

Technical Note

The successful implementation of a licensed data management interface between a Sunquest® laboratory information system and an AB SCIEX™ mass spectrometer

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Abstract

Background: Interfacing complex laboratory equipment to laboratory information systems (LIS) has become a more commonly encountered problem in clinical laboratories, especially for instruments that do not have an interface provided by the vendor. Liquid chromatography-tandem mass spectrometry is a great example of such complex equipment, and has become a frequent addition to clinical laboratories. As the testing volume on such instruments can be significant, manual data entry will also be considerable and the potential for concomitant transcription errors arises. Due to this potential issue, our aim was to interface an AB SCIEX™ mass spectrometer to our Sunquest® LIS. **Materials and Methods:** We licensed software for the data management interface from the University of Pittsburgh, but extended this work as follows: The interface was designed so that it would accept a text file exported from the AB SCIEX™ × 5500 QTrap® mass spectrometer, pre-process the file (using newly written code) into the correct format and upload it into Sunquest® via file transfer protocol. **Results:** The licensed software handled the majority of the interface tasks with the exception of converting the output from the Analyst® software to the required Sunquest® import format. This required writing of a “pre-processor” by one of the authors which was easily integrated with the supplied software. **Conclusions:** We successfully implemented the data management interface licensed from the University of Pittsburgh. Given the coding that was required to write the pre-processor, and alterations to the source code that were performed when debugging the software, we would suggest that before a laboratory decides to implement such an interface, it would be necessary to have a competent computer programmer available.

Key words: Data management interface, mass spectrometry, sunquest

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INTRODUCTION

The use of complex instruments has become commonplace in the clinical laboratory.^[1,2] An example of such complex

equipment is a liquid chromatography-tandem mass spectrometry (LC-MS/MS) system, which, in recent years has become a frequent addition to clinical laboratories for a variety of applications including testing for drugs of abuse,

therapeutic drug monitoring and steroid analysis.^[3-6] Such devices offer high potential sample throughput,^[7,8] but, as they are not currently accompanied by vendor-supplied interfaces to enable them to be connected to a laboratory information system (LIS), they also impose a potentially burdensome requirement for manual data transfer with the concomitant risk of transcription errors.

To the authors' knowledge, the only commercially available software to software interface that exists for the mass spectrometer in use here, is from Data Innovations LLC (South Burlington, Vermont, USA).^[9] The advantage of using a commercially available product is that the company already has software developed for a number of different instruments and the laboratory does not require expertise in computer programming to implement such an interface. However, the disadvantages are the significant cost of such an interface and the decrease in control and ease of adaptability of such a product as far as the laboratory is concerned.

A group in the Department of Pathology at the University of Pittsburgh Medical Center developed a data management interface to help solve this problem^[10] successfully interfacing a Waters 2795 LC-MS/MS to a Sunquest[®] LIS. We describe here the implementation of the same data management interface using the same LIS, but a different mass spectrometer that is in use in our laboratory and we extend their work by describing the pre-processor code that was required to convert the data output from the mass spectrometer into a format accepted by the LIS.

MATERIALS AND METHODS

Liquid chromatography-tandem mass spectrometry system

The targeted analytical mass spectrometer was the AB SCIEX[™] × 5500 QTrap[®] (AB SCIEX[™], Foster City, CA) coupled to a Shimadzu Prominence UFLC (Ultra-Fast Liquid Chromatography, Shimadzu Scientific Instruments, Pleasanton, CA) LC system. The standalone computer running the LC-MS/MS was a Dell Optiplex 960 that uses the Microsoft Windows 7 operating system (Microsoft Corporation, Redmond, WA). The Analyst[®] 1.5.1 application (AB SCIEX[™], Foster City, CA) acquires data from the mass spectrometer and generates a results table upon the user's request. A text file (txt) of the results table can then be exported from Analyst[®] by the user and saved in the appropriate folder.

Data management software

The data management software was licensed from the University of Pittsburgh (Automated File Transfer for MIM Batch Style Interfaces; ID01516).^[10] The data management software and the other support modules are written in AutoHotKey (AHK), a free open-source

scripting language for automating activities on a computer operating under the Windows operating system.^[11] Both the compiled executable programs and the source text files are included with the data management software. The software program was installed solely on the computer running the LC-MS/MS system.

Laboratory information system

The LIS utilized was Sunquest[®] (Sunquest Information Systems Inc., Tuscon, AZ). Standard parameters such as analyzer and assay identification codes as well as quality control (QC) definitions for the LC-MS/MS assay were defined by adding them to the Sunquest[®] maintenance, using the straightforward and well-documented methods provided by the vendor.

RESULTS AND DISCUSSION

Data required to transfer results to Sunquest[®]

Four discrete data are required to successfully transmit an individual patient result from the LC-MS/MS output text file to Sunquest[®]: The unique patient container identification number (CID - a barcode affixed to the patient sample container that is scanned by a barcode reader, electronically entering the CID into the LC-MS/MS software); the Sunquest[®] test code for the assay being performed (in this case test code PTES for pediatric total testosterone); the assay result for each patient and the QC data (the total testosterone concentrations obtained from running 3 QC materials with each batch of patient samples with mean concentrations of 9, 168 and 535 ng/dL respectively in this case).

Data management software

The data management software consists of libraries of code that are called from a primary compiled program that handles the various aspects of export file management and transfer to the LIS via file transfer protocol (FTP).^[12] The documentation included with the licensed data management software was comprehensive; however, minor discrepancies were discovered between the documented installation file locations and the actual locations specified in the software source code (included with the software). Accurate placement of the library and resource files in appropriate directories and subdirectories was required for the compiled program to find them. Although the author was not familiar with AHK at the time of installation, its similarities to other scripting languages permitted casual review to catch these discrepancies.

File pre-processing

The documentation supplied with the data management software clearly describes the process of integrating a pre-processor, which is required if the data output format from the LC-MS/MS software does not match the input

format of the LIS, but is not supplied with the data management software. In this case, pre-processing of the text file exported from the Analyst® software was required

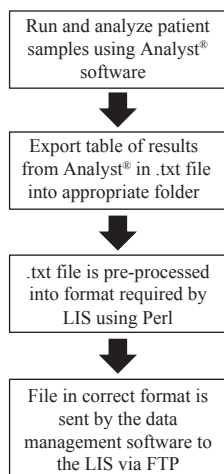


Figure 1: The workflow process from the Analyst® software to the pre-processor, the data management software and finally to the transfer by file transfer protocol to the laboratory information system

in order for Sunquest® to accept the data and Perl was chosen by the authors for writing the pre-processor. Perl is a popular and well-established open-source scripting language used in many contexts, including biomedicine,^[13] is freely available for multiple platforms and can be installed on Windows platform (as well as others) via ActivePerl installer.^[14] Perl stands for “Practical Extraction and Report Language” and is highly suitable for parsing text, making it an ideal language to use for a pre-processor in the context of the Analyst®-Sunquest® interface. A particularly helpful feature of Perl utilized extensively in the pre-processor is its implementation of “regular expressions,” which facilitates searching for particular patterns in a given text string and optionally replacing them with another string. Although the data management software includes a log file, we found that additional logging was helpful during the debugging process, and thus we added additional logging to the Pittsburgh software source files, which were then recompiled. With this in mind, the pre-processor includes a separate log with output to verify that the various steps in the program occur each time it is run. A flow chart documenting the steps in

```

1 use strict;
2 use Readonly;
3 use File::Slurp;
4 use File::Copy;
5 use File::Spec::Functions;
6 use Data::Dumper;
7
8 Readonly my $BASEDIR => 'd:\LCMS1';
9 Readonly my $PROCESS_DIR => '_ReportOutput';
10 Readonly my $OUTPUT_DIR => 'converted';
11 Readonly my $ARCHIVE_DIR => 'archive';
12 Readonly my $METHOD_CODE => 'LCMS1';
13 Readonly my $LOG => 'c:\ahk\app\log_lcms1_preprocessor.txt';
14 Readonly my $LOGDELIM => (' ' x 60) . "\n";
15
16 # open LOG
17 my $fh;
18 open ($fh, ">>$LOG") || doError("Could not open $LOG for writing - $!");
19 print $fh $LOGDELIM . (scalar(localtime)) . "\n";
20
21 # get all files in the to process directory
22 my $dir = catdir($BASEDIR, $PROCESS_DIR); # uses File::Spec::Functions
23 opendir DIR, $dir || doError("Could not opendir '$dir' - $!");
24 my @files = sort(grep !/^\.?$/|\./, readdir DIR);
25 closedir DIR;
26 #doError( Dumper(@files) );
27
28 if (@files < 1) {
29   print $fh 'No files encountered in: '$dir.'"';
30 }
31
32 FILE: foreach my $f (@files) {
33   print $fh 'Processing '$f.'"';
34   my $fpath = catfile($dir, $f);
35   # get current date/time
36   my ($sec, $min, $hr, $mday, $mon, $year) = (localtime(time))[0..5];
37   $year = $year + 1900;
38   $month = $month + 1;
39   my $stamp = sprintf("%u%02u%02u%02u%02u", $year, $mon, $mday, $hr, $min,
$sec);
40   my $newfname = "lcms1_.$stamp._txt_out";
41   my $newfpath = catfile($BASEDIR, $OUTPUT_DIR, $newfname);
42   my @lines = read_file($fpath); # uses File::Slurp
43   #doError( Dumper(@lines) );
44   while (@lines > 0 && $lines[0] !~ m/^Sample Name\tSample ID/) {
45     shift @lines;
46   }
47   shift @lines;
48   my @data;
49   if (@lines < 1) {
50     print $fh ' *** NO DATA encountered in file: '$f.'"';
51     next FILE;
52   }
53   LINE: foreach my $line (@lines) {
54     next if $line =~ m/^s*$/;
55     my @cells = split(/\t/, $line);
56     my $sample_id = $cells[0];
57     # only want QC or CID numbers
58     next LINE unless ( $sample_id =~ m/^s*c\./i || $sample_id =~ m/^s*E\d\./i );
59     my $stest = $cells[17];
60     my $stestcode;
61     if ($stest =~ m/^Testosterone/i) {
62       $stestcode = 'PTES';
63     }
64     push @data, join(' ', $METHOD_CODE, $sample_id, $stestcode, $cells[75]);
65   }
66   print $fh ' Attempt to output new file: '$newfpath.'"';
67   open (OUT, ">$newfpath") || doError("Could not open '$newfpath' for writing - $!");
68   print OUT join("\n", @data);
69   close OUT;
70   print $fh ' File created: '$newfpath.'"';
71   move($fpath, catfile($BASEDIR, $ARCHIVE_DIR, $f));
72   print $fh ' '$fpath.' moved to archive directory: '$ARCHIVE_DIR.'"';
73 }
74
75 print $fh "\n";
76 close $fh;
77
78 exit 0;
79
80
81 sub doError {
82   my ($err, $fh) = @_;
83   print $fh "**** '$err.'"";
84   die $err;
85 }
  
```

Figure 2: Source code written in Perl to pre-process the text file output from the liquid chromatography-tandem mass spectrometry system to a format suitable for transfer to Sunquest® via file transfer protocol

Table 1: Key to the purpose of each line of the source code that was used to pre-process the data output file from the liquid chromatography-tandem mass spectrometry system

Line number	Purpose
1-6	Specify modules that are used in the script
8-14	Specify constants that are used in the script body
16	Text that is not programming code called a “comment” that is included to clarify or document the script/program (Perl comments begin with the pound character “#” and can start at the beginning of a line or afterwards. The # character signals the start of non-code section of the script)
17	Initializes a variable, \$fh, that will be used to print to the log
19, 29, 33, 66, 70, 72, 75, 83	Print information to the log file
22-25	Opens the directory location for the LC-MS/MS output file and obtains a list of the files. The LC-MS/MS file output process is a manual process, including specifying the name of the output file. Therefore, all files are processed to account for manual errors in naming the file in a standard format. The script will verify the types of results by reading the contents of the output file, and thus determine what test code should be sent to Sunquest®
26	A debugging line that was used to verify that all files were properly read from the directory. The comment character “#” ensures that this line is not run in the production code
28-30	Exit the program if no output files are found
32-73	Loop through each output file
34	Obtains the full path of the output file
35-41	Calculate a date stamp and assign the output file name, including a date stamp
42	Reads the file into an array, with each line of the file one element of the array, stripping away the end of line character. This simplifies line by line processing of the file contents. The LC-MS/MS output file contains much more information than the desired assay results and QC data
44-46	Identify initial lines that do not contain the pertinent information and eliminates them (the Perl “shift” function removes the first element of an array, shortening the array by 1)
47	Eliminates the result header line from the LC-MS/MS output file
48	Initializes an array variable (@data) to hold the assay and QC results
49-52	Exit the script if there are no additional lines beyond the result header in the LC-MS/MS output file
53-65	Loop through the remaining lines of the LC-MS/MS output file
54	Illustrates a “regular expression”, which jumps to the next array element if the input line consists of an empty line or a line consisting entirely of white space (space, tab, etc.)
55	Takes the tab delimited line and creates an array (@cells), with each element of the array the text between tab characters
56	Assigns the variable “\$sample_id” to the first element of the @cells array
58	Looks at the value of \$sample_id, and if does not begin with a “c” followed by a “dash” (QC data) or an “E” followed by numbers (a CID), the script skips to the next element of the array (i.e., next line)
59	Assigns the test name as defined in Sunquest®
60-63	Look for the text “Testosterone” in order to assign the test code of “PTES.” This is the internal check on the files to ensure that the LC-MS/MS output file contains testosterone results. These lines can be expanded to include more checks for different assays as they are developed
64	Populates the @data array with the assay result or QC information, comma-delimited, in the prescribed order that Sunquest® expects the data
67-69	Create the file in the location expected by the data management software that will be uploaded to Sunquest® via FTP

LC-MS/MS: Liquid chromatography-tandem mass spectrometry, QC: Quality control, CID: Container identification, PTES: Test code for pediatric total testosterone, FTP: File transfer protocol

the process is shown in Figure 1. The source code for the pre-processor is shown in Figure 2, and an explanation of each line of the code can be found in Table 1.

Testing and implementation

During the validation of the PTES assay, the interface was tested by exporting the text file containing calibrator, QC and patient assay results into a specific folder; in this case the “report output folder” on the computer running the mass spectrometer. The log files on the same computer

were then checked. The correct order of events is as follows: The text file containing the results will disappear from the “report output folder;” when the pre-processing has been completed, a text file will then be found in the “converted folder;” this file disappears from the “converted folder” and will then be found in the “sent folder;” the original text file exported from the LC-MS/MS system will then be placed in the “archived folder.” In order to determine if the interface was performing as expected, when the pre-processed file was found in the “sent folder,” the Sunquest® LIS was

accessed (after a delay to allow Sunquest® to perform its periodic scan of the stipulated upload location for the data) to determine if the QC results and patient assay results had indeed been transferred via FTP, and that the calibrator results were essentially ignored by the pre-processor. As this process was working successfully, it was implemented once the PTES assay was placed into clinical use. To date, there have been no software problems or failures. The interface has eliminated the need for manual data entry and any associated manual transcription errors.

CONCLUSIONS

We successfully implemented a licensed data management interface between Sunquest® and an AB SCIEX™ mass spectrometer that may allow the laboratory more control and adaptability than a commercially available software to software interface. Currently, this interface has only been used to transmit results from one test to individual patients, but the authors are confident in the adaptability of this interface in order to be able to handle more complex results, such as pharmacokinetic analysis consisting of a number of samples from the same patient over a given time period, each with a different concentration. Although the licensed software from the University of Pittsburgh was extremely useful in facilitating an interface between the LC-MS/MS system and the LIS, local expertise in programming was necessary to perfect the data transfer process.

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