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FACTORS ASSOCIATED WITH THE ADOPTION AND USE OF OPEN SOURCE ELECTRONIC HEALTH RECORDS IN THE UNITED STATES

By

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ABSTRACT

The aim of this study is to examine the prevalence and usage of Open Source Software (OSS), and it is adoption by healthcare providers in the United States, along with the factors influencing or inhibiting this adoption process. Moreover, exploring characteristics of healthcare provider systems that associated with the adoption of HIT, with a focus on open source EHR. The study research questions includes:

- What types of OSS products that healthcare providers use?
- What is the extent of OSS adoption in healthcare providers?
- What factors promoting or inhibiting the adoption of OSS products in healthcare providers?
- What is the adoption trend of OSS in the past years?
- Do OSS applications benefit from the government incentives programs such as Meaningful Use Incentives?
- How are the prevalence and the adoption rate of OSS applications compared to proprietary systems in the available datasets?

A secondary data analyzes were used to investigate these issues, also to examine and characterize the types of OSS products adopted by healthcare providers.

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CHAPTER 1 INTRODUCTION

1.1 Background

1.1.1 Electronic Health Records Overview

In this era of the developing technology such as smartphones, tablets, and web-enabled devices have changed our lives and the way we communicate. Healthcare is no exception of this progress; in which, integrated health care is transforming our routine and the healthcare infrastructure. Under those perspectives, our health, and medical records are being kept, accessed, changed and updated digitally, using mentioned technologies such as computers, tablets or other devices, and they called (Electronic Health Records) or EMRs (Electronic Medical Records). We will see the specific definition of each terminology. However, both terms can be used interchangeably; however, in this study, we will be using the term 'Electronic Health Record' (EHR) despite their different definitions.

1.1.2 Definitions

According to the Health Insurance Portability and Accountability Act (HIPAA)- which provides national standards to protect the privacy of personal health information- the "Health Information" is:

> "Any information, whether oral or recorded in any form or medium, that— (A) is created or received by a health care provider, health plan, public health authority, employer, life insurer, school or university, or health care clearinghouse; and (B) relates to the past, present, or future physical or mental health or condition of an

individual, the provision of health care to an individual, or the past, present, or future payment for the provision of health care to an individual." [1]

There are different terminologies and definitions of systems that deal with *health information.* According to the Health Information Management Systems Society's (HIMSS) definition of EHR is:

"The Electronic Health Record (EHR) is a longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting. Included in this information are patient demographics, progress notes, problems, medications, vital signs, past medical history, immunizations, laboratory data, and radiology reports. The EHR automates and streamlines the clinician's workflow. The EHR has the ability to generate a complete record of a clinical patient encounter, as well as supporting other care-related activities directly or indirectly via interface—including evidence-based decision support, quality management, and outcomes reporting." [2]

The International Organization for Standardization (ISO) defines EHR as a "repository of patient data in digital form, stored and exchanged securely, and accessible by multiple authorized users. It contains retrospective, concurrent, and prospective information and its primary purpose is to support continuing, efficient and quality integrated health care." [3]

There are several acronyms of EHR in the literature; the National Alliance for Health Information Technology (NAHIT) differentiates between those terms, electronic medical record (EMR), electronic health record (EHR), and personal health record (PHR).

"Electronic Medical Record (EMR): An electronic record of health-related information on an individual that can be created, gathered, managed, and consulted by authorized clinicians and staff within one health care organization.

Electronic Health Record (EHR): An electronic record of health-related information on an individual that conforms to nationally recognized interoperability standards and that can be created, managed, and consulted by authorized clinicians and staff across more than one health care organization.

Personal Health Record (PHR): An electronic record of health-related information on an individual that conforms to nationally recognized interoperability standards and that can be drawn from multiple sources while being managed, shared, and controlled by the individual." [4]

1.1.3 EHR History

The beginning of computer-based HIS emerged in the late 1960s.[6-9] Their primary use was for communication between various parts of the hospital. Despite containing some clinical information such as test results and drug orders, their major purpose was to identify all chargeable services rather than to assist with clinical care. It was difficult to analyze the collected information since they were stored as text in many of the early HISs. Beside that, those information were not retained for an extended time after the patient's discharge.[6]

The HIS projects encountered several technical difficulties. These include, non-standard vocabularies and system interfaces, which is, still an issue faced nowadays. Moreover, the technology at that time was underdeveloped to be of any use in the healthcare. The motivation to adopt new inventions, as computer-based order entry, was

not high due to the incompatibility of that era's clinical reference systems to match data and care processes to patient outcomes other than death or very serious injury. It is not only that the healthcare industry is known to be slow in following new technologies, but also organizations were not eager to invest in such system without granting an income. Physicians, on the other hand, trusted their knowledge and experience more then the HIS.[7]

In spite of that, EHR began to appear in the 1960s, Summerfield and Empey reported, "at least 73 hospitals and clinical information projects and 28 projects for storage and retrieval of medical documents and other clinically relevant information were underway."[5] Most of those systems were created as projects in the early 70's. They used the pioneering techniques in workflow, display, and user interface in which they are considered as standard today. Moreover, many of the strategies that were visualized at the beginning of the EHR systems are still in focus today. These include encounter note documentation, coded information and more active decision support.[8]

The concern of the initial work in medical informatics was about the clinical computing aiming to improve clinical decisions process to limit medical errors.[7] The idea was to provide faster access to related medical information along with decision support functionality such as reminders and alerts. Nowadays, the same idea is being proposed. While taking the advantage of the development in technology, it will be much easier to offer timely medical information that is accurate.[7,8]

Some of the notable projects include:

- (HELP): the Health Evaluation through Logical Processing system is one of the first EHR which had CDS sure of which was developed by the University of Utah together with 3M corporation.
- (TDS): Technicon Data Systems, Developed by Lockheed. Some of its main characteristics include the processing speed and flexibility allowing multiple simultaneous accesses to the system. It considered a groundbreaking computerized provider order entry (CPOE) system.[8,9]
- (TMR): The Medical Record, developed at Duke University Medical Center in Durham. A comprehensive medical information system, which was a major step forward in the history of EHR. It was one of the first widely used systems that utilized hierarchical data structure with variable-length text. It also incorporated an advanced data dictionary that included an extensive medical vocabulary, algorithms, decision-making rules and user passwords.[10]
- (COSTAR): the Computer Stored Ambulatory Record was developed in 1968 by Harvard and Massachusetts, which was utilized globally after it was used in the public domain in 1975.[8,9]
- (DHCP) and (CHCS): the Decentralized Hospital Computer Program is an EHR system that was utilized by the federal government with the Department of Veteran Affairs.[8,9]

The composite health care system was also started by the federal government to serve as the Department of Defense's (DOD) clinical patient record system used globally.[8,9]

As medical experts realized the possibilities of EHR technology to enhance the health care, more efforts were made in the 1980's to use EHR's more often. The Institute of Medicine (IOM), the health advisory arm of the National Academy of Science published a study on the potential of EHR to improve patient clinical care. "The Computer-Based Patient Record" was published in 1991 and a revised version in 1997, was the first to bring the attention to the broad implementation of EHR to offer timely and accurate health data, in addition to improving the quality of care with less expenses.[8,9]

To overcome the standardization issues surrounding the use of EHR, EHR standard-developing organization named Health Level Seven International (HL7) was developed in 1987. HL7 realized that different components of EHR, made by multiple manufacturers, must be standardized specifications and language to facilitate communication especially throughout various institutions' EHR systems. The HL7 develops standards by members from more than 55 countries. These standards are utilized in the exchange, integration, sharing and retrieval of health information from one application to another. [8]

Greater Than One (GTO) LABS have provided a great summary of EHR History Timeline[8], Table 1.

Mid-1960s	● University of Utah and 3M developed HELP ● Lockheed developed EHR
1968	● Harvard and Massachusetts General Hospital developed COSTAR
1970s	● DHCP implemented by Department of Veteran Affairs ● CHCS implemented in DoD
1975	● COSTAR launched in public domain
Mid-1980s	● IOM initiated EHR study
1987	● Standards-developing organization HL7 formed
1991	● IOM study on EHR first published
1997	● Revised IOM paper on EHR published
2004	● EHR certifying organization CCHIT founded ● President George W. Bush State of the Union address ● ONC created
2006	● CCHIT began certifying EHR
2009	● HITECH Act passed under President Obama
2011	● First year of federal incentive payments for providers demonstrating meaningful use of EHR

Table 1. History of EHR: Timeline [8]

1.1.4 Advantages of Electronic Health Records

EHR have several possible advantages, however there are many debates argued on the level of benefits gained from implementing these systems. Some of the advantages are directed toward the healthcare provider, and some others directed to the patients in such providing them with better quality and safer care. Some of the benefits include:

- Accurate, current, and comprehensive information about patients at the point of care, which can improve the quality of care since more and better information about the patient will lead to better care.[11] Also, tracking patients' markers of disease control over time.[19]
- Fast access to patient records for more coordinated efficient care, especially in emergency cases where patient's medical history, allergies, and medications are needed to be analyzed and to make the correct decisions. Moreover, this will reduce the waiting time for patients.[11]
- Efficient diagnosis by reducing medical errors and reliable prescribing. Also, Identify drug interactions and verify medications and dosages, which can minimize the need for risky tests and procedures.[11]
- Improving privacy and security of patient data and sharing it in an efficient manner with patients and other providers and entities such as pharmacy and laboratory.[11]
- Reduce healthcare costs through decreased paperwork, improved safety, reduced redundant of testing, and improved health.[11]

1.1.5 Disadvantages of Electronic Health Records – Barriers to Adoption

Despite the several advantages of the EHR system, studies in the literature highlight some disadvantages associated with these systems. The use of patient records electronically has increased the danger of unrestrained distribution of patient's data, which increase the potential perceived privacy and confidentiality concerns. In addition, failure of equipment or network facilities, software errors, and difficulties in operating the system caused by disruptions to workflows that contribute to temporary losses in productivity. Moreover, high upfront acquisition costs, ongoing maintenance costs and lack of standardization and multiple organizational issues.[12]

High Costs of Ownership, implementation and maintenance

The literature provides evidence of failed clinical system implementations due to number of mentioned disadvantages and barriers. One of the main obstacles for healthcare providers to adopt EHR is cost, especially for implementing proprietary EHR systems. Proprietary EHR systems are expensive to purchase, implement, and maintain. Hani Safadi and colleagues argued, "Cost is the primary barrier to adopting EHR. A recent estimate of the cost of purchasing an EHR in the US is $15,000 to $50,000 per physician. Operating expenses may reach $20,000 per year".[13] Also, they addressed that for some proprietary systems it costs $7000 yearly license fee per doctor, $1500 yearly support fee per doctor, and $140 per hour for training and extra tasks.[13]

Interoperability" and "Usability

Many healthcare providers who have switched to EHR systems had issues regarding "Interoperability" and "Usability" [14-16]. "Interoperability" means that the ability of EHR technology to support the sharing of electronic health information. Whereas "Usability" as defined by the International Organization for Standardization (ISO 9241), is "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [17]. A case study in 2008, evaluates the usability of a commercial EHR in a pediatric hospital system. This case study demonstrates predictive usability evaluations that can provide both immediate results, through configuration changes and directed user education and training, and long-term results, through feedback to the vendor. Since there are many of potential errors as the result of usability problems with the interface, therefore, this can lead to a disastrous implications[14]. The study also mentioned the reasons behind the usability problems, while EHR systems often contain several applications and functions for tracking, monitoring, and entering medical information, such as patient medical history, allergies, test/lab results, diagnoses, and medications.

In addition to the complexities associated with the number of work processes supported, there is a range of users to EHR systems such as physicians, nurses, pharmacists, therapists, other clinicians, and support staff. Moreover, many healthcare providers implement commercial systems, which limits the healthcare provider's ability to change certain aspects of the system, since they are dependent on the vendor to make changes that impact the base product.[14] Many of doctors and hospitals are seeking different software systems for their practice, making interoperability even more harder to

achieve. Without usable and interoperable systems, providers and patients cannot gain the potential benefits of EHR systems.

Others critique EHR systems[18,19,45], they argued that these systems resulted in serious negative unintentional consequences, foremost of which are disrupting the doctor-patient relationship and interfering with quality patient care. Sine the process of taking the history and retelling the story during the patient's visit contributes to the doctor-patient relationship and the care of the patient. This also leads to better patient understanding of their illness. "Physicians are distressed, dismayed, and dissatisfied—an indication of how much the use of EHR has undermined the doctor patient relationship. EHR have failed to make patient care better, more efficient, or more satisfying for the patient or the doctor, and they have not improved safety." [18]

In 2013, RAND Corporation conducted a report on "Factors Affecting Physician Professional Satisfaction and Their Implications for Patient Care, Health Systems, and Health Policy"[19], they have listed some of EHR characteristics that make patient care harder for minority of physicians:

- Data entry is time consuming, ineffective, and confusing.

- User interfaces do not match the clinical workflow, particularly non-intuitive order entry. Complex menus resulted in struggles for physicians to interact with patients.

- Interference with Face-to-Face Care with the doctor-patient interaction, interjecting a computer between doctor and patient, compromising the level of attention doctors could devote to patients.

- Insufficient health information exchange, frustration when health information was not exchanged among multiple EHR systems within given practice, which restricts information flow. Therefore, it creates interoperability issues.

- Information overload such as the continuous volume of messages and alerts in some EHR systems, which are distracting.

- The EHR's meaningful use criteria and the most important elements of patient care do not match. Physicians reported that the documentation burden of satisfying meaningful-use criteria detracted from patient care.

- The high cost of acquiring the EHR and the cost of ongoing maintenance and support are financial risks due to factors beyond a practice's control.

- EHR require physicians perform tasks that others could perform, which decrease their clinical care and efficiency.

- Misuse of template-based notes or "macros" degrades the quality of clinical documentation and care.[19]

1.1.6 Open Source Software (OSS)

Many barriers facing the adoption of EHR systems could be diminished through the tools and techniques available through Open Source Software (OSS) model. First, it is important to know the definition of the term "Open Source". Open Source means that the source code for an application is available for anyone to review, critique, modify and redistribute to others.[63] Open source software has a long history of use in different domains, including computer operating systems such as Linux, and Internet browsers such as Mozilla. Computer scientists at the University of California, Berkeley began the tradition of software sharing in the mid-1970s with BSD UNIX and distributed the primary Internet network protocols as source code without a fee.[67] Other open source software programs such as Apache, which is a web server software that allows a computer to act as a server for web pages on the World Wide Web, it dominates the web server market by over 65 percent of all active websites. Another example of open source software is MySQL, which is a popular database program.[64,69] In the late 1990s, one of the most successful implementations of open source software has formed, which called LAMP. It is a software stack that stands for (Linux, Apache, MySQL and PHP/Python/Perl). Amazon's Cloud and other public cloud services mainly built with open source components like MySQL, JBoss, Tomcat, Xen and Linux. Nearly 40 percent of the major American companies use Linux in some form; Google is one of those companies.[69] Ruby is another example of open source object-oriented scripting language. Another example of open source product is OpenOffice, which is a word processor application. BIND, the system that resolves Internet addresses and the primary component underlying the Internet, is open source.[64,65,69] Thousands of other open source

projects in various fields can be also found at SourceForge.net, which is a free project management and source code repository host for open source projects. It has about 3.5 million registered users, and over 320,000 projects, and increasing. The existing projects continue to develop software, committing over 5,000 changes a day, closing tickets, and pushing out new releases, every day.[66] According to some studies,[69] many large companies consider open source model:

> "Large parts of the U.S. government, including the Defense Department, the Department of Energy, and the National Security Agency, work with open source software. National, state, and municipal governments from Germany to Peru to China are considering and in some cases mandating the use of open source software for e-government applications. IBM is now a major champion of open source after publicly declaring in 2001 a $1 billion commitment to developing technology and recasting central parts of its business models around Linux and other open source programs. Hewlett-Packard, Motorola, Dell, Oracle, Intel, and Sun Microsystems have all made serious (if less radical) commitments to open source software." [69]

However, with proprietary software the source code is kept hidden from the user and the only thing that can be accessed and executed is the software. Open source software differs from proprietary software in terms of development process in which open source is developed in a collaborative and distributed way leveraging the Internet for coordination leveraging ideas, creativity and contributions. The methodology associated with open source development, is more flexible than the traditional, isolated approaches used by most proprietary software developers. Open source encourages a sustaining philosophy of collaboration where developers tend to work in environments where they are encouraged primarily to develop and enhance software innovations, rather

than developing software products on a deadline. In addition, vendors of open source software can share development costs among a community of developers and users.[64,68,70] Moreover, open source software has many advantages over proprietary software such as, low cost of acquisition and maintenance, a greater possibility of customization, and a lower exposure to vendor failure or vendor "locks-in" which means that it is difficult to change vendors or migrate data to a different system. It could also reduce the lack of common data standards and increase flexibility and interoperability through openness; since developers of open source software are known for embracing standards.[13,70]

There are three main types of open source licenses: [68,71]

- Strong copyleft (highly restrictive), such as General Public License (GPL), which permits free use of the software but requires that any modifications be contributed back to the public domain under the same license.
- Weak copyleft (restrictive), such as Lesser General Public License (LGPL). The LGPL and GPL licenses differ with one major exception; with LGPL the requirement that you open up the source code to your own extensions to the software is removed. It permits linking to differently licensed software but requires code changes to be released under the original software license.
- Non-copyleft (Non-restrictive/Permissive), such as BSD, provides the language and structure needed to enable users to redistribute software and even sell it commercially. It can be released under a different license than the original in case it is modified and it can be linked with other software that has a different license.

The main difference between these categories is if the software can be released under a different license than the original in case it is modified and if it can be linked with other software that has a different license. The type of the license affects the number of contributors and accessibility of the source code. Therefore, highly restrictive licenses attract more developers, and increase the chance of success.[68,71] The following table (Table 2) demonstrate the some of the differences between Open Source Licenses:

License Status	GPL	LGPL	BSD	Apache
Copyright notice must be attached	√	√	√	
User can modify code	√	√	√	√
User can create derivative works	√	√	√	√
User must return modifications	√	√		
User can charge for derivative works			√	√
User can distribute derivative in binary form		√	√	√
GPL-compatible	√	√		

Table 2. Open Source Licenses Types (Goulde M., 2006).

Many studies discuss the differences, advantages, and disadvantages of different Open Source licenses in comprehensive details.[72,73] Sometimes Open Source is confused with freeware or shareware. Although both can be obtained free and can be shared but freeware or shareware are closed-source products that come with considerable restrictions on its use and may even contain advertising.[71]

1.1.7 Open Source Software in Healthcare

The Open Source Software model can be an excellent solution to the barriers of EHRs for the potential benefits of it. The same benefits of Open Source, in general, can be applied to the healthcare sector. Open Source Software has moved from specific Information Technology (IT) areas such as computer networks, operating systems, and software that provide the infrastructure for business applications into the healthcare IT sectors such as EHRs, which includes practice management, Clinical Decision Support Systems (CDSS), and billing. It has also reached to new technologies such as mobile phones, personal digital assistants, and other smart devices, all of which have a place in healthcare.[75] Even though "Open Source" is a term that relates to the source code, it also can be used to refer to the openness, transparency, and collaboration ecosystem. For example, the Health Information Exchange (HIE) gives the ability to send and receive health information electronically between healthcare providers in a safe and efficient manner. Therefore, the collaboration is critical for successful healthcare reform, to get provider's interoperability and meaningful use of patient records, where openness is necessary to access and exchange the data.[60] However, the healthcare activities rely heavily on information that may have come from different sources at different points of care, which add complexity to the providers' workflows.[76] So, it is important to have Open Source solutions that allow providers to customize their software to accommodate their unique business needs and how they deliver healthcare to their particular populations.[77] The proprietary software model that provides technology but without financial incentive will give healthcare providers difficulties to be able to transform operations, and the provision of care.[80] "Open Source Software is well suited for

healthcare, as it mimics the evidence-based health model; it, too, engenders better outcomes and continual improvement."[75] A recent study by Goldwater and colleagues shows that the cost of ownership for open source EHRs was 30% to 60% less than the cost of equivalent proprietary EHRs systems, based on a limited amount of cases for which cost data was available. The limited amount of data on the actual cost of the proprietary EHRs systems is due to the anti-free market practice in which vendors of the proprietary software force Non-Disclosure Agreement (NDA) conditions on providers that adopt their systems.[78] There are a limited number of vendors that support open source products such as Medsphere and DSS. They have developed a service model called "software as a service" to support and implement the open source EHRs. The cost of this support is lower than the proprietary alternatives.[84]

In February 2010, an open content platform for Free Medical and Open Source Software was launched "Medfloss.org" to provides a comprehensive and structured description of Free and Open Source Software projects in medical and healthcare delivery. It provides ideas, knowledge and experiences with existing projects and the related ecosystem. In addition to actual software projects, also professional service providers, events and scientific publications are listed. Currently, more than 300 projects are listed and still growing.[79]

There are many successful implementations of Open Source EHRs in the Untied States and around the world, such as VistA, OSCAR, GNU Med, OpenEMR, and OpenMRS, to name but a few. VistA is the Veterans Health Administration software that grew out of the Department of Veterans Affairs (VA) in the United States, and It is one of the first open source EHRs projects. In the early 1970s, the VA started the development

of a clinical system using the ANSI MUMPS computer language to support a solid framework of applications, till it completed the VistA EHR in the mid-1990s. The potential value of the VA's health IT investments is roughly $3.09 billion. VistA has implemented into the Indian Health Service (IHS). The IHS serves more than 3 million American Indians and Native Americans for medical care. Having collaboration with the VA for many years, IHS developed EHRs system called "Resource and Patient Management System (RPMS)", is deployed at more than 600 medical facilities.[82] Moreover, because of its success, vendors such as Medsphere started commercial versions derivation of VistA such as WorldVistA and OpenVista. Another successful open source EHR system implemented in Europe is called Care2X. It is a web-based application and has built upon other open source projects that include the Apache web server and MySQL database. It has more that 100 members developer.[62] However, The use of open source projects in healthcare is still low in Europe, and there is also no organized OSS health IT community to support these projects. But the UK has made substantial development by having the most active and vibrant OSS health IT community in Europe.[71] The Britain's National Health Service (NHS) "has contributed more than $40 million worth of tools and terminology to the open source community."[82]

OpenHRE is another open source project, which is funded by the U.S. Department of Health and Human Services (HSS) to develop a secure EHRs system in Mendocino County, California. These initiatives have sufficient momentum to suggest that an open source is a viable approach to developing healthcare applications.[64,71,75] In 2001, OSCAR (Open Source Clinical Application Resource) an open source clinical system started by the Department of Family Medicine at McMaster University in Canada;

and now it is widely adopted by primary care units and family physicians. It is also used, for example in Argentina, Africa, Caribbean, and Vietnam.[13]

There have been a lot of successful implementations of open source healthcare projects in the developing countries as well because the lack of financial and technical resources. Started in 2004, OpenMRS is widely implemented in Africa, to support one of the largest HIV/AIDS health systems strengthening initiatives in western Kenya. It is also implemented in South Africa, Rwanda, Lesotho, Tanzania, Uganda, and Malawi.[64,81] Figure 1 below shows the distribution for OpenMRS.

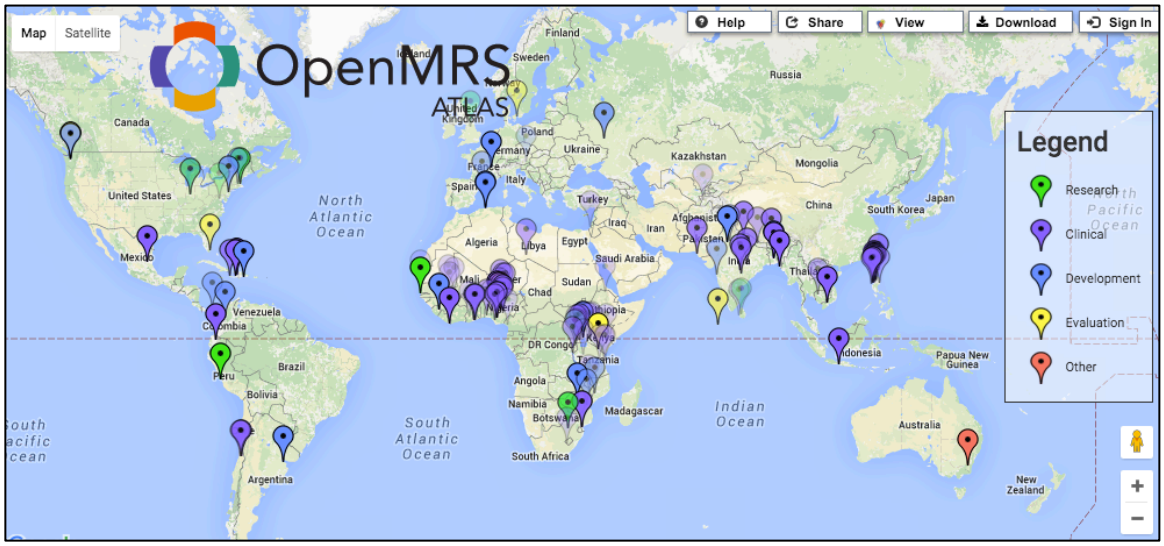


Figure 1: Distribution of OpenMRS around the world (atlas.openmrs.org, 2016)

We will be discussing more on Open EHRs, previous findings and gaps in further chapters.

1.2 Goals and Objectives

- The goal of this study is to identify the factors associated with the adoption and use of Open Source EHR in hospitals.
- Specifically, the objectives are:

  - Identify factors influencing the adoption of EHR – proprietary and open source.

  - Determine the association between hospital characteristics (Type, Size, Location, Number of staff, etc.) with the adoption of Open Source EHR.

1.3 Significance of the Problem

There are no previous studies that examine the prevalence and adoption of Open Source EHR. Many studies provide evidence that Open Source system works, and has been implemented and used in different settings, and it has been proven to be efficient and successful. However, there are no studies that explore the use and spread of open source EHRs by healthcare providers. Also, how hospital characteristics such as bed size, teaching status and location (urban, rural) affects the adoption of open source EHRs systems.

The purpose of the present paper is to explore characteristics of hospital systems that are associated with the adoption of HIT, with a focus on Open Source EHR. Identify challenges and best practices for success in achieving the advanced stages of the EHR.

1.4 Hypothesis and Research Questions:

Hypothesis 1:

Given that Open Source Solutions in Healthcare have the potential to save providers the expense of implementing and adopting Health IT solutions, it is hypothesized that there will be a significantly greater number of Open Source EHR compared to proprietary EHR.

Hypothesis 2:

There is a relationship between the number of physicians in healthcare provider with the use of Open Source EHR.

Hypothesis 3:

Healthcare provider with greater IT resources and a greater number of IT Staff will be associated with greater likelihood of adopting Open Source EHR use.

Hypothesis 4:

Smaller size healthcare provider will be more likely to use Open Source EHR.

Hypothesis 5:

There is a relationship between the location/region of healthcare provider with the use of Open Source EHR.

1.5 Related Research Questions

- What are the types and names of Open Source products that healthcare providers choose to adopt?
- What is the extent of Open Source adoption in healthcare providers?
- What factors promoting or inhibiting the adoption of Open Source products in healthcare providers?
- What is the adoption trend of Open Source in the past years?
- Do Open Source applications benefit from the government incentives programs such as Meaningful Use Incentives?
- How are the prevalence and the adoption rate of Open Source applications compared to proprietary systems in the available datasets?

CHAPTER 2 LITERATURE REVIEW

2.1 Review of the U.S. Healthcare Information Systems

The healthcare market for Health IT and especially for EHR Systems is developing rapidly. The use of information technology in health care is essential for significant improvements in the quality of care. That is why governments worldwide including developed and developing countries are trying to improve quality and safety of healthcare services and reduces costs by embracing those technologies. In 2009, the federal government passed the Health Information Technology for Economic and Clinical Health (HITECH) Act to encourage widespread adoption of health information technology.[20] It provides the U.S. Department of Health and Human Services (HHS) with the authority to establish programs to improve health care quality, safety, and efficiency through the promotion of health IT, including electronic health records and private and secure electronic health information exchange. The Centers for Medicare and Medicaid Services (CMS) is an agency within the HHS responsible for the administration of several key federal health care programs. The CMS has been charged with several key tasks for advancing health IT, including the implementation of electronic health record (EHR) incentive programs, a definition for the meaningful use of certified EHR technology. Moreover, CMS charged with the drafting of standards for the certification of EHR technology and the updating of health information privacy and security regulations under HIPAA. Much of this work is done in conjunction with the Office of the National

Coordinator for Health IT (ONC).[20,21] The programs' eligibility criteria were defined in the law and limited participation to specific Medicare and Medicaid providers and hospitals, with different criteria for each public program. Eligible Professionals (EPs) and Eligible Hospitals (EHs) must adopt and meaningfully use certified EHR technology to achieve specific objectives to qualify for incentive payments.[20,21]

As detailed by CMS[21], the meaningful use criteria, objectives, and measures evolve in three stages, Stage 1 of the CMS EHR Incentive Program began in 2011, and it sets the basic functionalities for EHR. The requirements focused on providers capturing patient data and sharing that data either with the patient or with other healthcare professionals to track key clinical conditions and communicating this information for care coordination purposes. EPs, EHs, and critical access hospitals will successfully attest to two stage 1 reporting periods before moving to stage 2.

Stage 2 of the CMS EHR Incentive Program began in 2014. It uses advanced clinical processes. The requirements are focused on health information exchange between providers and promote patient engagement by giving patients secure online access to their health information. In addition to encouraging the use of health IT for continuous quality improvement at the point of care and the exchange of information across diverse health care units.

Stage 3 of the CMS EHR Incentive Program is scheduled to begin in 2017, but the rule has not been finalized.[22] Policy and Standards committees are developing recommendations to continue to expand meaningful use objectives to improve health care outcomes. The focus of this final stage will be on promoting improvements on quality, safety and efficiency; and also decision support on national priority conditions.[21]

The Meaningful Use framework timeline is summarized in Figure 2 below.

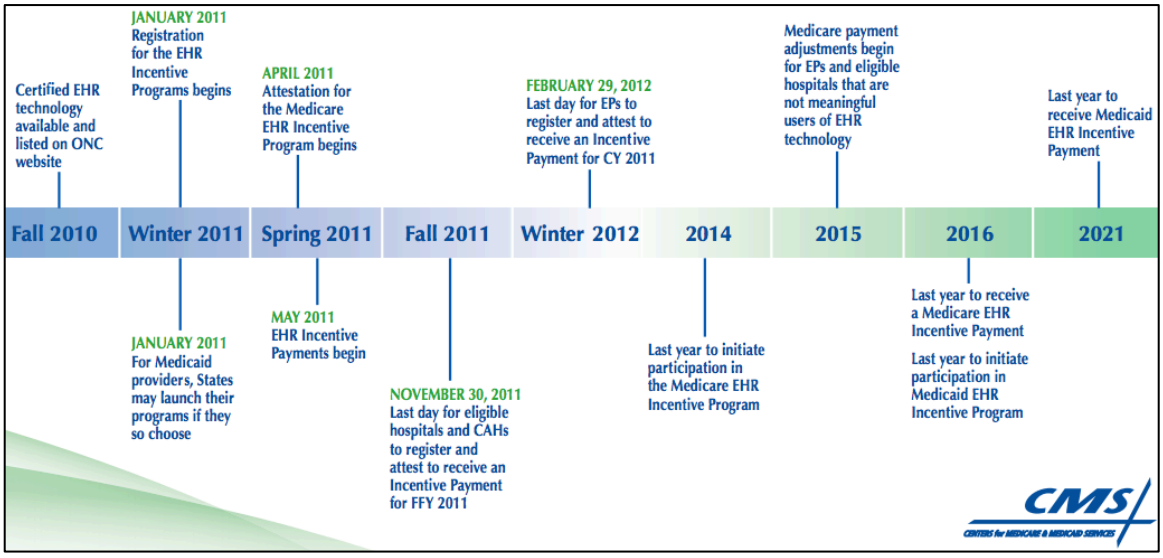


Figure 2: The Meaningful Use Milestone Timeline (CMS, 2010)

Ultimately, vendors can ensure that their systems match up to the required capabilities; and providers be assured that the system they acquire will help them achieve "meaningful use" objectives by using certified EHR technology to improve quality, safety and efficiency at a lower cost.

Apparently, there was a strong tendency toward EHR adoption among health care providers because of the incentive programs. According to a study by the National Center for Health Statistics (NCHS) estimates approximately 78% of providers are using an EHR in 2013, up from 2001 estimates of 18%.[23] Moreover, nearly half (48%) of physicians reported having a system that met the criteria for a basic system, up from 11% in 2006.[23] The percentage of physicians with basic systems by state ranged from 21% in New Jersey to 83% in North Dakota. In addition, 69% of office-based physicians

reported that they intended to participate (i.e., they planned to apply or already had applied) in "meaningful use" incentives.[23] About 13% of all office-based physicians reported that they both intended to participate in meaningful use incentives and had EHR systems with the capabilities to support 14 of the Stage 2 Core Set objectives for meaningful use.[23]

Figure 3 below shows the trend of the increasing adoption of EHR systems in the US from 2001 to 2013.

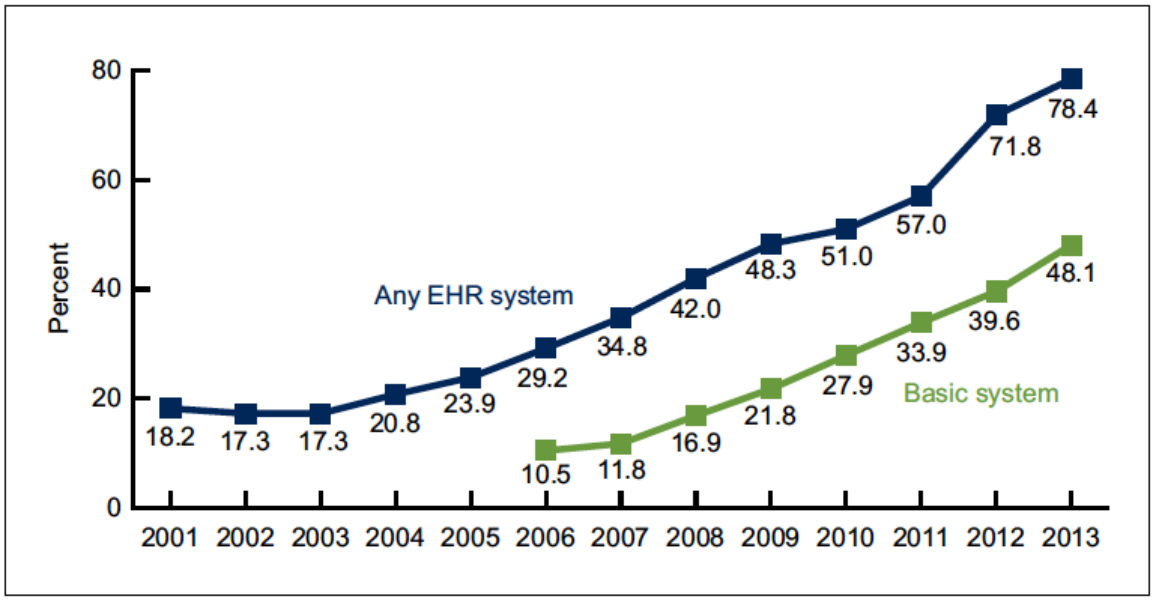


Figure 3: Percentage of providers with EHR: United States, 2001–2013 (NCHS, 2014)

Despite the increasing adoption rates of EHR, still some challenges persist. The gap between the adoption rates among small rural and other hospital settings are a concern. According to some studies,[25-27] small, rural healthcare providers are less likely to have adopted EHR than large, urban, and teaching hospitals. Findings concluded that a require attention must be in place for the small and rural healthcare providers. [27] Therefore, the ONC Regional Extension Centers (RECs) are assigned to help these health care providers, focusing on assisting organizations including small practices, community health centers, and practices that serve underserved populations. Through the American Recovery and Reinvestment Act (ARRA), ONC has established 62 RECs that assist more than 100,000 primary care providers in the adoption and meaningful use of electronic health records. RECs work to optimize the use of EHR so that providers can become meaningful users.[28] Their focus is to provide on-the-ground assistance for individual and small practices, including primary care providers, physicians, physician assistants, and nurse practitioners. In addition to medical practices lacking resources to implement and maintain EHR, and those providing primary care services in public and critical access hospitals, community health centers, and other settings that often serve those who lack sufficient medical care. As a result of this effort, over 157,000 providers are currently enrolled with a Regional Extension Center; of these, more than 146,000 are now live on an EHR and more than 116,000 have demonstrated Meaningful Use.[29]

2.2 **Health IT in Developing Countries:** Saudi Arabia as an Example

The Electronic Health Records (EHR) is a major forward step in improving patients' care. It provides a tool to archive and retrieve patients' clinical data at online basis. As any new technology, one would expect some resistance at the beginning of its implementation. This is more noticeable in the developing countries. Several researchers studied the status of EHR in some of the developing countries. Saudi Arabia is a good example of a developing country that invests heavily in the Health sector. The first Public Health service in KSA was established in Mecca in 1925. However, EHR was not introduced (on large scale) in Hospital environments until the turn of this century. The Saudi government allocated a budget of US$ 1.1 billion to run a 4-year development program to develop e-health services in the public sector (2008–2011).[30]

The health services in KSA are provided to Saudi citizens on free of charge basis by Ministry of Health (MOH) hospitals. MOH covers about 60% of the health care services in the country, while other governmental institutions cover the remaining portion (Military, National Guard, Security Forces, Universities and Research Centers) and Private sector. This spectrum of health service providers makes it more crucial to develop a unified patients' Electronic Medical Records at the National level. It is common for a patient to start a treatment at one institution and seek a second opinion from another one. A different treatment protocol might be considered as well as a full range of duplicated laboratory tests and radiological examinations. With national electronic patients' records, these health hazards and waste of resources problems can be avoided.[32,33]

The National Guard Health Affairs (NGHA) in KSA deployed a computerized physician order entry (CPOE) system in their largest tertiary Hospital in Riyadh. The project started by implementing the system in a pilot department, which was the intensive care unit (ICU) in order to assess its benefits and risks and to test the system. After the assessment of the survey, NGHA decided that the potential benefits of the CPOE are greater than any possible risks and concerns as raised by the Physicians. The project was then expanded to cover all NGHA clinics and hospitals in a phased approach.[32]

Another successful example of partial implementation of e-health systems in KSA is the radiological Picture Archiving and Communication System (PACS). Most of the Governmental and large private Hospitals in KSA have turned to fully digital radiology services. The expected resistance at the beginning of this era has caused some delays in the full implementation of this system. Some hospitals had to force the radiologists and other physicians to interact with this digital environment by shutting down the film based radiological services completely. In addition, the high cost of implementing EHR is a major barrier.

2.3 Previous Findings and Gaps in the Research

2.3.1 EHRs Previous Studies

The factors influencing the adoption of EHR are very important. Previous studies have found that there is variation in adoption rates related to hospital characteristics such as bed size, teaching status and location, etc.[35-39] A study by Wang and colleagues has found that HIS adoption was influenced by the hospital market, organizational, and financial factors. Larger, system-affiliated, and for-profit hospitals with more preferred provider organization contracts are more likely to adopt organizational information systems than their counterparts. Hospital bed size was significant, positively related to the adoption of all categories of healthcare information systems.[35] Another study finds that children hospitalized in a rural hospital are less than half as likely to be treated using advanced EHR since rural hospitals face significant barriers to the adoption of advanced EHR.[36] A study conducted by the American Medical Informatics Association (AMIA) on the impact of the meaningful use incentive program on EHR adoption by US children's hospitals, concludes that a majority of hospitals do not have systems optimized for pediatrics, and the meaningful use program may fail to encourage the inclusion of pediatric features. Which result in widespread adoption of EHR that lack pediatric capabilities.[40] There is also literature that explores the common sequence in which hospitals adopt EHR functions, and how does this sequence differ based on the size, rural/urban location, and teaching status of the hospital. The study found that with small, rural, and non-teaching hospitals it shows greater homogeneity compared to the larger, urban, teaching hospitals. That is because "small hospitals are likely to rely more heavily on vendors, who have standard approaches to EHR adoption, while larger hospitals may

use multiple vendors or have home-grown systems, and therefore make internal decisions about sequencing. Moreover, larger hospitals are more complex and deal with a more diverse group of stakeholders."[41] The same reasons applied to teaching and non-teaching hospitals and rural hospitals compared to urban hospitals, in which rural and teaching hospitals would have more homogeneous sequence.[41]

There are many studies explored the extent use of EHR by healthcare providers in different settings.[42-44] In 2009, the New England Journal of Medicine (NEJM) has published an article in which the researchers surveyed all acute care general medical and surgical member hospitals with a collaboration of the American Hospital Association (AHA). They have found that less than 2% of acute care hospitals have a comprehensive EHR implemented in all clinical units, and 7.6% of hospitals have a basic EHR that included functionalities for doctors' notes and nursing assessments in at least one clinical unit. Larger hospitals, those located in urban areas, and teaching hospitals were more likely to have EHR.[42] In a similar study where the focus was on physicians; the study found that 4% of doctors reported having a comprehensive, fully functional EHR system, and 13% reported having a basic system. Moreover, EHRs were "more prevalent among physicians who were younger, worked in large or primary care practices, worked in hospitals or medical centers." [43] Both of the previous studies found that the financial barriers had the greatest effect on decisions about the adoption of EHR.[42,43] Moreover, low capital is also an issue, since it impacts the acquisition and installation of EHRs, especially for small community and critical access hospitals, despite the availability of the incentives programs.[46] In a recent study by ONC, it describes trends in adoption of EHR systems both basic and certified, among non-federal acute care hospitals from 2008

to 2014. Basic EHR represents a minimum use of core functionality determined to be fundamental to an EHR system. Whereas certified EHR must meets the technological capability, functionality, and security requirements adopted by the HSS. See Figure 4 below.[44]

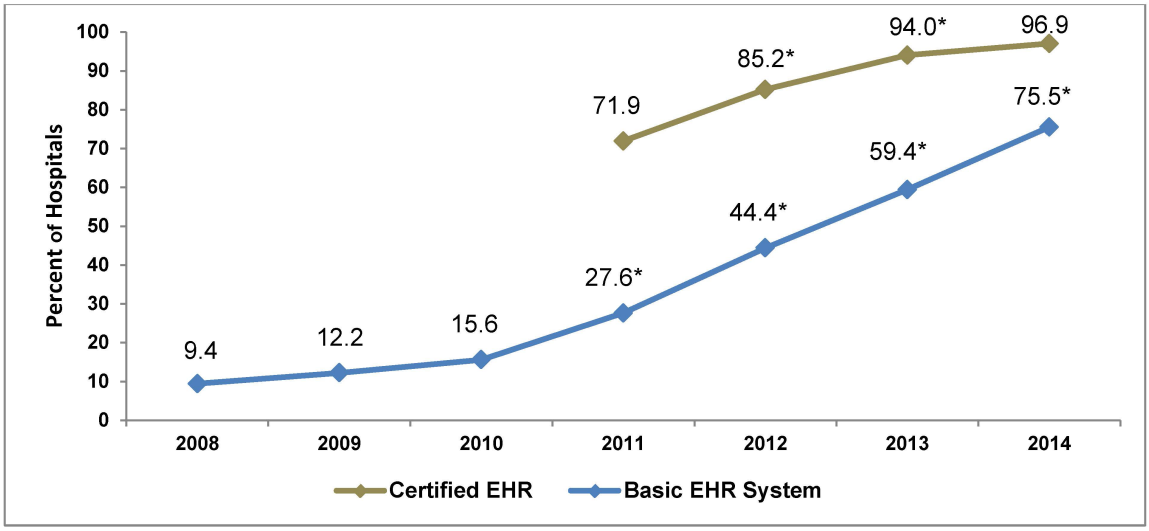


Figure 4: Percent of non-Federal acute care hospitals with Basic EHR and certified EHR: 2008-2014 (ONC, 2015).

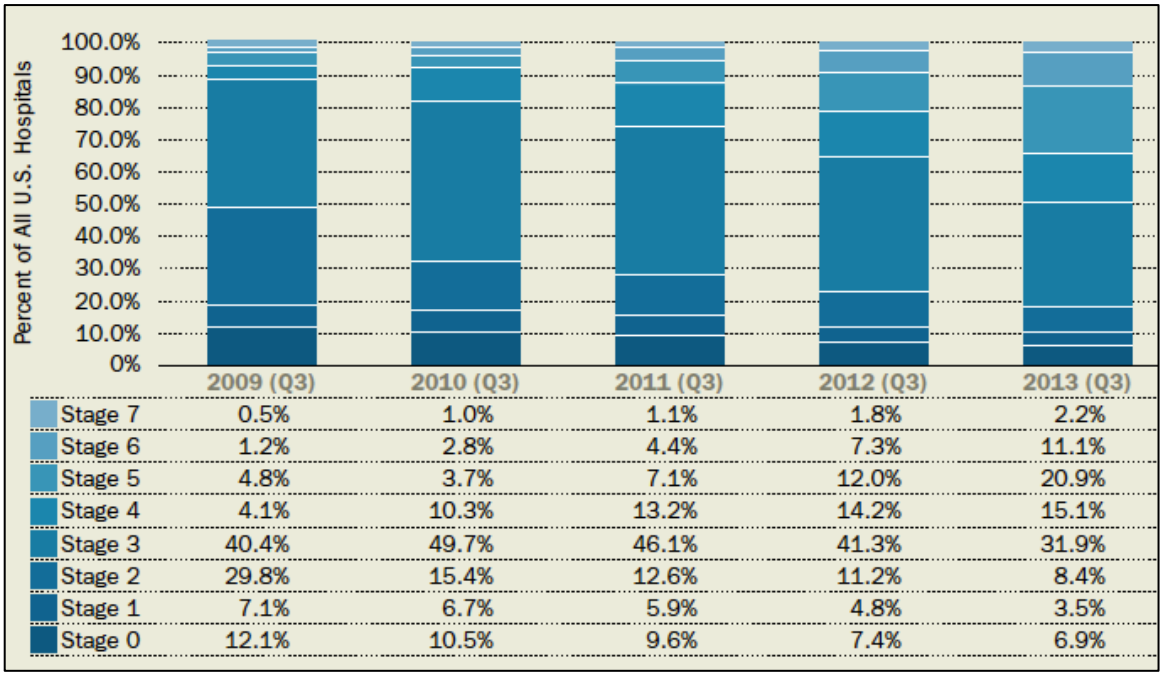
In 2014, 76% non-federal acute care hospitals had adopted at least a Basic EHR system, and nearly 97% of all reported hospitals possessed a certified EHR while 34.4% had adopted a comprehensive EHR system which requires that each function had to be implemented in all units.[44]

The Healthcare Information and Management Systems Society (HIMSS) Analytics has developed a methodology to score healthcare providers on their level of EHR implementation. The "Electronic Medical Record Adoption Model" (EMRAM) identifies and scores a healthcare provider's EHR capabilities, ranging from limited ancillary department systems to a fully comprehensive EHR environment.[46] The stages of the model are as descried below in Table 3:

Stage	Description
0	• Some clinical automation may exist. • Laboratory and/or pharmacy and/or radiology not installed.
1	• All three major ancillaries (laboratory, pharmacy and radiology) installed.
2	• Major ancillary clinical systems feed data to clinical data repository (CDR) that provides physician access for retrieving and reviewing results. • CDR contains a controlled medical vocabulary (CMV) and the clinical decision support system and rules engine for rudimentary conflict checking. • Optional for extra points - Information from document imaging systems may be linked to the CDR.
3	• Clinical documentation installed (e.g. vital signs, flow sheets, nursing notes, care plan charting, and/or the electronic medication administration record (eMAR) system are scored with extra points and are implemented and integrated with the CDR for at least one service in the hospital. • First level of clinician decision support is implemented to conduct error checking with order entry (i.e. drug/drug, drug/food, drug/lab, conflict checking normally found in the pharmacy). • Some level of medical image access from picture archive and communication systems (PACS) is available for access by physicians via the organization's intranet or other secure networks.
4	• Computerized practitioner/physician order entry (CPOE) for use by any clinician added to nursing and CDR environment. • Second-level of clinical decision support related to evidence-based medicine protocols implemented. • If one patient service area has implemented CPOE and completed previous stages, this stage has been achieved.
5	• The closed loop medication administration environment is fully implemented in at least one patient care service area. The eMAR and bar coding or other auto-identification technology, such as radio frequency identification (RFID), are implemented and integrated with CPOE and pharmacy to maximize point-of-care patient safety processes for medication administration.
6	• Full physician documentation/charting (structured templates) are implemented for at least one patient care service area. • A full complement of radiology PACS systems is implemented (i.e. all images, both digital and film-based, are available to physicians via an intranet or other secure network.
7	• Clinical information can be readily shared via electronic transactions or exchange of electronic records with all entities within a regional health network (i.e., other hospitals, ambulatory clinics, sub-acute environments, employers, payers and patients).

Table 3. EMR Adoption Model (HIMSS Analytics, 2013)

In 2014, a study by HIMSS Analytics found that there has been a gradual adoption of EHRs functionalities. See Figure 5 for details from 2009 to 2013[47]:



	2009 (Q3)	2010 (Q3)	2011 (Q3)	2012 (Q3)	2013 (Q3)
Stage 7	0.5%	1.0%	1.1%	1.8%	2.2%
Stage 6	1.2%	2.8%	4.4%	7.3%	11.1%
Stage 5	4.8%	3.7%	7.1%	12.0%	20.9%
Stage 4	4.1%	10.3%	13.2%	14.2%	15.1%
Stage 3	40.4%	49.7%	46.1%	41.3%	31.9%
Stage 2	29.8%	15.4%	12.6%	11.2%	8.4%
Stage 1	7.1%	6.7%	5.9%	4.8%	3.5%
Stage 0	12.1%	10.5%	9.6%	7.4%	6.9%

Figure 5: Array of U.S. Hospitals by EMRAM Stage Status (2009 – Q3 2013) (HIMSS Analytics, 2014).

The percent of hospitals with low functioning EHR capabilities in EMRAM Stage 0 to Stage 2 shows that there has been a decrease in the number of hospitals in these stages. Also there was a change in distribution of hospitals in EMRAM Stage 2 between 2008 and 2009, in which the federal incentive programs started at that time. There is also an increase in the percentage of hospitals with advanced capabilities. At the end of 2007, there were only 40 hospitals in Stage 6 with no hospital in Stage 7. By the third quarter of 2013, 658 hospitals reached Stage 6 and 160 hospitals achieved Stage 7.[47]

As discussed by Ken Terry in his article,[48] although the EMRAM stages have no direct relationship to the stages of Meaningful Use incentive program, concerns about the ability of hospitals' EHRs occurs to meet the requirements of Meaningful Use stage 2. For example, hospitals in Stage 4 of the EMRAM model might be missing some functions that are required in Meaningful Use stage 2 such as closed-loop medication administration, physician documentation and full clinical decision support, and the ability to exchange standardized summary documents with other providers. However, hospitals could still be able to attest for stage 1 Meaningful Use even though they lack some of functions required in EMRAM Stage 4, such as having medication, lab, imaging and other orders to be made electronically. Many hospitals are still having difficulties to achieve Meaningful Use stage 2.[48] For that reason, HIMSS recommended that Meaningful Use Stage 2 to be extended in order to give healthcare organizations the time to overcome short-term obstacles that presently exist.[49]

2.3.2 Open Source EHRs

The literature review reveals many aspects of Open Source EHRs systems, either discussing its advantages or disadvantages, examine their functionalities,[13,87,92,94,103] or by discussing case studies on particular applications in different settings.[81,93,97,105,106,107,109] Also, there are some studies on the diffusion and adoption of Open Source EHRs in narrow regions.[78,101] Some researchers used qualitative field study to view the use of open source software in healthcare delivery.[89,100] Other studies reviewed the prevalence of these systems based on reviews of scientific literature but not based on quantitative analysis.[74] Other studies developed a prototype and platforms using open source tools which can be used as a core system for the development of new clinical applications and for prototyping research ideas.[98,99]

A survey study by Munoz-Cornejo and colleagues conducted in three States (Baltimore, Washington, and Northern Virginia) to investigate adoption of open source software in hospitals in those States. Main outcomes of their research indicate that contextual factors such as type of the hospital, size, IT budget, organizational culture, and organizational structure may facilitate or inhibit the adoption of open source software. Also, causal factors such as lack of in-house software development lack of IT personnel, and satisfaction level with software vendors plays a significant role in the decision for adopting open source software. They concluded from their survey sample that there are 23% (n=7) of the hospitals have adopted open source software and four of them are open source EHRs. The percentage of hospitals was not adopting open source software were 76% (n=23). A key finding from their research is that hospitals adopt general-purpose

open source software such as MySQL, Linux, Apache, Firefox, PHP and Perl. However, domain-specific software such as EHRs or other clinical products were lower that general-purpose open source software.[83]

In an exploratory study, researchers examine the state of open source projects in healthcare by searching SourceForge website. They found 174 projects, 60% did not have an organization sponsor. They emphasize that the sponsorship by stakeholders such as users, developers, and managers in addition to government and privet organizations, be necessary to increase the adoption of the open source projects, especially in healthcare. The study also discussed other variables related to the open source projects, such as license type, the number of downloads, and development status. The other 40% of open source projects having a sponsor indicates that there is a growing interest in OSS by healthcare providers.[68]

Vest and Stephens investigate the use of open source applications in the United States hospitals. They interviewed the chief information officer at 17 not-for-profit and public hospitals and found nine hospitals are using OSS HIT while eight are not using them. The healthcare IT leaders response varied from eager to adoption because of OSS applications while others refused the idea of the perceived risk of patient health. Some hospitals were gaining success with their OSS HIT applications; however, they still relying on vendors for installation, customization, and technical support. Therefore, vendors can be held accountable for their software. Also, they found that there was a distinction in using OSS applications as interface engines and back-end business

processes but not much as a clinical care application such as EHRs. They concluded that the decision to adopt OSS HIT was not consistent but contingent upon different factors such as existing IT capabilities of the hospital and financial risks. [91] The California HealthCare Foundation published a report of the available open source EHR systems for ambulatory care. They evaluate some applications such as ClearHealth, FreeMED, OpenEMR, and WorldVistA. The study identified several challenges facing the adoption of open source EHRs and provided some practical solutions to overcome those challenges. Raising awareness of open source EHRs and facilitating cooperation among open source EHR projects are some of the general recommendation of the study.[93]

In similar approach, Abajo and Ballestero overviewed some of the critical open source software and comparing them to offer the best opportunities in healthcare to developing countries. Including in their study OpenMRS, OpenVistA, and OpenEMR, where they compared several characteristics of the three programs related to core technology, interaction with the database, interface type, operating systems, and level of development.[94] A report by Paul Webster in 2011 support that there is a rising trend of healthcare providers using open source EHRs, especially in developing countries such in Latin American and Africa where commercial systems are unaffordable.[95] However, other studies found that the implementation of an international and interoperable EHRs systems is very hard to achieve since each country has a different level of development of these systems.[74] Helms and Williams evaluate access control of some open source EHRs and found that indicate that "open source EHR system designers are not implementing robust access control mechanisms for the adequate protection of patient data."[102] Another

case study conducted by Austin and colleagues using three open source EHRs to aid in the selection of vulnerability discovery techniques by comparing the vulnerabilities detected by each and comparing their efficiencies.[104]

Palmer and Simms-Cendan from the University of Central Florida implemented an open source EHRs in the Dominican Republic, their goal was to assess the feasibility of implementing OpenMRS at various resource-poor rural sites. They have successfully deployed a highly-portable EHR system for three different resource-poor communities. The accomplishment of this project demonstrates the practicability of implementing EHRs system to record patient data during a primary care setting of a short term international medical trip (STIMTs), even in groups of providers and students with limited training.[96] Marsan and Pare used a qualitative approach to investigate factors associated with the decision of healthcare providers to adopt or not to adopt open source software. They identified three main groups of factors, characteristics of the innovation, characteristics of the organization, and characteristics of the organization's external environment. They concluded their findings by stating "the adoption decision is positively influenced by the fact that OSS is a popular subject matter, actual adoption is hindered by the lack of clarity, consistency and richness of the public discourse surrounding OSS, whether the discourse comes from magazines or other media."[89] In a questionnaire survey conducted by Millard and colleagues, evaluating all open-source point-of-care EMRs for use in resource-limited settings without reliable Internet access. They emphasize the need for "global funding agencies to move beyond disease-specific EMR systems and develop a universal open-source health informatics platform."[88]

Kiah and colleagues conducted a hands-on study by implementing a set of open source applications on separate virtual machines to analyze the systems to a set of assessment measures. Therefore, providing more comprehensive guidance from an implementer perspective toward the available OSS applications. Their finding suggests that many OSS applications are found to be lacking in security, interoperability, and the absence of developers' support.[86] In contrast, Dinevski and colleagues discussed the significant use of open source approach to integration and interoperability in healthcare delivery. It contributes essentially to the failure in HIS investment in healthcare, therefor "if systems can communicate with each other, the potential benefits they can bring to patients will increase significantly."[108]

CHAPTER 3 RESEARCH METHODOLOGY

3.1 Methods and Statistical Analysis

The aim of this study is to explore the diffusion of open source EHR in comparison with proprietary applications used by healthcare providers in the United States. Moreover, characteristics of healthcare providers that may also affect the adoption of these different types of EHR will be studied and analyzed, such as the size, type and specialty of the healthcare provider.

An extensive search of publications has performed to build a list of OSS HIT products from previous studies and journals. Also, by searching "Sourceforge" website, which is a free project management and source code repository host for open source projects. That revealed more than 130 open source EHR systems available worldwide. See Table 9. Then, multiple datasets used to identify providers using any of these applications. The study will use HIMSS Analytics to determine the healthcare providers not using OSS HIT, matching roughly on control, bed size, and geography.

Descriptive statistics will be used to summarize the healthcare data on organizational characteristics and to understand their statistical data distributions. For descriptive statistical data on data variables, the study will use the most recent five years available data during the year 2009 to 2013. The analysis will be performed using SAS / R. Logistics regression will be used to test hypotheses of this study.

3.2 HIMSS Dataset Review - Secondary Datasets

The data for this study was obtained from the Dorenfest Institute, which is a research division of the Health Information and Management Systems Society (HIMSS) Analytics. The data is available from 1986 - 2013, and contains information of health care facilities on several dimensions including a self-reported level of compliance with HIPAA privacy, and security rules, hiring of HIPAA consultant, hospital bed size, tax status, academic status, and geographical location. The HIMSS dataset was available in an MS Access database format. This data set is collected and administered by the Health Information Management Systems Society (HIMSS), which is a health care industry membership organization focused on the use of information technology and its application in the health sector. Moreover, the survey results are stored in a market intelligence database that contains a detailed profile of each provider along with information regarding software and hardware IT usage and adoption. The database provides information for 1,500 independent health care delivery systems operating more than 40,000 health care facilities. The large sample size should result in a test with high power that is capable of detecting small effect sizes. The most recent data available is from 2013.[54]

The participants in the data collection instrument include chief information officers and directors of the information systems, planning, and marketing at the integrated health care delivery systems, as well as representatives from the vendors of automation products and services. The database presents profiles of each healthcare organization as accurately as possible by conducting independent and in-depth research,

consulting healthcare industry experts, and collecting experiences by interviewing the top planning, marketing, and information systems officers of the integrated health care delivery systems. As a result, these databases are recognized as an authentic source of healthcare information systems by many academicians, as well as by leading HIT companies, market leaders, and hardware and software vendors (HIMSS).[54]

To ensure the data in the database is current and accurate, HIMSS Analytics' dedicated research staff contacts each healthcare organization's senior information technology (IT) executive at least once a year, with a request to provide information to complete his or her organization's profile. Once the executive completes his or her self-reported profile, the data undergoes an extensive quality review before it is made available for researchers (HIMSS).[54]

3.3 CMS Meaningful Use Attestation Dataset Review - Secondary Datasets

In another aspect, The "Meaningful Use" report dataset can be used to validate the prevalence of open source EHR and their eligibility for incentives. This dataset provided by the Department of Health and Human Services' Office of the National Coordinator for Health Information Technology (ONC) and the Center for Medicare and Medicaid Services (CMS), which is an updated list of all certified EHRs products used by healthcare providers for attestation to the Incentive Program. There are over one million attestations. This data set results from the merge of attestation data from the CMS EHR Incentive Program with certified EHR product information from ONC's Certified Health IT Product List (CHPL).[21,22] The dataset provides information about:

- Names of EHR products and their vendors
- The certification classification of each product (Complete or Modular), Complete products meet all the Meaningful Use (MU) requirements. Modular products meet one or more of the MU requirements but not all.
- The healthcare setting for which the product was certified (Ambulatory or Inpatient)
- The type of provider attesting to "meaningful use" of an EHR, Eligible Professional (EP) or an Eligible Hospital (Hospital).
- The Incentive Program the provider attested in (Medicare or Medicare)
- The Stage of Meaningful Use that the provider attested to (Stage 1/Stage 2).

3.4 Regional Extension Centers (RECs) Dataset Review - Secondary Datasets

In every region, the ONC's Regional Extension Centers (RECs) are established to serve as a support and resource center to help healthcare providers in EHR implementation. The RECs helps healthcare providers to work through the EHR adoption process from vendor selection and workflow analysis to implementation and meaningful use.[28] "Through the American Recovery and Reinvestment Act (ARRA), ONC has established 62 RECs that assist primary care providers in the adoption and meaningful use of electronic health records. The REC program was designed to leverage local expertise to provide practical, customized support to meet the needs of local healthcare providers."[29] Currently, there are over 157,000 healthcare providers with a Regional Extension Center. Over 146,000 are now live on an EHR, and more than 116,000 have demonstrated Meaningful Use. Also, 46% of Primary Care Physicians (PCPs) nationwide are enrolled with an REC; 54% of rural PCPs are enrolled. 93% of REC-enrolled providers are live on an EHR while 73% live on an EHR in the general provider population. Moreover, 1,403 Critical Access Hospitals (CAHs) and small Rural Hospitals (RHs) are enrolled with an REC. Of these, 85% have demonstrated Meaningful Use.[28,29]

3.5 Study Variables

Dependent Variable

Whether the healthcare provider uses Open Source applications. This variable will be coded "0" for not using Open Source, "1" for using Open Source product.

Independent Variable

- *Healthcare Provider Size*
- *Ownership Status*
- *US Region*
- *Service Type*
- *Number of Physicians*
- *Number of Beds*
- *Product Classification*
- *Product Setting*
- *Provider Type*
- *Provider Stage Number*

CHAPTER 4 RESULTS

4.1 HIMSS Dataset Statistics

- Demographic and IT data from nearly 45,000 facilities that includes:
    - 32,810 Ambulatory Facilities
    - 5,467 Hospitals
    - 2,362 Sub Acute Care Facilities
    - 2,357 Home Health Care Facilities
    - 1,837 Single Hospital Health System
    - 489 Integrated Delivery System (IDS) / Regional Health Authorities (RHA)
    - 209 In-Hospital Data Center
    - 185 Free Standing Data Centers
    - Market share and purchasing plan data for over 100 software applications.

The most recent data is from the year 2013. There are more than 1,400 vendors of Health IT systems in the dataset that includes both types, Open Source and Proprietary systems. The dataset also has more than 40,000 healthcare providers, about 62% of them are "Live and Operational" using EHR systems, and about 22% "Not Automated" meaning that not using EHR. While the rest is divided between "Service Not Provided, Not Reported, To Be Replaced, Contracted/Not Yet Installed, Installation In Process and Not Yet Contracted". See Table 4.

Table 4.
Application Implementation Status (HIMSS 2013 Dataset)

Implementation Status	Frequency	Percentage
Live And Operational	463,234	62.90
Not Automated	166,734	22.64
Service Not Provided	31,766	4.31
Not Reported	22,361	3.04
To Be Replaced	17,988	2.44
Contracted/Not Yet Installed	15,966	2.17
Installation In Process	14,193	1.93
Not Yet Contracted	4,184	0.57

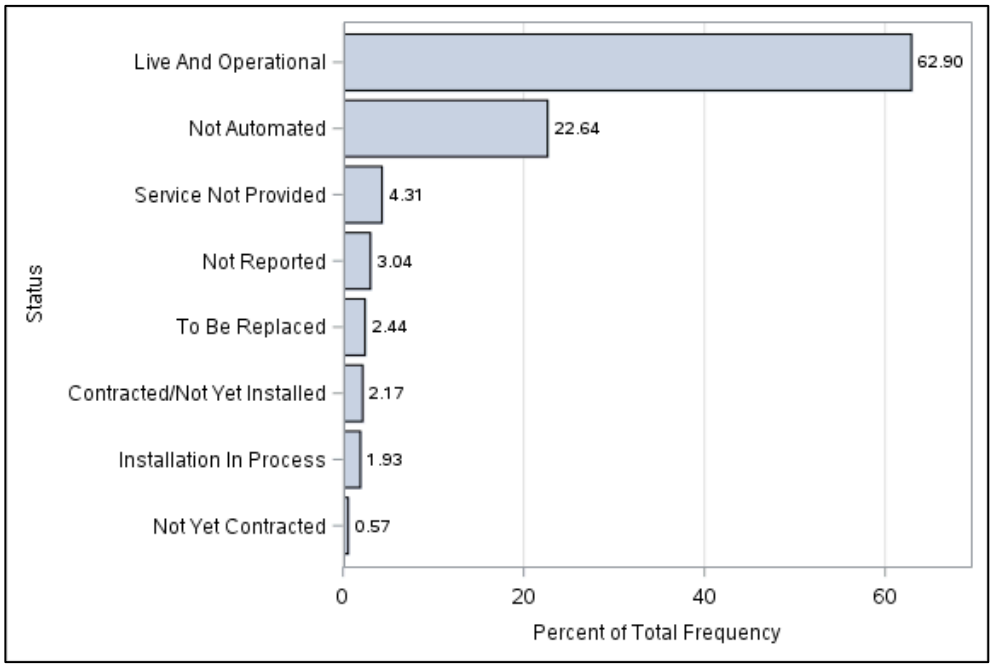


Figure 6: Application Implementation Status, (HIMSS 2013 Dataset)

The dataset includes general categories of software and their detailed applications, such as Computerized Practitioner Order Entry (CPOE), Clinical Decision Support System (CDSS), Physician Documentation, etc.) See Tables 5 and 6.

Table 5.
Top Category of the Software Application (HIMSS 2013 Dataset)

Category	Frequency	Percentage
Ambulatory	76824	10.43%
Radiology & PACS	66677	9.05%
Revenue Cycle Management	61443	8.34%
Electronic Medical Record	54847	7.45%
Health Information Management (HIM)	54749	7.43%
Clinical Systems	51607	7.01%
Laboratory	45124	6.13%
Nursing	44759	6.08%
Cardiology & PACS	38938	5.29%
Human Resources	38254	5.19%
Financial Decision Support	34038	4.62%
Supply Chain Management	27166	3.69%
IS Infrastructure	25878	3.51%

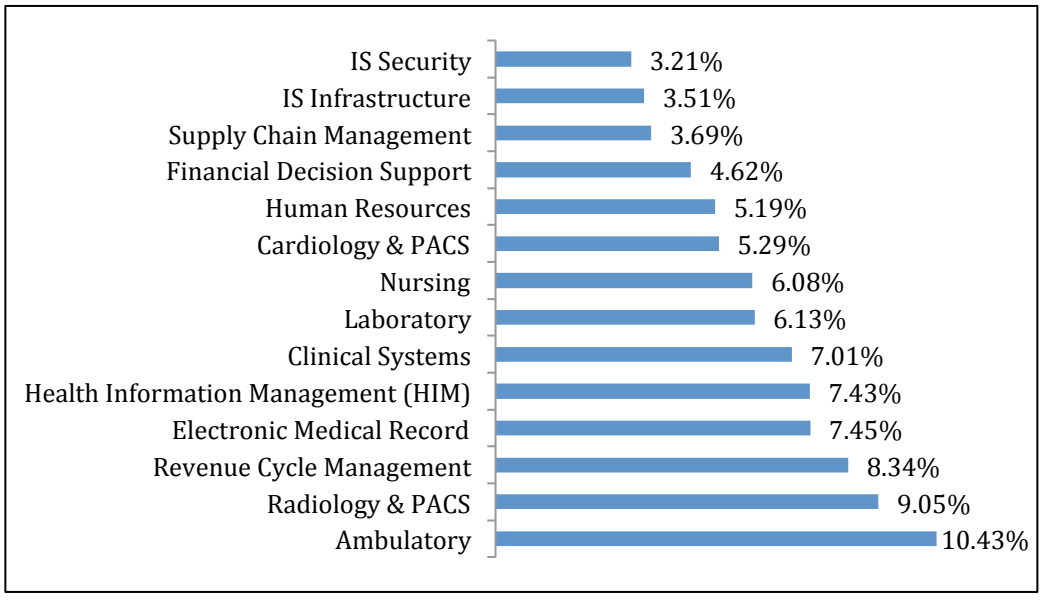


Figure 7: Top Category of the Software Application, (HIMSS 2013 Dataset)

Table 6.
Top Applications Used (HIMSS 2013 Dataset)

Application	Frequency	Percentage
Practice Management	37,299	5.06
Ambulatory EMR	34,308	4.66
Clinical Decision Support System (CDSS)	9,675	1.31
Order Entry (Includes Order Communications)	8,474	1.15
ADT/Registration	8,463	1.15
Clinical Data Repository	8,462	1.15
Patient Billing	8,431	1.14
Patient Scheduling	8,429	1.14
Nursing Documentation	8,367	1.14
Electronic Data Interchange (EDI)	8,366	1.14
Computerized Practitioner Order Entry (CPOE)	8,346	1.13

Note. The distribution of applications is for all implementation levels. The rest proportion is less than one percent for some other applications.

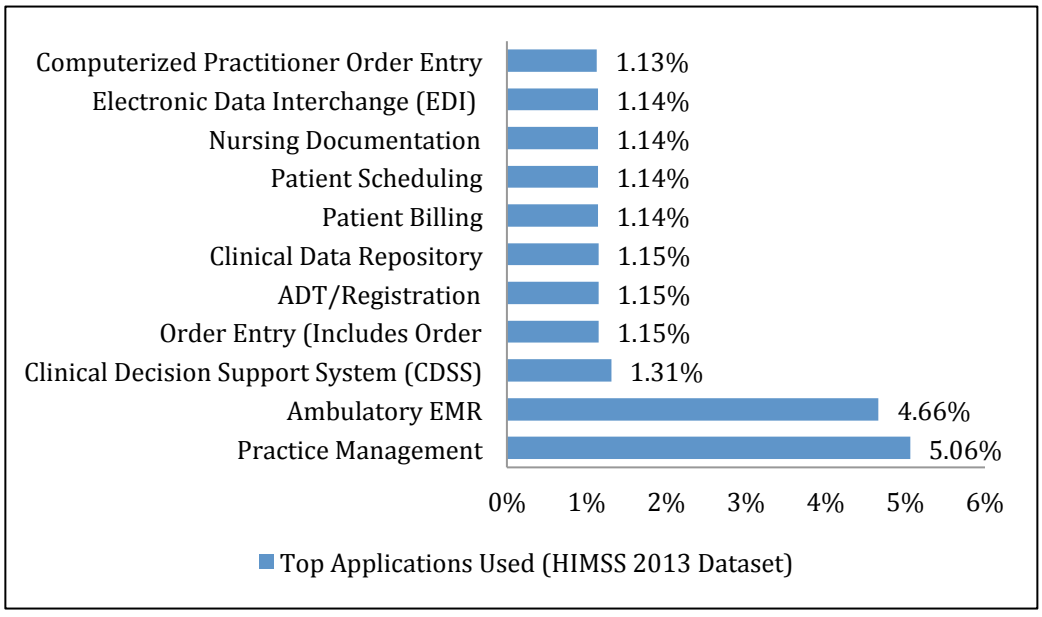


Figure 8: Top Application Used, (HIMSS 2013 Dataset)

4.2 Most used Vendors and Products in HIMSS 2013 Dataset

Some vendors have many products that are used by the healthcare facility, and each product serves a particular type of application. On the other hand, other vendors specialized in a particular type of application; therefore, they have only one product.

In the 2013 HIMSS dataset, there are more than 736,000 records of systems used by all healthcare providers in all their departments. About 31% of those observations did not report on the system they use "Not Reported", mostly because it is "Not Automated".

Table 7 lists the most used software Vendor's Names in healthcare providers; this list includes vendors providing all different type of Health IT systems, including the most used products for each vendor. Under each vendor, there is a percentage of the product "Not Reported".

Table 7.
Top Software Vendors and Products Used (HIMSS 2013 Dataset)

Category	Most Used Products	Frequency	Percentage
MEDITECH	MAGIC, CLIENT SERVER, MEDITECH 6.0, MEDICAL & PRACTICE MANAGEMENT	61,259	8.32
Epic	EPICCARE, CADENCE, PRELUDE, ENTERPRISE, RESOLUTE, MYCHART	50,507	6.86
McKesson	HORIZON, PARAGON, STAR, PATHWAYS, SERIES, TRENDSTAR	47,875	6.50
CERNER CORP.	MILLENNIUM, MILLENNIUM PATHNET, SURGINET, CLASSIC, CLAIRVIA	32,394	4.40
CPSI	SYSTEM 2000, IMAGELINK, CHARTLINK EMR Portal, CLIENTWARE	22,635	3.07
GE Healthcare	CENTRICITY, IDXTEND, IMAGECAST, QS, DYNAMIC IMAGING	21,673	2.94
SIEMENS	INVISION, SOARIAN, MEDSERIES4, SYNGO IMAGING, SIENET PACS	20,794	2.82
Infor Healthcare	Lawson/HUMAN Resources Suite, Financial Suite, INSIGHT.	15,478	2.10
Allscripts	ECLIPSYS, TOUCHWORKS, EPSI, HealthVision, Professional EHR	14,785	2.01

MedHost	Healthcare Management Systems (HMS), EDMS, E-forms, HMS PACS, Clinical View	14,203	1.93
Self Developed	Self Developed	13,197	1.79
HEALTHLAND	HEALTHCARE INFORMATION SYSTEM, Centriq, APS HOSPITAL SYSTEM, CLARUS	12,273	1.67
3M Health IS	CODEFINDER, CHARTLOCATOR, CHARTSCRIPT, health data management system	10,638	1.44
Philips Healthcare	STENTOR, INC./ISITE, XCELERA, CALYSTO CARDIAC CATH, OB TRACEVUE	7,883	1.07

Note. The rest proportion is less than one percent for other Software Vendors.

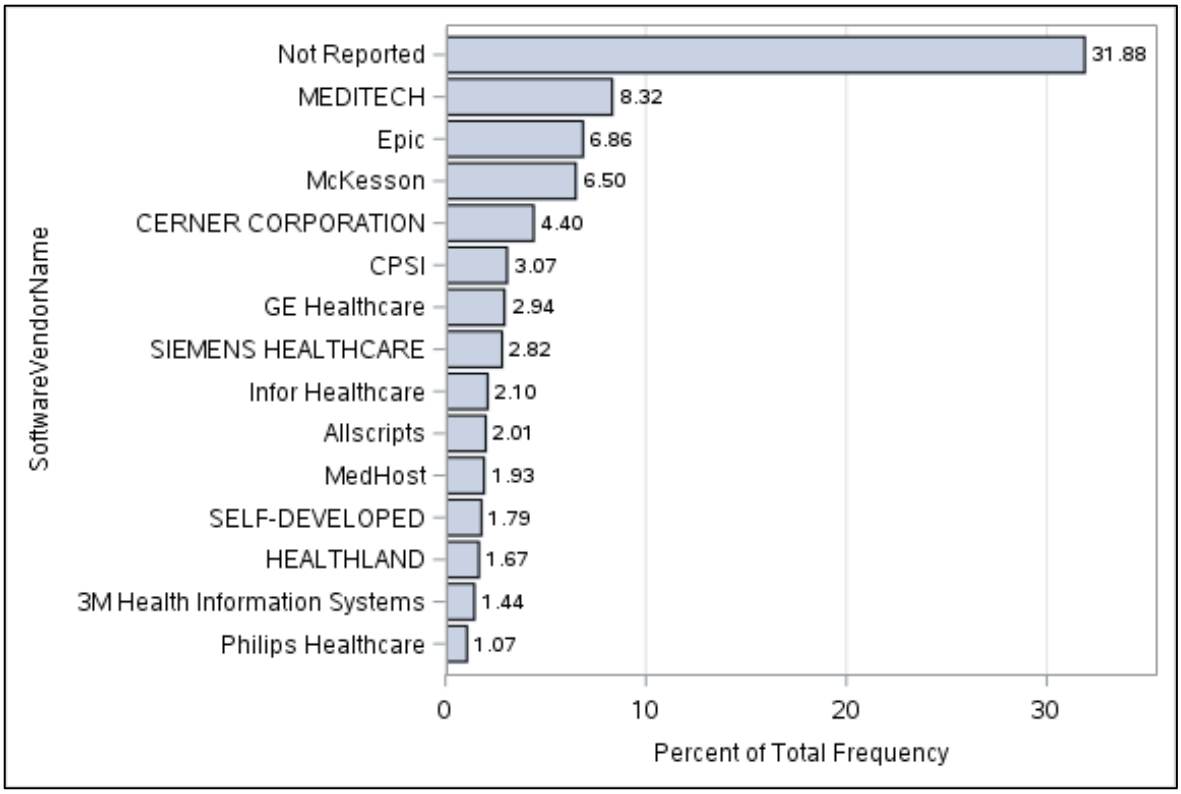


Figure 9: Top Software Vendors Used*, (HIMSS 2013 Dataset)

Table 8 lists the most used software Vendor's Product utilized in healthcare providers; this list includes vendors providing all different type of Health IT systems. There are about 38% of the observations "Not Reported" which is more than the 31% in the Vendor's Name list, which is because some of the observations report Vendor's Name without providing the Product name of the vendors, and that explains the difference in the percentage.

Table 8.
Top Software Vendor's Products Used (HIMSS 2013 Dataset)

Category	Frequency	Percentage
MILLENNIUM	27,244	6.00
MAGIC	23,039	5.08
SYSTEM 2000	21,667	4.77
HORIZON	21,621	4.76
CLIENT SERVER	21,483	4.73
EPICCARE	15,343	3.38
CENTRICITY	14,551	3.21
HEALTHCARE MANAGEMENT SYSTEMS, INC./HMS	13,237	2.92
SELF-DEVELOPED	13,196	2.91
MEDITECH 6.0	11,359	2.50
HEALTHCARE INFORMATION SYSTEM	9,482	2.09

Note. "Not Reported" was excluded

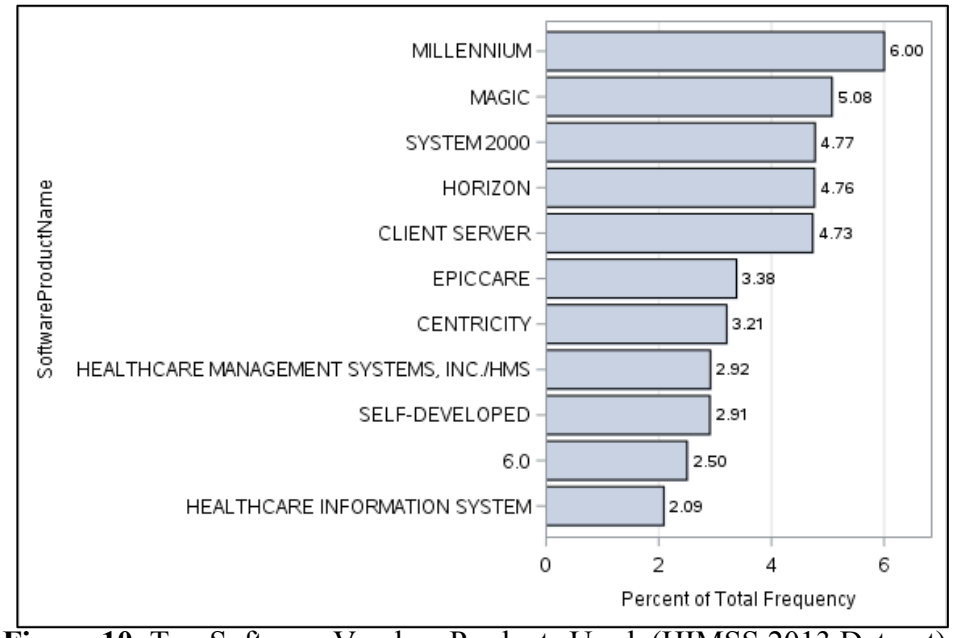


Figure 10: Top Software Vendors Products Used, (HIMSS 2013 Dataset)

4.3 Healthcare Provider's Characteristics HIMSS 2013 Dataset

The data in the table that describes the demographics of the healthcare provider had to be filtered, since it contains all different "Status" of the health IT system. The filtering done by selecting only "Live and Operational, Contracted/Not Yet Installed, Installation in Process and Not Yet Contracted" while excluding "Not Automated, Service Not Provided, Not Reported and To be Replaced". Some of the characteristics, which were analyzed, include "ownership Status, facility type and description of the facility primary service provided". See Tables 9, 10 and 11.

Table 9.
Ownership Status (HIMSS 2013 Dataset)

Status	Frequency	Percentage
Owned	40,677	96.24
Managed	1,079	2.55
Leased	345	0.82

Note. Frequency Missing = 164, (0.39%)

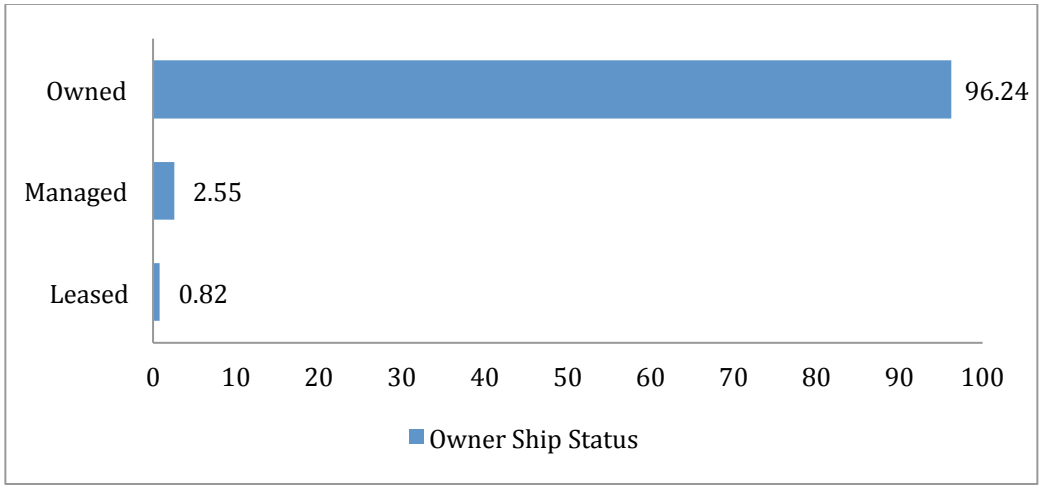


Figure 11: Ownership Status, (HIMSS 2013 Dataset)

Table 10.
Healthcare Provider Type (HIMSS 2013 Dataset)

Provider Type	Frequency	Percentage
Hospital	368963	74.15
Ambulatory	66114	13.29
Sub-Acute	56897	11.43
Home Health	4464	0.90
Free Standing Data Center	1139	0.23

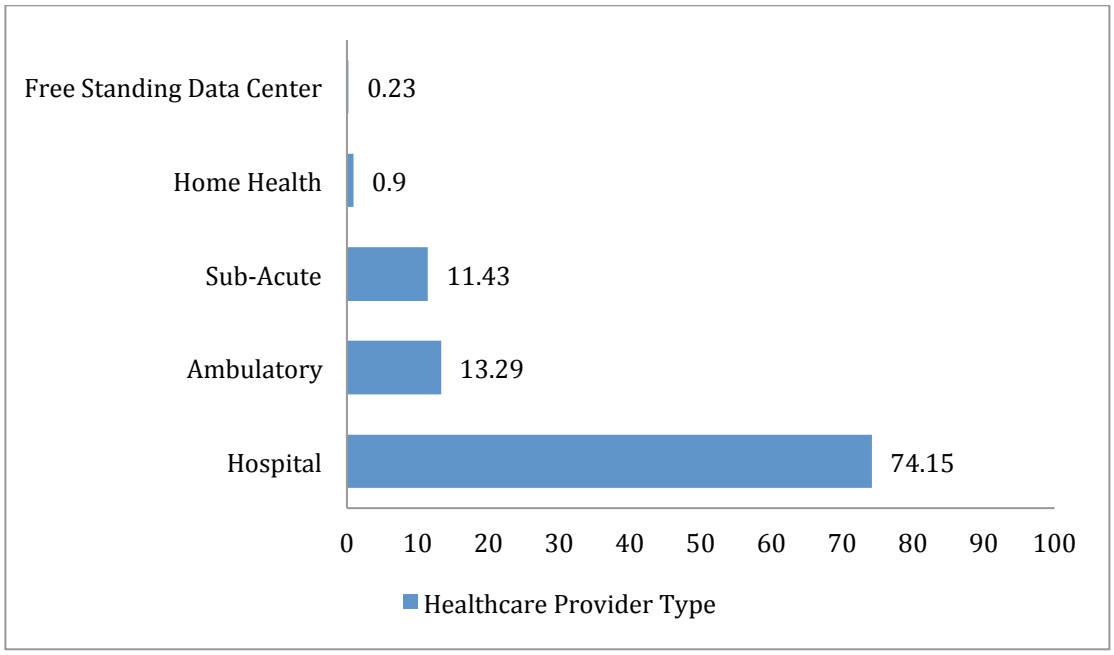


Figure 12: Healthcare Provider Type, (HIMSS 2013 Dataset)

Table 11.
Primary Service (HIMSS 2013 Dataset)

Category	Frequency	Percentage
General Medical & Surgical	237819	47.80
Critical Access	73578	14.79
Long Term Acute	18204	3.66
Academic	17917	3.60
Long Term Care	12622	2.54
Skilled Nursing	11848	2.38
Family Practice	11803	2.37
Pediatric	10285	2.07
Rehabilitation	9205	1.85
Behavioral Health	6961	1.40
Other Specialty	6173	1.24
Multi-Specialty Clinic	6080	1.22
Psychiatric	5731	1.15

Note. Frequency Missing = 1139, Others = 68212, (13.94%)

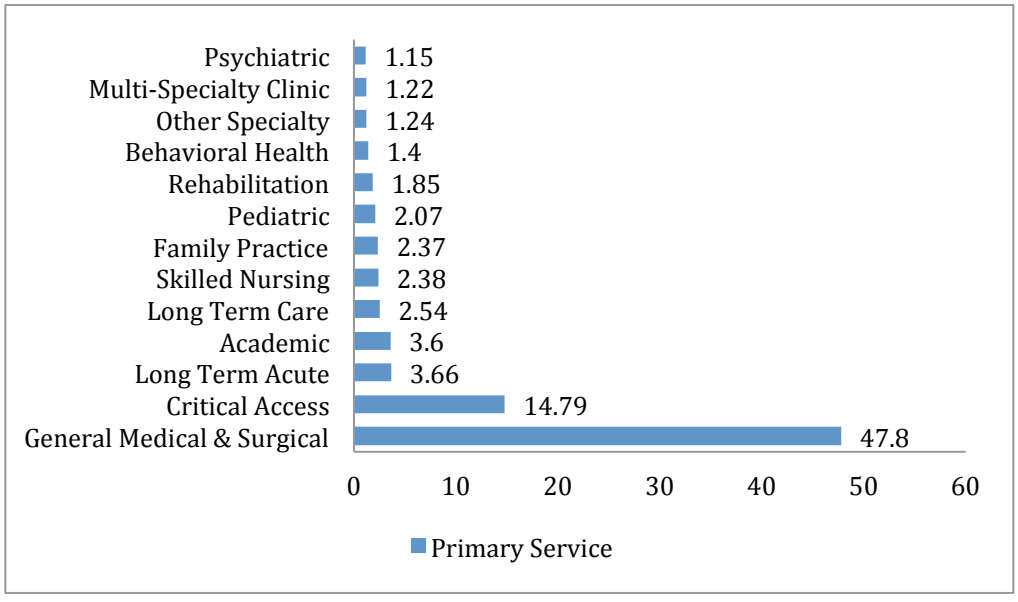


Figure 13: Healthcare Primary Service, (HIMSS 2013 Dataset)

4.4 Open Source Health IT Systems

There were more than hundred applications identified from the literature and open source projects repository such as "SourceForge.net." These systems used in the U.S. and worldwide. See Table 12.

Table 12. Open Source Projects

3D Slicer	Epi Info	iRad	OpenVista
Ambulatorio - Web based outpatients managing software	epispider	ITK-SNAP Medical Image Segmentation Tool	OphMedRecords - Simple Ophthalmic Medical Records Archive
AMIDE	ESPnet	Kareo EHR	Orthanc
ANTS	Eviewbox DICOM	kradview	OSCAR McMaster
Bika LIMS	ezDICOM	LOINC - Database	OSHIP - Open Source Health Information Platform
Bio-Knoppix	fEMR - free EMR, Haiti	MARiS - Radiological OpenSource Project	OsiriX - DICOM Viewer
Bio-Linux	FFEHR	MedConsult - Medical Consultation & Electronic Medical Records Software	ParaView
BioImageXD	FreeLIMS	MEDILIG	Patient Runner
BioSLAX	FreeMED	MedinTux	PatientOS
BloodBank - A BloodBank Administration Software	FreeMedForms	MicroDicom	PHP-Nuke Healthcare
caisis	GaiaEHR	MiniWEBPACS	PHYAURA EHR
CARE2X - Integrated Hospital Info System	GELLO	MirrorMed	Practice Fusion
CDMedic PACS	GIMIAS - Graphical Interface for Medical Image Analysis and Simulation	Mirth Connect	Res Medicinae - Alpha Applications for use in Medicine
Chikitsa - Patient Management System	Ginkgo CADx	MITK - The Medical Imaging Interaction Toolkit	rMayamSVN - DICOM workstation in Java
CHITS - Community Health Information Tracking System	GNU Health	MITO - MEDICAL IMAGING TOOLKIT - DICOM Viewer	SAGUISaude
ClearCanvas	GNUmed	Mountain Meadow Medical Records M	SmartCare - Electronic Health Record system (EHR), Zambia

ClearHealth	Grassroots DICOM	NHapi project	Tapeworm Health Profiler
ClinicWeb	HAPI - HL7 application programming interface	O3-DPACS	Tempo
CottageMed	HealthForge	O3-RWS	THIRRA
dcm4che	Hello Health	ODIN - A free open source disk imager	Tolven Healthcare
Debian Med	HIEOS - HEALTH INFORMATION EXCHANGE OPEN SOURCE	Office Manager	TORCH
DHIS	HL7 Inspector	Ogles2	Transparent Health
Dicom Open Viewer	Hospital Management System	OIO - Open Infrastructure for Outcomes	trilonis-mc
dicom4j	Hospital OS	Open Dental	Ubuntu-Med
DicomRouter	HOSxP	Open Hospital	Ultimate EMR
DNALinux	HRHIS - Human Resource for Health Information System	Open PatientOS	Virtual PACS
DVTk (DICOM, HL7, IHE)	IHE open source	Open-LIMS	VistA
e-Svaasthya - Open source hospital information system from CDAC, Mumbai	iHRIS Suite	OpenClinic GA	Voreen
EDFbrowser	ImLib3D	OpenClinica	VTK Visualization Toolkit
EHRflex	Indivo	OpenEMed	WebEMS
elementalClinic	InfluSim	OpenEMR	World VistA
Elexis Praxisprogramm - An Eclipse RCP program for all aspects of a (Swiss) medical practice	Insight Toolkit	OpenHRE - Open Source Health Record Exchange	Xebra
Endrov	InVesalius	openMEDIS	Zephyr Open
	iPath Telemedicine Platform	OpenMRS	ZEPRS
		OpenTAPAS	Zyxware Health Monitoring System

The highlighted projects from the above table are the only open source systems identified in the Datasets, 14 systems namely (VistA, World VistA, Open Dental, OpenVista, OpenEMR, Mirth Connect, GaiaEHR, BloodBank, Kareo, PHYAURA, Tolven, Hello Health, Clear Health, and Practice Fusion). “Practice Fusion” software is a “Free” application and it is Not Open Source.

4.5 Open Source Statistics from HIMSS 2013

The dataset of the Open Source System (OSS) includes different application associated with EHR systems, such as Computerized Practitioner Order Entry (CPOE), Clinical Decision Support System (CDSS), Physician Documentation, etc.) See Table 13.

Table 13.
OSS Applications (HIMSS 2013 Dataset)

Application	Frequency	Percent	Application	Frequency	Percent
Interface Engines	57	15.75	Radiology Information System	8	2.21
Health Information Exchange (HIE)	46	12.71	Document Management	6	1.66
Ambulatory EMR	29	8.01	Laboratory Information System	6	1.66
Practice Management	26	7.18	Abstracting	4	1.10
Nursing Documentation	19	5.25	Microbiology	4	1.10
Clinical Data Repository	18	4.97	OR Scheduling	4	1.10
Clinical Decision Support System (CDSS)	17	4.70	Physician Portal	4	1.10
Computerized Practitioner Order Entry (CPOE)	17	4.70	ADT/Registration	2	0.55
Order Entry (Includes Order Communications)	16	4.42	Anatomical Pathology	2	0.55
Physician Documentation	15	4.14	Blood Bank	2	0.55
Electronic Medication Administration Record	13	3.59	Chart Deficiency	2	0.55
Emergency Department Information System (EDIS)	10	2.76	Chart Tracking/Locator	2	0.55
Medication Reconciliation Software	10	2.76	Oncology Information System	2	0.55
Pharmacy Management System	10	2.76	Operating Room (Surgery) - Post-Operative	2	0.55

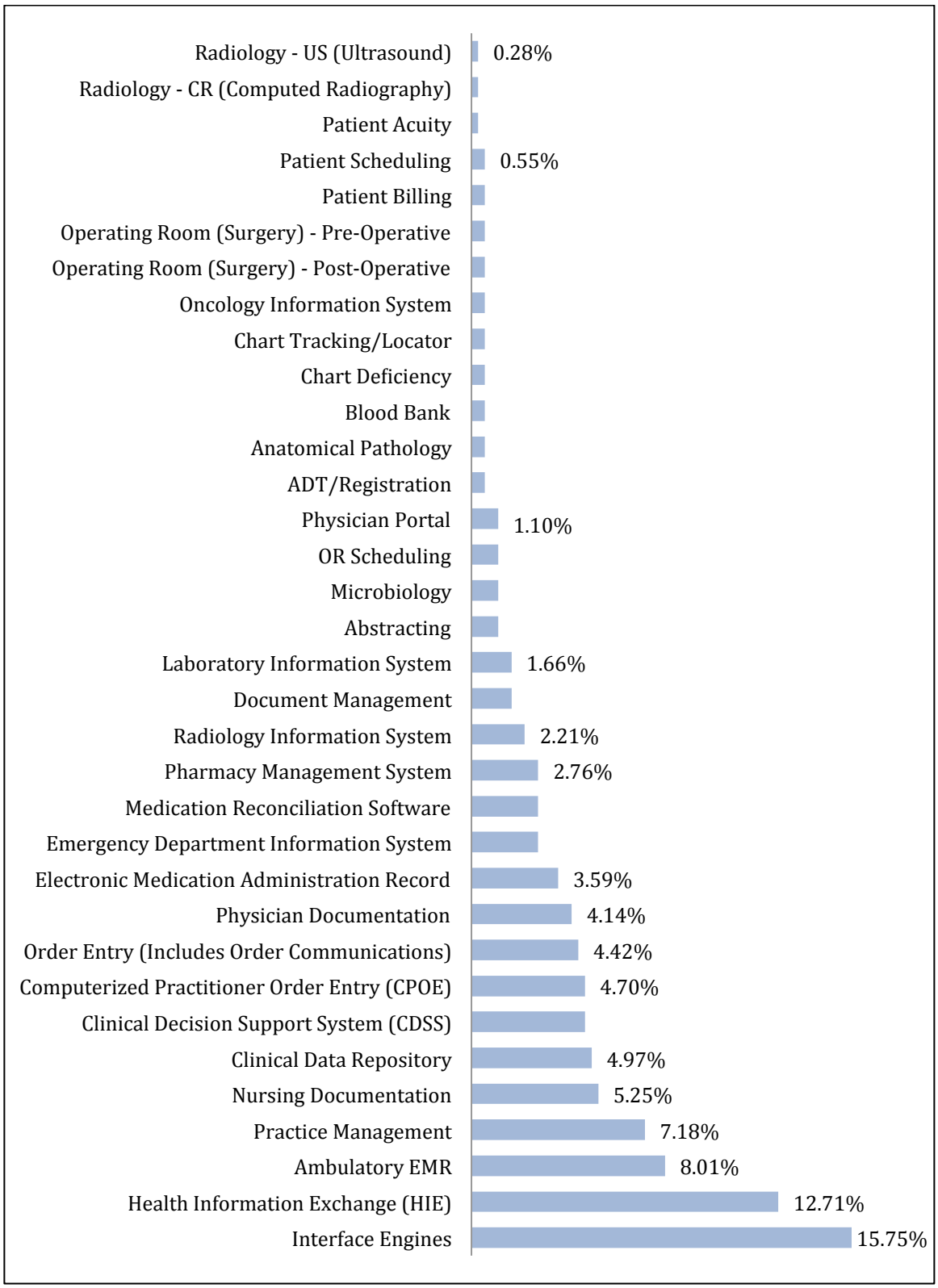


Figure 14: OSS Applications, (HIMSS 2013 Dataset)

Tables 14, 15 list the Status and Category for the OSS.

Table 14.
Status of OSS (HIMSS 2013 Dataset)

Status	Frequency	Percentage
Live and Operational	329	90.88
Installation in Process	20	5.52
Contracted/Not Yet Installed	11	3.04
Not Yet Contracted	1	0.28
To be Replaced	1	0.28

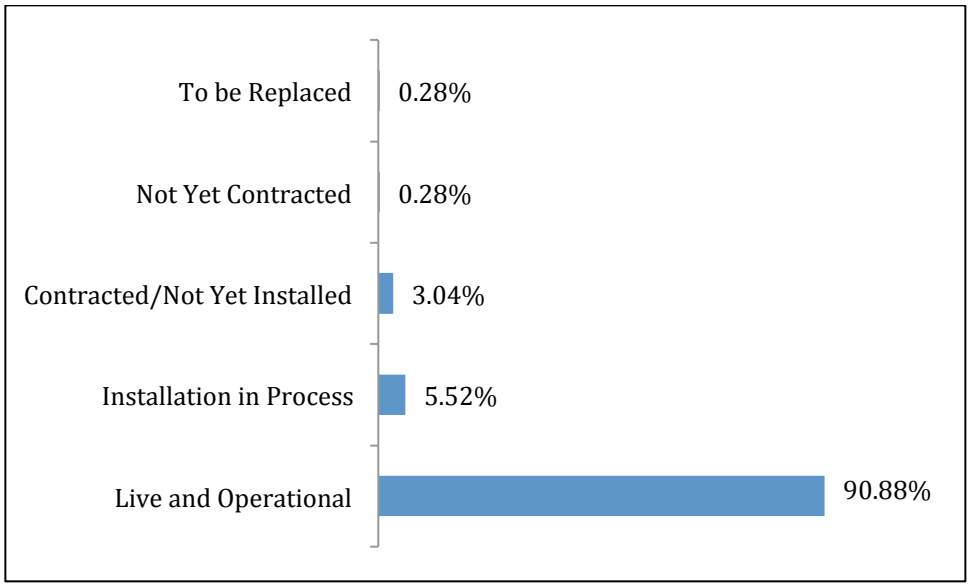


Figure 15: Status of OSS Applications, (HIMSS 2013 Dataset)

Table 15.
Category of OSS (HIMSS 2013 Dataset)

Category	Frequency	Percentage
Electronic Medical Record	87	24.03
IS Infrastructure	57	15.75
Ambulatory	55	15.19
Health Information Exchange (HIE)	46	12.71
Nursing	43	11.88
Clinical Systems	20	5.52
Laboratory	14	3.87
Pharmacy	10	2.76
Radiology & PACS	10	2.76
Health Information Management (HIM)	8	2.21
Document/Forms Management	6	1.66
Revenue Cycle Management	6	1.66

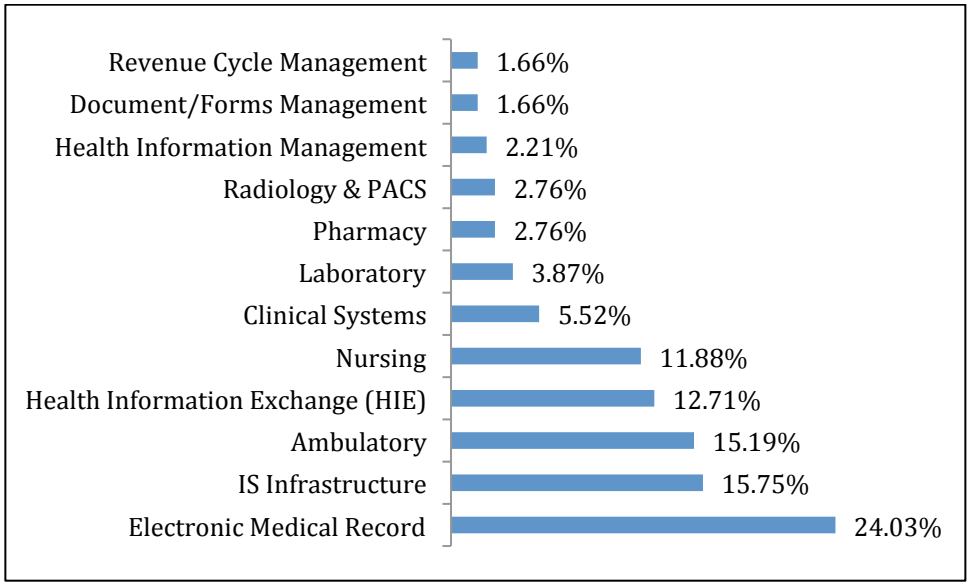


Figure 16: Categories of OSS Applications, (HIMSS 2013 Dataset)

4.6 Open Source Vendors and Products Distribution

Tables 16, 17 and 18 list the frequency of each OSS application in the dataset.

Table 16.
OSS Software Vendors (HIMSS 2013 Dataset)

Software Vendor Name	Frequency	Percentage
MEDSPHERE SYSTEMS CORPORATION	154	42.54
QUALITY SYSTEMS, INC.	107	29.56
WorldVistA	69	19.06
DEPARTMENT OF VETERANS AFFAIRS	24	6.63
BLOOD BANK COMPUTER SYSTEMS, INC.	2	0.55
Document Storage Systems (DSS)	2	0.55
INDIAN HEALTH SERVICES	2	0.55
Practice Fusion	2	0.55

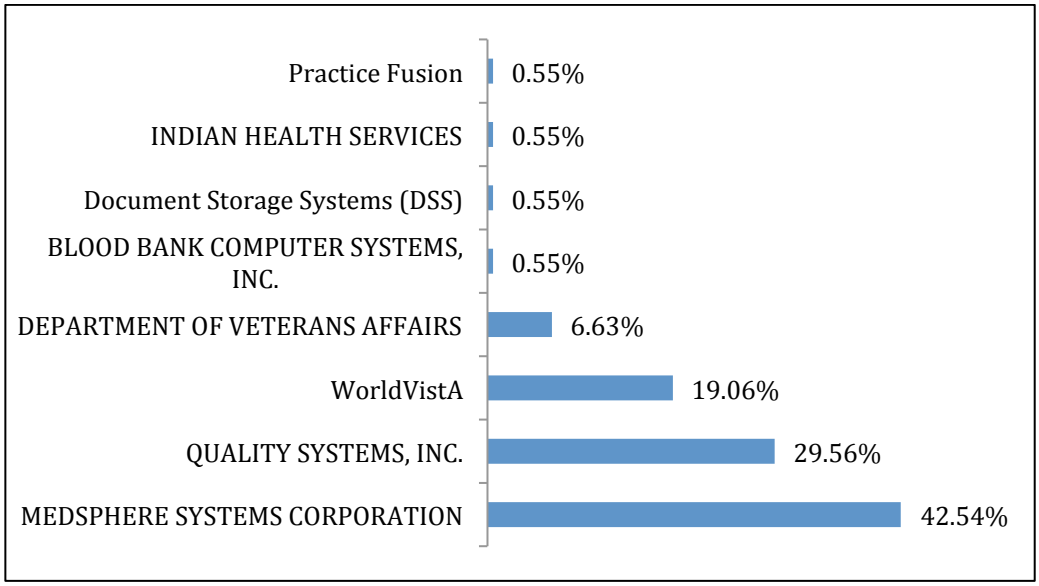


Figure 17: OSS Software Vendors, (HIMSS 2013 Dataset)

Table 17.
OSS Software Products (HIMSS 2013 Dataset)

Software Product Name	Frequency	Percentage
OPENVISTA	154	42.54
MIRTH	105	29.01
WorldVistA	69	19.06
VistA	26	7.18
BLOOD BANK CONTROL SYSTEM	2	0.55
Practice Fusion EHR/EMR	2	0.55
THE POSEIDON GROUP, INC. /NAVIGATOR	2	0.55
VISTA IMAGING	2	0.55

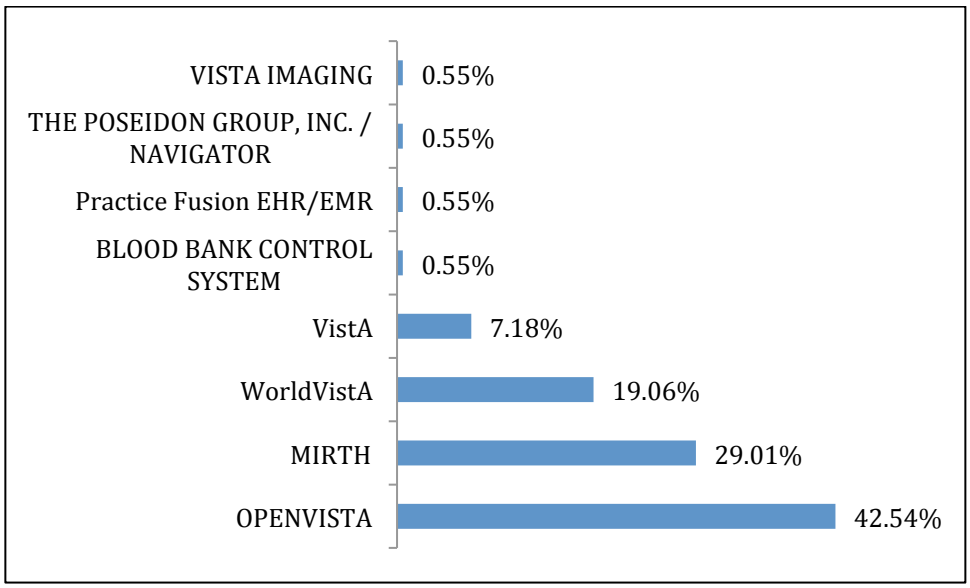


Figure 18: OSS Software Products, (HIMSS 2013 Dataset)

Table 18.
List the OSS Software Product Grouped by Vendors

OSS Software Product Grouped by Vendors	Total	Percentage
MEDSPHERE SYSTEMS CORPORATION	154	42.54
Not Reported	7	4.55
OPENVISTA	147	95.45
QUALITY SYSTEMS, INC.	107	29.56
MIRTH	103	96.26
Not Reported	2	1.87
THE POSEIDON GROUP, INC. /NAVIGATOR	2	1.87
WorldVistA		
WorldVistA	69	19.06
DEPARTMENT OF VETERANS AFFAIRS		
VistA	24	6.63
BLOOD BANK COMPUTER SYSTEMS, INC.		
BLOOD BANK CONTROL SYSTEM	2	0.55
Document Storage Systems (DSS)		
VistA	2	0.55
INDIAN HEALTH SERVICES		
VISTA IMAGING	2	0.55
Practice Fusion		
Practice Fusion EHR/EMR	2	0.55

Tables 19, 20 List some of the OSS provider's characteristics such as Type and Primary service.

Table 18.
Provider Type using OSS, (HIMSS 2013 Dataset)

Provider Type	Frequency	Percent
Hospital	121	76.10
Ambulatory	32	20.13
Sub-Acute	5	3.14
Free Standing Data Center	1	0.63

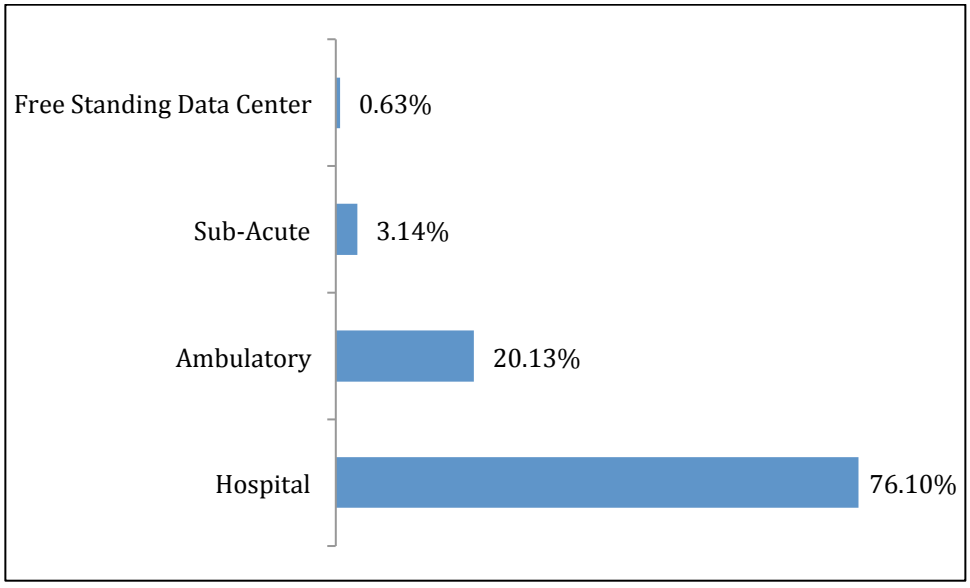


Figure 19: Provider Type using OSS, (HIMSS 2013 Dataset)

Table 20.
Primary service using OSS, (HIMSS 2013 Dataset)

Type	Frequency	Percent	Type	Frequency	Percent
General Medical Surgical	76	48.10	Nephrology	1	0.63
Critical Access	33	20.89	Ophthalmology	1	0.63
Academic	8	5.06	Physical Therapy	1	0.63
Family Practice	5	3.16	Podiatry	1	0.63
Diagnostic Imaging Center	4	2.53	Primary Care	1	0.63
Pediatric	4	2.53	Psychiatric	1	0.63
General Medical	2	1.27	Pulmonary Care	1	0.63
Internal Medicine	2	1.27	Rehab Skilled Nursing	1	0.63
Long Term Care	2	1.27	Skilled Nursing	1	0.63
Multi-Specialty Clinic	2	1.27	Wound Care	1	0.63
Oncology	2	1.27	Nephrology	1	0.63
Rehabilitation	2	1.27	Ophthalmology	1	0.63
Women's Health	2	1.27	Physical Therapy	1	0.63
Anticoagulation Center	1	0.63	Podiatry	1	0.63
Cardiology	1	0.63	Primary Care	1	0.63
Diabetes Center	1	0.63	Psychiatric	1	0.63
Gastroenterology	1	0.63	Pulmonary Care	1	0.63

Note. Frequency Missing = 1

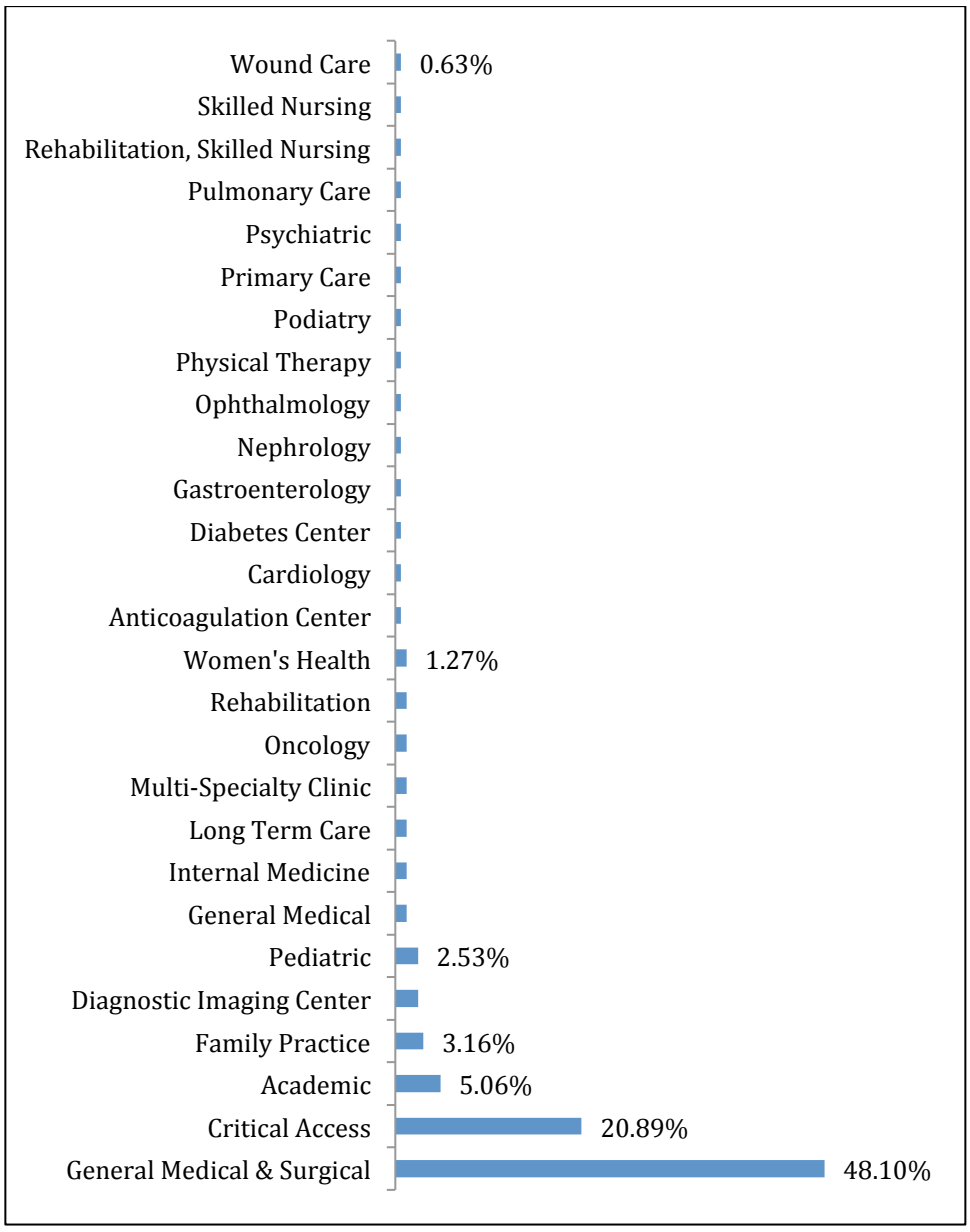


Figure 20: Primary service using OSS, (HIMSS 2013 Dataset)

4.7 Open Source Statistics from HIMSS 2008 - 2013

There are a growing number of open source applications each year. However, this figure is still low comparing with proprietary applications. Table 21 illustrate numbers of open source applications being used starting from 2008 to 2013.

Table 21.
List of OSS Software, (HIMSS 2008-2013 Dataset)

Software Product Name	2008	2009	2010	2011	2012	2013
OPENVISTA	87	80	138	176	177	154
VISTA	16	14	23	34	18	42
MIRTH	7	13	17	26	38	105
BLOOD BANK SYSTEM	2	4	4	3	3	2
World VistA	-	-	-	-	43	69
Practice Fusion EHR/EMR	-	-	-	-	6	2
Kareo Medical Software	-	-	-	-	6	8

Note. "Practice Fusion" is a Free software not open source

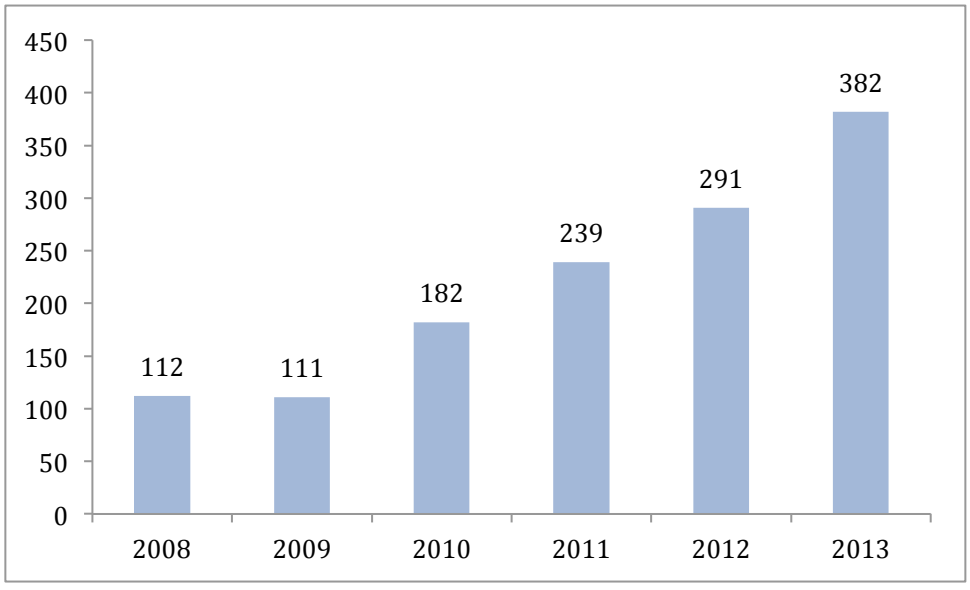


Figure 21: OSS Software, (HIMSS 2008 - 2013 Dataset)

4.8 Meaningful Use Dataset

There are more than 300,000 healthcare providers who attested over million attestations in the dataset for the meaningful use incentives. Only 2 percent of these attestations used open source EHRs (19850 applications). Also, there was a free application "Practice Fusion" having the major portion of that percentage (1.81%).

Table 22 and 23 list the frequency of each Vendor and EHR application in the dataset. Table 24 lists the frequency of each OSS application in the dataset.

Table 22.
Top Software Vendor's Products Used (Meaningful Use Dataset)

Category	Frequency	Percentage
Epic Systems Corporation	194921	18.88
Cerner Corporation	140238	13.58
Allscripts	101797	9.86
GE Healthcare	56173	5.44
eClinicalWorks LLC	52812	5.11
NextGen Healthcare	51484	4.99
Greenway Health LLC	31394	3.04
Intermountain Healthcare	30656	2.97
McKesson	24960	2.42
Athenahealth Inc	21500	2.08
Practice Fusion	18719	1.81
MEDITECH	16296	1.58

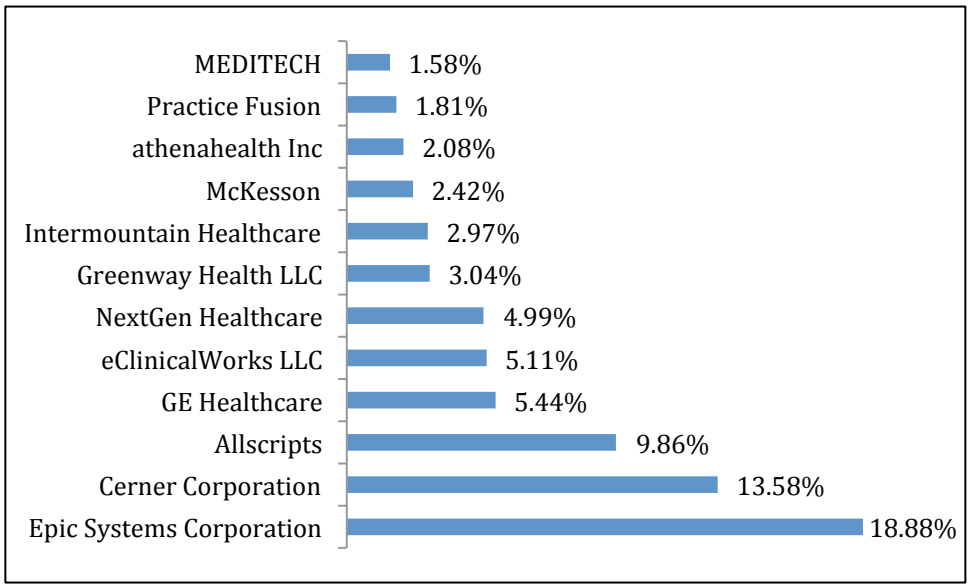


Figure 22: Top Software Vendor's Products Used (Meaningful Use Dataset)

Table 23.
Top EHRs Software Used (Meaningful Use Dataset)

Category	Frequency	Percentage
EpicCare Ambulatory - Core EMR	110233	10.68
EpicCare Ambulatory 2014 Certified EHR Suite	65758	6.37
eClinicalWorks	52796	5.11
NextGen Ambulatory EHR	50792	4.92
HealthSentry	44302	4.29
Allscripts Professional EHR	27725	2.68
Centricity EMR	24747	2.4
athenaClinicals	21497	2.08
Allscripts Enterprise EHR	19858	1.92
Practice Fusion	18719	1.81
HELP2 Clinical Desktop	17558	1.7
Allscripts Enterprise EHR (Complete)	15684	1.52
PrimeSuite	14000	1.36

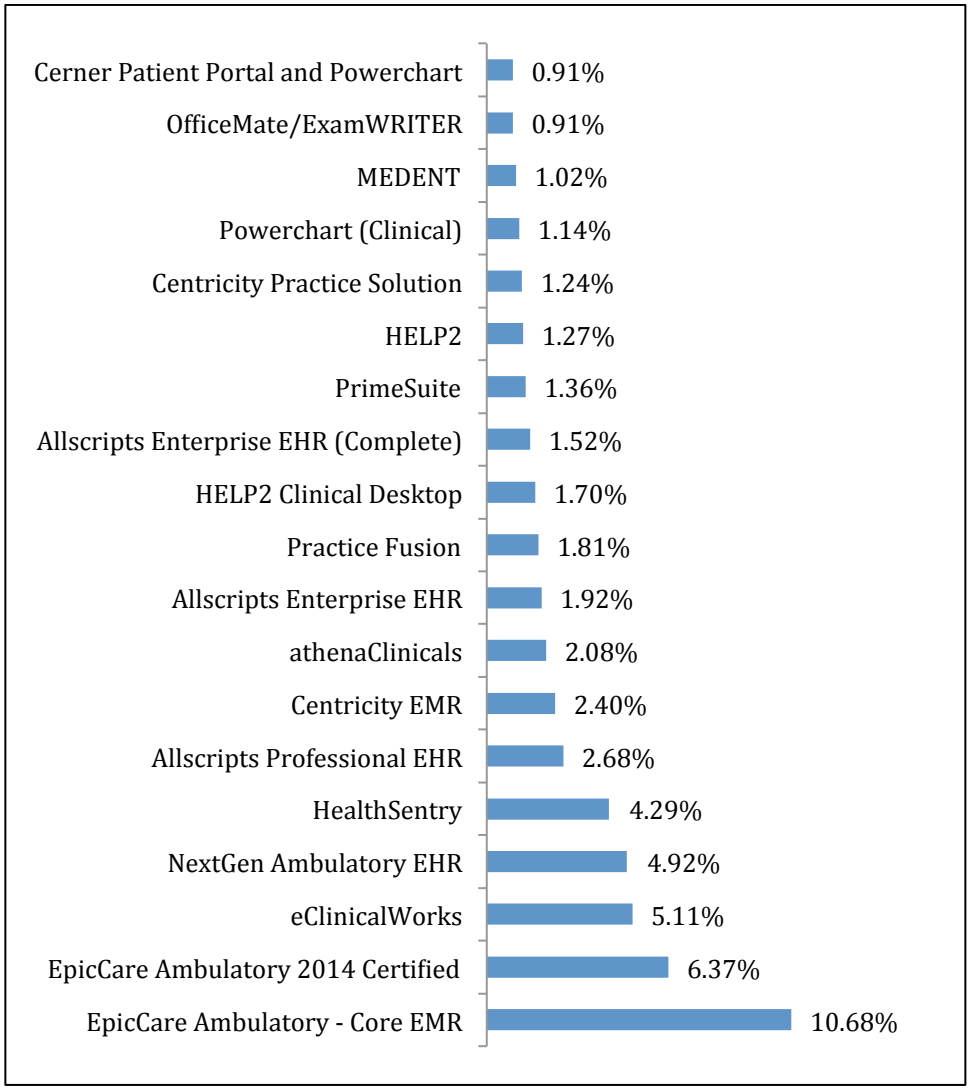


Figure 23: Top EHRs Software Used (Meaningful Use Dataset)

Table 24.
OSS Software Products (Meaningful Use Dataset)

Software Product Name	Frequency	OSS Percentage	Total Percentage
Kareo EHR	458	41.49	0.0444
OpenEMR	421	38.13	0.0408
OpenVista	61	5.53	0.0059
Hello Health	53	4.80	0.0051
ZHOpenEMR	51	4.62	0.0049
WorldVistA	27	2.45	0.0026
VistA	19	1.72	0.0018
ClearHealth	4	0.36	0.0004
Mirth Connect	4	0.36	0.0004
PHYAURA EHR	4	0.36	0.0004
Tolven	2	0.18	0.0002

Note. "Practice Fusion" is a Free software not open source; it has frequency of 18719 that accounted for 1.813 of the total percentage.

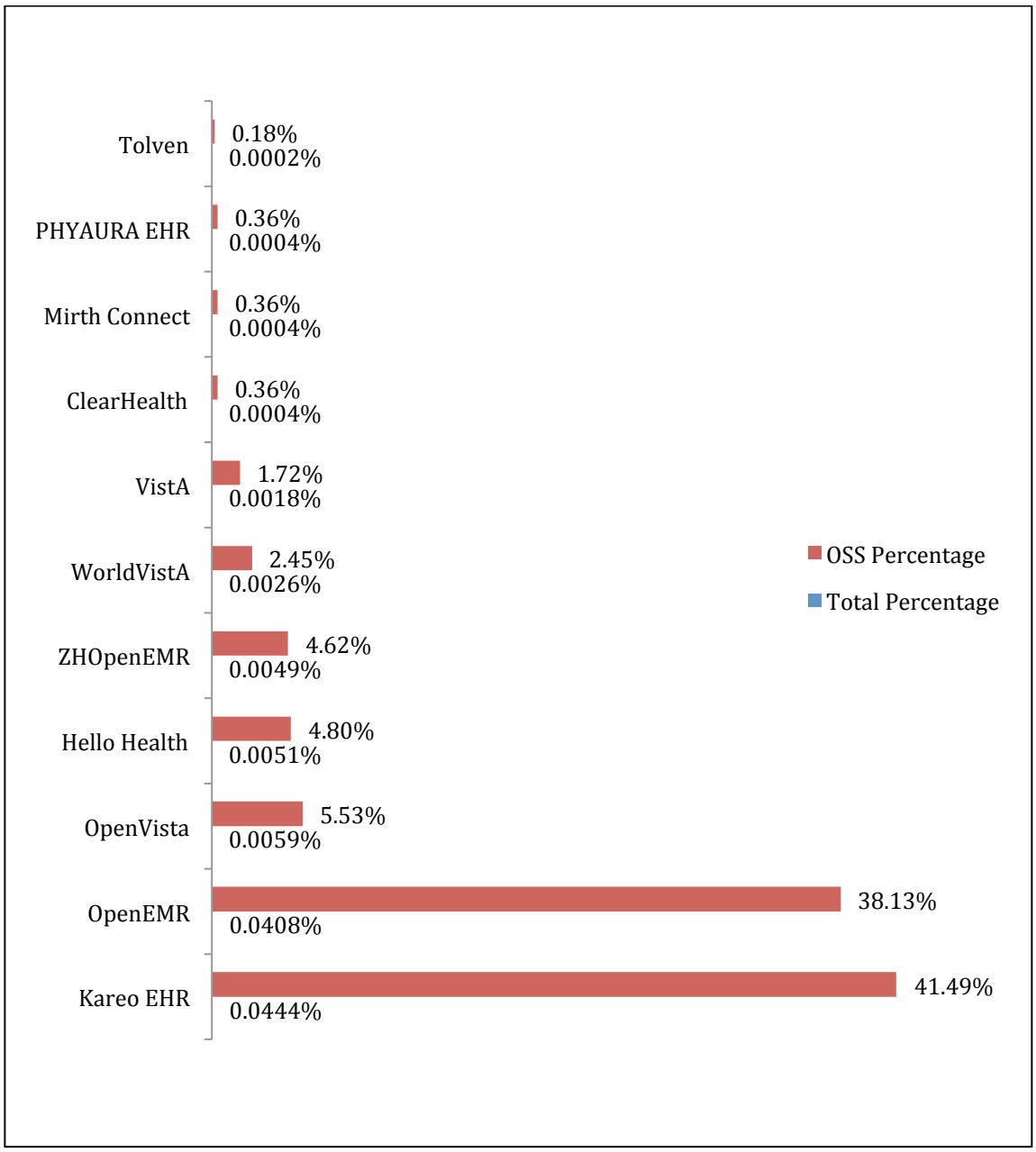


Figure 24: Top OSS Software Products (Meaningful Use Dataset)

Table 25 lists the provider type, whether the provider is an eligible professional (EP) or an eligible hospital (Hospital). Table 26 lists the provider stage number, the Stage of Meaningful Use that the provider attested to (Stage 1/Stage 2). Table 27 lists the program type, whether the provider attested under the Medicare or Medicare/Medicaid EHR Incentive Program. Table 28 lists the product setting, Ambulatory or Inpatient. Table 29 lists the product classification, Complete or Modular. Whereas "Complete" products meet all the Meaningful Use (MU) requirements, and "Modular" products meet one or more of the MU requirements but not all. Table 30 lists the specialty of the eligible professional who attested.

Table 25.
Provider Type (Meaningful Use Dataset)

Status	Frequency	Percentage
Eligible Professional (EP)	969247	93.86
Hospital	63380	6.14

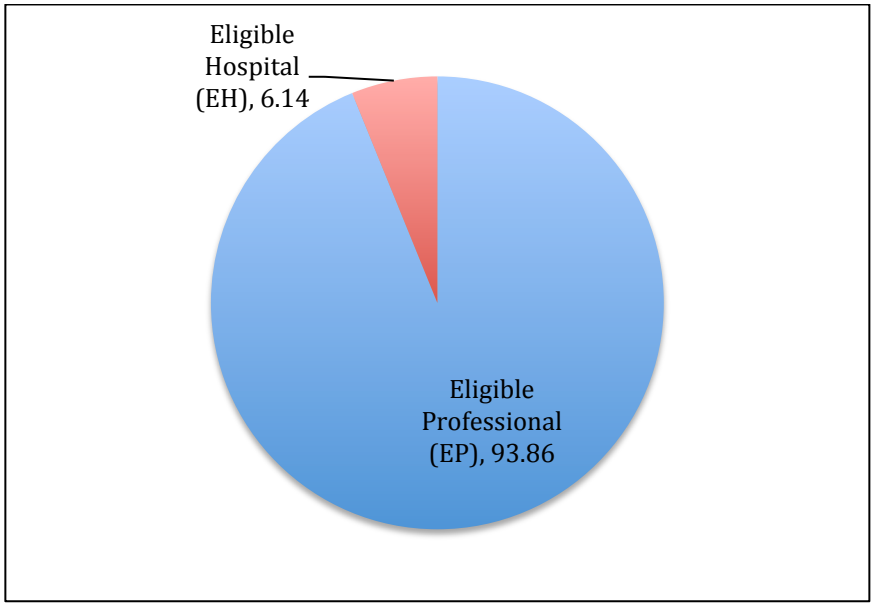


Figure 25: Provider Type (Meaningful Use Dataset)

Table 26.
Provider Attesting Stage Number (Meaningful Use Dataset)

Attesting Stage	Frequency	Percentage
Stage 1	937382	90.78
Stage 2	95245	9.22

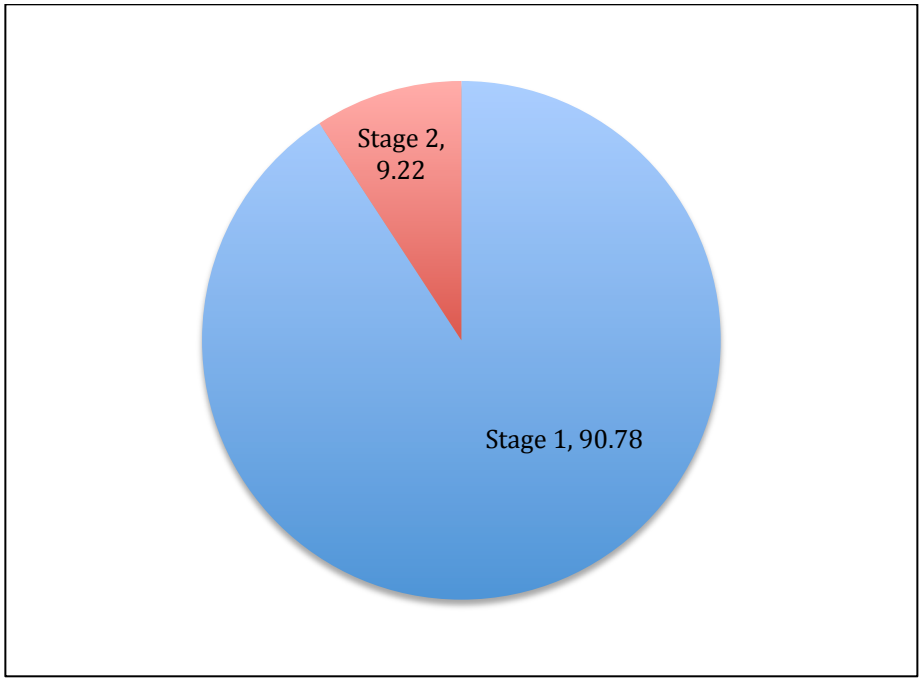


Figure 26: Provider Attesting Stage Number (Meaningful Use Dataset)

Table 27.
Program Type (Meaningful Use Dataset)

Status	Frequency	Percentage
Medicare	972409	94.17
Medicare/Medicaid	60218	5.83

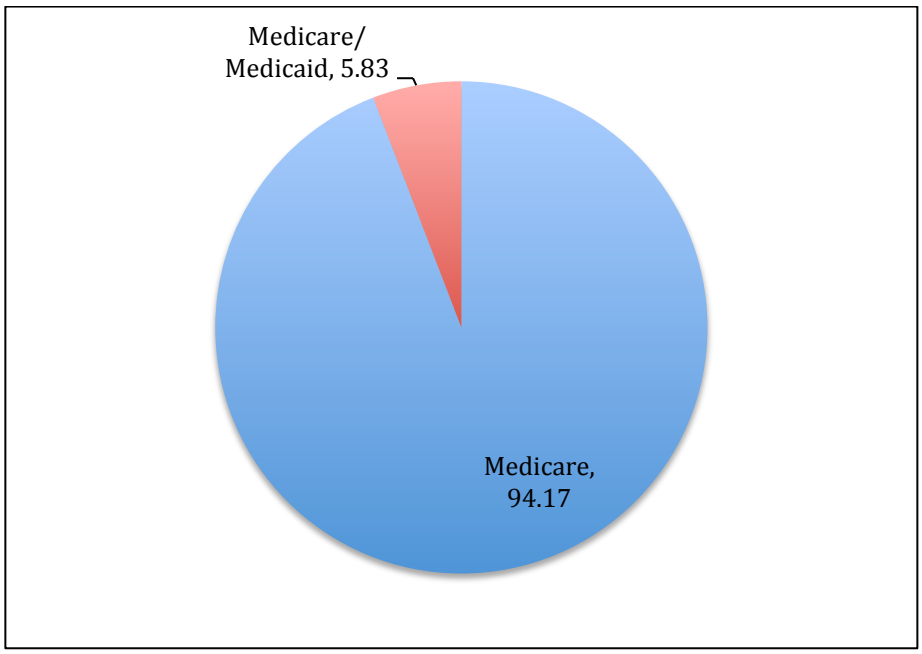


Figure 27: Program Type (Meaningful Use Dataset)

Table 28.
Product Setting (Meaningful Use Dataset)

Provider Type	Frequency	Percentage
Ambulatory	936152	90.66
Inpatient	96475	9.34

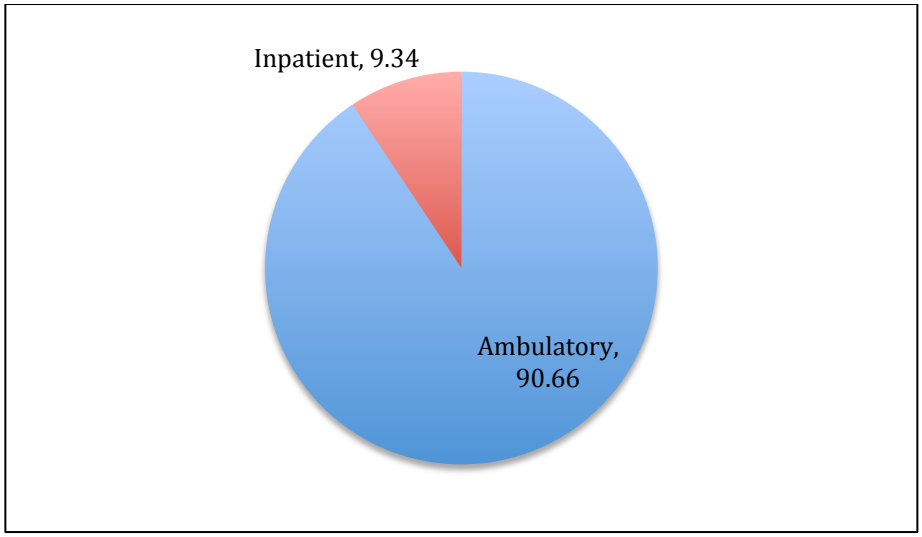


Figure 28: Product Setting (Meaningful Use Dataset)

Table 29.
Product Classification (Meaningful Use Dataset)

Status	Frequency	Percentage
Complete EHR	766913	74.27
Modular EHR	265714	25.73

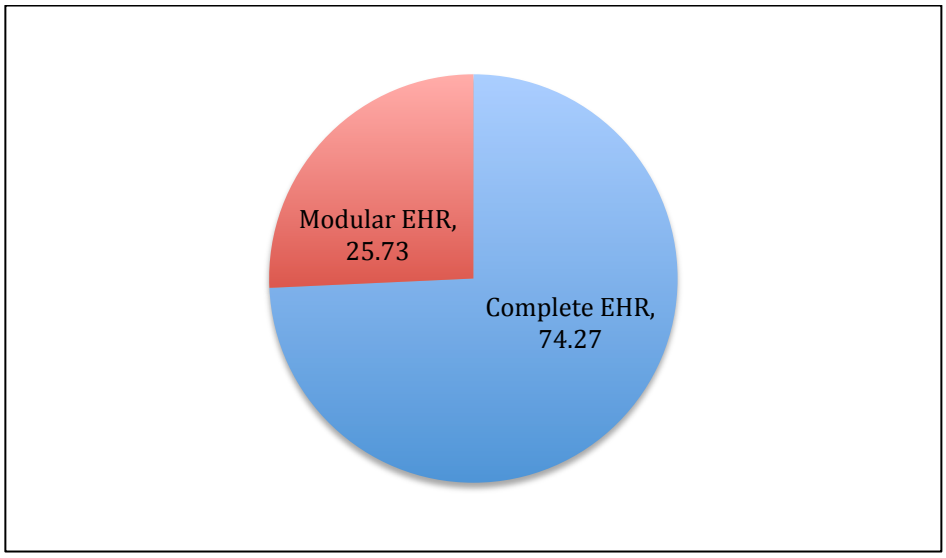


Figure 29: Product Classification (Meaningful Use Dataset)

Table 30.
The specialty of the eligible professional who attested (Meaningful Use Dataset)

Application	Frequency	Percent	Application	Frequency	Percent
UNKNOWN	341494	33.07	UROLOGY	15677	1.52
FAMILY PRACTICE	107250	10.39	PULMONARY DISEASE	14057	1.36
INTERNAL MEDICINE	97336	9.43	DERMATOLOGY	12757	1.24
N/A	63380	6.14	OTOLARYNGOLOGY	12188	1.18
CARDIOVASCULAR DISEASE (CARDIOLOGY)	37110	3.59	HEMATOLOGY/ONCOLOGY	12104	1.17
ORTHOPEDIC SURGERY	28345	2.74	DIAGNOSTIC RADIOLOGY	11762	1.14
OBSTETRICS/Gynecology	26713	2.59	NEPHROLOGY	11294	1.09
OPTOMETRY	24359	2.36	ENDOCRINOLOGY	8544	0.83

GASTROENTEROLOGY	22248	2.15	ANESTHESIOLOGY	7643	0.74
GENERAL SURGERY	22190	2.15	RHEUMATOLOGY	7166	0.69
PODIATRY	20237	1.96	PHYSICAL MEDICINE AND REHABILITATION	6976	0.68
OPHTHALMOLOGY	18499	1.79	PSYCHIATRY	6255	0.61
NEUROLOGY	18358	1.78	NEUROSURGERY	4972	0.48
CHIROPRACTIC	17645	1.71	INFECTIOUS DISEASE	4426	0.43

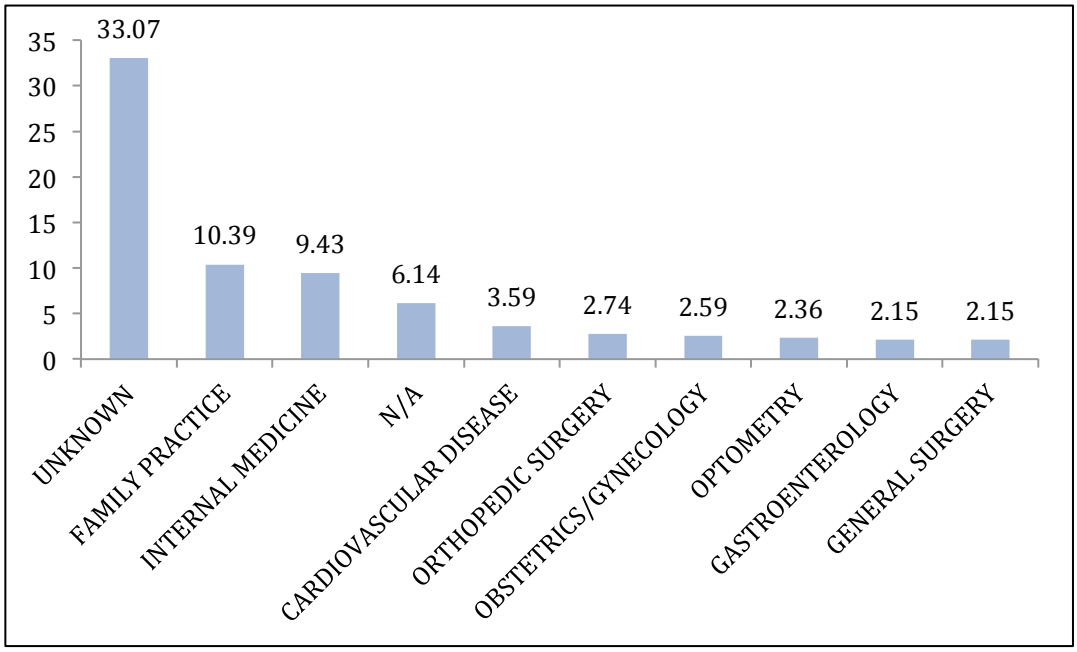


Figure 30: Top specialties of eligible professional attested (Meaningful Use Dataset)

4.9 Regional Extension Centers (RECs) Dataset

This dataset contains data form all providers enrolled with a Regional Extension Center (REC). The most recent data is from the year 2013. There are more then 360 vendors of Health IT systems in the dataset that includes both types, Open Source, and Proprietary systems. The dataset has more than 29,000 healthcare practices having over 145,000 healthcare providers; about 83% of them are "Live on EHR" and 45% has met the Medicare and Medicaid EHR Incentive Program criteria for meaningful use of an EHR. The "Practice Type" were categorized into "Small Primary Care Practice" which is a private practice focused on primary care with fewer than ten primary care providers. Also, "Practice Consortia" which are defined by RECs as formerly-small practices that have joined under a single tax ID to streamline administrative management. Other Underserved Settings defined to include providers serving high levels of Medicaid and medically-underserved patients. See Tables 31, 32 and 33.

Table 31.
Practice Type (REC Dataset)

Practice Type	Frequency	Percentage
Small Primary Care Practice	51555	35.22
Community Health Center	22643	15.47
Practice Consortium	21629	14.78
Public Hospitals	17847	12.19
Other Underserved Setting	17728	12.11
Critical Access Hospitals	4745	3.24
Other Private Practice	4013	2.74
Rural Health Clinic	3671	2.51
Rural Hospital	2552	1.74

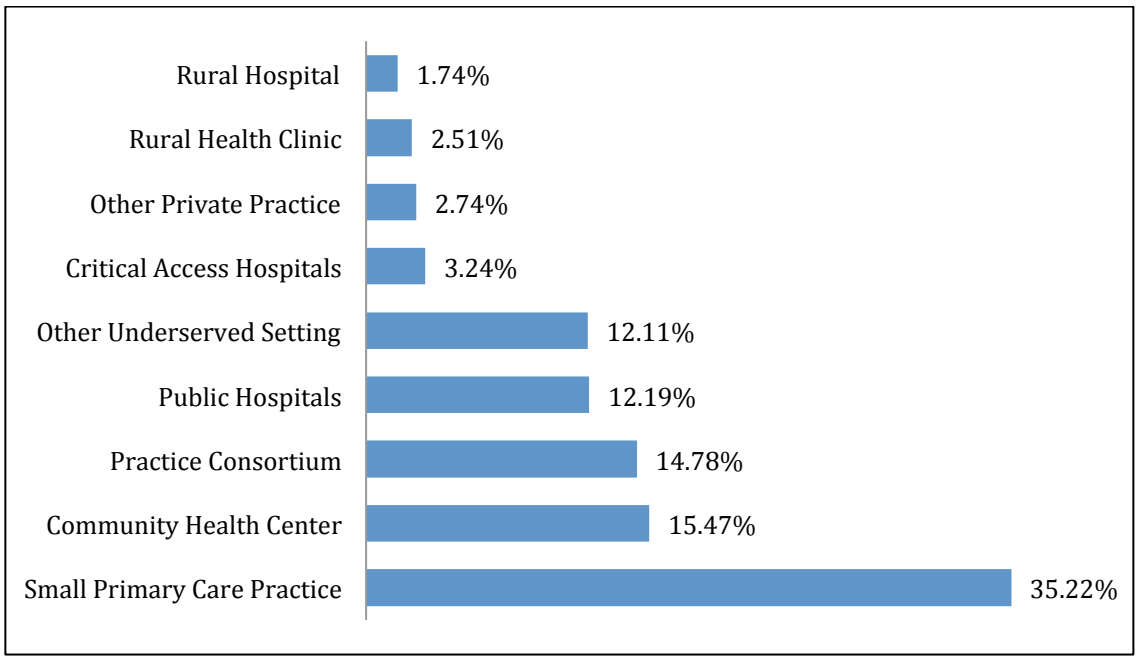


Figure 31: Practice Type (REC Dataset)

Table 32.
Live on EHR (REC Dataset)

Status	Frequency	Percentage
Not Live yet on EHR	24857	16.98
Live on EHR	121531	83.02

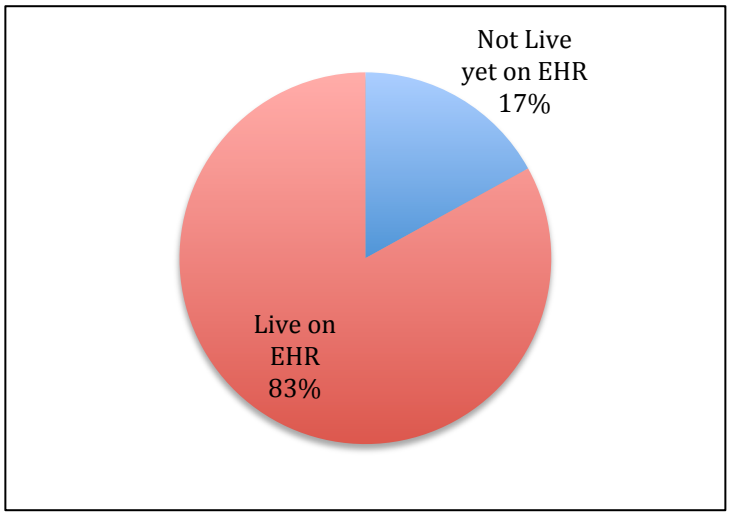


Figure 32: Live on EHR (REC Dataset)

Table 33.
Demonstrating Meaningful Use MU (REC Dataset)

Status	Frequency	Percentage
Not yet Demonstrating MU	80879	55.25
Demonstrating MU	65509	44.75

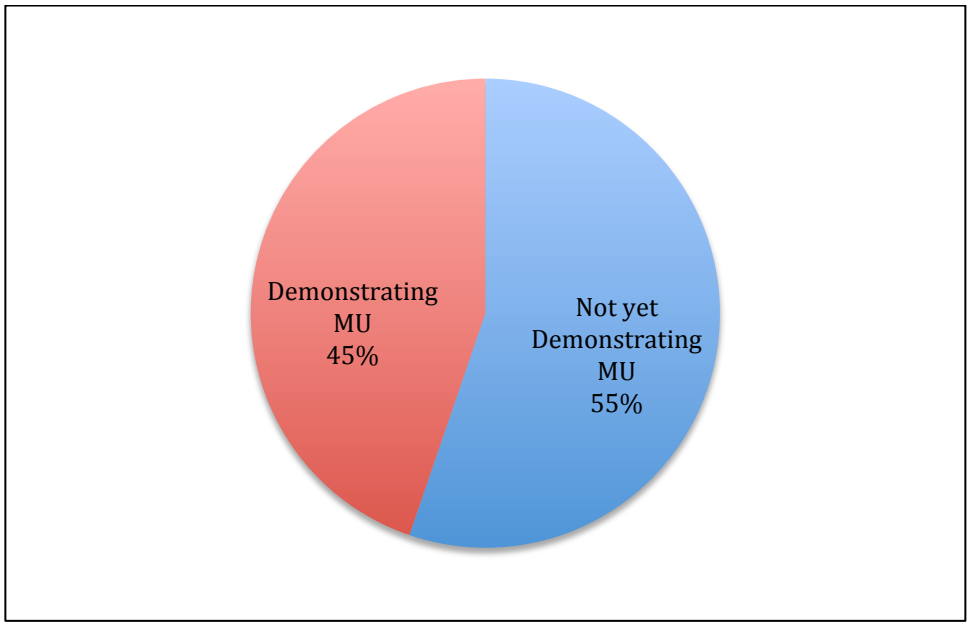


Figure 33: Demonstrating Meaningful Use MU (REC Dataset)

Table 34.
Top Provider Specialty (REC Dataset)

Practice Type	Frequency	Percentage
Family Practice	55157	37.68
Internal Medicine	29510	20.16
Pediatrics	21399	14.62
OB-GYN	15482	10.58
General Practice	5723	3.91
Dentistry	1773	1.21
Psychiatry	1342	0.92
Surgery	1220	0.83

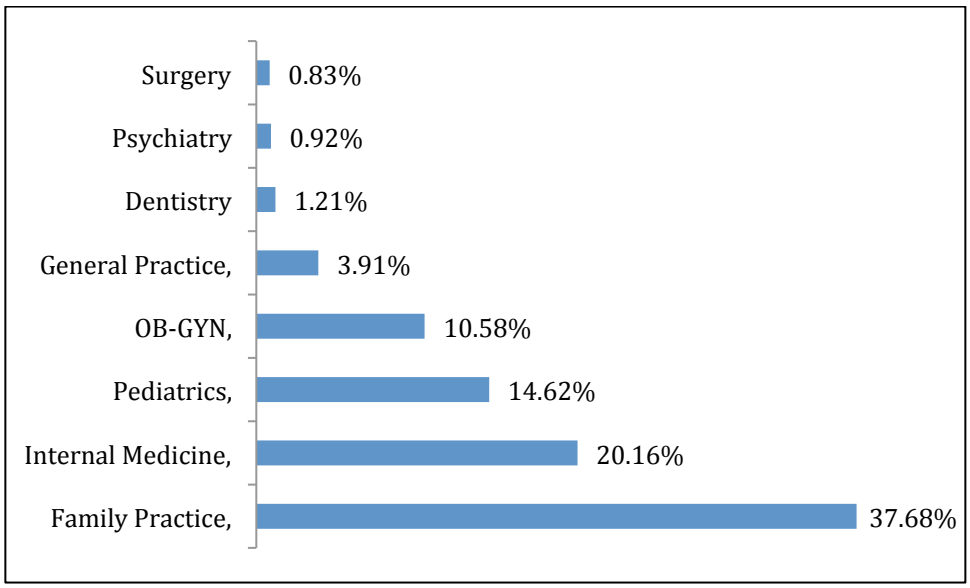


Figure 34: Top Specialties of Providers (REC Dataset)

Table 34 above lists the top specialty of the providers in the dataset. Table 35 below lists the top EHR Vendor in the dataset.

Table 35.
Top Software Vendor (REC Dataset)

Category	Frequency	Percentage
eClinicalWorks	18124	13.40
Allscripts	17736	13.12
Epic	16863	12.47
NextGen Healthcare Information Systems Inc	15001	11.09
GE	10943	8.09
Cerner	4722	3.49
Vitera Healthcare Solutions	3831	2.83
Greenway Medical Technologies Inc	3701	2.74
e-MDs	3447	2.55
McKesson	3409	2.52
Other	3229	2.39
Practice Fusion	2040	1.51
Indian Health Service	1960	1.45

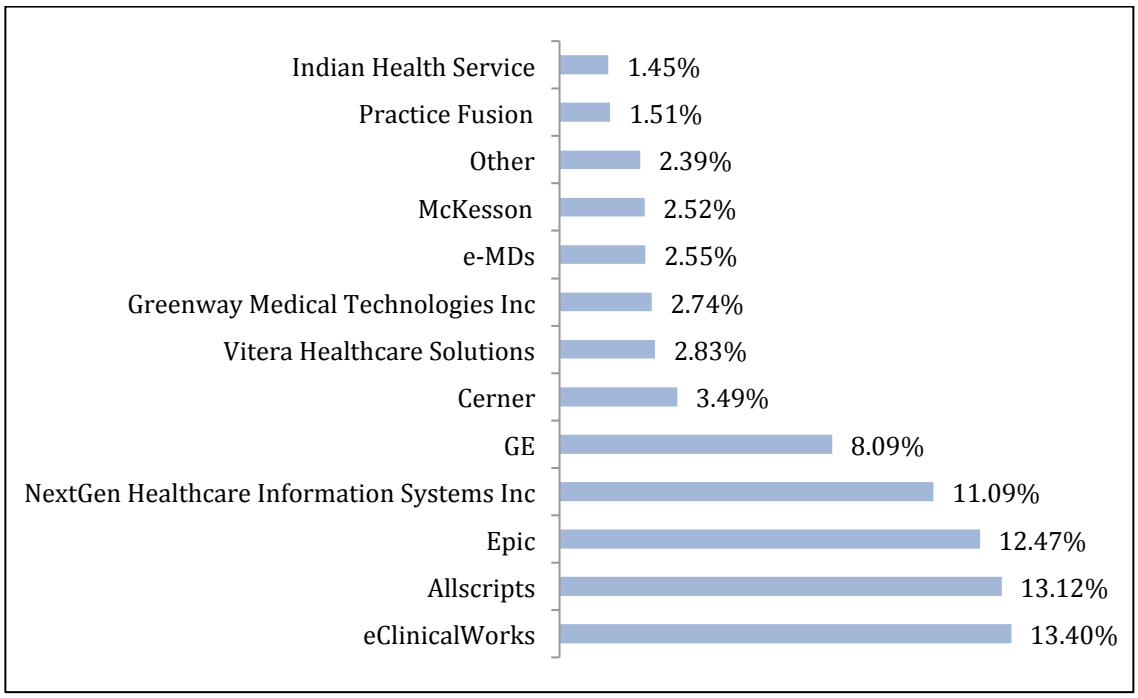


Figure 35: Top Software Vendor (REC Dataset)

There are four open source vendors in this dataset (OEMR, Open Dental Software, WorldVistA and Indian Health Service), and only one free EHR application (Practice Fusion). Table 36 lists the frequency of OSS EHR Vendor in the REC dataset.

Table 36.
OSS Vendors (REC Dataset)

Vendor/Product Name	Frequency	Percentage
Practice Fusion	2040	49.20
Indian Health Service	1960	47.27
OEMR	70	1.69
Open Dental Software	61	1.47

Note. "Practice Fusion" is a Free software not open source

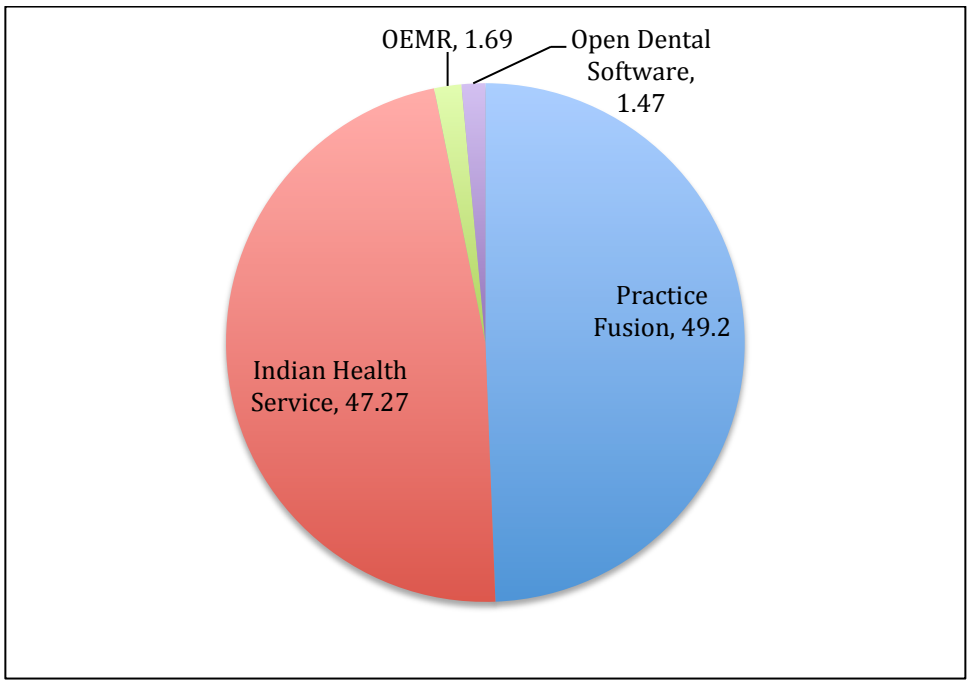


Figure 36: OSS Vendors/Products (REC Dataset)

The following Tables 37, 38, 39 and 40 list the Provider Specialty, Practice Type, Statues of EHR and Meaningful Use demonstration respectively.

Table 37.
Top OSS Provider Specialty (REC Dataset)

Practice Type	Frequency	Percentage
Family Practice	1982	47.81
Internal Medicine	717	17.29
Pediatrics	411	9.91
OB-GYN	260	6.27
General Practice	220	5.31
Dentistry	163	3.93
Other	60	1.45
Psychiatry	40	0.96

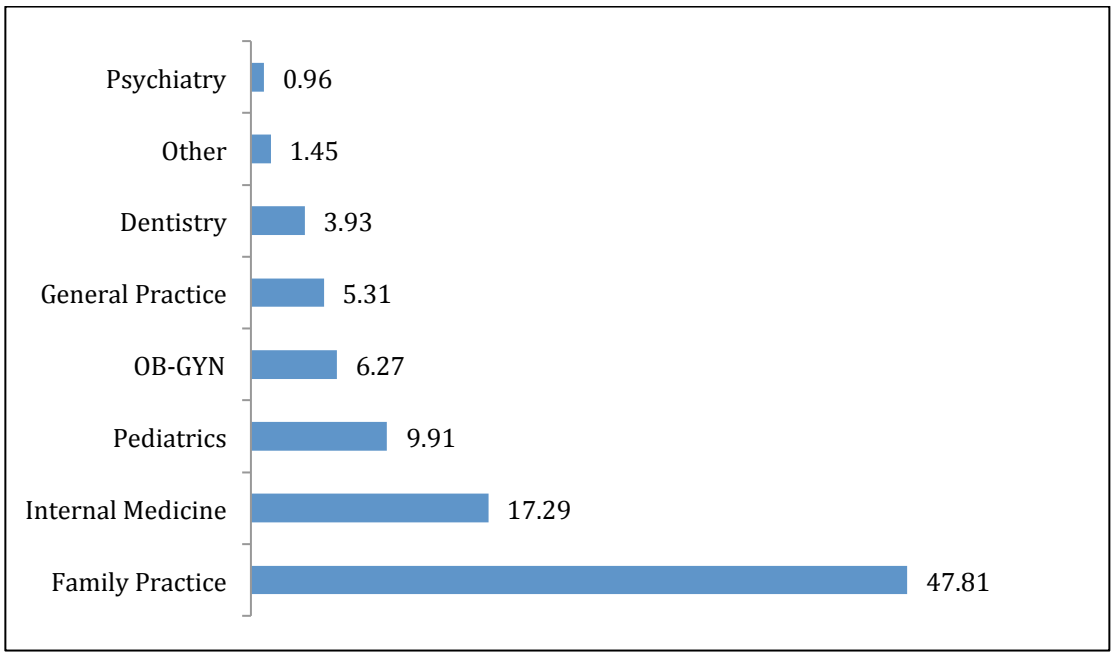


Figure 37: Top OSS Provider Specialty (REC Dataset)

Table 38.
OSS Practice Type (REC Dataset)

	Frequency	Percentage
Small Primary Care Practice	1883	45.42
Other Underserved Setting	1527	36.83
Rural Hospital	219	5.28
Other Private Practice	173	4.17
Community Health Center	144	3.47
Critical Access Hospitals	129	3.11
Rural Health Clinic	60	1.45
Public Hospitals	11	0.27

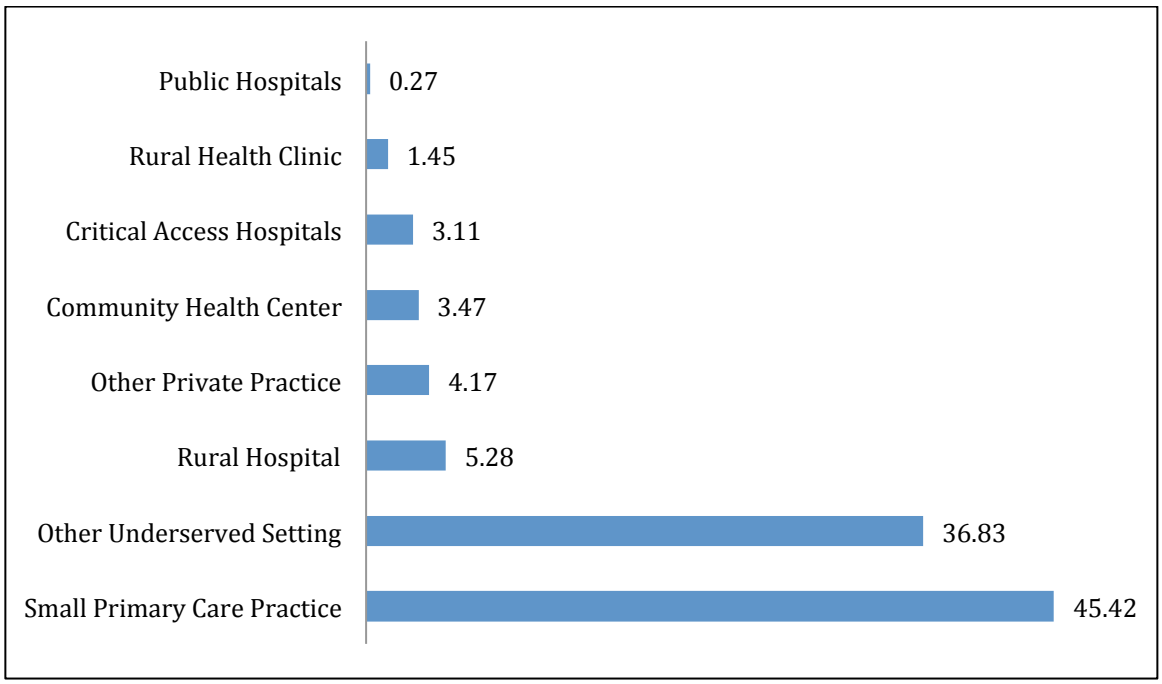


Figure 38: OSS Practice Type (REC Dataset)

Table 39.
OSS Live on EHR Status (REC Dataset)

Status	Frequency	Percentage
Not Live yet on EHR	359	8.66
Live on EHR	3787	91.34

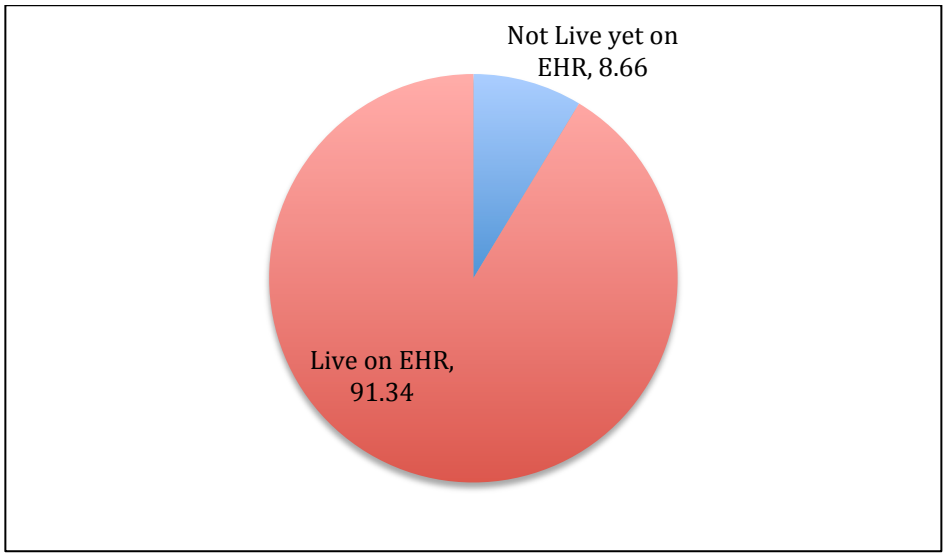


Figure 39: OSS Live on EHR Status (REC Dataset)

Table 40.
OSS Demonstrating Meaningful Use MU (REC Dataset)

Status	Frequency	Percentage
Not yet Demonstrating MU	2676	64.54
Demonstrating MU	1470	35.46

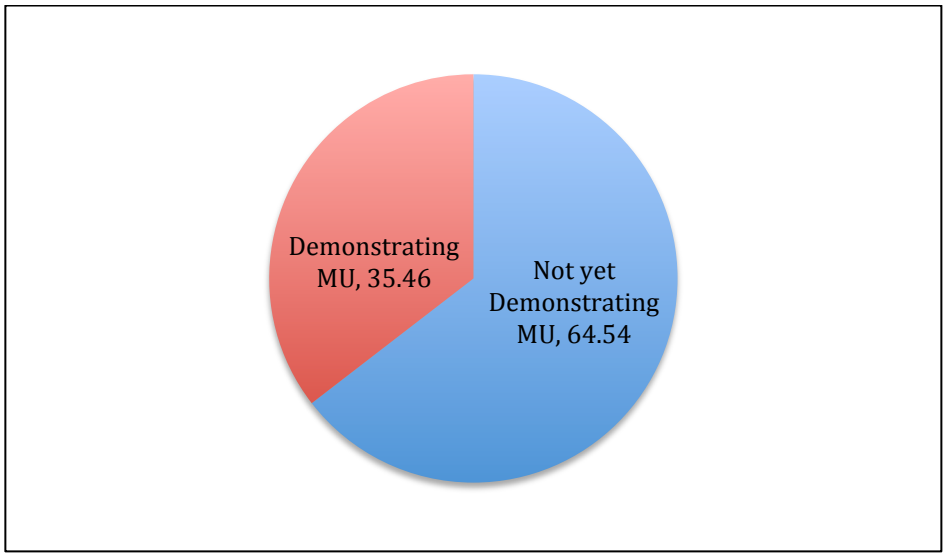


Figure 40: OSS Demonstrating Meaningful Use MU (REC Dataset)

4.10 Regression Analysis Results

Logistic regression was used to analyze the study hypotheses. The relationship between the number of physicians, the number of beds, whether there was an acute care facility in the hospital, the type of ownership of the hospital (owned, leased, or managed), the geographic location of the health care provider, and whether the health care provider used open source software. The dependent variable was whether the healthcare provider uses an open source applications. This variable was be coded "0" for those facilities not using open source, "1" for using open source product. The independent variables used in the regression analyses were the number of physicians, the type of ownership, the number of beds, whether there was an acute care facility at the healthcare provider, and the geographic region of the healthcare provider.

Table 41 displays the results of the logistic regression analysis. There no statistically significant relationship between the number of physicians and whether the health care provider used open source software. However, healthcare providers with no beds or those that did not report having beds were less likely to use open source software, OR = .12, z = -1.997, p = .0046. Those healthcare providers with acute care facilities were more likely to use open source software, OR = 10.07, z = 0.462, p < .001. There was also a statistically significant relationship between region and whether a health care provider used open source software. Those healthcare providers located West were more likely to use open source software than healthcare providers in the Midwest, Northeast, and South, OR = .61, z = -2.670, p = .0008, OR = .33, z = -3.961, p < .001, and OR = .28, z = -5.633, p < .001, respectively.

Table 41.
Results of the Logistic Regression with Open source Use as the Dependent Variable

	β	*SD*	*Z* - value	*p*-value
Constant	-4.001	1.205	-3.320	0.001
Reference (between 5 and 20)				
Number of Physicians (less than five)	0.634	0.418	1.517	0.129
Number of Physicians (Missing)	-1.484	1.068	-1.389	0.165
Number of Physicians (Over 20)	-0.463	1.070	-0.432	0.665
Number of Physicians (Zero)	0.430	0.505	0.851	0.395
References (Not Owned)				
Type of Ownership	-0.006	0.319	-0.019	0.985
Number of Beds (reference: Less to 100)				
Number of Beds (Between 100 and 200)	-0.004	0.252	-0.016	0.988
Number of Beds (Between 200 and 300)	-0.010	0.311	-0.032	0.974
Number of Beds (No Beds or Not Reported)	-2.190	1.096	-1.997	0.046
Number of Beds (Over 300)	0.275	0.240	1.146	0.252
Acute Care	2.310	0.462	5.004	0.000
Region (reference: West)				
Region Midwest	-0.498	0.186	-2.670	0.008
Region Northeast	-1.091	0.275	-3.961	0.000
Region Pacific	-0.774	1.017	-0.761	0.447
Region South	-1.216	0.216	-5.633	0.000

Data for the meaningful use report was also analyzed. The meaningful use dataset provides comprehensive list of all certified products for healthcare provider as well as the types of providers using them. The relationship between product setting (ambulatory, or impatient), the provider type (eligible professional, or hospital), the providers stage number (stage 1, or stage 2), and whether the healthcare provider is using open source or free software was analyzed using logistic regression. The dependent variable was whether the provider was using open source software and the independent variables were the product setting, the provider type, and the provider stage number.

Table 42.

Results of the Logistic Regression with Open source Use as the Dependent Variable for Meaningful Use Dataset (without free software that is not open source)

	B	S.E.	z- statistic	Sig.
Constant	-11.016	.397	-.27.748	< .001
Product Setting (Reference: Inpatient)				
Product Setting: Ambulatory	1.210	.309	3.916	< .001
Provider Type (Reference: Hospital)				
Provider Type: Eligible Professional	-2.375	.309	-7.686	< .001
Provider Stage (Reference: Stage 2)				
Provider Stage: Stage 1	2.185	.290	7.534	< .001
Product Classification (Reference: Modular)				
Product Classification: Complete	3.482	.271	12.848	< .001

Table 43.

Results of the Logistic Regression with Open source Use as the Dependent Variable for Meaningful Use Dataset (with free software that is not open source)

	B	S.E.	z- statistic	Sig.
Constant	-8.374	.127	-65.937	< .001
Product Setting (Reference: Inpatient)				
Product Setting: Ambulatory	2.795	.159	17.578	<. 001
Provider Type (Reference: Hospital)				
Provider Type: Eligible Professional	-.594	.159	-3.736	<. 001
Provider Stage (Reference: Stage 2)				
Provider Stage: Stage 1	-.088	.025	-3.520	<. 001
Product Classification (Reference: Modular)				
Product Classification: Complete	2.64	.051	51.76	<. 001

CHAPTER 5 DISCUSSION AND CONCLUSION

From the previous analysis of the different datasets (HIMSS, CMS Meaningful Use and REC datasets), results show that it is evident that vendors providing proprietary applications are dominating the market share comparing with open source vendors or open source EHR applications. Figure 20, the HIMSS dataset shows that there is a slow increase in the number of open source applications, from 2009 (n = 111) and (n = 382) in 2013. In the HIMSS dataset (n = 497,577), 97.16% of the applications used were proprietary, and only 0.08% were open source. The rest 2.76% did not report on the name of the system that healthcare provider was using. Moreover, in the CMS Meaningful Use dataset (n = 1,032,627), about 98% of the applications used were proprietary, and 2% were open source. Lastly, in the REC dataset (n = 146,388), 97.18% of the applications used were proprietary, and 2.82% were open source. Therefore, our hypothesis that there will be a significantly greater number of open source EHRs compared to proprietary EHRs is rejected. The main reason for this is the limited number of vendors that provide and support open source EHR applications. Also, proprietary EHR vendors can exert pressure to interrupt open source solutions. For example, the American Academy of Family Physicians (AAFP) in 2003 began to support a development of an open source product for a group member; commercial software vendors start offering discounts to this group, and the AAFP then lost the interest in the effort to move the open applications forward.[58,70] Another reason for the low penetration of open source EHR application is that most of the proprietary companies have a substantial advertising and marketing budget, which open source does not have. Therefore, this causes a lack of awareness

among decision makers of healthcare providers regarding open source solutions and expanding misperceptions about theses systems.

In the second hypothesis, whether there is a relationship between the number of physicians in healthcare provider with the use of Open Source EHR, the results of the logistic regression analysis in Table 41 shows that there no statistically significant relationship between the number of physicians and whether the health care provider used open source software, Number of Physicians (less than five), $P = 0.129$, Number of Physicians (over 20), $P = 0.665$.

Our third hypothesis that Healthcare provider with greater IT resources and a greater number of IT Staff will be associated with greater likelihood of adopting Open Source EHR use could not be tested due to plenty of missing values in the number of IT staff in healthcare provider's facilities, especially in the open source EHR application subset. However, Goldwater concluded in his study that "organization which lacks the appropriate technical experience and understanding of the product will need to hire consultants or companies with the acumen to install and maintain the product as well as train staff to use it." That means healthcare providers might choose the option of outsourcing their IT needs, especially in small healthcare organizations.

That lead us to our fourth hypothesis that smaller size healthcare provider will be more likely to use open source EHR. We categorize the size of healthcare providers into five categories according to the number of beds, (less than 100, between 100-200,

between 200-300, over 300, and no beds or not reported). Healthcare providers with no beds or those that did not report having beds were less likely to use open source software, (OR = .12, z = -1.997, p = .0046). Lastly, by testing our fifth hypothesis, there was a statistically significant relationship between region and whether a health care provider used open source software. Those healthcare providers located West were more likely to use open source software than healthcare providers in the Midwest, Northeast, and South, OR = .61, z = -2.670, p = .0008, OR = .33, z = -3.961, p < .001, and OR = .28, z = -5.633, p < .001, respectively.

Table 42 displays the results of the logistic regression with open source use as the dependent variable for the meaningful use dataset. The data revealed several findings. Open source software was much more likely to be used in an ambulatory setting, *OR* = 3.35, *z* = 3.916, *p* < .001. Open source software was also much less likely to be used by an eligible professional than in a hospital setting, *OR* = .093, *z* = -7.686, *p* < .001. Additionally, open source software was more likely to be used by providers to be eligible for incentives in Stage 1 than in Stage 2, *OR* = 8.89, *z* = 7.534, *p* < .001. The healthcare provider was much more likely to use open source as a complete than a modular system, *OR* = 32.482, *z* = 12.848, *p* < .001.

Table 43 displays the results of the logistic regression with open source or free software use as the dependent variable for the meaningful use dataset. The data revealed several findings. Open source or free software was much more likely to be used in an ambulatory setting, $OR = 16.36$, $z = 17.578$, $p < .001$. Open source or free software was also much less likely to be used in a an eligible professional setting than in a hospital setting, $OR = 0.55$, $z = -3.736$, $p < .001$. Additionally, open source or free software was less likely to be used in Stage 1 than in Stage 2, $OR = 0.92$, $z = -3.520$, $p < .001$. The healthcare provider was much more likely to use open source or free as a complete than a modular system, $OR = 14.013$, $z = 51.76$, $p < .001$.

Previously from the descriptive analysis, we saw that there are more than 1,400 vendors of Health IT systems in the HIMSS dataset that includes both types, Open Source and Proprietary systems. The dataset also has more than 40,000 healthcare providers, about 62% of them are “Live and Operational” using EHR systems, and about 22% “Not Automated” meaning that not using EHR. Therefore, future growth and adoption in open source applications will be adopted mostly by healthcare providers switching from paper-based or as we called it "Not Automated". The reason is that healthcare providers currently using proprietary systems will be lock-in with their current provider. Hence, adoption may be costly for them to shift to OSS solutions. Also, we find that 2.44 percent (n = 17,988) of the proprietary EHRs applications will be replaced. That implies that healthcare providers are dissatisfied with their current proprietary EHR systems. In contrast, only 0.28 percent (n = 362) of open source application set to be replaced, which implies that healthcare providers with open source systems are satisfied

with their current systems. The key reason might be the lack of customization and usability and functionality issues of some of the proprietary applications or whether vendor merged with another company or gone out of business, which is not the case in the open source model.

Another important finding when comparing top applications used by proprietary software in the HIMSS dataset (Table 6) and open source software (Table 13). The majority of applications for proprietary software are (Practice Management and Ambulatory EMR), which accounts for (9.72%) of the total applications. Though, (Interface Engines and Health Information Exchange (HIE)) dominate in open source applications (28.46%) followed by (Ambulatory EMR and Practice Management) (15.19%). That means healthcare providers are using open source software more as non-clinical application rather than clinical care applications. Furthermore, open source is critical in the domain of Health Information Exchange (HIE) where collaboration is essential to get healthcare providers to exchange patient records; therefore, openness is necessary to access and exchange the data.

Companies such as MEDITECH, Epic, McKesson, CERNER, CPSI, GE and SIEMENS are dominating the market share of EHR systems by (34.91%) in the HIMSS dataset (Tables 7). Epic and Cerner dominates by (32.46%) in the Meaningful Use dataset (Table 22). In the REC dataset eClinicalWorks, Allscripts, Epic and NextGen dominate by (50.08%). However, there are no many vendors that support open source applications. That is one of the main factors that open source EHR applications are not widespread as

proprietary applications. Hence, without more vendors supporting open source products, the widespread of theses systems will be limited.

Results from the Meaningful Use dataset and REC dataset shows that open source applications benefit from the government incentives programs (Tables 24 and 36). Since these open source applications in the datasets, which means that, there are certified EHRs and receiving incentives.

Since the government incentive programs started in 2009, EHR adoption rates have increased. Table and Figure 21 show the effect starts from 2010 and beyond. In 2009, there were 111 open source applications. From 2010 till 2013 the adoption rates start increasing (182 applications in 2010, 239 applications in 2011, 291 applications in 2012, and 382 applications in 2013). The number is still very low when comparing with proprietary applications. However, in some studies, the number of open source EHR is much more. For example, the Indian Health Service (IHS) developed an EHR in collaboration with the VA named Resource and Patient Management System (RPMS). This system has been deployed at more than 600 medical facilities.[82] This number is not reflected in our datasets because those facilities did not participate in the incentive programs and had not included in the HIMSS dataset, which is a limitation of this study.

In conclusion, the study analyzed the prevalence and usage of open source applications and EHRs compared to proprietary systems in the available datasets and studied some of the factors influencing or inhibiting this adoption process. Also, exploring characteristics of the healthcare providers adopting EHRs. We investigated the types of OSS products that healthcare providers use and the adoption trend of OSS. Further investigation is needed to study more recent datasets as they become available since the recent dataset for this study was from 2013.

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APPENDIX A: **List of abbreviations and acronyms**

AHIC	American Health Information Community
AHIMA	American Health Information Management Association
AHRQ	Agency for Healthcare Research and Quality
ANSI	American National Standards Institute
ASTHO	Association of State and Territorial Health Officials
ARRA	The American Recovery and Reinvestment Act
HIE	Health Information Exchange
CAHs	Critical Access Hospitals
CDC	Centers for Disease Control
CCHIT	Certification Commission for Healthcare Information Technology
CDS	Clinical Decision Support
CHC	Community Health Centers
CHPL	Certified Health IT Product List
CIO	Chief Information Officer
CMS	Centers for Medicare and Medicaid Services
CONNECT	NHIN gateway
CPOE	Computerized Provider Order Entry
CPRS	Computerized Patient Record System
DICOM	Digital Imaging and Communications in Medicine
DoD	Department of Defense
EHR	Electronic Health Record
EMR	Electronic Medical Record

EH	Eligible Hospital
EP	Eligible Provider
FDA	Food and Drug Administration
HHS	Department of Health & Human Services
HI	Health Information
HIE	Health Information Exchange
HIMSS	Healthcare Information Management Systems Society
HIPAA	Health Insurance Portability and Accountability Act
HIT	Health Information Technology
HITECH Act	The Health Information Technology for Economic and Clinical Health Act
HL7	Health Level 7
HRSA	Health Resources and Services Administration
IDS	Integrated Delivery System
IHS	Indian Health Service
IOM	Institute of Medicine
IT	Information Technology
NAHIT	National Alliance for Health Information Technology
NHIE	NHIN Health Information Exchange
NHIN	Nationwide Health Information Network
NIH	National Institutes of Health
OIS	Office of Interoperability & Standards
OSS	Open Source Software

ONC	Office of the National Coordinator for Health Information Technology
PACS	Picture Archiving and Communication System
PCPs	Primary Care Physicians
PHR	Personal Health Record
REC	Regional Extension Centers
RHs	Rural Hospitals
RHA	Regional Health Authorities
ROI	Return on Investment
SNOMED	Systematized Nomenclature of Medicine
SQL	Structured Query Language
VHA	Veterans Health Administration
VistA	Veterans Health Information Systems and Technology Architecture