Original Article

Big data and the eyeSmart electronic medical record system - An 8-year experience from a three-tier eye care network in India

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Purpose: To assess the demographic details and distribution of ocular disorders in patients presenting to a three-tier eye care network in India using electronic medical record (EMR) systems across an 8-year period using big data analytics. **Methods:** An 8-year retrospective review of all the patients who presented across the three-tier eye care network of L.V. Prasad Eye Institute was performed from August 2010 to August 2018. Data were retrieved using an in-house eyeSmart EMR system. The demographic details and clinical presentation and ocular disease profile of all the patients were analyzed in detail. **Results:** In an 8-year period, a total of 2,270,584 patients were captured on the EMR system with 4,730,221 consultations. More than half of the patients presented at tertiary centers (n = 1,174,643, 51.73%), a quarter at the secondary centers (n = 564,251, 24.85%) followed by the vision centers (n = 531,690, 23.42%). The ratio of males and females was 1.18:1. Most common states of presentation were Andhra Pradesh (n = 1,103,733, 48.61%) and Telangana (n = 661,969, 29.15%). In total, 3,721,051 ocular diagnosis instances were documented in the patients. Most common ocular disorders were related to cornea and anterior segment (n = 1,347,754, 36.22%) followed by refractive error (n = 1,133,078, 30.45%). **Conclusion:** This study depicts the demographic details and distribution of various ocular disorders in a very large cohort of patients. There is a need to adopt digitization in geographies that cater to large populations to enable insightful research. The implementation of EMR systems enables structured data for research purposes and the development of real-time analytics for the same.

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The earliest mention of a medical record dates back to 1600 BC of an Egyptian case report from a papyrus text on surgery.[1] Case records of Hippocrates from the 5th BC were instrumental in describing the natural causes and the clinical course of illness.[2] The progress of science and understanding of the human body through the centuries further reinforced the need to document new knowledge to be passed down from generation to generation. A precursor to modern medical records first appeared by early 19th century in the form of loose paper files in major centers, such as Berlin and Paris.[3] The medical record continued to evolve over the 19th century to include patient history, clinical examination, treatment instructions, and investigations. A major innovation in 1907 was the introduction of the medical record number to patients at St Mary's Hospital and the Mayo Clinic.[4] Electronic medical record (EMR) systems are increasingly replacing paper-based records with benefits in increasing efficiency and standardizing quality while reducing costs of health care.[5] Today with the rapid adoption of different technologies impacting people's lives, there is an exciting potential for clinical research to embrace the same. However, the use of digital systems differs between the western and eastern hemispheres of the world. There is a lack of adequate data from the eastern part of the world detailing the use of EMR systems to describe the distribution of ocular disorders and its effect on population health. Research done by reviewing paper records is not only cumbersome but also prone to human errors. The amount of time taken to retrieve and analyze the large volumes of data from the EMR is minimal. The EMR system can collect large datasets ("big data") that are characterized by the four 'V's - volume, variety, velocity, and veracity.[6] Given the challenges of connectivity, power and volume, digitization of hospitals in India is limited and evolving. The aim of this study was to evaluate the demographic details and distribution of ocular disorders from an indigenously developed EMR system (eyeSmart™) of a large three-tier eye care network in India and to describe the possibility of real-time analytics from the structured datasets.

Methods

An 8-year retrospective review of all the patients who presented across the three-tier eye care network of L.V. Prasad Eye Institute (LVPEI) was performed from August 2010 to August 2018. The patient data were retrieved using the information captured through the in-house EMR system eyeSmart™. The study was approved by LVPEI's Institutional Review Board on

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11.9.2018 with reference number of LEC 09-18-150 and adhered to the tenets of Declaration of Helsinki. A standard consent form for electronic data privacy was filled by the patient or their parents or guardians at the time of registration.

The three-tier eye care model of LVPEI includes 176 Vision Centers that provide primary care in the districts and villages of Andhra Pradesh, Telangana, Odisha, and Karnataka. These are linked to 18 Secondary Eye Care Centers, which are, in turn, linked to LVPEI Tertiary Centers in Visakhapatnam, Vijayawada, and Bhubaneswar. LVPEI's Center of Excellence at Hyderabad is at the apex of the Eye Care Pyramid. The medical records of all patients who presented to any of these Centers during August 2010 to August 2018 were reviewed retrospectively using the eyeSmart EMR database.

In total, 2,270,584 patients were captured on the EMR system and their total consultations were 4,730,221 in this 8-year period. All the patients who were registered onto the EMR system were included in the study. The variables in the collected data include age, gender, geographical location, laterality of eye affected, and ocular diagnosis. The geographical location and country as reported by the patients at the time of registration were documented in the EMR system and were included in the study.

Each eye of the patients was diagnosed separately, and each individual diagnosis was considered cumulatively for the analysis. The LVPEI coding diagnosis developed in-house was used for the patients, which includes a comprehensive list of ocular disorders, and the ICD-11 coding was automatically mapped to the relevant diagnosis. The ocular diagnosis made were categorized into different ocular disorders, such as amblyopia, cataract, cornea, and anterior segment disorders, glaucoma, neuro-ophthalmology, ocular trauma, refractive error, retina, uvea, and strabismus.

The age, gender distribution, demographic details, and proportion of ocular disorders were calculated through an SQL query written to extract information from all the databases of the centers across the network during the 8-year period. The individual numbers and percentages of the parameters to be studied were calculated through the query and exported to an excel sheet for further analysis. A detailed representation of the process is provided in the supplementary material. No identifiable information of the patient was used for analytical purposes. The de-identified information was replicated into another database from where analytics were visualized using tools for the same in real time. "eyeSmart EMR" is an indigenously built EMR system at the LVPEI, India. This system was developed in-house by using open source tools such as PHP (Zend Technologies, Cupertino, CA, USA) for programming and MySQL (Oracle Corporation, Redwood City, CA, USA) for database management. The eyeSmart App was developed on the Android platform (Google LLC, Menlo Park, CA, USA). The system allows the documentation of clinical information of patients significantly in a structured format that allows analysis for research purposes, and unstructured information is also captured. The information from the database was analyzed to provide a real-time overview. All tables for age, gender, location, and diagnosis category were drawn by using Microsoft Excel.

Results

In total, 2,270,584 patients were captured on the EMR system and their total consultations were 4,730,221 in the 8-year period.

Age

The age of the patients ranged from 0 to > 100 years. Based on the age category, pediatric population (≤16 years) presented were *N* = 304,100 (13.39%) and the adult population (>16 years) were *N* = 1,966,484 (86.61%). The most common age group of the patients who presented were between 51 and 60 years (*n* = 372,571, 16.41%) and followed by 41 and 50 years (*n* = 364,298, 16.04%). The detailed distribution of the age category is shown in Table 1.

Gender

The ratio of males (*n* = 1,228,538, 54.11%) and females (*n* = 1,042,046, 45.89%) presenting to the network was 1.18:1. Table 2 details the distribution of patients as per gender on EMR across various levels of the LVPEI eye care network.

Patient distribution according to level of care

More than half of the patients presented at tertiary centers (*n* = 1,174,643, 51.73%), a quarter at the secondary centers (*n* = 564,251, 24.85%) followed by the vision centers (*n* = 531,690, 23.42%).

Table 1: Age distribution of the patients based on level of care

Age Category (Year)	Tertiary Center	%	Secondary Center	%	Vision Center	%	Total Count	%
0-10	104,800	71.1	25,773	17.5	16,773	11.4	147,346	6.5
11-20	132,181	49	50,909	18.9	86,404	32.1	269,493	11.9
21-30	183,125	54.6	56,551	16.9	95,738	28.5	335,415	14.8
31-40	145,123	47.8	64,835	21.4	93,280	30.8	303,238	13.4
41-50	185,768	51	87,391	24	91,139	25	364,298	16.0
51-60	192,350	51.6	103,233	27.7	76,988	20.7	372,571	16.4
61-70	162,235	47	126,540	36.6	56,472	16.4	345,248	15.2
71-80	58,235	51.6	41,662	37	12,907	11.4	112,803	5.0
81-90	10,138	53.9	6,875	36.6	1,783	9.5	18,796	0.8
91-100	661	52.6	456	36.3	141	11.1	1,257	0.1
>100	27	22.7	26	22.7	65	54.6	119	0.0
Grand total	1,174,643	51.7	564,251	24.9	531,690	23.4	2,270,584	100.0

Ocular diagnosis

In total, 3,721,051 ocular diagnosis instances were documented in the patients. The two most common ocular disorders were from the following categories of cornea and anterior segment (n = 1,347,754, 36.22%) followed by refractive error (n = 1,133,078, 30.45%), respectively. Table 3 details the ocular disorder distribution captured through EMR. A significant proportion of diagnosis was made in both eyes (n = 1,985,373, 53.36%) followed by right eye (n = 810,132, 21.77%) and left eye (n = 784,725, 21.09%).

Geographical distribution

Patients presented from 109 countries to the LVPEI eye care network in the 8-year period. The highest number of patients presented from India (n = 2,264,230, 99.72%) followed by Bangladesh (n = 1608, 0.07%) and Oman (n = 1189, 0.05%). Table 4 provides details of geographical distribution of patients from around the world.

The patients presented from 33 different states of India and the most common states of presentation were

Table 2: Gender distribution of the patients based on level of care

Gender	Tertiary Center	%	Secondary Center	%	Vision Center	%	Total Count	%
Male	666,803	54.3	272,817	22.2	288,918	23.5	1,228,538	54.1
Female	507,840	48.7	291,434	28	242,772	23.3	1,042,046	45.9
Grand total	1,174,643	51.7	564,251	24.9	531,690	23.4	2,270,584	100.0

Table 3: Distribution of ocular disorders based on level of care

Ocular Diagnosis	Tertiary Center	%	Secondary Center	%	Vision Center	%	Total Count	%
Cornea and anterior segment	612,301	45.4	467,398	34.7	268,055	19.9	1,347,754	36.2
Refractive error	609,569	53.8	242,355	21.4	281,154	24.8	1,133,078	30.5
Cataract	261,219	44.7	253,500	43.4	69,104	11.8	583,823	15.7
Retina	204,025	88	26,719	11.5	1,197	0.5	231,941	6.2
Glaucoma	130,663	85.6	20,213	13.2	1,821	1.2	152,697	4.1
Oculoplasty	74,541	78.3	18,139	19	2,562	2.7	95,242	2.6
Neuro ophthalmology	41,859	85.8	6,493	13.3	445	0.9	48,797	1.3
Ocular trauma	28,296	64	10,626	24	5,312	12	44,234	1.2
Strabismus	35,195	85.5	4,119	10	1,836	4.5	41,150	1.1
Amblyopia	22,795	83	4,113	15	540	2	27,448	0.7
Uvea	11,388	84.9	1,966	14.6	67	0.5	13,421	0.4
Paediatric ophthalmology	1,345	91.8	121	8.2	0	0	1,466	<1
Grand total	2,033,196	54.6	1,055,762	28.4	632,093	17	3,721,051	100

Table 4: Distribution of the gender and age categories based on the geographical location (country)

Country	Total patients	%	Male	%	Female	%	<16 Years	%	>16 Years	%
India	2,264,230	99.7	1,224,550	54.1	1,039,681	45.9	303,258	13.4	1,960,972	86.6
Bangladesh	1,608	0.1	1,066	66.3	542	33.7	325	20.2	1,283	79.8
Oman	1,189	0.1	736	61.9	453	38.1	112	9.4	1,077	90.6
Somalia	1,127	<1	605	53.7	522	46.3	79	7	1,048	93
Yemen	578	<1	416	72	162	28	77	13.3	501	86.7
Sudan	240	<1	151	62.9	89	37.1	29	12.1	211	87.9
United Arab Emirates	198	<1	116	58.6	82	41.4	36	18.2	162	81.8
Kenya	186	<1	105	56.5	81	43.5	22	11.8	164	88.2
Nepal	117	<1	78	66.7	39	33.3	17	14.5	100	85.5
United States of America	118	<1	65	55.1	53	44.9	18	15.3	100	84.7
Ethiopia	114	<1	65	57	49	43.0	8	7	106	93
Afghanistan	79	<1	72	91.1	7	8.9	9	11.4	70	88.6
Nigeria	71	<1	41	57.7	30	42.3	16	22.5	55	77.5
Tanzania	57	<1	32	56.1	25	43.9	4	7	53	93
Liberia	12	<1	11	91.7	1	8.3	2	16.7	10	83.3
Others	660	<1	429	65	231	35	88	13.3	572	86.7
Grand total	2,270,584	100	1,228,538	54.1	1,042,046	45.9	304,100	13.4	1,966,484	86.6

Others indicates the cumulative count of the rest of the countries

Andhra Pradesh (n = 1,103,733, 48.61%) followed by Telangana (n = 661,969, 29.15%). The least number of patients presented from the union territory of Daman and Diu (n = 3; 0.00%). Table 5 provides details of the geographical distribution of patients from India.

Further a real-time dash-board of the demographic details and ocular disorders of patient presenting to the LVPEI network from August 2010 on the EMR system was developed using the data and can now be accessed at the following link – http://www.lvpei.org/aeye/eyesmart.html.

Discussion

This study has demonstrated the demographic and ocular disorders' distribution in a large cohort of patients presenting to a three-tier eye care network in India. Gender predisposition was not noted in the presentation of patients with an equitable distribution accessing eye care services. A significant proportion of ocular disorders were in both eyes and there was no predisposition to laterality in either of them. It is of utmost importance to digitize clinical information to uniformly capture the data and assess the burden of ocular disease. In our study, we found that the cornea and anterior segment disorders and refractive error constituted about two-thirds of the ocular disorders seen in the network. The scope of this study was to provide an overview of the ocular disorders and other similar studies from the eyeSmart EMR system have reported them in detail as in dacryology and dry eye.[7,8]

Ophthalmology is particularly conducive for data science in medicine due to structured quantifiable outcome measures that are significantly numeric and image based. This information allows us to perform big data analytics that have now evolved from the hundreds and thousands to millions and billions of

Table 5: Distribution of gender and age categories based on the geographical locations of India

State	Total patients	%	Male	%	Female	%	<16 Years	%	>16 Years	%
Andhra Pradesh	1,103,733	48.6	578,383	52.4	525,351	47.6	130,291	11.8	97,3442	88.2
Telangana	661,969	29.2	349,431	52.8	312,538	47.2	97,593	14.7	56,4376	85.3
Odisha	286,501	12.6	171,002	59.7	115,500	40.3	46,292	16.2	240,209	83.8
Maharashtra	40,032	1.8	24,782	61.9	15,250	38.1	6,683	16.7	33,349	83.3
Karnataka	37,992	1.7	20,291	53.4	17,701	46.6	4,176	11	33,816	89
West Bengal	47,017	2.1	29,929	63.7	17,088	36.3	5,586	11.9	41,431	88.1
Not Applicable*	22,524	1	13,205	58.6	9,318	41.4	3,599	16	18,925	84
Orissa	33,530	1.5	17,212	51.3	16,318	48.7	4,521	13.5	29,009	86.5
Jharkand	5,290	0.2	3,407	64.4	1,883	35.6	715	13.5	4,575	86.5
Chhattisgarh	5,369	0.2	3,339	62.2	2,030	37.8	817	15.2	4,552	84.8
Madhya Pradesh	4,612	0.2	3,126	67.8	1,486	32.2	752	16.3	3,860	83.7
Uttar Pradesh	4,052	0.2	2,736	67.5	1,316	32.5	623	15.4	3,429	84.6
Bihar	3,933	0.2	2,653	67.5	1,280	32.5	528	13.4	3,405	86.6
Assam	4,753	0.2	3,072	64.6	1,681	35.4	535	11.3	4,218	88.7
Rajasthan	1,804	0.1	1,240	68.7	564	31.3	305	16.9	1,499	83.1
Tripura	2,128	0.1	1,375	64.6	753	35.4	220	10.3	1,908	89.7
Gujarat	1,152	0.1	757	65.7	395	34.3	244	21.2	908	78.8
Delhi	854	<1	526	61.6	328	38.4	109	12.8	745	87.2
Kerala	531	<1	340	64.0	191	36.0	98	18.5	433	81.5
Tamil Nadu	671	<1	424	63.2	247	36.8	70	10.4	601	89.6
Jammu and Kashmir	367	<1	261	71.1	106	28.9	78	21.3	289	78.7
Haryana	485	<1	298	61.4	187	38.6	97	20.0	388	80.0
Punjab	266	<1	166	62.4	100	37.6	42	15.8	224	84.2
Goa	164	<1	96	58.5	68	41.5	31	18.9	133	81.1
Uttarakhand	208	<1	139	66.8	69	33.2	21	10.1	187	89.9
Meghalaya	127	<1	70	55.1	57	44.9	13	10.2	114	89.8
Manipur	105	<1	57	54.3	48	45.7	7	6.7	98	93.3
Himachal Pradesh	95	<1	56	58.9	39	41.1	11	11.6	84	88.4
Arunachal Pradesh	96	<1	43	44.8	53	55.2	13	13.5	83	86.5
Pondicherry	70	<1	48	68.6	22	31.4	12	17.1	58	82.9
Sikkim	70	<1	36	51.4	34	48.6	8	11.4	62	88.6
Nagaland	47	<1	23	48.9	24	51.1	6	12.8	41	87.2
Mizoram	34	<1	13	38.2	21	61.8	3	8.8	31	91.2
Daman & Diu	3	<1	2	66.7	1	33.3	1	33.3	2	66.7
Grand total	2,270,584	100	1,228,538	54.1	1,042,046	45.9	304,100	13.4	1,966,484	86.6

*Not Applicable is for patients who do not have a State classification

data points. eyeSmart™ EMR is an indigenously developed EMR system at the LVPEI. The project that began in August 2010 has now completed the digitization of the 198 centers of the LVPEI network, which comprises of 1 Center of Excellence, 3 Tertiary Centers, 18 Secondary Centers, and 176 Vision Centers across the states of Telangana, Andhra Pradesh, Odisha, and Karnataka. It has facilitated about 4.7 million consultations since its inception. The system allows the documentation of clinical information in structured forms and images, which are stored in the database of the respective centers. All information from various centers is synced to a central database that allows the real-time analysis of the entire network.

The process of digitization poses different challenges in any large organization. Scholl *et al.* described the experience of the implementation of EMR in a large hospital in India.[9] The successful adoption of digital systems in complex organizations requires an alignment between the working protocols and needs of the organization and the functionality of the system. The various reasons that effect successful implementation include dynamic design strategies, user-friendly work flows, and demonstration of benefit for easy reporting of statistics. In our experience, demonstration of successful pilots at each level of the LVPEI pyramid was the most crucial step before expansion of eyeSmart™ in 198 centers across different geographies. Replication of the system across each level of Tertiary, Secondary, and Vision Center level was then achieved in a phase wise manner. Sharing of best practice patterns of utilization of EMR by different groups across the network provided the motivation to adopt the system. Time is a crucial component in the implementation strategy and the 176 rural vision centers were digitized in 90 days. Rapid implementation also provides rapid feedback that can be utilized positively to refine the application for the users.

The use of EMRs in population health management holds promise. Cavallo *P et al.* conducted a retrospective study of 14,958 patients and 1,728,736 prescriptions obtained from family doctors to understand the associations of comorbidities in the general population.[10] The network analysis extracted information from the prescriptions generating insights impacting both clinical practice and health system policy making. The various applications of EMR assisting population health management include quantifying treatment outcomes,[11] quantify and stratify the severity of disease,[12,13] collect patient-reported outcomes,[14] document lifestyle patterns,[15] and potential to guide medicines regulation.[16] The use of large datasets helps to understand factors influencing health such as geographical location, nutrition, lifestyle, and their temporal evolution. The application of artificial intelligence in public health is also increasing.[17]

The population of India is 1.3 billion people. Access to health care is a challenge and nonavailability of information at scale in real time across geographies can limit policy planning. Big data analytics are a key to understanding distribution of ocular diseases in India. The ability to understand the burden of disease is very crucial to plan strategies to combat avoidable blindness. A real-time dash-board of the demographic details and ocular disorders of patients presenting to the LVPEI network from August 2010 on the EMR system can be accessed at the following link – http://www.lvpei.org/aeye/eyesmart.html.

The limitations of this study include the lack of population data, patient referral bias to a tertiary care in emerging economies, and reflection solely based of the distribution of ocular disorders and not their management. Patient duplication was also assessed as a limitation in the respective tertiary centers and was found to be negligible (0.28%) across the network. However, the strengths of the study include a very large cohort of patients and focused study of demographics and distribution of ocular disorders in patients seeking eye care in a large three-tier hospital network in India across 8 years.

Conclusion

To the best of our knowledge, this is the first description of a large cohort of patients using EMRs in a large multi-tier ophthalmology network in India. In conclusion, this study lists out the detailed demographic distribution and distribution of ocular disorders in patient seeking eye care and demonstrates the potential for real-time analytics using EMR systems.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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