EPOCH®: A Web-Based Platform for Integrating Outcomes Research and Healthcare Delivery

GE Soto, JA Spertus

University of Missouri - Kansas City, MO, USA

Abstract

EPOCH® is a unified web portal and services framework for healthcare IT applications based on Microsoft®'s .NET® platform that has been specifically designed to help bridge outcomes research and healthcare delivery. A signature feature of the EPOCH® platform is a visually driven interface that allows outcomes researches to create sophisticated data collection and decision support tools with little or no programming effort. Existing modules include: (1) eCliPSE™, an HL7-compliant enterprise data services platform for integrating EPOCH® with third-party clinical information systems; (2) eRAPTOR™, a longitudinal data capture tool for clinical data collection; and (3) ePRISM®, a real-time risk modeling and decision support system. To date, EPOCH® and its related technologies have been used in several thousand patient encounters across multiple institutions.

1. Introduction

The field of outcomes research is dedicated to assessing the impact of healthcare practices on patients and populations. Quantifying the complex relationships between patient-specific determinants, care practices and policies, and outcomes requires the implementation of systems and processes for the collection and management of patient clinical data, often utilizing electronic health information systems (HIS). Although a broad spectrum of HIS systems currently exist and are in use—most fall short of meeting the diverse set of needs required for effective outcomes research. Furthermore, such data collection—and more importantly, application of the clinical knowledge derived from such studies—is often not integrated into the healthcare delivery process.

Over the past several years, a multidisciplinary effort has been underway aimed at the development of a robust information technology infrastructure geared towards the outcomes research and healthcare communities. This effort has focused on the delivery and use of evidence-based risk prediction models at the point of patient care, as well as on building the infrastructure necessary to collect the data required to drive the generation and validation of such models. Herein, we present a general overview of this technology platform. Details of specific components and clinical experiences with the technology have been published elsewhere [1-5].

2. EPOCH®

EPOCH® is a unified web portal and services application framework built on Microsoft®'s (MS) .NET® platform which utilizes multiple client- and server-side technologies including ASP.NET and AJAX to allow users to create and deliver dynamic web applications and XML web services.

2.1. System architecture and design

EPOCH® features a visually driven set of web-based management and content authoring tools to facilitate the rapid development of web sites and clinical tools for intranets as well as the internet. A role-based access control system, coupled with support for group membership, Forms and Windows® authentication, as well as multiple modes of user registration, offers a broad range of options for creating and managing user accounts and controlling access to application content. EPOCH® utilizes MS Internet Information Services (IIS) and MS SQL Server for web services and data storage, respectively, although other database platforms can be supported. A multi-tier system architecture offers the ability to scale application components as needed, and EPOCH® offers out-of-the-box support for web gardens and multi-server deployments. A modular design and extensible application programming interface (API) facilitates the incorporation of new functionality through the creation of custom modules.

A tightly integrated XML web services infrastructure allows for the management of web services and portal access through a single administrative interface. It also provides a mechanism by which third-party developers and IT staff can gain easy access to Web Services Description Language (WSDL) contracts and other online documentation in order to rapidly develop web service clients.

2.2. Data modeling framework

The *CommonDataModelingFoundation* (CDMF) namespace within the EPOCH® API provides a unified framework for all data modeling operations. The CDMF encompasses logic governing primitive and composite data types, mathematical data transformations, regression models, and output rendering. The CDMF in essence defines the set of rules governing the representation and manipulation of clinical data within EPOCH® and modules such as *e*CliPSE™, *e*RAPTOR™ and *e*PRISM®.

2.3. Data security

EPOCH® makes full use of the MS Code Access Security (CAS) model to protect data and vital system resources from unauthorized access, blocking all read/write operations to the system registry and file system outside of the application root directory on the host server. Additional restrictions are placed on access to unmanaged code assemblies and serviced components (COM+).

A managed code-based cryptography class provides those modules handling protected health information (PHI) with access to encryption algorithms implementing the Advanced Encryption Standard (AES). All cryptographic ciphers are dynamically generated from composite key values that are unique to each EPOCH® deployment, reducing the chances of PHI becoming vulnerable even if the underlying SQL data store is compromised. Stored procedures in the SQL data access tier help mitigate the risk of SQL injection attacks.

3. EPOCH® modules

In addition to standard content management functions (*e.g.*, contacts, documents, events, *etc.*), a series of modules have been created aimed at bridging outcomes research and healthcare delivery: (1) *e*CliPSE™, an HL7-compliant enterprise data services platform for integrating EPOCH® with third-party clinical information systems; (2) *e*RAPTOR™, a longitudinal data capture tool for use in clinical trials and registries; and (3) *e*PRISM®, a translational risk modeling platform that allows regression models to be deployed as decision-support tools or embedded within document templates.

3.1. *e*CliPSE™

The *Clinical Data Integration Platform Services for Enterprises* module for EPOCH® (*e*CliPSE™) is an enterprise-level data services platform for managing patient information and data within EPOCH® and its modules. All clinical data operations are managed and audited through *e*CliPSE™, which provides a consistent database transaction layer.

The *e*CliPSE™ *Data Integration Service* is an XML web service that offers a robust yet flexible mechanism for linking EPOCH® to existing clinical information systems (*e.g.*, ADT and ORU feeds). The service supports both single and bulk data transmission transactions, along with web methods for retrieving the data element definitions in use by a particular EPOCH® deployment.

*e*CliPSE™ *Connect* is a relay application that runs as a Windows® service hosted on a server located within an institution's network firewall, and can transmit incoming clinical data to an instance of the *e*CliPSE™ *Data Integration Service* running on an EPOCH® deployment hosted either within an institutional network or at an offsite data center. In addition to being protected via SSL, all data is encrypted via the Advanced Encryption Algorithm (AES) utilizing ciphers that are dynamically generated from cryptography keys that are unique to each institutional deployment. When coupled with a third-party HL7 gateway [6], eCliPSE® *Connect* can accept incoming HL7-compliant feeds over a variety of transport layers including TCP/IP, HTTP, FTP, and email.
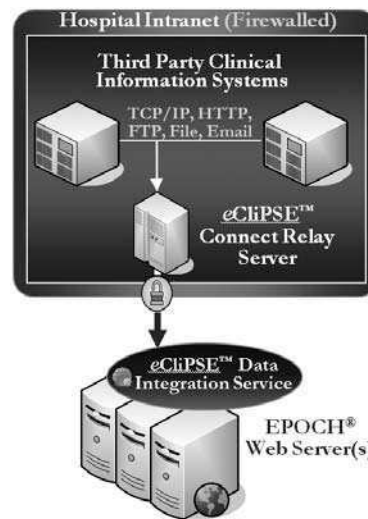

Figure 1. Data transport model for the exchange of patient data between third-party clinical information systems and EPOCH® via *e*CliPSE™.

3.2. *e*RAPTOR™

The *Rapid Acquisition Platform for Translational and Outcomes Research* module for EPOCH® (*e*RAPTOR™) provides an easy to use yet robust solution for web-based clinical trial and registry data collection. Data element definitions can be created via a visual interface utilizing any of the primitive and/or composite data types supported by the CDMF (*e.g.*, Boolean, categorical, continuous, date-time, character). A robust scripting

language allows complex relationships between parameters to be defined, allowing for implementation of scoring systems and imputation of missing data elements.
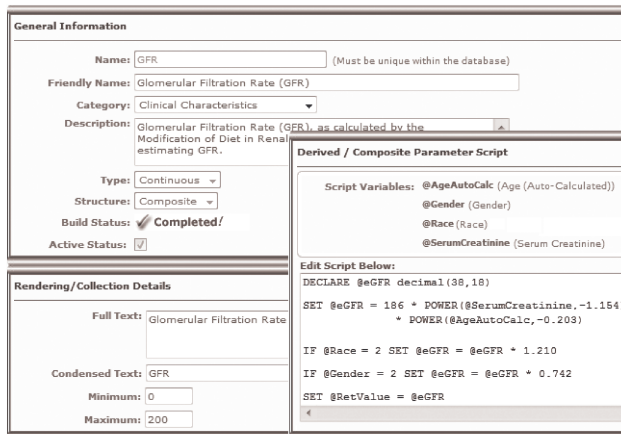

Figure 2. Composite screen shot of the data element definition interface.

Once defined, data elements can be organized into clinical research forms (CRFs), which can then be further organized into collection sets comprised of one or more CRFs. Data elements can be re-used across CRFs, facilitating standardization of data definitions and terminology across studies.

*e*RAPTOR™'s rendering engine can automatically generate web-based forms for data collection based on the data elements assigned to those forms; changes in the definitions of assigned data elements or the addition/removal of data elements are automatically reflected in the rendered forms. When combined with *e*CliPSE™, the forms can be pre-populated with values that have been imported from third party clinical information systems (each value bearing its own time stamp), thereby streamlining the data collection process and minimizing the risk of manual data entry errors.

A visual query design interface allows data to be readily extracted from the underlying SQL database and exported in a tabular format for subsequent analysis.

3.3.   *e*PRISM®

The *Personalized Risk Information Services Management* module for EPOCH® (*e*PRISM®) provides a powerful and versatile platform for translating complex risk-prediction models into web-based tools that can be used for a broad range of clinical applications including expert decision support, real-time patient risk stratification, generating patient-specific documentation for resource utilization reviews and audits, and patient education (including creating informed consent documents customized to a specific patient's risk profile).

A signature feature of *e*PRISM® is its visual model editing environment, which allows complex mathematical models to be rapidly defined in a matter of minutes, utilizing dynamic on-screen instructions and rendering of prediction formulae as well as robust validation services; no coding is required. Once defined, models can be delivered via EPOCH® in any number of forms, ranging from standalone web-based prediction 'calculators' to robust patient-specific clinical documentation systems to XML web services.
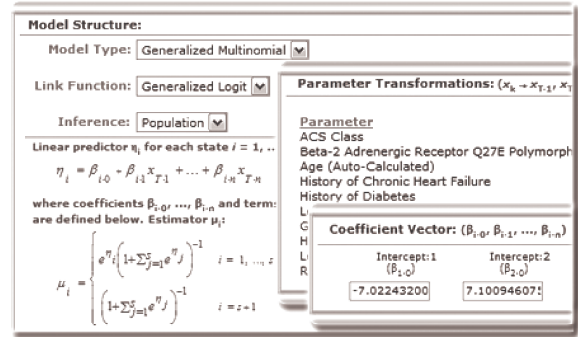

Figure 3. Composite screen shot of the model building interface, showing the on-screen rendering of a model.

*e*PRISM® employs a general regression modeling framework based on the CDMF for expressing predictions, encompassing all major types of prognostic models including linear, generalized linear, cumulative multinomial, generalized multinomial, proportional hazard and other custom model types. Full details of *e*PRISM®'s modeling framework have been presented elsewhere [1].

Once models have been defined within *e*PRISM®'s modeling library, they are readily available to users of EPOCH®. Models can be executed either individually or in user-selected groups. *e*PRISM® dynamically creates a data input form containing only those data elements required by the requested model(s); as with *e*RAPTOR™, when combined with *e*CliPSE™ the form can be pre-populated with patient-specific information derived from third-party clinical information systems or previously stored inputs. An intelligent data collection engine automatically maps related data fields and eliminates any redundant data elements across multiple selected models.

Institutions can also create customized documentation templates containing the embedded outputs of modeling results, allowing for the rapid creation of patient-specific documentation solutions for such applications as informed consent and resource utilization audit defense. Custom documents can be readily created using *e*PRISM®'s built-in MS Word®-like editing capabilities, with a broad range of graphical output options to meet

specific needs. Documents can either be rendered as HTML or PDF files, and can be updated on-the-fly by institutions as needed. Whenever a model definition is updated within *e*PRISM®'s modeling library, all document templates utilizing that definition are automatically updated, ensuring that users have access to the most up-to-date models.

In additional to being accessible via the web portal interfaces described above, models can also be executed via the *e*PRISM® *Remote Modeling Service.* This XML web service allows third-party developers to directly integrate their applications with *e*PRISM®'s modeling engine: patient data can be submitted anonymously to the web service, executed against one or more selected models, and results returned to the calling web client. As is the case with the portal interface, when a model definition is updated within *e*PRISM®'s modeling library, all XML web services utilizing that definition are automatically updated, ensuring that web service clients have access to the most current models.

4.   Clinical applications

EPOCH® and its related modules can be used for a broad range of applications, from data collection for use in clinical research to the creation of powerful evidence-based tools that deliver decision support and patient-specific documentation services at the point-of-care. EPOCH®'s visual design and management tools allow robust web applications to be rapidly developed and implemented with minimal effort and without the need for programming skills or services.

The unique risk modeling translational platform offered by *e*PRISM® allows outcomes researchers to rapidly translate their work into clinical tools for use in routine healthcare delivery. Indeed, risk prediction tools utilizing robust models from a broad range of sources— including the Mid America Heart Institute of Kansas City, Missouri, the Blue Cross Blue Shield of Michigan Cardiovascular Consortium, the Northern New England Cardiovascular Disease Study Group, and the American College of Cardiology—have already been created and are currently deployed at multiple hospitals in the Midwestern United States. These tools have been used in several thousand clinical encounters to date, where they have provided both clinicians and patients with the ability to readily view and understand the complex relationships between patient clinical characteristics, treatments, compliance and outcomes.

Multiple clinical trials assessing the impact of EPOCH®-based technologies have either been published or are currently ongoing [3-5].

5.   Discussion and conclusions

As a field dedicated to assessing the impact of healthcare practices on patients and populations, outcomes research is becoming an ever more integral part of the healthcare delivery process. EPOCH® and its related modules provide a technology framework for clinical research and data collection that can be readily integrated with enterprise-level healthcare operations, and which can ultimately be used to deliver evidenced-based risk prediction tools derived from these and other research efforts to clinicians at the bedside. EPOCH® offers a seamless link between health care providers, clinical information systems, and outcomes researchers, and provides a robust infrastructure for integrating outcomes research efforts with the delivery of routine clinical care.

Disclosures

The authors wish to disclose that each has a significant equity position in Health Outcomes Sciences, which owns and distributes EPOCH® and related technologies.

References

[1]   Soto GE, Jones P, Spertus JA. PRISM: A Web-based Framework for Deploying Predictive Clinical Models. Computers in Cardiology 2004;31:193-6.
[2]   Soto GE, Spertus JA. EPOCH® and ePRISM®: A Web-Based Translational Framework for Bridging Outcomes Research and Clinical Practice. Computers in Cardiology 2007;34:205-8.
[3]   Decker C, Arnold SV, Olabiyi O, Ahmad H, Gialde E, Luark, J, Riggs L, DeJaynes T, Soto GE, Spertus JA. Implementing an Innovative Consent Form: The PREDICT Experience. Implementation Science 2008;3,58-68.
[4]   Arnold SV, Decker C, Ahmad H, Olabiyi O, Mundluru S, Reid KJ, Soto GE, Gansert S, Spertus JA. Converting the Informed Consent From a Perfunctory Process to an Evidence-Based Foundation for Patient Decision Making. Circulation: Cardiovascular Quality and Outcomes 2008;1,21-8.
[5]   Decker CJ, Ahmad H, Soto GE, Kosiborod M, Reid KJ, Jones PG, Spertus JA. Patient Refined Expectations Deciding Invasive Cardiac Treatment (PREDICT). Journal of the American College of Cardiology 2007;49:286A.
[6]   Kestral Computing Pty Ltd. Heidelberg, Australia.

Address for correspondence

John Spertus, MD, MPH, FACC
Mid America Heart Institute - CV Research
4401 Wornall Road, Kansas City, MO 64111

Web: http://www.HealthOutcomesSciences.com.