Developing Enterprise-Wide Provider Analytics

James P. McGlothlin[1], Hari Srinivasan[1], Ilija Stojic[1]
[1]*Fusion Consulting Inc, Irving, TX, USA*
{jmcglothlin, hari, istojic}@fusionconsultinginc.com

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Abstract: In recent years, the growth of electronic medical records for hospitals has exponentially increased the quantity of healthcare data available for analysis and performance improvement. However, the general consumption of this data by providers has still been limited to analysts and power users. Most data is delivered via static reports which serve only a single purpose. This paper describes a project to deliver a vast quantity of data in a simple and secure manner to all hospital physicians and administrative leaders. This includes clinical, operational and cost information. The delivery is with versatile and intuitive interactive dashboards which are integrated into the EMR yet come from many different sources. This allows physicians to look at their performance and compare it to their peers. Executives are able to identify improvement opportunities across the system and directors are able to identify improvement opportunities within their service. Quality and performance improvement specialists can perform data analysis without having to generate report requests and wait for delivery. This allows them to target specific initiatives and patient populations, and to tailor improvement programs to the needs of the organization. These analytics and dashboards are designed to facilitate quality improvement, efficiency, treatment standardization and cost reduction.

1 INTRODUCTION

Hospitals are under constant pressure to reduce cost of care and improve outcomes. This includes reducing length of stay, readmissions, resource utilization, complications, hospital-acquired infections, and mortality while increasing patient experience and satisfaction. Generally, the methods to improve these key performance indicators (KPIs) involve changing provider behaviour or changing hospital processes. However, it is not readily apparent to most providers where the opportunities for improvement are and often providers do not think they have any issues. Furthermore, holding providers accountable is difficult.

The use of advanced electronic medical records (EMRs) for hospitals has grown exponentially in the past decade. Many hospitals have developed enterprise data warehouses specifically designed to support advanced reporting and analytics. Technologies to integrate data from auxiliary systems have become common. At this hospital, auxiliary systems exist for the catherization lab, imaging, interventional radiology, laboratory, pathology, risk management, infection control, cost accounting, supply chain, human resources, time and attendance, decision support, pharmacy acquisition, and more. As we continue to bring in these outside sources and continuously optimize and advance our EMR and data warehouse, the amount of data available continues to grow at an astronomical pace.

There are many challenges to delivering this information to a provider in a meaningful way. Physicians are trained in medicine not in computer science and are extremely busy, so it is unrealistic to ask them to learn new, complex technology. Also, there is so much data available, it is challenging to determine which information to deliver to a specific provider. This is further exacerbated by strict privacy laws that make it essential that providers do not get access to patient information for patients they do not treat. Additionally, there are laws limiting the financial, referral and utilization information users can see in order to prevent collusion or market interference.(Office of Inspector General, 2018)

Currently, we have thousands of reports but they are each directed towards a limited scope and

audience. Most of our reports are primarily static where they look at specific orders or diseases or medications, but do not allow you to change these parameters. They are created in response to user requests, so the requirements were generated by users who already had an idea what they wanted to analyse or change and how.

We have also had great success in the past with targeted initiatives to optimize specific type of utilization such as red blood cells (McGlothlin 2017), imaging (Wyatt 2018), broad spectrum anti-biotics, opioids and metabolic panels (Wyatt 2018). However these were specific programs targeting particular types of utilization and made available to specific users in relevant situations. Furthermore, development of each of these projects incurred significant level of effort. The goal of this project is to provide general analytics that can be utilized to evaluate all types of encounters, diseases and resources, and will be available to the large audience of all hospital physicians and leadership.

One of the most effective ways to drive performance improvement is to target quality initiatives and clinical decision support to specific acute diseases. Our own experience (McGlothlin 2016) and previous research (Kitchiner 1996) demonstrates the effectiveness of these programs. The Joint Commission has established clinical pathways as a fundamental approach to improving healthcare performance (Joint Commission on Accreditation of Healthcare Organizations 1996). Studies have consistently shown that clinical pathways reduce length of stay and cost (Stephen 2003) (Pearson 2001) (Wazeka 2001). The care path can encourage providers to use specific medications, images and labs and to utilize them at specific times. This not only gives the opportunity to choose the lower cost option when there are multiple equally appropriate alternatives, it also gives the hospital an opportunity to make treatment and utilization more predictable. This can be very important. If we can predict how many images will be ordered, we can optimize our equipment, resources and schedules. If we can predict utilization of medications, then we can better manage inventory and negotiate acquisition costs. If we can predict length of stay, then we can improve bed assignment and staff scheduling." However, each disease program requires 12-20 weeks of effort to build (McGlothlin 2018). Also, it can be challenging to evaluate the effectiveness of each program in a standardized manner. A common set of metrics and shared analytics tool can provide this evaluation.

Analytics are needed for hospitals to intelligently choose which diseases to target. Furthermore, it is not realistic to build pathways for every disease. There are over a thousand diagnosis related groups (DRGs), 68,000 ICD-10 disease codes and more than 10,000 research papers proposing specific care paths (Vanhaecht 2006) (Rotter 2007). Therefore, the goal of this project is to both provide leadership insight into which disease programs can provide the most benefit, and to provide some meaningful information for every disease treated at the hospital.

For the remainder of this paper we will describe our challenges, how we overcame each, and our solution and results.

2 ATTRIBUTION AND SECURITY

As previously discussed, one of the most important aspects of our project is to only show users data related to them and to secure our system so no user sees patient data unless they are authorized.

We achieve this by attributing metrics to the correct provider, attributing the provider to the correct service, and then applying security using the provider and service information.

2.1 Provider Attribution

We allocate providers differently depending on the role that is responsible for the metrics in the chart. So far we have identified five roles:

- Discharge provider
- Admitting provider
- Emergency department provider
- Authorizing provider
- Surgeon

The discharge provider is assigned at the grain of the hospital visit- i.e. each hospital visit has exactly one discharge provider. The discharge provider is attributed to the hospital visit based on who signed the discharge summary. Discharge provider is used for readmission and mortality metrics and for metrics related to discharge efficiency.

The admitting provider is assigned also at the grain of the hospital visit based on the provider who authorized the admitting order. The admitting provider is used primarily for metrics around admissions efficiency.

The emergency department (ED) provider is assigned also at the grain of hospital visit based on the provider who chose the emergency department disposition. The ED provider is primarily used for the metrics around ED efficiency.

The authorizing provider is assigned at the grain of an order. The authorizing provider is the provider

who authorized the order. This provider is used for metrics around order utilization and cost.

The surgeon is assigned at the grain of surgery. The surgeon is currently used only for surgical site infections.

2.2 Service Attribution

Service attribution was one of our greatest challenges. Our data warehouse assigns service at all points during the patient stay in a patient movement table. However, extensive data profiling and validation determined this value was often incorrect due to the current workflow and the large number of users who have the ability to change this value in the EMR.

For this reason, we chose to attribute the service based on the provider we already attributed in the last section. In other words, the discharge metrics are attributed to a service because the provider who discharged the patients was in that service. However, we determined that our provider records were insufficient to accurately assign the service. As an example, we have providers credentialed in anesthesiology yet performing the role of surgical intensivist (service of SICU) or neurosurgery attending provider. This provider role information is not available in any system we have available.

Therefore, we determined to assign the providers manually. This problem was further exacerbated because many of the providers perform multiple roles. Some examples are providers who serve internal medicine in the adult hospital and also act as pediatrics providers in the children's hospital, providers who work in obstetrics and gynecology, provider who work in the SICU and acute care surgery, providers who work in the NICU and the emergency department. Therefore, we had to develop options that allow the service to vary based on:

- The patient's hospital
- The patient's level of care
- Whether the event happened during a surgical episode
- Whether the event happened in an outpatient setting
- The patient's unit
- The patient's service in patient movement

Which values we use for the identifiers depends again on the type of metrics. For discharge metrics we use last value, for admission metrics we use first value and for cost and order utilization metrics we use values based on the time of the order. Figure 1 shows our methodology for service attribution of orders and costs based on authorizing provider and patient location at the time of the order. Provider attribution for discharges and admits is similar but simpler since anesthesiologists and gastroenterologists do not discharge patient.

Additionally, there are some metrics where we want to attribute service but not provider. For census, we use the service at the time according to our patient movement table. For hospital-acquired infections, we manually attribute the service during our infection control process. For patient experience data, we assign service based on the discharge provider but we then aggregate the data only at the service level.

2.3 Service Attribution and Security Forms

There are over 800 providers in our hospital who have discharged patients in the last three years, and over 1800 who have authorized orders. Certainly, the analytics team cannot accurately assign the service(s) for each of these providers. In our initial attempt, we allowed the quality department leadership to fill these values in an Excel spreadsheet. However, we found that not only was this very time consuming, it also was prone to errors and inconsistencies which then had to be manually resolved by the analytics team. It also presented challenges for incremental updates.

For this reason, we have now developed a set of custom secured forms for the operation. There are five forms that drive our security. All of the person columns in these forms (provider, director, executive, support team) allow the user to search and select the person using their name based on the network security data and our software finds their identifying information.

1. Service Form

We want to group some of our services together. For example the set of providers for liver transplant and kidney transplant are the same, so we want these services to rollup to the service of "transplant". Our service form simply gives the user the opportunity to specify the "service rollup" from a drop down list for each service in the system. The services are prepopulated from two sources. We acquire all the services from the EMR in our patient movement table. Additionally, because some of our critical care services are not assigned in patient movement, we have a set of inferred ICU services based on unit, level of care and service. We populate this table with those services as well.

Orders & Cost Service Attribution Process

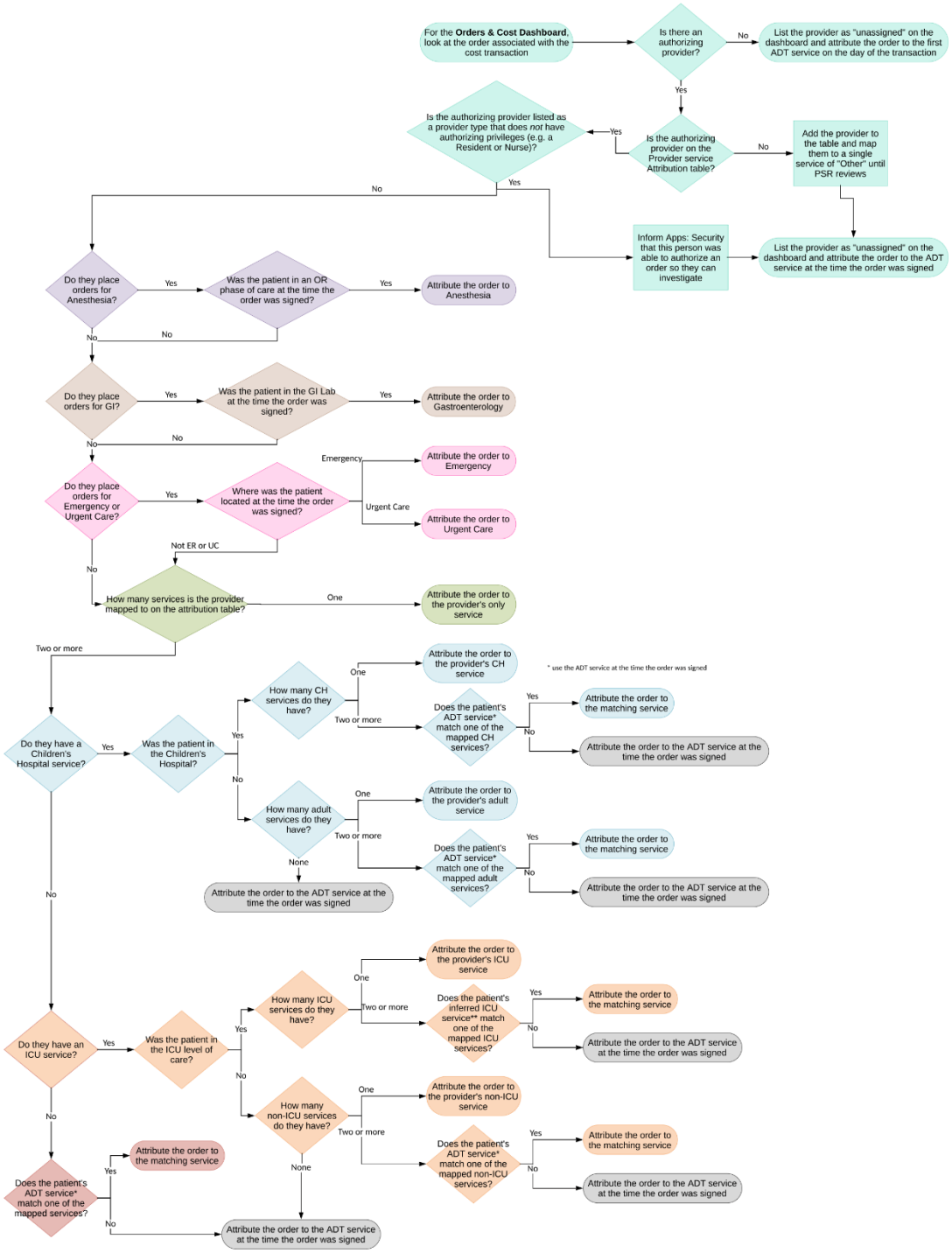

Figure 1: Service attribution for orders and cost

2. Service Rollup Form

We assign our attribution at the grain of service rollup. The user can create new "service rollups" which will then be available in drop-down lists within the service form and the provider and director forms. They can also specify the abbreviation the dashboard will use for this category. The key fields they populate for each service rollup is a set of yes/no fields:

a. Adult? Is this service in the adult hospital sytem?
b. Children's Hospital? Is this service in the children's hospital?
c. Surgical? Is this service a surgical service?
d. ICU? Is this a critical care service?
e. Other? For each of dashboards should this service be shown on the dashboard or bucketed in "other".

These values are used both to determine what executives are allowed to see, and to populate drop down boxes for the provider form. Figure 2 shows the entry form for service rollups.

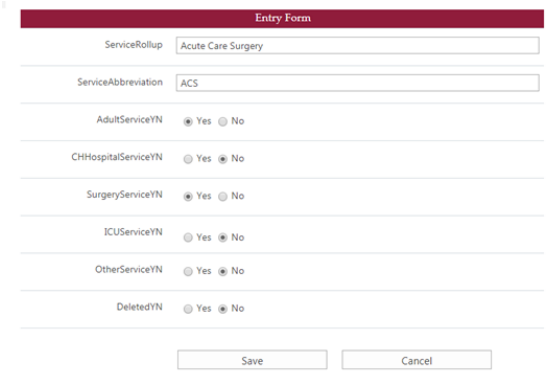

Figure 2: Entry form

3. Provider Form

We allow the user to add a provider based on a look up into the system. Then they can attribute the patient's service based on the diagram in Figure 1. They can choose any service rollup from the drop down as the provider's single service, or they can choose any adult service rollup (from the service rollup form) as their service when the patient is in an adult hospital, or any ICU service rollup as their service when the patient is in the ICU level of care, etc. The form insures they choose only valid services and rules which are not contradictory.

Additionally, our provider service attribution form has four check boxes specific to service attribution for orders and cost. There is an anesthiology check box which says this provider should be attributed to anesthesiology only for orders which they place during a surgical episode and there are ED and urgent care flags and gastroenterology which say this provider should be attributed to that service only for orders placed while the patient is in that unit.

4. Director Form

This form allows the user to assign one or more users as "directors" for specific services.

5. Executive Form

This form allows the users to assign executives. The executive are grouped based on the options in the service rollup form. So an executive can be assigned as an executive only for surgical services or children's services, as examples.

All of our forms are secured. The director and executive forms can only be updated by analytics or leadership within the Patient Safety and Reliability department. However, directors can add providers who are attributed to their service. In this way, we have distributed the maintenance effort for the service attribution without reducing the security.

2.4 Security

We have three different types of dashboards: executive, director and provider. In this section, we will describe the security for each type of dashboard.

2.4.1 Executive Dashboards

Executive dashboards include charts which compare performance across different services. This is only true for executive dashboards. Each user is limited to services which they have access to based on the executive form described in the last section. Executive users can see patient data for all encounters in the services they can access. Executive dashboards can drill down into director dashboards.

2.4.2 Director Dashboards

Director dashboards show metrics and performance within a service but cannot compare services. They can however compare providers within their service.

If a user has access to multiple director service dashboards, they can still only look at one service at a time. All data will be limited to that service. All patient information is available.

2.4.3 Provider Dashboards

Provider dashboards are our most important dashboards for mass consumption and user adoption. Within a provider dashboard, the provider sees performance for himself compared only to his service. He can see patient information for his encounters but not for the other encounters in his service. He can compare himself with his peers but the other provider names are redacted and replaced with numbers. Figure 3 shows an example of length of stay (LOS) provider comparison chart with redact names. It shows this provider has the second highest LOS in his service. The provider's metrics are calculated using the provider attribution described earlier. When the user opens the dashboard we acquire their system login and use this to automatically filter to their encounters and the redacted information for other encounters only in this service.

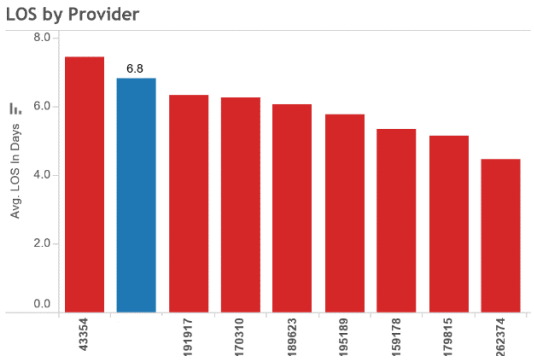

Figure 3: LOS by Provider

2.5 Support Users

We frequently find the need to emulate other users for support and testing purposes. For example, to test that the dashboard correctly works for a provider with both adult and pediatric services, we need to emulate such a provider. Additionally, a provider may call us with questions and we want to reproduce what he sees. Our visualization tool does not have this feature built in. Since none of our analytics developers or quality analysts actually treat patients, we would never be able to see data in the provider dashboard.

To solve this problem we created one more form, the support users form. This form allows any user on the support team, whether from analytics or from business departments such as the Patient Safety and Reliability department or the finance department, to login and alias themselves to specific provider.

Our visualization tool, Tableau, does support "live" data providers versus extracted data. We have set just this one query as live. What this means is that we can alias ourselves, press save on the form, refresh the dashboard in the browser and immediately see the dashboard as though we were that provider.

3 IMPLEMENTATION

Our solution is developed in our enterprise data warehouse. This primarily sources from our EMR data warehouse. We have created more than 70 extension facts from previous projects and we have created a set of data warehouse foundation tables which model the business and our rules rather than showing the specific implementation details of the EMR. For example, our EMR sets the inpatient admission time based on the planned admission time for planned post-op admits, but we have calculated the true inpatient admission time. Our EMR defines discharge provider based on the discharge order, but we are instead using the hospital bill as the source for discharge provider who signed the discharge summary. This gives us a single version of the truth.

Our solution requires several outside sources to acquire cost data, hospital acquired infection data and patient experience data. We integrate these sources into our data warehouse using data virtualization techniques as described in (McGlothlin 2017).

Our visualizations are written in Tableau and user row level security based on the user() function. They are secured and published to the provider via Microsoft Sharepoint and integrated into the EMR via the EMR's integration techniques. The users do not have database access to data warehouse, only access to the Tableau dashboards.

4 METRICS AND DASHBOARDS

4.1 Common Features

All of our dashboards have the features below which have reduced the learning curve for users and allowed us to achieve user adoption.

4.1.1Filters

All of our dashboards include standard filters such as date range, primary diagnosis, diagnosis-related group (DRG), payor, benefit plan, admitting and discharging departments, location and services, and admission type (elective vs urgent). This allows a user to choose any disease based on diagnosis or DRG and see how they are performing for that specific

patient cohort. This allows us to target disease populations globally rather than only through specific custom analytics dashboards. All of our filters are dynamic and cascading. As an example, this means if you filter to a specific DRG, the discharge service filter will now only show those services which discharged patients with that DRG.

4.1.2 Drill down

When the user has access to the patient information, all relevant data is available for the drill down include encounter, patient, and order information. Even when the user does not have access to the patient information, all information used in the metric calculations and filters is available in drill down. This increases the user's trust in our data. This has also enabled the users to look at specific events and encounters in order to do root cause analysis and learn how to improve.

4.1.3 Outlier rulers

A small number of encounters can drastically influence some calculations such as averages. We provide rulers for user's to filter out outliers. Figure 4 shows an outlier ruler for the length of stay chart. As an example, the user could move the ruler to 2 and 30 to only look at patients who were in the hospital at least 2 days and less than 30 days. Alternatively, the same ruler can be used to investigate outliers, perhaps by looking only at those encounters under 1 day or over 30 days.

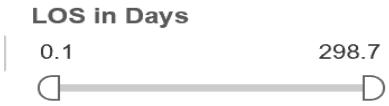

Figure 4: LOS Outlier Ruler

4.1.4 Hover information

Throughout our dashboards you can hover over any point in a chart to get additional information. This is especially useful to tell the user the volume of encounters. Many of our hovers even include additional charts specific to the portion of data that is being selected. Figure 5 shows an example of utilization information available by hovering over one specific procedure.

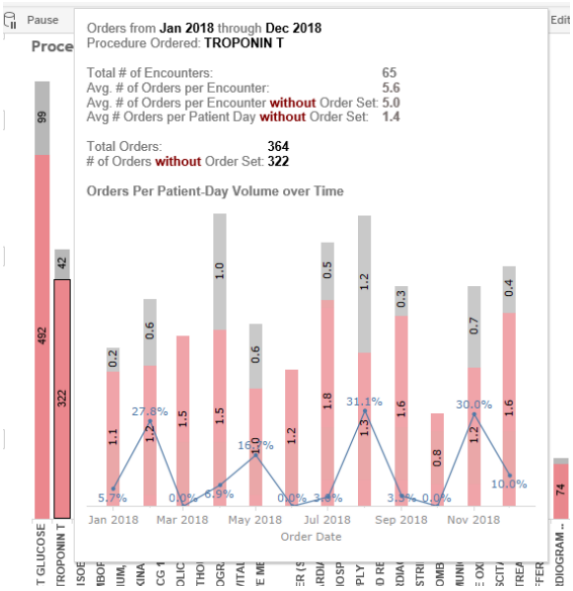

Figure 5: Hover information

4.1.5 Interactive charts

All of our charts are clickable and interactive. Clicking a specific bar in bar graph will filter all other charts to that value. For example, if the dashboard is displaying cost by service and by procedure, clicking on the service will show what procedures cost the most in that service, or clicking on the procedure will show what services use that procedure the most.

4.1.6 Dashboard companions

We have created dashboard companions in PDF for each dashboard. On every tab of every dashboard we have added a question mark icon that opens that section of the dashboard companion. These documents explain how to use the dashboard, what the charts represent and how the data points are calculated. We also are developing a searchable data dictionary.

4.2 Length of Stay

One of the most important metrics is how long the patient stayed in the hospital. Length of stay is one of the most important outcomes and can be used as a valid surrogate for hospital cost (Kitchiner 1996). Unlike government LOS measures, we count length of stay for every hour and present it as a real number instead of a whole number of days. Every hour a

patient remains at the hospital requires nursing support, occupies a bed another patient could utilize and decreases patient experience.

At the provider level we show both length of stay and CMI (case mix index) adjusted length of stay for the provider. Adjusting length of stay using CMI allows us to adjust for when the provider simply treated sicker or less sick patients. We compare the provider to benchmark length of stay information from CMS, our state public health insurance, the Children's Hospital Association and benchmark vendors. We also compare the provider to their service and rank them against their peers as shown in Figure 3

At the executive level, we compare length of stay across services and we look for length of stay opportunity: (length of stay – benchmark) * volume. The diseases with the greatest length of stay opportunity represent patient cohorts and workflows we want to target with performance improvement initiatives. Figure 6 shows LOS opportunities.

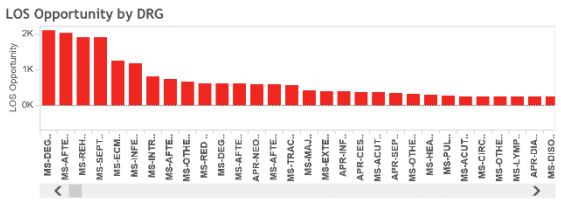

Figure 6: LOS Opportunity by DRG

4.3 Outcomes

In this category we focus on the metrics of readmissions, mortality and discharge disposition. Our metrics are as follows:

1. Encounter Disposition
2. Inpatient unplanned readmissions
    a. 7 day
    b. 14 day
    c. 30 day
3. ED readmissions
    a. 7 day
    b. 14 day
    c. 30 day
4. In-hospital mortality

We additionally stratify readmissions by disposition. The goal is to maximize discharges to home and to reduce readmissions and mortality.

At the provider level, the provider sees metrics for encounters they discharged compared to their service and their redacted peers. Readmissions and mortality are also stratified over time based on discharge date and compared to their service over the same time frame. At the director level, the director sees the metrics for their service and comparisons for each metric by discharging provider. At the executive level, all metrics are shown for the system and then stratified both by service and DRG. When it is stratified by DRG it is sorted both by highest % (who readmitted the highest % of patients) and by highest volume (who readmitted the most patients even if the percentage was lower).

Literature shows that providers have the greatest impact on seven day readmissions. Therefore we focus on opportunities to improve seven day readmission rates. Unlike CMS specifications, we allow readmissions to also be indexes. We also include the DRG and diagnosis of the readmit encounter. This allows us to filter on any disease and see how often they are coming back and why.

Figure 7 shows an example of charts analyzing readmission by days. Figure 8 shows an example readmission chart stratified by index DRG.

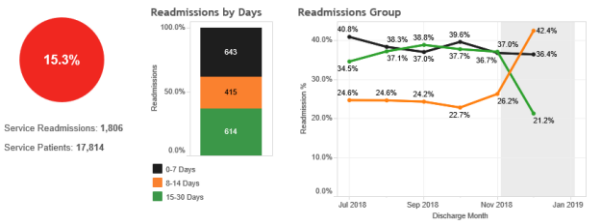

Figure 7: Readmission by readmit days example

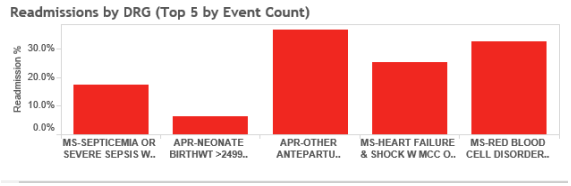

Figure 8: Readmission by index DRG

4.4 Discharge Efficiency

For discharge efficiency, the goal is to discharge the patients as early as possible. This saves resources and, as we are a very full institution, allows us to put another patient in that bed. We look at when the discharge order was written and when the patient departed. We measure both percentage of discharge orders written by 10am and noon. Providers have more control over when the discharge order is written than when the discharge occurs so this is the primary provider and service-based metric.

Additionally, we have a goal of departure by noon and discharge order to departure in under two hours so we track both of these metrics. These metrics are tracked primarily by unit as the unit staff has more influence over this measure than the discharging

provider. On the provider dashboard, these values are still shown only for patient's the provider discharged.

Finally we stratify both metrics by time and day of the week to look for opportunities for improvement. Figure 9 shows this chart. This is an example of a metric than can improve length of stay and cost without requiring us to target specific diseases.

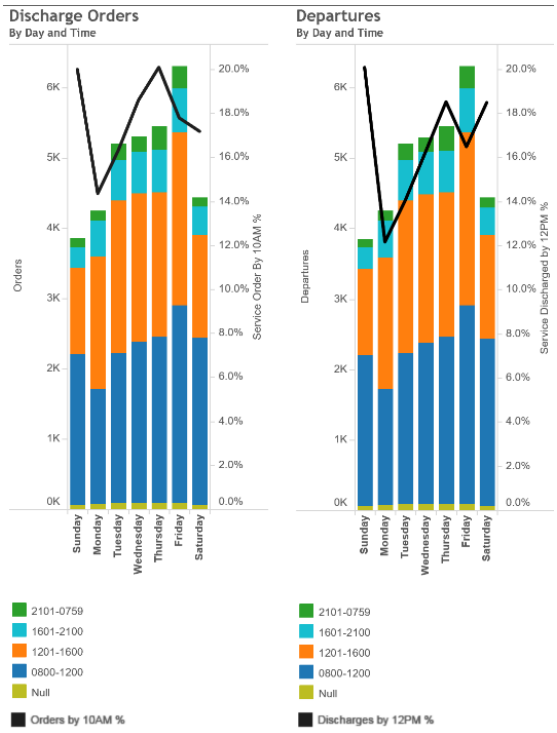

Figure 9: Discharge efficiency by day of week

4.5 ED and Admissions Efficiency

For these metrics, we track ED length of stay, time from decision to admit to admit order and time from admit order to the patient departing the ED. The attributed provider is the admitting provider though stratification for the director and executive dashboards includes the ED providers for ED length of stay. The provider is compared against their service for decision to admit to admit order. The time from admit order to ED departure is stratified by the inpatient unit the patient was moved to.

4.6 Patient Experience

We have a third party vendor who surveys the patient experience of our hospital patients. The set of questions is different for adults and children. We have set up a secure FTP location to receive and import these results monthly. We are attributing them to the encounter information so that filters by hospital, discharging service and DRG can still be supported. However, we do not attribute them to providers as the sample size is too small and we do not allow any users to see the actual patient name or encounter number. Provider and directors both see the responses to each set of questions, and the percentile compared to other hospitals. The executives are also able to compare the patient experience scores across the services. The results are benchmarked based on percentiles from other hospitals through our vendor. We are bringing this data in from the vendor through secure FTP. Figure 10 shows an example of patient experience information.

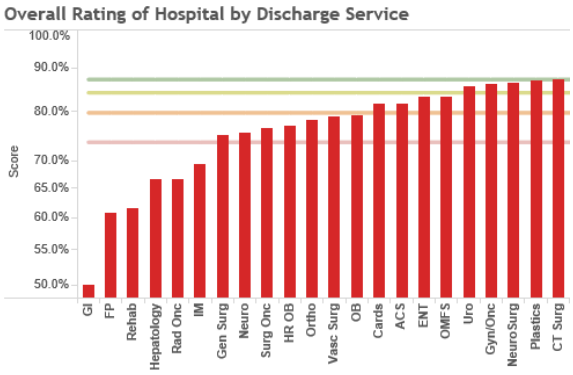

Figure 10: Patient experience by service

4.7 Bed Blocks and Room Turnaround Time

There are many reasons a bed can be blocked. Because our hospital doesn't have private rooms, it can be because the other patient in the room has an infectious disease, is a VIP or is considered dangerous. It can also be from mechanical or staffing issues. We have created metrics and dashboards which allow the user to see volume of bed blocks by day, stratified by type of block, unit or time. This allows us to analyse issues effecting occupancy, patient movement efficiency and timeliness of care.

Room turnaround time shows the average or median time from when a patient leaves a bed until it is cleaned and the average or median time from when it is cleaned until when it is occupied.

These metrics allows the user to analyse issues effecting occupancy, patient movement efficiency and timeliness of care.

Neither of these metrics is directly influenced by services so they are both stratified by unit, and all

users can see this data. There is no patient information.

4.8 Orders Utilization

For orders utilization, we calculate how many procedure or medications are ordered, stratified by authorizing provider, service and what was ordered. We also show what % of the orders used an orderset. These metrics are calculated four ways: total (for the time period), per encounter, per patient day (for each day the patient was in hospital), per service day (for each day the provider ordered anything for that patient). For the provider they can only see patient information for patients they wrote an order on, and they can only see any information for patients a provider in their service wrote an order on. They cannot see orders outside of their service even for the patients they wrote orders for.

For a provider, this is primarily useful for them to see what they are ordering most for different diseases and how their utilization compares to their peers. For a director, they can look across their providers and see who are utilizing more orders per patient day than others for the same disease and attempt to adjust practice.

At the executive level, the executive can look at order sets and see which items are being used most, and they can look at diseases and see which orders outside of the orderset are being ordered. This allows for orderset optimization. They can also compare orders across services or providers to drive performance improvement.

4.9 Cost

For all cost besides medications, we integrated data from our hospital's decision support system to acquire cost per unit and location based on revenue code and used that to calculate cost for every single hospital billing transaction including fixed direct, variable direct, and indirect cost. We added an extra calculation that applies current cost to past transactions. As an example if a chest x-ray's cost increased 10% but we were able to decrease utilization 5%, this allows us to apply today's cost to the old transactions and thus demonstrate the savings created by the 5% reduction, rather than losing the ability to quantify this return on investment (ROI) due to price fluctuations.

The finance department was unable to give us accurate unit cost for medications. This becomes challenging because some medications are single use. For example, if a patient only has albuterol once from an inhaler, the entire inhaler is still utilized. For now, the best surrogate we were able to do was to reverse the markup applies to the pharmaceutical charge as a surrogate for cost. We did special logic to adjust this for 340-B medications (Health Resources and Services Administration 2018). This is an accurate surrogate for cost with a consistent bias, but it does not allow us to provide current costing to past transactions.

78% of our costs are associated with an order. If the order is attached, we attribute the cost to the provider and the provider's service attribution. In the event the provider is not attributed or is a resident, we utilize the service at the time of the order using our patient movement data. Similarly, if there is no associated order, we use the first service on that service date. In these instances the provider is unassigned but the service is still assigned.

Similar to orders, we calculate cost in our dashboards in total, per encounter, per patient day and per service day. For the provider dashboard a provider is allowed to see their direct costs over time compared to their service. The greatest opportunity for provider improvement is in labs, images, and medications. Therefore we break these three categories out and bucket all remaining costs into one category. The provider dashboard does not show indirect costs as the provider cannot affect these values. Within lab, imaging, medication and other the provider can see their cost and their services cost by the procedure or medication that was ordered.

At the director level, the director can compare providers in their service by their cost in each category. At the executive level they can look at all revenue groups, compare cost by service and look at indirect costs as well. Moreover, the executive can compare analyse total cost by disease in each category. At the executive level we have also created separate charts for room and board cost and ICU cost. Executives can also look across the entire system for the highest cost medications and procedures and investigate opportunities to use a more economical option. Additionally, quality experts can look at the cost related to specific disease cohorts, ordersets and care paths to optimize the ordersets to minimize cost. Furthermore, this cost data provides valuable feedback to know which quality and performance initiatives are delivering financial return on investment.

Figures 11, 12 and 13 show some examples of cost charts.

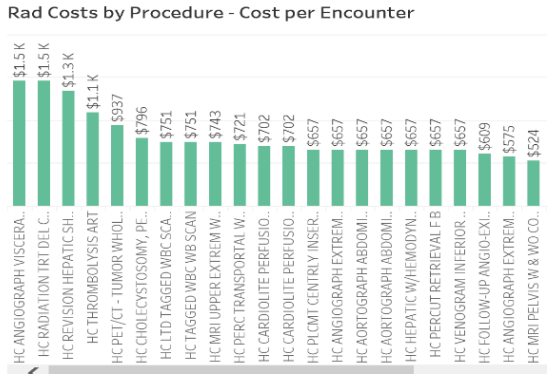

Figure 11: Imaging cost by procedure

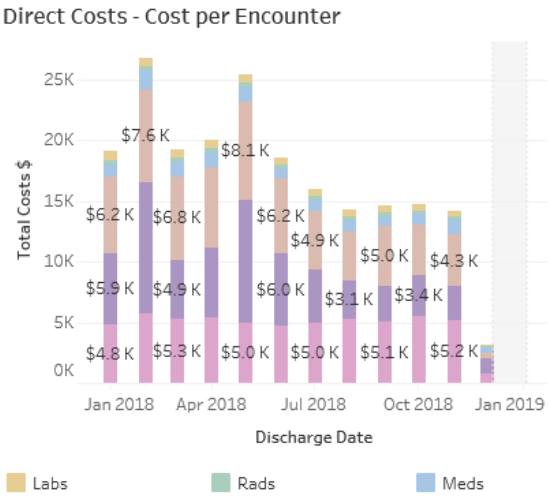

Figure 12: Direct cost per encounter by category

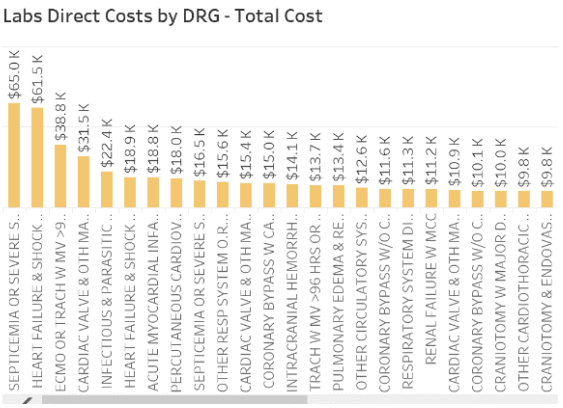

Figure 13: Total lab costs by DRG

4.10 Complications

For hospital-acquired infections such as catheter-associated urinary tract infection (CAUTI), central line-associated blood stream infection (CLABSI) and methicillin-resistant Staphylococcus aureus (MRSA), the hospital documents and attributes the infection in an Excel spreadsheet. We import this spreadsheet daily using a shared drive and checking for updates. For complications such as falls, the incidents are reported in the risk management software. We import this data programmatically. For surgical site infections (SSI), we acquire this data from the web registry used to report it.

All of these metrics are associated to services and sometimes departments. We show the volumes with the ability to drill down to the details to enable performance improvement. Additionally, we adjust and standardize the rate and compare it to benchmarks. All of this is done with outside reporting registry and risk management software, and then integrated into our data warehouse.

5 RESULTS

We have delivered 14 dashboards with 46 tabs for this project. We currently have over 500 users, over 300 who have viewed dashboards in the last month, and over 10,000 distinct views. All of this is accessed from a single location with a common look and feel.

Since going live 5 months ago, we have been able to reduce length of stay by 4.3% and the number of days over benchmark (length of stay – benchmark) by 12%. Readmissions have been reduced by 6.4%. Room turnaround time has been reduced by 51%. Our cost phase went live only this month so we do not have sufficient data to analyse results yet.

We used the information from the executive dashboard to choose disease to design programs around. So far, we have developed care paths for sickle cell anemia, heart failure, pediatric sepsis and acute coronary syndrome (ACS). We are currently developing solutions for pre-eclampsia, adult sepsis and asthma. All of these show in the top 5 for either volume, length of stay opportunity, cost or readmissions. Early results for heart failure show a savings of over 1.5 days in the length of stay when the care path was utilized. Additionally, we were able to identify high cost unnecessary orders (compound narcotics urinary analysis was second highest cost) and variations in care (two providers averaged almost two chest x-rays per visit while most averaged only one). For ACS, we have demonstrated statistically significant and consistent reduction of 51.6% in

emergency department length of stay since development of the care path.

6 FUTURE WORK

We plan to analyse our results more after we have been in production for a full year. Our infection and complications phase is still in final development. We have planned future phases including productivity, additional complications, surgical efficiency, boarder time in ICU and PACU, supply cost details, waste, and appropriate utilization. Additionally, we plan to develop many more care paths for specific diseases with high opportunity. We plan to evaluate cost savings from each of these care paths. Finally, we plan to integrate additional benchmarks to measure hospital performance versus our peers.

7 CONCLUSIONS

We have developed a set of simple, meaningful, easy to use and secure dashboards for enterprise-wide consumption by providers and service lines across multiple types of devices. We have demonstrated the ability to create performance improvement utilizing these dashboards. Early user adoption has been good. We have a framework for continued expansion and a set of secure configuration and attribution forms for simplified maintenance. We can continue to develop care paths based on these analytics, and create meaningful changes, outcome improvement and cost reduction.

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REFERENCES

Office of the Inspector General, 2018. A Roadmap for New Physicians: Fraud & Abuse Laws. Viewed November 2018. https://oig.hhs.gov/compliance/physician-education/01laws.asp.

Kitchiner, D., Davidson, C and Bundred, P., 1996. “ntegrated Care Pathways: effective tools for continuous evaluation of clinical practice. Journal of Evaluation in Clinical Practice, vol. 2, no. 1, pp. 65–69, 1996.

Joint Commission on Accreditation of Healthcare Organizations, 1996. An Integrated Approach to Medical Staff Performance Improvement.

Stephen, A.E. and Berger, D.L., 2003. Shortened length of stay and hospital cost reduction with implementation of an accelerated clinical care pathway after elective colon resection. In Surgery, vol. 133, no. 3, pp. 277–282, 2003.

Pearson, S., Kleefield, S., Soukop, J., Cook, E., Lee, T., 2001. Critical pathways intervention to reduce length of hospital stay. In American Journal of Medicine.

Wazeka,A., Valacer, D., Cooper, M., Caplan, D.W., and Dimaio, M., 2001. Impact of a pediatric asthma clinical pathway on hospital cost and length of stay. In Pediatric Pulmonology, vol. 32, no. 3, pp. 211–216.

Rotter, T., Koch, R., Kugler, J., Gothe, H.,Kinsman, L. and James, E., 2007.Clinical pathways: effects on professional practice, patient outcomes, length of stay and hospital costs. In Cochrane Database of Systematic Reviews.

Vanhaecht, K., Bollmann, M., Bower, K., Gallagher,C. Gardini, A., Guezo, J., Jansen, U., Massoud, R., Moody, K., Sermeus, W., Zelm, R.V., Whittle, C., Yazbeck, A.-M., Zander, K. and Panella, M., 2006. Prevalence and use of clinical pathways in 23 countries - an international survey by the European Pathway Association.In International Journal of Care Pathways, vol. 10, no. 1, pp. 28–34, Jan. 2006.

McGlothlin, J.P. Madugula, A., and Stojic, I., 2017. The Virtual Enterprise Data Warehouse for Healthcare. In Proceedings of the 10th International Joint Conference on Biomedical Engineering Systems and Technologies.

Libby, P., 2001. Current Concepts of the Pathogenesis of the Acute Coronary Syndromes. Circulation, vol. 104, no. 3, pp. 365–372, 2001.

Health Resources and Services Administration, 2018. 340B Pricing Program. Viewed November 2018. https://www.hrsa.gov/opa/index.html.

McGlothlin, J.P., Crawford, E., Srinivasan, H., Cianci, C., and Dorotta, I, 2017. Reducing Red Blood Cell Transfusions. In ITBAM.

Wyatt, J., Vaks, Y., Moretti, A., Pappas, J., Wilson, M., Samayoa, C., McGlothlin, J., Lopez, M., 2018. The Future of Healthcare: Avoiding Pain, Unnecessary Interventions and Reducing Cost in the PICU. In Critical Care Medicine, vol 46, issue 1.

McGlothlin, J..P., Vedire, S., Crawford, E, Pappas, J., Bruneau, B., and Obregon, L., 2016. Improving Patient Care Through Analytics. In ISCBI.

McGlothlin, J.P., 2018. Accelerating Analytics for Clinical Pathways to Drive Cost Reduction and Quality Improvement. In IEEE International Conference on Iwnformation Reuse and Integration.