We are learning there are many ways of approaching the need to provide a reliable source of truth for our healthcare environment. This includes establishing an enterprise-wide data warehouse (EDW) that brings together data from multiple disparate sources and is expected to ultimately support the patient care, research and educational missions of the institution. As part of an extensive needs assessment, interviews were conducted with key institutional leaders representing academic, research and patient care areas. It became clear that expectations for an EDW would require a daunting effort and necessitate an incremental approach. With the recognition that the EDW would need to be built upon a proven architecture but with the flexibility to adapt to increasing demands, the current collection of database, ETL and business intelligence (BI) tools was implemented with an initial focus on retrospective analyses based on clinical research requirements. One of the factors leading to a historical focus was the potential value provided by an initial load of extensive clinical data beginning in June 1993 from the clinical data repository (CDR). This
was aided by the CDR replication process and the support and design of the OACIS Health Data Warehouse (HDW) product provided by Telus Health.

Research queries were initiated against the EDW, intended primarily to assist researchers in identifying and quantifying potential subjects for clinical trials. A self-service research component remains in use, allowing selection of clinical and administrative data employing simple filters and metrics to obtain results without exposing protected health information (PHI). For those with institutional review board (IRB)-approved protocols, more complex searches can be obtained, often with special assistance from a trusted broker, currently someone with a PhD in biometry and the background and experience to guide requestors in the best use of the EDW. One example now being used on a daily basis requires the identification of patients scheduled for a biopsy who fulfill defined diagnostic parameters, so their attending physician can be approached about a potentially beneficial research study prior to their scheduled visit. Attributes from other sources (e.g., CPT coding and biorepository/tissue data) are still being added, and we are finding that analyses found to benefit the research community increasingly involve more current rather than historical data.

It is apparent that the U.S. healthcare industry is moving from a largely fee-for-service, volume-based system to a value-based system. With the rise of Meaningful Use (MU) and additional Centers for Medicare and Medicaid Services’ (CMS) measures, along with Value-Based Purchasing and Accountable Care Organization (ACO) trends, an EDW positioned to support an emphasis on improvements that can be made in clinical and operational processes is needed. Identifying high-priority projects is consistent with our incremental approach. While not itself an Office of the National Coordinator (ONC)-certified product necessary to obtain Stage 1 MU funding, it was recognized that the EDW could be utilized to monitor compliance with an initial set of MU measures. An MU scorecard was developed that identified areas within the hospital in which existing EHR data capture was incomplete. This helped to jump-start improvements in the collection of numerator and denominator information necessary to meet Stage 1 thresholds. While a continuous effort is being maintained to derive, validate and integrate data from additional sources, we are being charged with transforming our more traditional EDW from a primarily retrospective tool into one that leverages more timely, actionable views of clinical data.

**FIGURE 1: Pressure Ulcer Data Entry Form for Survey**

![Pressure Ulcer Data Entry Form for Survey](image-url)

**NDNQI Pressure Ulcer Survey Saves Time**

Problems Addressed: MUSC rejoined the National Database of Nursing Quality Indicators (NDNQI) in 2011. Several of these indicators are captured by a prevalence survey, which is the intention of using the survey. Every inpatient who meets stated criteria is surveyed on the same day for the presence of pressure ulcers, restraints, and/or peripheral intravenous infusion infiltrates. In the past, the prevalence survey required two nursing staff
members per inpatient unit eight hours to complete (resulting in approximately 352 man hours). The majority of that time was actually used to review documentation to determine if the pressure ulcers were nosocomial, as well as to validate prevention strategies and interventions for the restraints and intravenous infusions.

Solution: With the use of the EDW, data were identified that could be used to pre-populate a database for the survey. These data rely on logic to answer some of the questions posed by the survey. The data are then available to the clinical staff on a daily basis via a newly created web application (Figure 1).

Our first pilot study occurred March 2012. It took only two hours to survey all adult inpatient units compared to the previous eight hours. A data extractor and data analyst then spent an additional eight hours retrieving missing data and determining if pressure ulcers were nosocomial. The total manpower used was significantly less than during previous surveys.

Once the survey is completed, administration has the ability to pull results directly from the web application and/or run reports from our reporting tool (Figure 2).

TIMELY MONITORING OF PATIENT EDUCATION

Problems Addressed: Pharmacists first had to login to the Pharmacy system and print a list of patients who were taking anticoagulants. Next the pharmacists had to login to the Clinical Documentation system, search for each patient individually, drill and navigate into the patient chart in order to view the education required for each category for the particular anticoagulant prescribed for the patient. If the entire education was not documented or complete, pharmacists had to then make notes on which education needed to be provided and go to the patient and furnish the education. Finally, pharmacists had to log back into Clinical Documentation to record the education they provided.

Solution: The anticoagulant education report was created for the pharmacy group to ensure that patients on anticoagulation received education by a pharmacist on each drug they were taking. This is to achieve compliance with the national patient safety goal.

Process: An ETL workflow was created to import patient education data into the EDW. Additionally a script was created to combine patient education with current patient location information. This script is run nightly to rebuild the new Anticoagulant Patient table.

A report was created using this new data that shows patients, location, medication and pass/fail results (Figure 3). This report is also available for PC and/or mobile phone usage. Each individual patient line in the report is drillable, which will show the user which categories of education have been presented and which ones have not.
FOCUS: THE ENTERPRISE DATA WAREHOUSE

(Figure 4). In addition a dashboard for PC and/or mobile device was created for administration to view at a glance how each service is doing with respect to this education (Figure 5).

DAILY CLINICAL KPI MONITORING

Another example of a quick win which illustrates how the EDW’s analytic capabilities are being used to promote performance improvement and patient safety in a more real-time manner is the Clinical KPI report used by our providers on a daily basis (Figure 6). The goal was to identify and highlight key clinical areas of focus for our facility. By pulling the data together from numerous clinical systems into the warehouse, we are able to validate and review patient care information and quickly highlight areas of concern in this charted data. The report counts Foley catheter days and highlights two days in yellow and greater than two days in red. Venous Thromboembolism (VTE) prevention is measured by activity, mechanical, and pharmacological prophylaxis, including the medication and dosing frequency of the medication. Critical lab values identified by the laboratory are highlighted in red, as are any readmissions from the floor to the Intensive Care Unit (ICU). The design of the report also identifies patients who are on telemetry, have a pressure ulcer, are on a bowel regimen and who have been readmitted within 30 days, as well as those patients whose original point of contact was the emergency department. Usage of the report varies among medical services. Some pull up the report during morning conference, others use the report to ensure that a variety of clinical care concerns can be addressed during medical rounds. Feedback from the medical staff has been positive. Providing the opportunity to address care on an ongoing basis rather than using retrospective chart review after both patient and resident have left the service or hospital is invaluable to the care we can provide our patients. It has also provided the opportunity to target resident education using the report as another teaching tool, discussing how and when changes in care should occur.

Use of the report has also gained support among the staff at the bedside. A ventilator bundle report was created to provide a daily view of care for the ventilated patient based on the Institute for Healthcare Improvement (IHI) initiative. The report is made available to every ICU, respiratory therapist, infection control practitioner and manager in the hospital. For every patient on a ventilator, each data
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The enterprise data warehouse element is listed along with the compliance over the last 24 hours. The expectation is that for each shift the report is reviewed, and any areas highlighted are addressed with the healthcare team. The report has resulted in a standardized expectation of care for the ventilated patient. An effort is made to review any areas that are highlighted, discuss acceptable and unacceptable reasons for deviation and education where needed. This report is now being rolled up and provided to the Infection Control Department to use in identifying patients for reporting to the National Healthcare Safety Network (NHSN) for Ventilator Associated Events (VAEs).

As CMS began focusing on pressure ulcers, present on admission (POA) and pressure ulcers became an organizational focus for the hospital. The EDW was used to provide base data for the NDNQI pressure ulcer surveillance performed by a Skin team every quarter. Using chart reviews became cumbersome to identify where the pressure ulcer was located on the patient, whether it was present on admission, and the first nursing unit to document the pressure ulcer. The warehouse created logic to determine maximum stage, the unit on which an ulcer was first documented, and a percentage of ulcers present on admission. This enabled identification of areas for focus for the Skin team. Subsequent education has taken place, as well as more rigorous patient assessment, and more appropriate staging of ulcers. By adding pressure ulcers to both nursing and provider reports, and creating a report for the wound care nurses, our intent is to show a decrease in the number, stage and hospital-acquired pressure ulcers.

Our plan is to review the data again one year after implementation of the report. The data used to generate these reports is archived to facilitate this effort. We are also using the extensive bank of clinical data to build historical data prior to the implementation of these new business processes.

One of the more evident improvements, facilitated by the implementation of the clinical KPI and its regular use during morning reports and rounding, was the timely removal and reinsertion (where necessary) of Foley catheters on the trauma service where it was piloted.²

CMS COMPLIANCE AUTOMATION & REPORTING CONTRIBUTES TO PATIENT CARE IMPROVEMENTS

The CMS reporting process was automated with the EDW, giving ample time to identify and remedy system issues related to noncompliance with both CMS and the Joint Commission ORYX measures. A switch from a broad monthly review of a static PDF report to a true Business Intelligence process that allows the organization to drill through the data all the way down in granularity to patient and nursing unit level now gives the enterprise an opportunity to take corrective action and improve awareness. Armed with only a monthly snapshot, it was very difficult to take any corrective action or to initiate any process improvement in a timely and meaningful way. Now, rather than seeing results well after each month’s data are abstracted, the process is automated so that weekly real-time trends can be identified. Seeing the compliance on a weekly basis allows for corrective actions to be initiated much earlier. Additionally, the process is no longer manual. It has been automated, saving more than eight hours of labor each month and reducing the report preparation to a matter of minutes each week. This was accomplished through automating the data transfer via FTP and an ETL process to load the data into the EDW (Figure 7).

NURSING UNIT KPI—OVERALL ROLLUP

Using focused reporting from the EDW to facilitate changes in behavior is further illustrated in Figure 8. As the daily (it is also available as on-demand) report was initiated, the percentage of patients who had their influenza vaccine status checked hovered around 60 percent. As time progressed, one can clearly see that compliance increased to over 85 percent for flu over the months in those units who utilized the EDW KPI reports. The same dramatic increase can be seen in height and weight compliance; this Nursing Unit Overall compliance report reflects an average 25 percent across-the-board improvement in these measures.

TECHNICAL ARCHITECTURE AND OPERATIONAL CONSIDERATIONS

The EDW technical architecture consists of three principal components. These are the
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The Analytics Database Server uses Sybase IQ, a high-performance columnar database designed specifically for data warehousing, as its central repository of all enterprise data. IQ utilizes multiple indexes and data compression to provide fast loading of data and efficient query execution. Our IQ instance is release 15.3 and runs on a Solaris virtual server running Solaris 10.

The ETL Server primarily uses Informatica PowerCenter to extract, transform and load data from a wide variety of systems in use at our location, including relational databases such as Sybase ASE, Oracle, and Microsoft SQL Server. The ETL Server also facilitates import of data from non-relational sources, typically via file transfers of data extracts generated by some vendor reporting systems (where no direct access to their product’s underlying data store is available or supported). Our PowerCenter instance is version 9.1 and runs on a Solaris virtual server running Solaris 10. The Informatica PowerCenter metadata repository uses Sybase ASE 15.5 for its operational database. Some groups within the enterprise are also utilizing the Talend open source middleware products for ETL of their data.

The BI Server uses MicroStrategy Business Intelligence to deliver reports and dashboards supporting operational, analytical and decision support users. A mix of desktop, web and mobile clients is currently supported in this environment. Our MicroStrategy Intelligence Server is version 9.2.1m, and web access is by web servers running on both Microsoft’s IIS and Java Tomcat.

The current primary source of clinical data for the EDW is the Telus OACIS Clinical Data Repository. MUSC was the alpha site for the OACIS product, going live with it in 1993, so we were able to take the EDW project live with an extensive amount of historical clinical data, including ADT, Lab Results, Medications, Radiology, and a wide array of textual reports. Data entered into OACIS are loaded into staging tables for ETL of their data.

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ambulatory and Emergency Department (ED) modules are live, and data from ASAP (Epic’s ED module) are being loaded into the EDW to monitor ED throughput, as well as the administration of medications in the ED.

CONCLUSION

Implementation of the Enterprise Data Warehouse has allowed us to aggregate data from multiple disparate clinical and operational systems, bringing together information that has been locked away in silos for many years. This new collection of globally sourced data enables us to provide answers and insights into the care and well-being of our patient population.

It has become evident by the increased adoption rate of our users and the influx of new data and reporting requests that the analytics culture has definitely changed at MUSC. Our active user accounts have grown to over 900 and we continue to accumulate new EDW-related projects.

This diverse use of data by our users is hopefully made obvious by the concepts and ideas presented in this paper. Our users are constantly gaining a better understanding of what data are available in our enterprise, but also new and exciting ways that the data can be presented.

We were initially charged with transforming our EDW from a primarily retrospective tool into one that also allows timely, actionable views of clinical data and feel that we have demonstrated considerable progress toward that goal. Our efforts have taken the institution from a retrospective view of data to a more enterprise-level analytical view of the institution’s vast data resources. Clinical practitioners and staff, along with hospital administration, have demonstrated great acceptance of our work and are excited about what we will deliver in the future.

Our team feels we are just getting started and have set the stage for future work in predictive analytics, healthcare modeling and data mining.

We feel our efforts to date are making a positive impact on patient care, and feedback from the clinician community has been extremely positive. JHIM

Larry Gale, MS, CISSP, CPHIMS, has 32 years of IT experience in federal, state, military and private sector projects, focusing on software development, database implementation, systems administration and information security. He is currently the Analytics DBA and Lead ETL Developer for the Enterprise Data Warehouse at the Medical University of South Carolina.

Jeff Burdick, PMP, CPHIMS, originally obtained a BS in Medical Record Administration, followed by achieving his registry (RRA back then, now called RHIA). He has over 35 years of experience managing a wide variety of projects related to health information systems. He is currently working in a Senior Analyst role with the EDW he helped to implement at MUSC.

Pat Wagstaff, RN, MHA, has 15 years of experience in critical care nursing along with 9 years of neonatal nursing in a level-three center. She has 12 years of experience in the transport of critically ill infants and children by air and ground, including 5 years’ experience in management as coordinator of the pediatric critical care transport service. Wagstaff also has 11 years’ experience as Outcomes Manager for clinical services including neonatology, and this includes 10 years as CMS public reporting administrator for QNet Exchange. This was followed by three years of experience as Data Coordinator for the EDW.

Stan Flowers is a Senior System Analyst with the Medical University of South Carolina with over 14 years of experience at the Medical University in Finance and Administration/Clinical Warehouse. He currently works on the Enterprise Data Warehouse and holds a MicroStrategy Document Developer Certification.

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REFERENCES