Technical Note

Interfacing Complex Laboratory Instruments during a Change to Epic Beaker

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Abstract

Background: Implementing a laboratory-developed test sometimes requires incorporating an unconventional device into the laboratory information system (LIS) and customizing an interface to reduce transcription error and improve turnaround time. Such a custom interface is a necessity for complicated high-volume tests such as 25-OH Vitamin D by liquid chromatography-tandem mass spectrometry (LC-MS/MS) when there is no vendor-or LIS-supplied interface available. Here, we describe our work and experience interfacing a API 5000 LC-MS/MS instrument with our newly implemented LIS, Epic Beaker, using a combination of in-house scripting software and a middleware vendor, Data Innovations. **Materials and Methods:** For input interfacing, custom scripting software was developed to transcribe batched order lists generated by Epic into files usable by the instrument software, Analyst®. For output interfacing, results from the LC-MS/MS system were fed to a unidirectional instrument driver made by Data Innovations and selected data were transferred to the LIS. **Results:** Creation and validation of a new driver by Data Innovations took approximately 6 months. The interface was adopted for 25-OH Vitamin D and testosterone testing during periods of increasing test volume (4.5-fold over 8 years and 1.25-fold over 5 years). The amount of time spent reporting 25-OH Vitamin D results decreased 82% per order resulting in a savings of 1370 technician work hours and the amount of time spent reporting testosterone results decreased 75% per order resulting in a savings of 400 technician work hours. **Conclusions:** A mixed model using custom scripting and curated commercial middleware serve as a durable interface solution for laboratory instrumentation such as an LC-MS/MS and are flexible to future changes in instrument software, networking protocols, and the scope of LISs and work area managers.

Keywords: Beaker, Data Innovations, interface, middleware

Introduction

Liquid chromatography-tandem mass spectrometry (LC-MS/MS) has grown in popularity over the past 20 years for applications in clinical diagnostic laboratories, especially in areas of clinical endocrinology, therapeutic drug monitoring, and biochemical genetics. Mass spectrometry provides several advantages including superior sensitivity, ability to simultaneously measure multiple analytes, reduced need for costly reagents, and reduced interferences/improved specificity. Therapeutic drug monitoring such as cyclosporine, sirolimus, and tacrolimus, as well as Vitamin D testing fast-tracked LC-MS/MS into the clinical lab as demand sharply rose in recent years alongside a volatile immunoassay market (e.g. 2006 withdrawal of Nichols Advantage, and 2011 withdrawal of Siemens tacrolimus tests).[1,2] LC-MS/MS has since shown superior analytical reproducibility compared to immunoassays and has gained widespread adoption.[3,4]

We deployed a new LC-MS/MS instrument for a laboratory developed test (LDT) of 25-OH Vitamin D during this period of high volume send-out testing and have since expanded to other analytes including testosterone, urine and salivary cortisol, and other steroid hormones. However, these tests, especially the 25-OH Vitamin D test, produced large and multiplexed

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datasets which increased the risk of clerical errors and resulted in slower turnaround times due to manual result entry into the laboratory information system (LIS). Furthermore, during implementation of LC-MS/MS, our institution changed LIS vendors from Sunquest to Epic Beaker. Given the high volume and complexity of data generated by the LC-MS/MS paired with substantial changes to the LIS, an automated interface was deemed a necessity.

Interfacing laboratory equipment to the LIS is a challenging problem as newer classes of devices are adopted, ready-made interfaces are less frequently provided by the LIS vendor or instrument manufacturer, and complex functionality (e.g., autoverification) is moving out of the LIS and into intermediary software.[5] To the authors' knowledge, the only published LC-MS/MS interface used an in-house data management interface based on the scripting software, AutoHotKey,[6] and exported results to the Sunquest LIS. Given the lack of an available interface for Epic Beaker, we developed a mixed in-house and commercial interface with the goal of scalability and adaptability to further changes to the LIS and instruments.

Materials and Methods

Instrumentation

Our LC-MS/MS system is the API 5000®, a tandem mass spectrometer, which includes a triple quadrupole mass spectrometer with Turbo V™ source, dedicated computer (a Dell P2314H), and instrument software Analyst® (ver 1.6.2; SCIEX™, Redwood Shores, CA, USA).

Connectivity middleware

Data transfer to Epic Beaker used Instrument Manager made by Data Innovations (Burlington, VT, USA), a middleware company for supporting instrument connectivity. A new connectivity mapping driver between the result file and Epic Beaker was designed and validated over a period of 6 months. Of note, interface design for the mass spectrometer took longer than the typical 3–6 months duration because the LC-MS/MS does not use a standard American society for testing and materials (ASTM) or health level 7 [HL7] interface protocol. After the design and validation of an instrument driver, the duration for subsequent driver deployment at the same or a different institution is estimated to be between 4 and 6 weeks.

Laboratory information system

The recipient LIS for exported LC-MS/MS results is Epic Beaker (Epic Systems, Inc., Madison, WI, USA), a newer LIS and part of the Epic suite providing an enterprise-wide solution for laboratory and hospital systems.

Results and Conclusion

Middleware driver validation

The three steps for validation of our driver/instrument interface were performed as follows: (1) Testing connectivity between the instrument and Data Innovations. (2) Unit testing, which involved testing the individual test code mappings to ensure that data populates into the proper test code fields. (3) Functional testing: This testing involved the testing of rules that were built in Data Innovations, flagging of instrument error codes, reporting of linear limits, etc. [Figure 1]. These steps required end-to-end testing from the running of a sample through results reporting and display in the LIS. The most challenging step in interfacing the LC-MS/MS was determining what data fields out of the many created by the instrument were required for reporting patient results and configuring the driver to parse out those fields. A critical aspect to successful design and testing of the interface was a close working relationship between the systems analyst (C.S.) and an experienced instrument user (D.Z.) who was knowledgeable about the instrument, the instrument file types, and a general working knowledge about computers.

Input interfacing

Batch order lists are exported from Epic and a custom script, written in the programming language Perl,[7] parses these batch order files. Perl is a well-supported and widely used open-source programming language adept at file management, text parsing, and system input/output. Perl also has a longstanding history of usage in medical informatics.[8] The Perl script transcribes patient identifiers, container identifiers, and accession number data fields into a tab-delimited text file for import into Analyst®, the LC-MS/MS system software [see Figure 2 for code]. Analyst®, imports tab-delimited batched order files, controls instrument operations and sample batch runs, collects data,

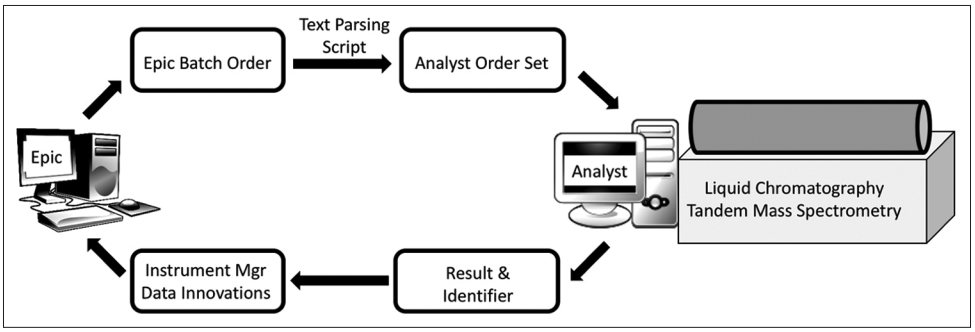

Figure 1: Instrument interface flow diagram showing steps from Epic Batch Orders to the liquid chromatography-tandem mass spectrometry Instrument (top) and from test results to the laboratory information system (bottom)

exports spectral data, and exports patient results. These steps automate the process of initiation of batched orders for the high-volume 25-OH vitamin D and other tests, and reduce the risk of off-target testing, transcriptional errors, and delays.

Instrument result

Analyst® exports files containing patient identifiers, spectral data (retention time, peak intensity, peak height, etc), and overall quantitative result values. Identifier and result data fields defined in the Data Innovations driver were extracted from the result file and were automatically transferred to servers hosted by Data Innovations. Further, data manipulation is not currently performed by the middleware and the only "true" rule is the rounding of result values. Future work will include autovalidation rules to flag results for manual review. Instrument manager driver settings define the translation of result codes as well as HL7 transfer to Epic Beaker and our broader enterprise-wide Epic electronic medical record system. This interface successfully transfers results to Epic Beaker and will be flexible to future instrument software updates and networking hardware changes. Importantly, this interface did not require ongoing support for computer programming or software and hardware changes lacking backward compatibility.

```
#!/usr/bin/perl -w
use strict;

#list export and import file
open(PENDING,'export.txt');
open(EXPORT,">import.txt");
my @pl=<PENDING>;

my $pl;
my @process;

foreach(@pl){
        $_=~s/[\s]//g;
        chomp($_);
        unless(!$_) {
            push(@process,$_);
        }
        print $_,"\n";
}
foreach(@process) {
    if($_=~/[\d]{1,3}[.]/) {
        print EXPORT $&,"\t";
    }
    if($_=~/STANDARD/) {
        print EXPORT $_,"\n";
    }elsif($_=~/BLANK/) {
        print EXPORT $_,"\n";
    }elsif($_=~/API5000/) {
        print EXPORT $_,"\n";
    }

    if($_=~/[()][0-9]{8}[)]/) {
        my $mrn=$&;
        my $patient_name=$_;
        my $last;
        my $first;
        $patient_name=~s/[\d]//g;
        $patient_name=~s/\(//g;
        $patient_name=~s/\)//g;
        ($last,$first) = split(",",$patient_name);
        my $name = $last.",".substr($first,0,1);
        print EXPORT $name,"\n";
    }
}
```

Figure 2: Source code for preprocessing Epic batch order lists to a format suitable for import into an analyst, the liquid chromatography-tandem mass spectrometry instrument software

Implementation

LDT of 25-OH Vitamin D was implemented and transitioned to the new automated interface to replace previously costly send-out testing. 25-OH Vitamin D test order volume increased from 5000/year to 24,000/year over the subsequent 8 years (a 4.5 fold rise) and the amount of time spent reporting results per order decreased from 0.6 to 0.104 × 100 h/1000 orders per year (a 82% reduction) resulting in a savings of 1370 technician work hours [Figure 3]. The interface's accuracy and fast turnaround time mitigated the paralleled increasing popularity for Vitamin D testing and having the test performed locally facilitated measures to improve utilization and appropriate ordering. Given the success of the interface, total testosterone was added to the automated workflow and we are currently in the process of implementing mycophenolic acid testing. Over the 5 years following implementation of the interface for testosterone, order volume has increased 1.25 fold (4000–5000 orders) and the amount of time spent reporting results per order decreased

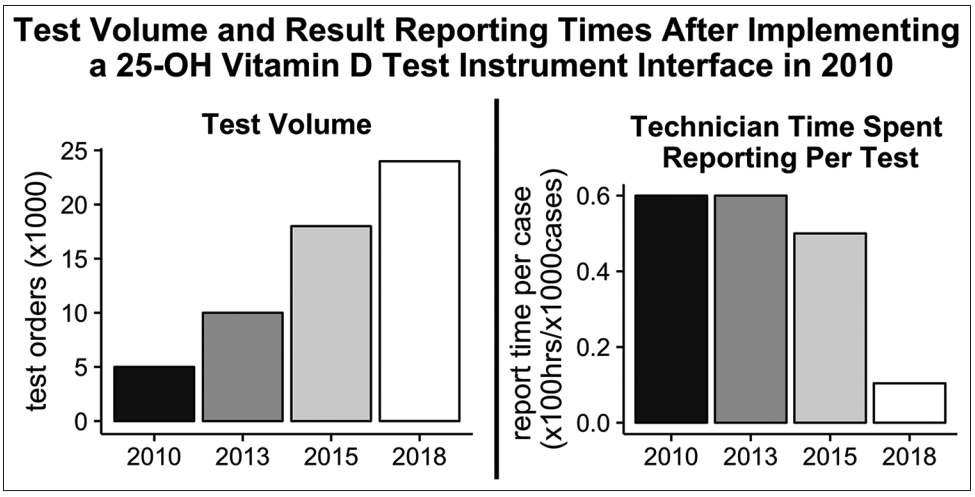

Figure 3: Annual test orders and time spent reporting results in laboratory information system for 25-OH Vitamin D liquid chromatography-tandem mass spectrometry test after implementation of instrument interface in 2010. Left panel: Test volumes from 2010 to 2018. Right panel: Technician time to report results from 2010 to 2018

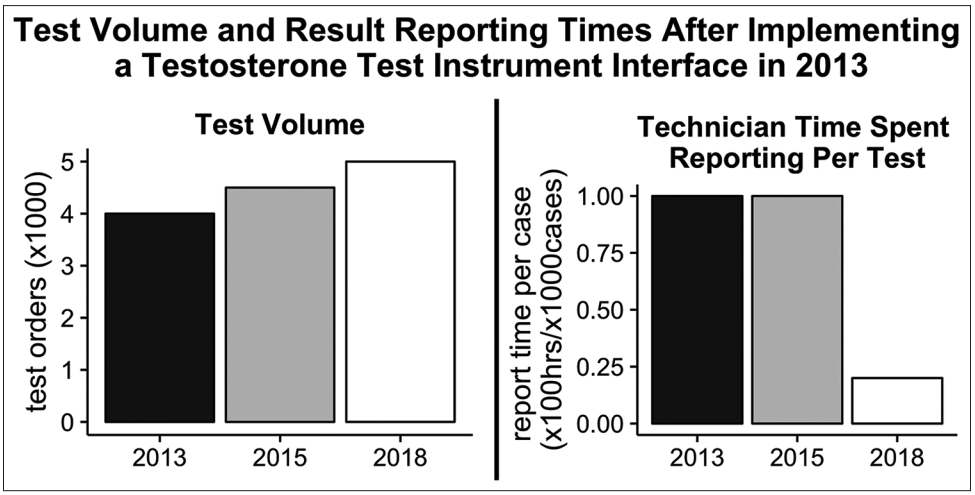

Figure 4: Annual test orders and time spent reporting results in laboratory information system for testosterone liquid chromatography-tandem mass spectrometry test after implementation of instrument interface in 2013. Left panel: Test volumes from 2013 to 2018. Right panel: Technician time to report results from 2013 to 2018

75% (from 4.0 to 1.0 × 100 h/1000 orders) resulting in a savings of 400 technician work hours [Figure 4].

Conclusion

Overall our work shows that a mix of custom and commercial solutions provides a durable interface for laboratory instruments.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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