Evaluation of DICOM compliance in ophthalmic imaging devices

By

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A CAPSTONE PROJECT

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School of Medicine

Oregon Health & Science University

Certificate of Approval

This is to certify that the Master's Capstone Project of

Nathan Skidmore

"Evaluation of DICOM compliance in Opthalmic imaging devices"

Has been approved

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Michael F. Chiang, MD

Table of contents

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Thank you everyone!

Part 1. Introduction

Abstract

Digital Imaging Communications in Medicine (DICOM)-compliant equipment is pervasive in radiology, but other domains such as ophthalmology lag behind in this regard. This is not due to a lack of need. Ophthalmologists create, interpret, store and retrieve medical images on a daily basis. These images are central to any clinician's decision making process and are a keystone in diagnosis and treatment. The ability to accurately and effectively incorporate the image and metadata into a workflow depends largely on adherence to the DICOM standard. To determine areas of possible improvement in DICOM adherence, the workflow of various modalities throughout an ophthalmology department were examined. Potential improvements were found. These options are discussed here, and possible solutions are provided.

Background

Imaging is an invaluable component to diagnosing and treating patients, and each image captured must travel through a hospital or clinic's network. It is easy to assume that the images produced flow easily back and forth between the various electronic devices found in a hospital, but there is more likely a digital chasm or bottleneck between the two. Regardless of this subtly turbulent stream, patients and clinicians desire advanced features,[1] and as new devices or software are introduced, expectations rise.

Additional functionality typically comes with increased network demand, either from new hardware pushing data, software tools utilizing that data, or financial pressure to achieve more

with less. To add a layer of complication, each specialty has its own unique needs. While a radiologist might work more with slices or voxels, an ophthalmologist is more likely to work with microscopic photography or visual fields.

Regardless of the specialist, feature or type of image, there is a universal need for sharing medical images. To do so, communication rules must be adhered to. Several standards exist to guide the communication of medical images. These include the Digital Imaging and Communications in Medicine (DICOM) standard, Integrating the Healthcare Enterprise (IHE) profiles and Health Level Seven International (HL7) framework.

DICOM history and development

DICOM is a well-accepted group of standards for medical image data, although it is commonly referred to here and elsewhere as a singular standard. The DICOM standard evolved from a prior collaborative effort between the American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA). The two groups began work in 1983 to set standards for the transfer and display of imaging information, which until then had been dominated by proprietary-focused vendor efforts.[2] The collaboration sought to develop an open standard, and established working groups to focus on three sub-domains: hardware and protocols (working group 1), data groups (working group 2) and system performance specifications (working group 3).

As a result of this joint effort, the first group of standards were made available in 1985, known as the ACR/NEMA Standard Version 1.0. In 1986 the first revision was released, followed by a second revision two years later. Since these versions still only allowed for point-to-point

connections, evolving network technology and the use of shared network bandwidth led to the need for a larger revision to the standard.[3]

In 1993 the standard was renamed DICOM to reflect the significant changes and the input from outside sources. By this time the original three working groups had expanded to include development input from the American National Standards Institute (ANSI), Japanese Industry Radiology Apparatus (JIRA), and the Institute of Electrical and Electronics Engineers (IEEE). [4] The changes made in this third version of the standard also included regulations for interfacing between modality vendors and the frameworks that would allow Picture Archiving and Communication Systems (PACS) to gain widespread use.[5] Development of the standard will continue, but it is currently complete enough to be the de facto standard used by clinicians, vendors and researchers around the globe.

DICOM components

Each DICOM file involves two sections of the same file: a header segment and an image segment. The header segment begins with a 128-byte buffer of zeroes, general header data, followed by grouped fields of image metadata.[6] This metadata includes modality, orientation, patient demographics, acquisition parameters and more, support for 2,000 fields or “tags” in total. The image segment contains the image data in several formats, the most common being either TIFF or JPEG2000 compliant formats (.tif or .jp2), represented in two-dimensional pixels of varying bit-depths and color palettes.[3] DICOM supports RGB and grayscale up to 16-bit depth, allowing images 65,536 shades of gray per pixel. Together, the color depth and resolution require a lot of information, and though lossy or lossless compression techniques are available, DICOM files are typically large. For example, a contrast-enhanced computed tomography (CT) DICOM file would be about 35 megabytes.[5] The data elements in DICOM

each have a uniquely labeled tag number, a value representation (VR) that describes the data type and the format of the attribute value, a value length, and a value field containing the actual attribute data. When sending these files, each element of the data stream begins with the tag, followed by the value representation, the value's length and finally the value field. For example, "Body Part Examined" is a value representation of type CS (for code string, a 16-byte maximum string of characters), and the unique tag is (0018,0015). The DICOM data dictionary defines over 200 of these attributes.[7]

DICOM data representations

DICOM exists purely in the upper three layers (Application, Presentation and Session) of the International Standards Organization's (ISO) Open Systems Interconnection (OSI) reference model. At the Application layer, DICOM accomplishes communication through DICOM Message Service Element (DIMSE). Data in the DICOM model is organized into objects, and the actions or relationships related to those objects. Due to this structure, DICOM is considered an object-oriented standard, similar in concept to the software programming paradigm. In this case, object-oriented means that there will be detail regarding the real-world objects being modeled, or the classes they are based on. However, the relationship between the models that DICOM specifies and the actual implementation is dependent on the implementation.[2]

Grouped or related sets of attributes of an object from the real world are represented in DICOM by Information Object Definition (IOD). For example, a patient has real world attributes such as name, gender, medical record number and date of birth. Together that data and the relationships between the attributes would form a patient IOD. The actions that can be performed on various objects are known as Service Elements (SE). For example, a device (or more likely a pair/group of devices) posesses the real world actions of storing, printing or

querying data (among others). Everything DICOM accomplishes relies on pairing these IODs with SEs. Since certain actions will frequently correspond to certain objects, the relationship between an IOD and SE is known as a Service-Object Pair (SOP). An example is the Storage Service Class, which specifies application of the storage *service* to a image *object*.[8] Furthermore, there is a subset of services for any given object, known as the DIMSE Service Group (DSG) to define only the relevant services (i.e. “Print” should not be available for files unreadable by humans). Putting it all together, a DICOM file includes the metadata described earlier and the data set represented by an SOP instance. This file is given context in a system by DICOM’s data dictionary.

DICOM data exchange

To help illustrate how these data representations work in practice, imagine any imaging exam, for example an optical coherence tomography exam. Once captured, the OCT hardware requests storage from the Picture Archiving and Communication System (PACS). Because the modality is the entity seeking to send and store data, it is known as a Service Class User (SCU).[9] The image archive device provides the service of storage for the OCT data object. Because it is providing the service, that archival device is known as the Service Class Provider (SCP). Every exchange of data between these users and providers is called an association, and like most network protocols, there is a “handshake” at the beginning of communication, in this case it is the Association Establishment-DICOM handshake. The information they exchange about each other is known as the Presentation Context.[9] The type of data exchanged in this handshake is available in human-readable form in the device manufacturer’s conformance statement. A conformance statement is essentially a description of what each device can or can’t do. This description of capabilities is crucial, and includes information about which services the device supports and whether it can act as an SCU, SCP or both for these services.

Other standards/frameworks

Although it is the only standard in the world guiding the transfer of medical images, DICOM does not exist in isolation. Because of this, it is important to have an understanding of the other standards that DICOM is frequently intertwined with. These are Health Level 7 International (HL7), Integrating the Healthcare Enterprise (IHE) and SNOMED CT.

HL7

The initial focus for DICOM was to provide solutions for imaging departments to share graphical data, while HL7 was developed to share textual data between clinical systems.[8] Developed in 1987 by ANSI,[10] this framework was created for the sharing, organization and utilization of healthcare services and data supporting clinical care. The goal was to set rules for the implementation of clinical information interfaces, so that the administrators of Radiology Information Systems (RIS), Health Information Systems (HIS), Laboratory Information Systems (LIS) and others could have frameworks for sharing clinical data between systems and organizations. There is now a joint HL7-DICOM working group to better define the links between the two.

IHE

Integrating the Healthcare Enterprise (IHE) was formed in 1997, with the goal of pushing adoption of standards for health information transfer.[11] It has been strongly supported by the industry, with more than 110 companies developing and cross-vendor testing IHE-compliant systems between 1999 and 2004.[11] The difference between IHE and DICOM is that IHE is not

designed with the goal of creating new standards; IHE would push acceptance of DICOM as a standard rather than compete with it.[8] One way in which IHE attempts to increase standards adoption is to specify profiles for the interfaces between health-care applications. For example, IHE offers a Cross Enterprise Document Sharing (XDS) profile with the goal of easier document sharing. This profile relies on existing standards to store healthcare documents in an XML-based repository. Other IHE Profiles exist, each aiming to improve clarity, and as a result communication, by pushing a common ”languages” such as DICOM and HL7 between vendors and users.

In 2005, the IHE Eye Care initiative was formed to address problems in ophthalmology, and several IHE profiles created. First, the Eye Care Workflow (EYECARE) for storage, acquisition, scheduling and viewing; the Eye Care Evidence Document (ECED) uses observational data to create Eye Care Evidence “objects” that help build a clinical report, and the Eye Care Displayable Report (ECDR) for creating those clinical reports.

Part 2. Project

Purpose

Unique needs of the Ophthalmologists

There is much crossover of imaging techniques across medical specialties, but the prevalence of use differs. A cardiologist may tend to use more “live” imaging techniques such as the combination of X-ray and angiogram, while an ophthalmologist is more likely to combine an angiogram with high-resolution still photographs. Each specialty has its own unique needs, and varying concepts of the ideal tools to help them diagnose and treat patients. For example, an internist may order a test or procedure, but likely wouldn’t perform it themselves. Ophthalmologists cross those borders, operating in both medical and surgical capacities. Most existing EHR systems are geared towards the internist and general physician work, so they don’t provide features like image annotation that ophthalmologists need.[1] Also the reporting format and data types are not typically geared towards ophthalmology, which not only has numerical data but often illustrative, graphical and photographic output. For example, a visual field or periphery exam tests the patient’s ability to detect objects throughout their field of view, resulting in a graphical representation of their visual field. Although the plot for the visual field has discrete sections, it is better represented as a plot rather than converted to purely numerical form. Accommodations for this and other data forms are lacking in most common EHRs. Ophthalmologists are often performing key portions of the exams, assessments and planning, so they need the functionality of modern EHRs with ease-of-use and features or interfaces tailored to their unique patient encounters.

Is it important that all modalities are completely DICOM compliant? Essentially yes, although there really is no such thing as “complete” DICOM compliance. It is a subjective term relative to the device and setting. It is important because minimally-compliant modalities introduce problems into the care workflow. For example, the Goldmann perimetry machine is used to check the field of view of a patient, and operates nearly completely without electricity, except for one small light at the rear (clinician-side) of the device. As the examiner moves and shines the light through various preset “holes”, they use a pencil to mark where the patient indicates they can see the light. The result is a piece of paper with a graphical representation of the strong and weak areas of the patient’s vision. To store that graphical representation in a versatile digital format, someone needs to scan it and add the relevant patient demographic data to the image header. This is a time-consuming waste of resources. On the flip side, it can consume a lot of financial resources to try to bring non-capable devices up to date. When DICOM capability is not included with the device, costs to add the ability typically range from $10,000 to $40,000.[12]

Mixed nature of a hospital/department

The need for DICOM compliance is effectively tied to the market for systems and modalities. Due to the timeframes of purchasing decisions, financial resources, clinical needs and availability, hospitals will always have hardware and software from different vendors. Still the push is “toward enterprise-wide image management solutions, where digital images from radiology, cardiology, and other ‘ologies’ are seamlessly linked.”[13] Integrating this unpredictable range of devices requires DICOM.

DICOM can act as a liaison between the semantics of SNOMED, and the syntax of HL7. When DICOM, HL7 and SNOMED are integrated, thorough DICOM compliance will help to increase

the ophthalmic EHR vendor's ability to offer products that integrate smoothly into a "seamlessly linked" mixed-vendor environment.

Reduced redundancy of effort

In less than ideal settings, patient demographic data sent to the PACS originated by the clinician manually entering it into the modality, despite the existence of the same data within the HIS or RIS. Modality worklists (MWL) are a relatively recent addition to the DICOM standard which prevent this redundancy.[14] A modality worklist allows for task-focused workflow in an organized manner. It is one of the most important features of DICOM when it comes to efficient workflow. Modality worklists reduce extra or duplicate effort, often seen when re-entering data from the HIS into the device (and rarely but sometimes back to the HIS).[15] Worklists also allow for the modalities to function as a short term repository for the HIS or RIS.[16] Depending on the archiving system in place, this may or may not be ideal.

Here is an example modality worklist workflow: First the ordering clinician requests an exam, for example a Humphrey Visual Field. If the order is made through the HIS, it will arrive as an HL7 message from the HIS. Sometimes a patient will arrive for a drop-in exam with no prior order, in which case the order is made by the receptionist. In both methods, a new record is entered into the worklist manager with the relevant information for the visual field technician to perform the examination.

Then the order is scheduled and assigned to the machine and/or room hosting the exam. Whether the room or machine is chosen depends on the department design and number of machines per room. Specifically, the assignment is made by setting the DICOM Application Entity (AE) title on the order and selecting a date, although this can vary depending on worklist manager implementation. Application Entities are essentially the DICOM term for the capabilities of the software running on a machine. The relevant entity or capability for this part of

the workflow is the “scheduled procedure step”. It’s a way of defining a task: what needs to be done, when, and by who. Finally, the VF machine makes a scheduled modality worklist query, retrieves the list of scheduled tasks and prompts the user to carry them out. [16]

Other benefits of DICOM

There are many more benefits to following the DICOM standard relevant to imaging and ophthalmic imaging in particular, and while some are achieved simply by the use of digital imaging techniques, it can be difficult and not always worthwhile to separate the two. First, there is versatility by design in the header metadata of a DICOM image. DICOM-based images aren’t locked in when changing vendors or systems; if a database is corrupted, metadata such as demographics or medical record number (MRN) can be used to identify and re-sort the images. Given a proper backup solution, there is little to no chance that a film will be lost to destruction or misplacement. There is also fidelity, something that comes along with any digital image. There is no degradation of the image as copies are made or transfers are performed. The Goldmann VF workflow described earlier in this paper is a perfect example of this non-DICOM, analog issue. As the exam results are transferred and scanned, there is loss of precise detail. This may not be a critical issue with the Goldmann test due to its infrequent use, but any loss of accuracy when dealing with patient data is not desirable. DICOM supports fidelity in other ways. Standards for image settings/capturing mean more consistent or reliable images, which should mean better reading. For example, DICOM includes the grayscale display standard, so that images appear the same on film as on each workstation.[17] DICOM also includes display rules to keep the orientation of an image correct to prevent display errors.

Yet another benefit of DICOM adherence is the ability to easily integrate. DICOM allows for network communication using the extremely common TCP/IP protocol, which allows for network compatibility with nearly all off-the-shelf network-capable hardware.[4] Following these common

protocols also allows for reduced costs and quicker deployment of new systems**,**[18] plus the potential eligibility for Meaningful Use incentives. The Health Information Technology for Economic and Clinical Health (HITECH) Act provides financial incentives to physicians and healthcare organizations to adopt Electronic Health Records for “meaningful use.” Meaningful Use defines the degree to which an organization must use their electronic health records for a variety of benefits, such as improved coordination of care, improved quality of care, and better security of patient data. Meaningful Use Stage 2 is currently in development.[19]

Development

Setting

This project took place at the Casey Eye Institute and Center for Health & Healing, both a part of Oregon Health & Science University’s (OHSU) campus in Portland, Oregon. OHSU is an academic hospital, serving 750,601 patient visits in 2011. [20] The photography lab at the Casey Eye Institute was a particular focus. This lab sees an average of 1112 patients per month in from 2008-2010 (see Appendix), the bulk of which are performed using color fundus cameras. This project was a little unusual because the employees using the various modalities *and* the imaging devices themselves were the subjects, to be observed simultaneously. The primary focus was to determine the capabilities or limitations of the machines. The secondary focus was to determine the priorities and workflow of the users.

This project is qualitative in design, the biggest component was observing and interviewing the users in the field. There were no focus groups, since themes were not a focus of the design. Instead, many one-on-one interviews and extended “shadowing”. Although videotaped observation may have proven helpful, the practicality, time constraints and cost of videotaped observation would not be worthwhile. To assist in recall, occasionally an audio recorder was

used, but the primary form of data collection were hand-written and electronically typed notes. Field notes and transcripts were the main forms of data collection. Technical manuals from the imaging device manufacturers were consulted, and proved to be valuable when combined with notes on “real-world” usage. Diagrams of the imaging data flows and work flows were created for each major modality (see Appendix).

There is effectively no intervention, due to potential interference of an operational system, and the scope of the project. Initial plans included a thorough plan for intervention, by selecting one modality that is not efficiently adhering to DICOM standards and hypothetically re-configuring it through software and/or hardware to achieve DICOM compliance. A guide was to be created detailing the why, how and cost of that hypothetical intervention, but time did not permit it.

There is one arm to the study, with a mix of three sampling approaches: some convenience sampling; some snowball (also known as chain) sampling - one subject suggests the potential value of another, and so on; and finally purposeful sampling. The purposeful sampling will have the most influence on the subjects chosen. For example, all long-term-employed photographers in the Casey Eye Institute photography lab were included and spoken with. Some of the photographers might not normally be included if just convenience or chain sampling were used. There are no quotas in this design, because of the relatively small number of subjects that can be interviewed. There are between 15 to 30 people that met the purposeful sampling criteria for interviews.

The inclusion criteria was generous: all practicing Ophthalmic group members throughout Oregon Health & Science University who use a medical imaging device on a daily basis. This includes various specialties (retinal photography, visual field testing, echography, etc.) at OHSU’s Casey Eye Institute and the Center for Health & Healing. Additionally, at least one

network administrator and/or systems administrator will be needed. Exclusion criteria were: ophthalmologists among that group who strictly retrieve exams or images for the purposes of research. These exclusions were needed because they expanded the user group too widely.

Data Analysis and Validation: Once the state of DICOM capabilities was assessed and workflow diagrams were created, they are verified with the clinicians and network/system administrators. This could have been the hardest part of the project, achieving even more buy-in from those involved, at a time when they are likely beginning to tire of the intrusion. However, in practice it was relatively easy to do, as the subjects were very gracious with their time.

Resources and workflow

Human resources and workflow

Four subjects in particular provided me with the most useful data for this project. Those were Christopher Howell the Casey Eye Institute photography lab manager, Rick Boney the Ophthalmology Department IT Analyst, Ophthalmic Technician Benel Ostin, and Ophthalmic Technician Kathy Burns. Mr. Howell is both manager and one of seven photographers working in the lab, and was available to demonstrate a variety of exams. The lab has 2.5 FTE of Ultrasound Technicians, and the lab tends to have three photography staff members available at all times. The bulk of the patients come from the retina clinic at the Casey Eye Institute, but can arrive from other OHSU departments such as pediatrics, genetics, or outside referrals. Mr. Boney provided valuable insight into the networking and technical aspects of the department, Mr. Ostin and Ms. Burns both were very knowledgeable about several modalities and their workflow.

Below is a generic exam workflow:

The ordering clinician triggers the exam request in the EHR. The patient arrives at the exam location, either as a drop-in or scheduled appointment. The procedure is performed, and the resulting data is either sent directly to the Ophthalmic PACS system (Axis from Sonomed Escalon) or after being transferred to a digital format. The clinician enters any relevant data into the HIS (Epic). Epic notifies the ordering clinician that images are ready for viewing. Finally, the clinician queries Axis to interpret the results of the exam performed.

Non-human resources and workflow

The non-human resources include 25 cameras under the Axis umbrella. 10 fall outside of that and are not networked. During the Fall and Winter of 2011-2012, the Ophthalmology department at OHSU underwent a significant transition from Topcon's Anka software to Sonomed Escalon's Axis. Axis is not the storage system, just the viewing portal. The data is archived at the Advanced Computing Center (ACC) in Hillsboro, Oregon. As the transition is completed, backups will be moved to a data center located in Portland but off-site of the OHSU campus.

The following types of ophthalmic imaging devices are available at the Casey Eye Institute: slit lamp, optical coherence tomography (OCT), retinal thickness analyzers, ultrasound scanners, specular microscopes, confocal scanning laser ophthalmoscopes, axial length measurers, other fundus and visual field devices. For a full list by make and model, see the Appendix.

Options for improving DICOM compliance

The first step that can be made towards improving DICOM compliance is to request conformance statements any time a new imaging device is being considered, or even for existing devices if the statements are not present. These documents clearly state the capabilities of the device in DICOM terms, whether it is acting as a User of Service or a Provider

of Service. Beware to never trust devices being advertised as “DICOM-compliant,” since the conformance statement and not the marketing truly reflects reality.[21]

The next option for improving DICOM compliance is to involve IHE integration. When composing a Request For Proposal (RFP) for the next hardware or software purchase, check that IHE standard support is included. IHE provides “profiles” that can pass demographics to the instruments, automatically correct those demographics based on the EHR data, and furhter automate the use of modality worklists. The IHE’s profiles act as IHE’s Acquisition Modality Importer, meaning they convert non-DICOM into DICOM & IHE. IHE’s Eye Care Workflow Integration Profile effectively acts as an Admission/Discharge/Transfer (ADT) Patient Registration Actor. Together, IHE and DICOM support in hardware and software will go a long ways towards a more automated, effective system.

To handle existing digital modalities, images sourced from non-compliant devices should be converted to PDF format (printing and scanning if necessary), then wrapped in a DICOM header for sending and storing in the Axis system. There is open-source software that will perform this task.[22]

If cost is a severely limiting factor, open source EHRs such as VistA have been shown to work with low cost off-the-shelf workstations[23] and there are at least eight open source DICOM viewers and five open source web-based PACS, all of which can be networked together.[22] If mobility or network port availability is an issue, note that the DICOM standard does not prohibit wireless connections. The standard allows for IPv4 and IPv6 connections using TCP/IP, as long as those are in place, there is a possibility for wireless transfer of data.[4] If secured properly, wireless data transfer of patient information is HIPAA compliant.[24]

Instead of software, hardware can be added to aid in standardization. Add-on external network interface boxes such as the Quatech SSE-100D serial-to-ethernet converter or the Aten SXP-325A parallel-to-serial converter can bridge the gap between older hardware and newer

networks, helping to convert the vendor's proprietary image data into DICOM-friendly, diagnostic quality digital images.[25]

Discussion

Future plans/proposal

The scope of this project was scaled back due to time constraints, but if more effective use of time or more time were allowed, the project would have included a "dry run" preparation of a hypothetical open source software installation. The software chosen would be a package that could wrap non-compliant images in a DICOM header for submission into the Ophthalmic PACS. That would improve the speed and ability of the department to store, retrieve, display or query images.[26] Noted in the previous section, there are quite a few software-based solutions to various common imaging software scenarios.

After all of the observations and investigation into the medical imaging workflows, it seems the most effective method for improving overall efficiency is to implement modality worklists whenever possible. In some cases, such as the Goldmann machine, it may not be possible. However, every time the ophthalmic technicians re-enter patient demographic data that is available through the EHR, the system is failing and the benefits of the DICOM Modality Worklist Service are being missed.

There is the issue of cost-benefit analysis of adding new hardware, which would need to be a part of any future work. This would of course include the more specific goals, project requirements and scope, costs and timetables for delivery of testing phases, installation and support. Lack of planning or time led to the inability to provide this comprehensive information.

Conclusion

While the idea of standards for the exchange of data may seem like a basic tenet to those in computer science and networking, in the medical field some guidelines have dominated, but not yet saturated. It is easy to blame the vendors' fight for proprietary dominance, but that accomplishes nothing. The solutions are available, adoption of standards is the key. The Ophthalmology workforce is both increasingly aware of the benefits of DICOM-compliant systems, and pressing vendors to offer solutions that adhere to the standard.[1] Vendors can't always be trusted; a successful solution requires open communication among purchasers and a balance between the work involved tweaking an open-source solution and the smoother but likely expensive offerings of private vendors. Hopefully this work has provided the starting point for those looking at their options for improving DICOM compliance in ophthalmic or other imaging modalities.

Appendix

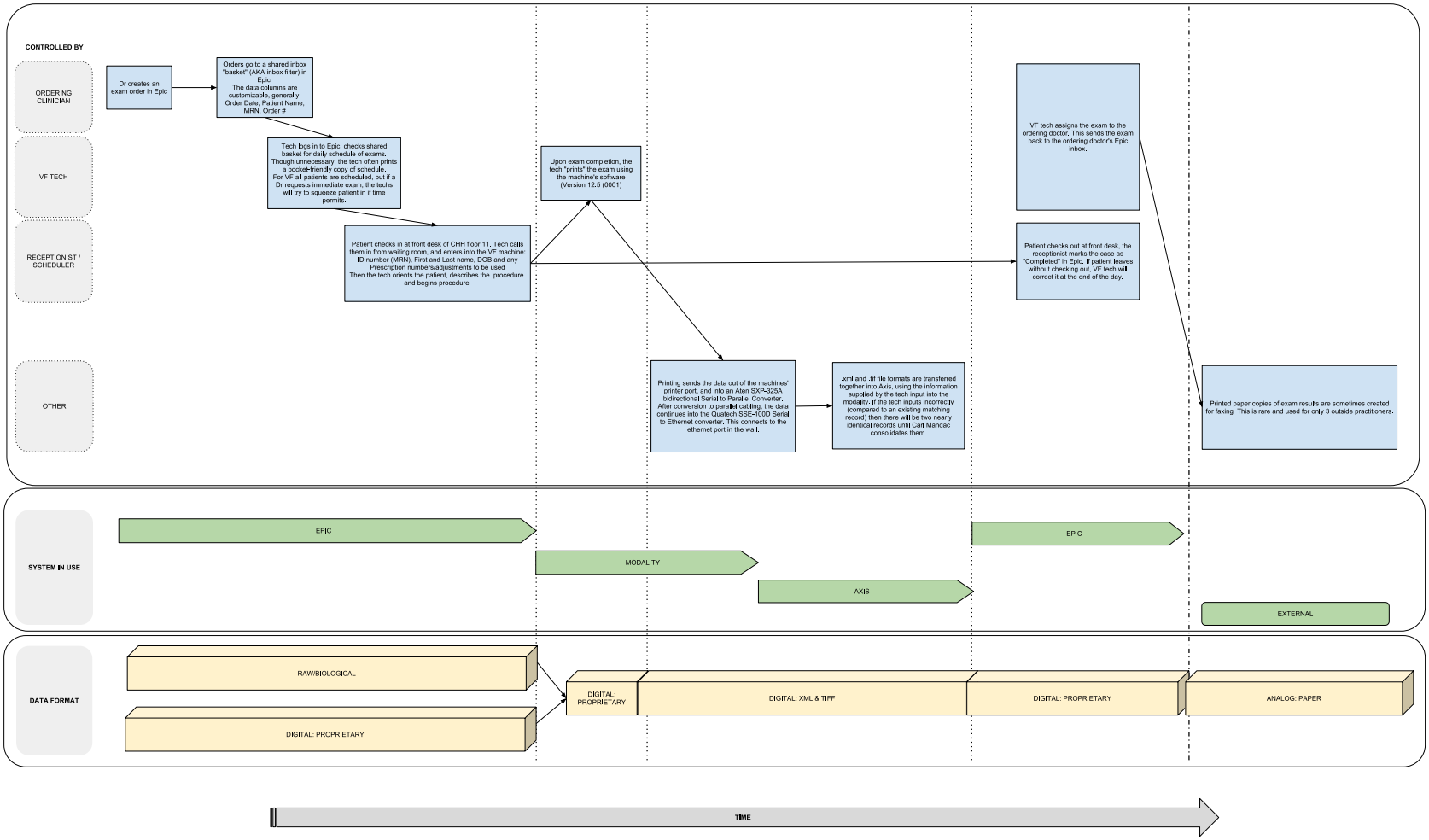
Acronyms

ACR: American College of Radiology
ADT: Admission, Discharge and Transfer
AE: Application Entity
CAD: Computer-Aided Diagnosis
CR: Computed Radiography
CT: Computed Tomography
DICOM: Digital Imaging and Communication in Medicine
HIPAA: Health Insurance Portability and Accountability Act
HIS: Hospital Information System
HL7: Health Level Seven International
IE: Information Entity
IEEE: Institute of Electrical and Electronics Engineers
IHE: Integrating the Healthcare Enterprise
IOD: Information Object Definition
ISO: International Organization for Standardization
JIRA: Japanese Industry Radiology Apparatus
LIS: Laboratory Information System
MRN: Medical Record Number
MWL: Modality Worklist
NEMA: National Electrical Manufacturers Association
OCT: Optical Coherence Tomography
PACS: Picture Archiving and Communication System
PMR: Practice Management System
RIS: Radiology Information System
RSNA: Radiological Society of North America
SCP: Service Class Provider
SCU: Service Class User
SNOMED CT: Systematized Nomenclature of Medicine, Clinical Terms
SOP: Service Object Pair
SR: Structured Report
SRIO: Structured Reporting Information Object (allows SNOMED codes to be mapped to DICOM)
VR: Value Representations
XML: Extensible Markup Language

Diagrams

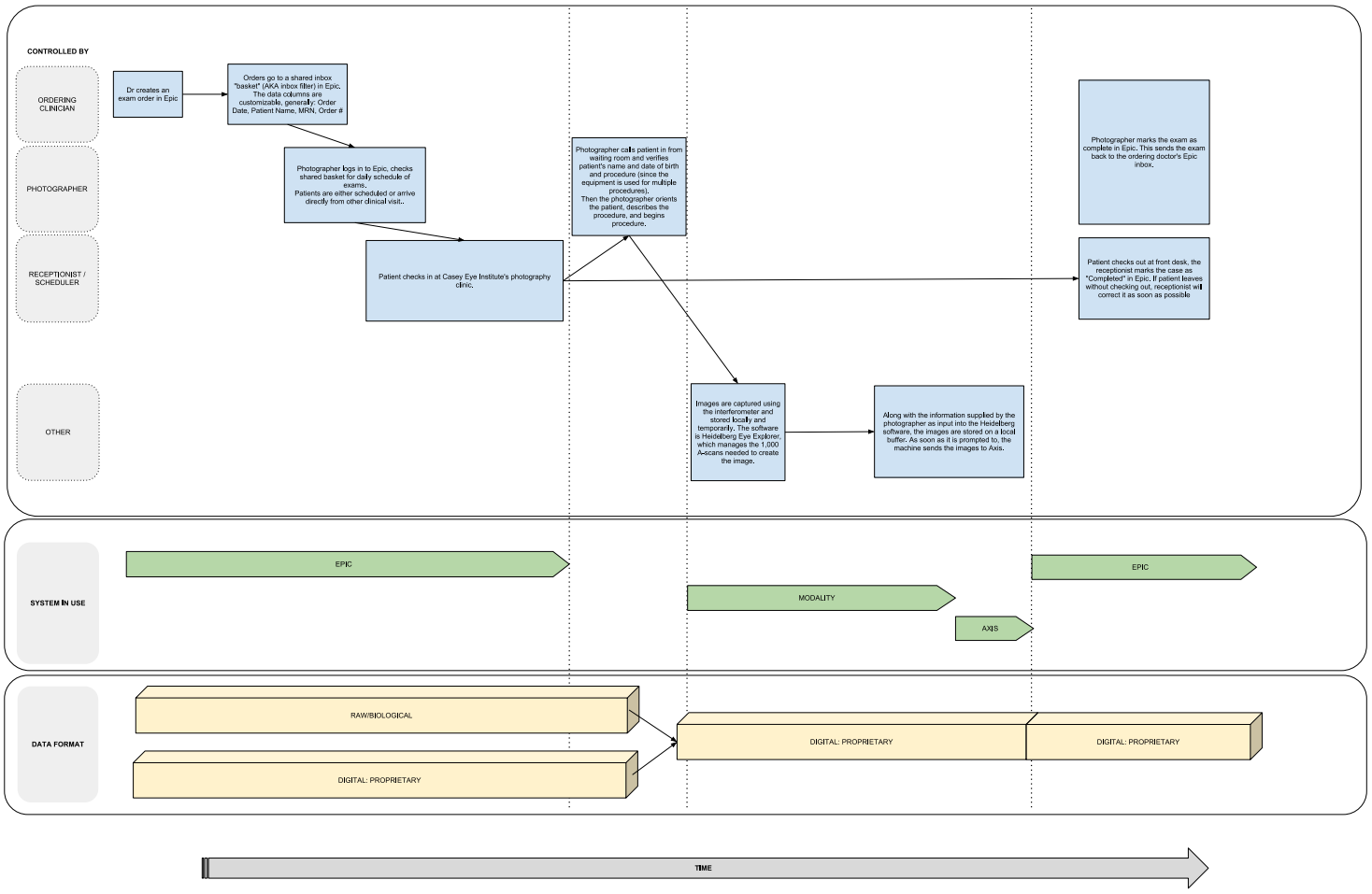
1. Visual Field Workflow

Data and workflow for Humphrey Visual Field



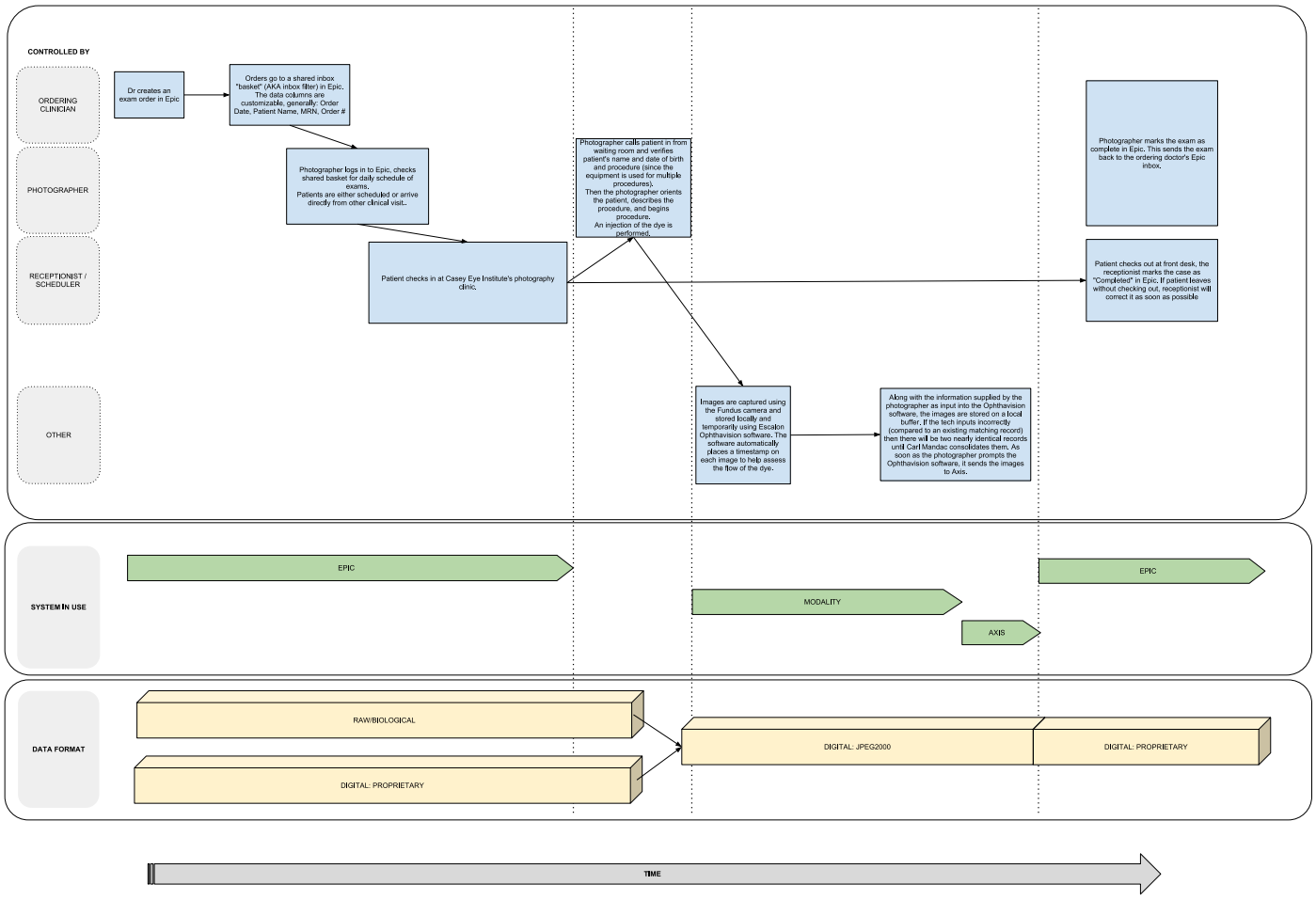
2. OCT Spectralis Workflow Diagram

Data and workflow for optical coherence tomography



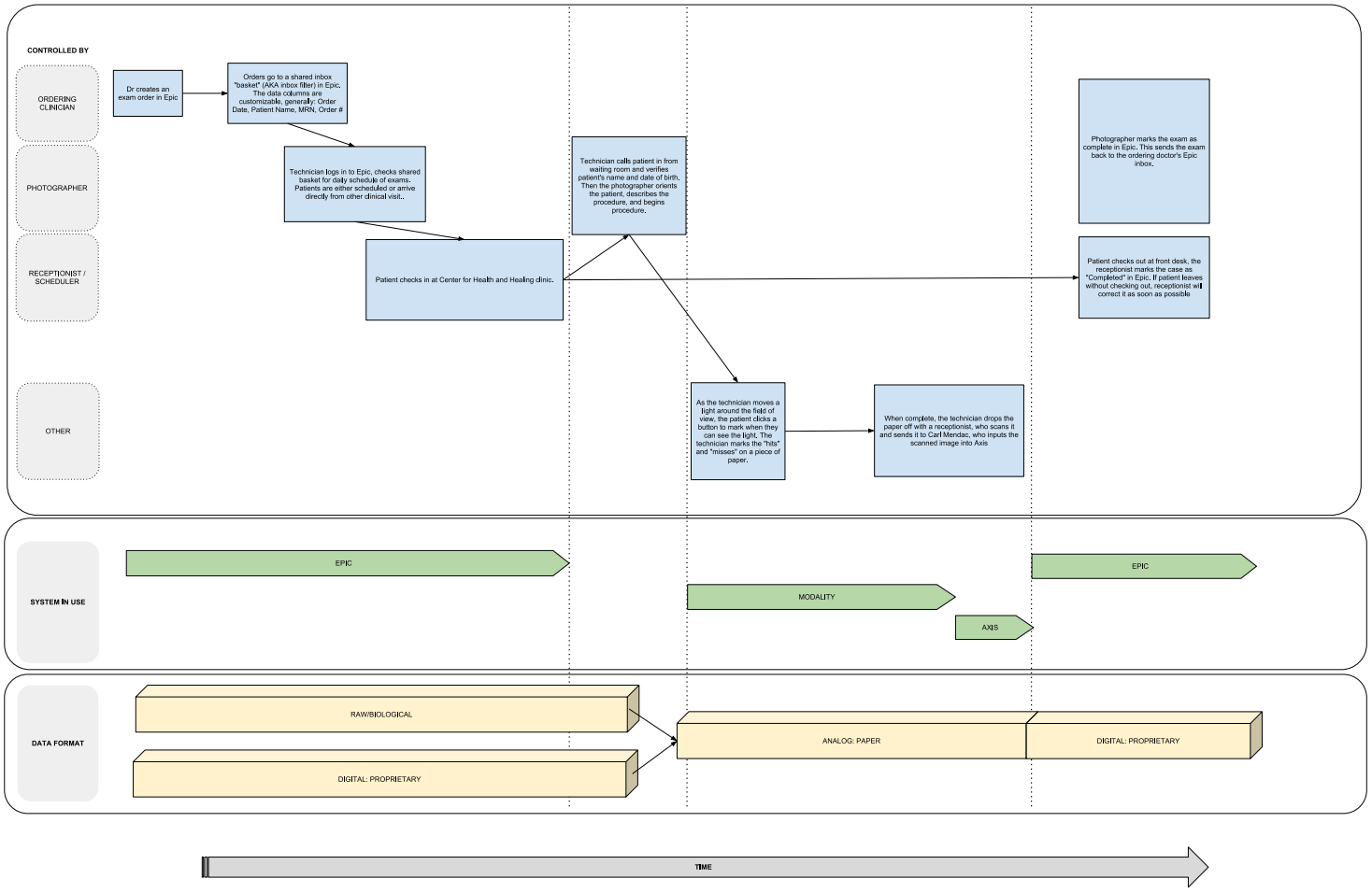
3. Fluorescein Angiogram Workflow Diagram

Data and workflow for fluorescein angiography



4. Goldmann VF Workflow Diagram

Data and workflow for Goldmann perimetry



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