the number of distinct patients who visited a unit. The number of new patients in a year is listed in Table II. The ratio of Visitwise/Distinct, as shown in table II, show the average number of visits per patient in a year, which remains almost the same (within 1.54 and 1.60) throughout this period. The number of new patients in a year also does not vary much. It broadly indicates that the steady and stable nature of the activities run by the program.

The telemedicine service has enabled doctors practising in the cities to communicate directly with patients residing in rural parts of India. The patient's demographics hailing from these rural parts are summarized in Table III. This data may also be considered as a potential representative of distribution of castes among the low income group of population in those rural districts. There may be bias among the genders, as the number of female patients (in both categories of child and adult) constitutes about 54% of the total patients. It may show that there is a gender bias in lack of health and hygiene facilities for women in our rural society.

In Table IV, numbers of patients treated for some of the frequently reported diseases are shown. We may note that the disease distribution among patients in rural areas may differ from that in urban areas. In this Table a few diseases with high average number of incidences (> 500) per year are highlighted in bold font. They include *Diabetes Mellitus*, *Hyperacidity*, *Hypertension*, *Polyarthritis*, and *Tinea*.

To assess how the telemedicine services are playing effective roles in treating patients suffering from chronic diseases, we define a measure, called *follow-up ratio*. The *follow-up ratio* ($flur(X;T)$) of a disease X for a given period T is defined the ratio of the number of visits and the number of distinct patients suffering from the disease X during that period, as expressed in the following Eq. 1.

$$flur(X;T) = \frac{\text{number of visits during T}}{\text{number of distinct patients during T}} \quad (1)$$

In Table V, we show the annual follow-up ratios of the frequently occurring diseases as listed in Table IV. From this list, the diseases with high average annual follow-up ratios (> 5.0, implying on the average a patient visits a TU every two months) are highlighted. The list includes *Chronic Obstructive Pulmonary*, *Common Mental Disorders*, *Diabetes Mellitus*, *Epilepsy*, *Hypertension*, and *Severe mental disorder*. The annual follow-up ratio of a disease roughly indicates the degree of adherence of treatment protocol by the patients for a healthcare service for a disease. It also provides a measure of how well the patients are responding to the services by making follow-up visits as needed in the treatment of a disease. In Table V, we observe that within these three years of study, follow-up ratios in most of the diseases have improved. For some diseases, the improvement is quite significant. For example, in diseases such as *Common Mental Disorders*, *Epilepsy*, *Chronic Obstructive Pulmonary*, and *Diabetes Mellitus* the improvements are by 38.08%, 36.73%, 27.63%, 20.02%, respectively. It indicates that the telemedicine services are getting increasing acceptance from the beneficiaries.

TABLE III
PATIENT DEMOGRAPHICS

	2021-2022	**2022-2023**	**2023-2024**
Age (in years) (mean ± sd)	45.20 ± 19.34	45.46 ± 18.74	46.12 ± 18.74
Adult (%)	M - 40.54 F - 48.33	M - 41.46 F - 49.42	M - 41.33 F - 49.62
Child (%)	M - 5.78 F - 5.36	M - 4.35 F - 4.77	M - 4.31 F - 4.74
Caste (%) (General- G, OBC- O, SC, ST, Muslim and other religious groups- U)	G- 11.11 O- 41.15 SC- 38.13 ST- 5.67 U- 3.93	G- 10.03 O- 41.40 SC- 41.11 ST- 5.50 U- 1.96	G- 10.13 O- 43.34 SC- 40.44 ST- 4.94 U- 1.15

TABLE IV
FREQUENTLY REPORTED DISEASES

Disease	**2021-2022**	**2022-2023**	**2023-2024**	**Average**
Anemia	340	294	552	≈395
Acute Respiratory Infection	387	306	542	≈412
Chronic Obstructive Pulmonary	128	132	152	≈137
Common Mental Disorders	199	188	87	158
Constipation	195	294	288	259
Diabetes Mellitus	457	593	654	568
Epilepsy	160	173	219	184
Hyperacidity	609	817	527	651
Hypertension	471	593	752	≈605
Itching	258	307	499	≈355
Osteoarthritis	246	240	370	≈285
Polyarthritis	652	586	426	≈555
Severe mental disorder	174	234	168	192
Tinea	841	1075	769	895

TABLE V
FOLLOW-UP RATIOS OF DISEASES

Disease	**2021-2022**	**2022-2023**	**2023-2024**	**Average**
Anemia	3.29	3.07	2.95	3.08
Acute Respiratory Infection	2.18	4.54	3.04	3.14
Chronic Obstructive Pulmonary	5.79	6.09	7.39	6.49
Common Mental Disorders	5.12	5.30	7.07	5.55
Constipation	3.28	4.48	4.70	4.26
Diabetes Mellitus	7.79	8.5	9.35	8.64
Epilepsy	10.97	13.40	15.00	13.33
Hyperacidity	3.80	3.59	4.54	3.91
Hypertension	6.48	6.66	7.18	6.83
Itching	2.17	2.04	2.66	2.36
Osteoarthritis	3.80	3.84	4.28	4.02
Polyarthritis	3.82	4.15	4.92	4.22
Severe mental disorder	10.36	11.26	9.93	10.60
Tinea	2.62	3.19	4.30	3.33

V. CONCLUSION

The acceptance of telemedicine in modern society has made it convenient for quality healthcare to become accessible from rural and remote parts of the nation. *Matri Seva* demonstrates how telemedicine becomes effective in providing much needed healthcare services in rural India. Apart from its benefit of providing day to day healthcare services, the medical and nonmedical data accumulated through these services for a longer period will become a valuable resource for researchers working in the domain of healthcare.

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