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Advanced Interactive Epidemiology Reports utilizing the BD Phoenix™ EpiCenter™ System

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ABSTRACT

OBJECTIVE: Determine if modern data visualization components and data integrity rules can be integrated into an effective epidemiology data mining tool for use with the new BD Phoenix™ Data Management platform. (EpiCenter,™ BD Biosciences, Sparks, MD USA)

METHODS: EpiCenter,™ a microbiology data management system for the new BD Phoenix™ automated microbiology system was developed that integrates state-of-the-art software components, an expert system, and data validation logic. This system was designed to overcome several common problems in interpreting microbiology test data. First, complete and accurate representations of microbiology results were designed into the schema of the database. Second, validation rules along with an expert system were built on top of the database to insure accuracy of the data being saved. Third, modern graphical user interface tools and techniques were combined to enable the data to be easily examined in a variety of ways. Finally, a sophisticated set of predefined queries and reports were generated to provide useful tools to examine historical microbiologic data.

RESULTS: 100+ predefined queries and 15+ predefined reports were developed to cover traditional epidemiology data tracking. These queries and reports included MIC trending, isolates with similar resistance patterns, multiply resistant isolates, isolates with resistance mechanisms, percent susceptible and organism incidence reports. The data is bundled in a flexible, dynamic, reporting format that allows the user to examine the data at a high level, or drill into detailed information on a specific isolate.

CONCLUSIONS: The BD Phoenix™ EpiCenter™ System provides a useful tool to track epidemiology of infectious diseases.

OBJECTIVES

■ The purpose of this software development effort was to integrate modern data visualization components and data integrity rules into an effective data mining tool for examining identification and susceptibility data within the new BD Phoenix™ Data Management platform (EpiCenter,™ BD Biosciences, Sparks, MD USA)

The objective was to design and build a complex state-of-the-art epidemiology system that was flexible and easy to use for clinical laboratory personnel who may not be experienced in the use of complex computer systems and relational databases. The system had to appear simple to the user but implement sophisticated features such as an expert system, automatic resistance mechanism detection, and resolution of identification and susceptibility test result conflicts. The system had to be easy to use for non-computer users, but could not impede a sophisticated user that needed to examine the database in complex ways.

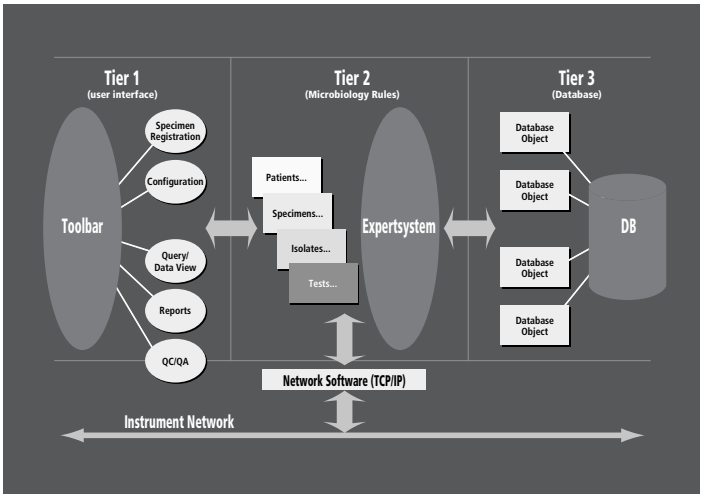
While simple workflow was a major objective, flexibility to develop custom reports was also important. The user had to be able to query the database in an unlimited number of ways without having to understand the database schema. To help demonstrate to the user how to develop custom reports, several predefined reports had to be developed to allow the epidemiology system to work immediately upon installation.

Data Integrity

■ EpiCenter,™ a microbiology data management system, integrates off-the-shelf software components, an expert system, and robust data validation logic. The schema of the database was designed for complete and accurate representation of microbiology results. The database stores a variety of test results including microbial growth and detection, organism identification, and antimicrobial resistance results. These test results can be offline results defined by the user, or instrumented results received over a Local Area Network that connects EpiCenter™ to a variety of BD instrumentation. Since data integrity was a major goal of the system, a 3-Tiered, Client/Server system was developed as illustrated in Figure 1. This design centralizes the analysis of the test results, and utilizes accepted microbiology business logic to "clean" the results before allowing them to be reported or included in epidemiology reports or other queries.

The Tier2 microbiology rules funnel the appropriate test results through the breakpoint interpretation engine as well as the BDXpert™ rule system to generate the final reportable results. (See Figure 2) At all times the original instrumented/user results are preserved. Tests that generate different results (regardless of method) are screened for inconsistencies, and the user is directed to resolve any conflict(s). Once conflicts are resolved, the BDXpert™ system is applied to further refine the result. Figure 3, illustrates such a conflict.

Figure 1. EpiCenter™ 3-Tier Architecture



Once conflicts are resolved, the BDXpert™ system reinterprets the susceptibility result prior to reporting the final result to the chart. Transfer of isolate results to a Laboratory Information System (LIS) can be done before or after executing the BDXpert™ system. If desired, both results can be sent to the LIS. Figure 4 shows an example of a BDXpert™ modified result.

Modern graphical user interface tools

■ To meet the objective of simple operation and use, the user interface was developed by integrating "best of class" commercial software components. Many of the EpiCenter™ software modules are made up of third-party software components that adhere to Microsoft® Windows NT standards. The main user interface is a Microsoft® "Office-like" toolbar that gives the user access to the various software modules. Each software module has the ability to start other modules, permitting quick access to all parts of the system. An example of this feature is shown in Figure 5.

Figure 2. Sample Microbiology Business Logic

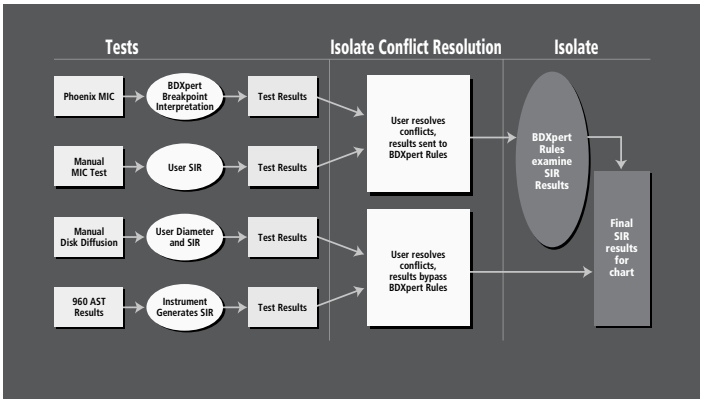


Figure 3. Conflict Resolution screen for Chloramphenicol with a Enterococcus faecalis isolate

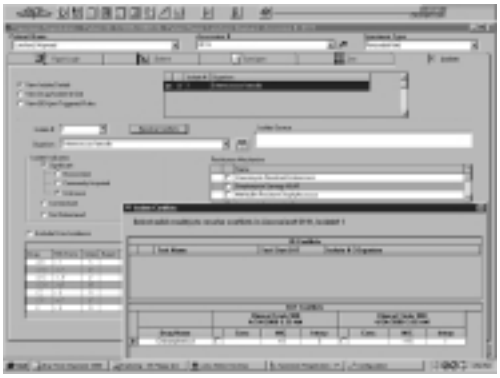
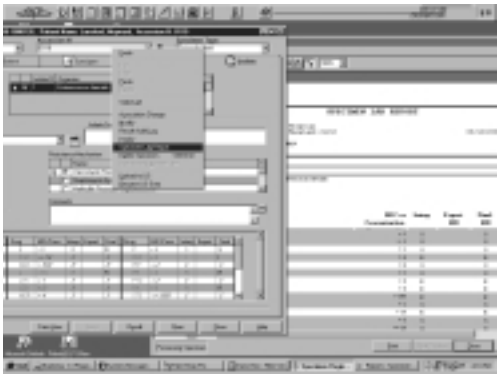


Figure 4. Sample BDXpert™ Rule firing to modify an isolate result

Figure 5. Sample User Interface allowing report generation from Results Review



One of the more critical ease-of use-objectives was to provide a simple user interface to the fields available in the database. The product had to support ad-hoc querying and end-user report design. Determining the simplest interface that still gives the user access to all of the database fields was of paramount concern. The method chosen evolved over several prototypes presented to end users/focus groups for review. The interface consists of a Microsoft® "Explorer-like" interface, with a field tree depicting available database fields as shown in Figure 6. The fields are presented in a logical order that a microbiologist can recognize. As fields are selected from the tree, they are displayed in a grid to the right along with the criteria the user has chosen. A diverse set of criteria is available (including criteria assigned by the user at run time) to give fine control over the results being generated. At no time does the user need to understand the underlying organization of the actual database.

Once a query has been authored, the user can view the data retrieved from the database in a simple spreadsheet-style grid. From this grid several batch operations are available, including assigning or finalizing a result. Perhaps more significant however, is the users ability to design a custom report based on the data that have been recalled. The user can chose to display the data in a traditional report format, a graphical format, or an interactive drill down format similar to a Microsoft Excel® Pivot table. This design frees the end user from being dependent on a local information technologist for his/her reporting needs, and allows the user to experiment with the view of the data in real time. The method used to implement these reporting options were based on third-party software tools.

Figure 6. Sample Query definition to recall all isolates with one or more Resistance Mechanism

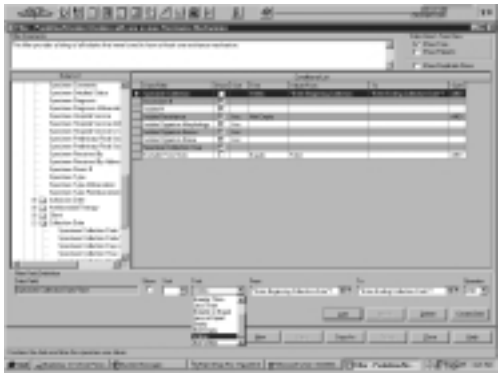
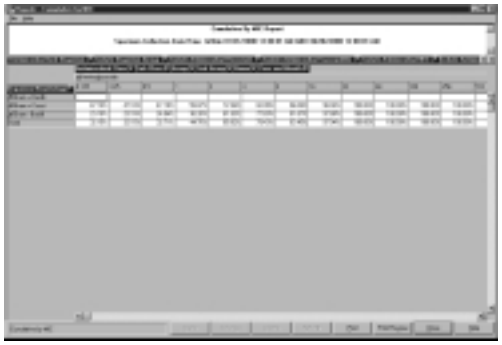


Figure 7. Sample High level Cumulative by MIC Report



RESULTS AND DISCUSSION

■ Over 100 predefined queries and a number of predefined reports were developed to permit easy generation of traditional views of microbiology data used for infection control and epidemiology purposes. These reports include the ability to observe MIC trends of any desired organism groupings (e.g., genus or species level); to identify isolates with similar resistance patterns; to determine the percentage of an organism or organism group that are susceptible to a given antimicrobial agent; and to calculate the incidence of organism groups and subgroups. When running the report, the user can specify many parameters to control the results included in the report.

Figure 7 shows an example of a high-level cumulative MIC report that presents MIC isolate results organized by drug classification and organism grouping (by gram morphology). The percentages displayed indicate the percent of the isolates that were susceptible at the given drug concentration. This display is interactive, and allows the user to drill into the result set.

Figure 8 depicts the same report, where the user has "drilled" into the data, looking at the more detailed results for different genera of Gram-negative, compared to all beta-lactam antimicrobials that were tested. Because this report is dynamic, the user can continue to refine the data at a more detailed level, eventually showing the results as they have varied from month to month, as well as the individual accession number (specimen) that created the statistical result. Since the data contained in the report and the format of the report are both user definable, this report can be quickly modified to suit the end users needs.

The same reporting tool can be applied to a completely different set of data. Figure 9 depicts organism incidence trending. The rows of data are segregated by Hospital Service, while the columns depict the taxonomy tree that has been "drilled into" to show the month in which the isolate was recovered. Further data mining on the grid would show incidence at the species level.

Figure 8. Sample Cumulative by MIC Report showing detailed results

Figure 9. Sample Organism Incidence Trending Report

Figure 10 shows the same information redisplayed in graphical form. Changing the view on the data requires just a few keystrokes.

Figure 11 demonstrates a different example of a graphical report generated by the ad-hoc reporting engine. This report is a bar graph that shows the incidence of the identified resistance mechanisms. These data were generated from 11 months of data collected at an anonymous hospital. The results were analyzed using the BDXpert™ system, which analyzed the AST results and detected these resistance mechanisms.

Figure 10. Sample Graphical Organism Incidence Trending

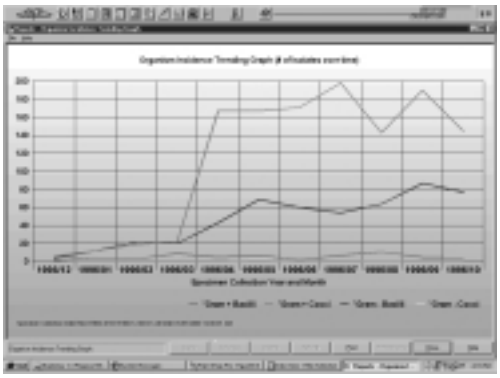
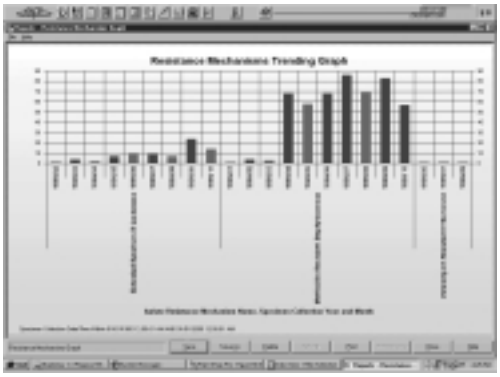


Figure 11. Sample Resistance Mechanisms Trending Graph



CONCLUSION

■ The BD Phoenix™ EpiCenter™ System has been designed to be a useful tool to examine the epidemiology of infectious diseases within a hospital, health-care system, or community. The use of data integrity enforcement, the BDXpert™ system, and modern reporting tools make the EpiCenter™ system a relatively easy and effective way to manage and evaluate complex data generated in the clinical microbiology laboratory. This system should provide valuable resources for strategies to monitor and control nosocomial infections and to promote appropriate and cost-effective antibiotic usage.