Adding Clinical Data to Statewide Administrative Data: Pilot Project

Analysis and Results Final Report

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INTRODUCTION

Hospitals' mortality rates will be affected by the types of patients they treat. Any comparison of hospital mortality rates must therefore be risk-adjusted for the case mix of each hospital. All hospitals routinely collect and submit to payers and government agencies standard data (referred to as administrative data) that includes demographic, diagnostic and procedure data on each patient.

The administrative data allows the determination of a patient's reason for admission, the severity of the condition that caused the admission, and the types and severity of comorbid conditions, which can then be used to describe a hospital's case mix. An accurate description of a hospital's case mix can then be used as the basis for risk-adjusting hospital mortality rate comparisons. By examining case-mix adjusted mortality rates – based on patients with comparable conditions who are at comparable risk – deviations from expected mortality rates can be determined and used to identify potential problems with the quality of care.

The diagnostic information contained in administrative data is coded using the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM). Although ICD-9-CM diagnosis codes identify the existence of a disease or illness, they frequently do not provide a complete description its extent or severity. Because of this limitation of ICD-9-CM, any description of a hospital's case mix may not fully capture the true risk of mortality associated with the patients being treated. For some diagnoses, clinical laboratory data can be used to augment the administrative data to provide a more complete description of the extent and severity of a patient's illness, thereby improving the accuracy of the risk adjustment method for comparing hospital mortality rates.

In order to test the degree to which clinical laboratory data can improve the accuracy of the risk adjustment methods for comparing hospital mortality rates, a risk adjustment method that uses only administrative data must be selected and then modified by adding clinical laboratory data. The performance of the risk adjustment method can then be assessed with and without the clinical laboratory data.

For the purposes of this project, the All Patient Refined Diagnosis Related Groups (APR DRGs) were selected as the administrative data based risk adjustment method because of their widespread use. APR DRGs are currently used by the Agency for Healthcare Research and Quality (AHRQ), Agency for Health Care Administration (AHCA), Joint Commission on Accreditation of Healthcare Organizations (JCAHO) and many other agencies as the risk adjustment model in either public or confidential reporting of inpatient outcomes including mortality. This project modified the administrative data based version of APR DRGs to include clinical laboratory data, and then compared the versions of APR DRGs with and without laboratory data in terms of their ability to predict inpatient mortality. The project involved five steps:

1. Using research literature and clinical input, identify the subset of candidate clinical laboratory tests to be evaluated
2. Create a database that includes both administrative and clinical laboratory data
3. Create standardized test result ranges (TRR) for each clinical laboratory test
4. Using research literature and clinical input to identify meaningful results outside normal ranges of laboratory tests, statistical tests were then used to identify the subset of clinical laboratory test results specified that improve the performance of APR DRGs for predicting inpatient mortality
5. Assess the overall incremental improvement due to the addition of the clinical laboratory test results on the performance of APR DRGs for predicting inpatient mortality

After a brief overview of APR DRGs, the methods and results for each step will be described, followed by a discussion of project limitations and conclusions.

Background on APR DRGs

The All Patient Refined Diagnosis Related Groups (APR DRGs) expand the basic DRG structure by adding two sets of subclasses to each base APR DRG. Each subclass set consists of four subclasses and addresses patient differences relating to severity of illness (SOI) and risk of mortality (ROM). Severity of illness is defined as the extent of physiologic decompensation or organ system loss of function. Risk of mortality is defined as the likelihood of dying. Since severity of illness and risk of mortality are distinct patient attributes, separate subclasses are assigned to a patient for severity of illness and risk of mortality. Thus, in the APR DRG system a patient is assigned three distinct descriptors:

- The base APR DRG (e.g., APR DRG 194 Heart Failure or APR DRG 440 Kidney Transplant)
- The severity of illness (SOI) subclass
- The risk of mortality (ROM) subclass

The four severity of illness subclasses and the four risk of mortality subclasses are numbered sequentially from 1 to 4 indicating respectively, minor, moderate, major, and extreme severity of illness or risk of mortality. For applications such as evaluating resource use or establishing patient care guidelines, the APR DRG in conjunction with severity of illness subclass is used. For evaluating patient mortality the APR DRG in conjunction with the risk of mortality subclass is used.

The underlying clinical principles of APR DRGs are that the severity of illness and risk of mortality of a patient are highly dependent on the patient's underlying clinical problems, and that patients with high severity of illness or risk of mortality are usually characterized by multiple serious diseases or illnesses. In the APR DRGs, the assessment of the severity of illness or risk of mortality of a patient is specific to the base APR DRG to which a patient is assigned. In other words, the determination of the severity of illness and risk of mortality is disease-specific. Thus, the significance attributed to complicating or comorbid conditions is dependent on the underlying problem. For example, certain types of infections are considered a more significant problem in a patient who is

immunosuppressed than in a patient with a fractured arm. In APR DRGs, high severity of illness or risk of mortality are primarily determined by the interaction of multiple diseases. Patients with multiple comorbid conditions involving multiple organ systems represent difficult-to-treat patients who tend to have poor outcomes.

APR DRGs are a joint development of 3M Health Information Systems (3M HIS) and the National Association of Children's Hospitals and Related Institutions (NACHRI). Thus, the APR DRGs provide a comprehensive and clinically specific classification of both Medicare and non-Medicare patients.

The development of APR DRGs involved an iterative process of formulating clinical hypotheses and then testing the hypotheses with historical data. Separate clinical models are developed for each of 314 reasons for admission (base APR DRGs), in which the risk factors that impact the severity of illness and risk of mortality are identified. Thus, the APR DRGs are a *clinical model* that has been extensively reviewed with historical data.

APR DRG Risk of Mortality Subclass

In APR DRGs, the process of determining the risk of mortality (ROM) subclass of a patient consists of three phases. In Phase I, the risk of mortality level of each secondary diagnosis is determined. Once the risk of mortality level of each individual secondary diagnosis is established, then Phase II determines a base risk of mortality subclass for the patient based on all of the patient's secondary diagnoses. In Phase III, the final risk of mortality subclass for the patient is determined by incorporating the impact of principal diagnosis, age, operating room procedure, non-operating room procedures, multiple operating room procedures, and combinations of categories of secondary diagnoses. An in depth description of the construction of the base APR DRGs and the 18 steps used to assign the risk of mortality subclass can be made available from the authors upon request.

Admission APR DRG

Hospitals report discharge diagnoses on the Medicare claim form that include diagnoses that were present on admission as well as diagnoses that develop post admission. As a result, the base APR DRG, severity of illness subclass and risk of mortality subclass represent the patient's condition at the time of discharge and include the impact of

conditions that developed during the hospital stay. The Deficit Reduction Omnibus Reconciliation Act of 2005 requires that hospital report a "present on admission" (POA) indicator for each diagnosis that specifics whether the diagnosis was present at the time of admission on all Medicare claims beginning in FY 2008. With the availability of the POA indicator an Admission APR DRG (including the base ARR DRG, and the severity of illness and risk of mortality subclasses) can be assigned in addition to the Discharge APR DRG. The assignment of the Admission APR DRG is accomplished through a seven step process that essentially eliminates certain diagnoses and procedures from consideration in the assignment of the APR DRG. The underlying clinical logic for assigning both the Admission APR DRG and Discharge APR DRG is identical. The one difference is that a reduced set of diagnoses and procedures – only those present at the time of admission – are used to assign the Admission APR DRG. The seven steps in Admission APR DRG assignment essentially represent a preprocessing that limits the diagnoses and procedures passed to the standard APR DRG assignment logic.

DATA SOURCE

We obtained hospital discharge data and clinical laboratory data from a nine months interval from 2007 and 2008 for twenty-two Florida hospitals from three health systems and two children's hospitals. (One hospital provided 12 months of data). Hospitals that did not have unique hospital identification numbers we combined based on the hospital identification number provided in the dataset. Table 1 lists the combined seventeen participating hospitals and the number of discharges from each hospital within the specified discharge time periods. The administrative dataset provided to 3M HIS from AHCA contained a total of 223,468 discharges.

The standard patient discharge data elements provided in the administrative dataset included diagnosis codes for principal and secondary diagnoses, procedure codes and the number of days after admission they were performed, age, gender, patient discharge status, and the present on admission indicator for each secondary diagnosis. The administrative data also included a unique identification (ID) number for each patient discharge that was used to link to the hospital's clinical laboratory data.

Table 1: Florida Hospitals Participating in the Project

Health System - Hospital Name	Number of Discharges	Discharge Time Period
All Children's Hospital	5,947	April 2007 - December 2007
BayCare - Mease Countryside Hospital	12,929	April 2007 - December 2007
BayCare - Mease Dunedin Hospital	4,793	April 2007 - December 2007
BayCare - Morton Plant Hospital	23,662	April 2007 - December 2007
BayCare - Morton Plant North Bay Hospital	4,838	January 2007 - December 2007
BayCare - South Florida Baptist Hospital	4,524	April 2007 - December 2007
BayCare - St. Anthony's Hospital	8,158	April 2007 - December 2007
BayCare - St. Joseph's Hospital	37,214	April 2007 - December 2007
Broward - Broward General Medical Center	21,896	April 2007 - December 2007
Broward - Coral Springs Medical Center	9,876	April 2007 - December 2007
Broward - Imperial Point Medical Center	5,318	April 2007 - December 2007
Broward - North Broward Medical Center	10,120	April 2007 - December 2007
Memorial - Memorial Hospital Miramar	8,142	April 2007 - December 2007
Memorial - Memorial Hospital Pembroke	5,185	April 2007 - December 2007
Memorial - Memorial Hospital West	20,405	April 2007 - December 2007
Memorial - Memorial Regional Hospital	28,401	April 2007 - December 2007
Miami Children's Hospital	12,060	January 2008 - December 2008

METHODS

Step 1: Identify the subset of candidate clinical laboratory tests to be evaluated

Before obtaining the hospital data, the research team, based on clinical grounds and a review of the literature, selected candidate laboratory tests that were:

- Thought likely to contribute to predictions of in-hospital mortality and therefore useful to incorporate into the APR DRG model
- Based on information routinely ordered by health care professionals
- Derived, whenever possible, from standardized items already tested in the literature.

The list of selected candidate clinical laboratory data elements collected for the project is shown in Table 2.

Step 2: Create a database with that includes both administrative and clinical laboratory data

The selected laboratory tests were identified according to Logical Observation Identifiers Names and Codes (LOINC) standards, which allowed them to be indentified by standardized codes in electronic reports.[1] LOINC codes are highly specific and assign separate codes not only for the type of laboratory test but also the source of the specimen and the specific analytic technique. A single laboratory test can therefore have multiple associated LOINC codes.

The data elements contained in the clinical laboratory dataset included the LOINC codes, test result, units of measure, date and time of the specimen, type of test performed, and reference range of the test. Each record in the clinical laboratory dataset included the unique patient discharge identification number that was included in the administrative dataset in order to link a patient's clinical laboratory data with the associated administrative discharge data.

Each of the laboratory test record in the clinical laboratory dataset was standardized to a LOINC code using the mapping file developed by 3M HIS specific to the children's hospitals and the hospitals within each health system. Each LOINC code was associated with one of the selected clinical laboratory data elements, and some of the laboratory tests were associated with multiple LOINC codes.

Appendix A contains the fifty-five LOINC codes associated with the laboratory data elements selected for the project as well as the number of laboratory test records in the clinical laboratory dataset provided by the hospitals for the project. The LOINC codes shown in Appendix A are organized by clinical laboratory data element so that an overall picture of the frequency of the clinical laboratory data element could be assessed. Over 11.7 million clinical laboratory test records were contained in the clinical laboratory dataset.

[1] LOINC is one of the accepted standards of the Consolidated Health Informatics Initiative; recommended for use by the Office of National Coordinator (ONC) and its supporting workgroups within the American Health Information Community (AHIC).

Table 2: Candidate Clinical Laboratory Data Elements Collected

Clinical Laboratory Data Element
SGOT
CPK MB
Potassium
Sodium
Troponin T
pH
PO2.sat
pCO2
Prothrombin Time
Albumin
Base Excess
Total bilrubin fractions
Calcium (total and ionized)
Creatinine
Glucose
Alkaline phosphatase
Blood urea nitrogen (BUN)
Hematocrit
Mean cell hemoglobin
Mean cell volume
Platelets
White blood cell (WBC) count
Chloride
Bicarbonate
Gamma glutamyl transferase
SGPT
Phosphorous
Total hemoglobin
Partial thromboplastin time
Blood/Lymph culture-positive

Administrative Data Exclusions

After compiling the linked administrative and clinical laboratory data sets, we applied additional criteria to the administrative dataset and excluded discharges from the analysis if:

- The discharge was classified to an ungroupable or error APR DRG (APR DRG 955 or 956)
- Charges for the discharge were less than $200
- Charges for the discharge were greater then two million dollars
- The length of stay for the discharge was over one year

- The discharge had a duplicate unique discharge ID number
- The discharge was from a hospital during a three month period (quarter) in which less than 65% of the administrative discharges had at least one linked clinical laboratory data record
- The hospital did not meet the POA data quality screening criteria (none of the 17 hospitals failed to meet this criterion)

Applying the patient level data quality screening criteria to the administrative dataset, 34,913 discharges were excluded from the administrative dataset. Table 3 shows the number and percent of administrative discharge data records that failed one or more of the data quality screening criteria.

The majority of the discharges excluded from the administrative dataset based on the data quality screening criteria were due to a hospital having a low percentage of linked lab data for a three month quarter of data. In particular, data from Miami Children's Hospital was excluded entirely because it had less than 15% of administrative data records linked to at least one laboratory data record across all four quarters (twelve months) of data. Five other hospitals had one of their three quarters of administrative data in which failed this criterion. The number and percent of discharges with one or more laboratory test record linked to the administrative data for each hospital for each quarter of data is included in Appendix B.

For this project, we applied five specific criteria for evaluating the quality of the present on admission coding. This POA screening criteria was developed using administrative data from California, and applied to the Florida administrative data to ensure POA coding accuracy. All 17 hospitals passed the POA data quality screen criteria. Eight hospitals had slightly over 10% of the secondary diagnosis codes with a blank (empty) POA indicator. For these hospitals a blank POA indicator was set to "Y"(yes) if the code was on our pre-existing list, "E" (exempt) if the code was on the National Center for Health Statistics POA list of exempt diagnosis codes, and otherwise was assumed to be not POA and labeled "N". The detailed description of the POA data quality screen criteria can be found in Appendix C.

Table 3 Frequency of Discharges Excluded Due to Data Quality Screening Criteria

Data Quality Screening Criteria	Number of Discharges Failed Data Quality Screening Criteria	Percent of Discharges Failed Data Quality Screening Criteria
Ungroupable - Error DRG 955 or 956	53	0.02%
Total Charges Equal to Zero	0	0.00%
Total Charges Less Than $200	0	0.00%
Total Charges Greater Than 2 million	17	0.01%
Length of Stay Greater Than One Year	3	0.00%
Duplicate Admin Link IDs	16	0.01%
Percentage of discharges Less Than 65% in One Quarter With at Least One Linked Laboraory Record	34,891	15.61%
Hospital Did Not Met the POA Quality Screening Criteria	0	0.00%

The final administrative analysis dataset contained 188,555 discharges from 16 Florida hospitals for discharges from April 2007 through December 2007.

Clinical Laboratory Data Exclusions

Over 11.7 million clinical laboratory data records were provided from hospitals participating in the study. Clinical laboratory data records that did not link to the 188,555 administrative discharge records in the analysis file were excluded. The remaining clinical laboratory data records were reviewed for data quality.

Each of the laboratory test record in the clinical laboratory dataset was standardized to a LOINC code using the mapping file developed by 3M HIS specific to the hospitals within each health system and to the children's hospitals. Inconsistent laboratory test results were then identified and excluded according to the following criteria:

- The number of clinical laboratory data records for the LOINC code for the specified clinical laboratory data element were not provided for more than one of the three health systems or two children's hospital
- The LOINC code values were missing or coded as "unknown"
- Extreme variation or errors values for the specific laboratory test results.

Four of the fifty-five LOINC codes were either not provided by any of the hospitals or only provided by only one of the three health systems or two children's hospitals. These four LOINC codes, shown below, had limited usability and were excluded from the analysis.

- 2703-7 Oxygen
- 48425-3 Troponin T, Blood
- 664-3 Mycobacterium species, Blood by Culture
- 6598-7 Troponin T, Serum or Plasma

57,649 clinical laboratory data records were coded with one of the four LOINC codes list above. Further, an additional 65,442 clinical laboratory data records were missing LOINC code values or coded as "unknown".

The frequency of the laboratory test result values was also examined and extreme or error test results for each of the specific clinical laboratory data element were identified and excluded. 253 laboratory test results from among thirteen of the clinical laboratory data elements were determined to have either extreme or error test result values and were excluded. The complete list and frequency of the test results identified as extreme or in error are shown in Appendix D.

Step 3: Create standardized test result ranges (TRR) for each clinical laboratory test

After creating the linked administrative and clinical laboratory test data set, the next step was to create test result ranges for each of the laboratory tests that could be evaluated for their ability to improve the APR DRG prediction of mortality.

We removed five of the original candidate laboratory tests from the study after reviewing the test result values and frequencies (Mean cell hemoglobin, Mean cell volume, Chloride, Partial thromboplastin time, and positive blood/lymph culture). Mean cell hemoglobin and mean cell volume have limited predictive ability and prognostic value for identifying high risk mortality patients. Serum chloride was excluded since it provided no additional information to the results for serum sodium. Partial thromboplastin time, while useful for monitoring anticoagulation, has limited value for identifying patients at high risk of mortality. Blood/lymph culture positive was provided for only a limited number of records from the hospitals.

The research team reviewed the distribution of test results for each individual LOINC code across hospitals and determined that the variation in both the reference (normal) ranges and the overall distribution of results was not significant. Therefore, the normal ranges did not require modification in order to be comparable across hospitals, and the actual numeric laboratory test result values were used directly in the analysis.

For each of the clinical laboratory data elements retained in the study, we categorized the test results into clinically determined ranges test result range (TRR) categories, based on clinical judgment and literature review[2,3,4]. The highest number of abnormal test result ranges defined for a clinical laboratory data element was six. The normal test result ranges were labeled "NTRR", and the six abnormal test result ranges were labeled "ABNTRR1" through "ABNTRR6". For example, the normal test result range for sodium is defined as 135-145. We defined five additional abnormal test result range categories for sodium: less than 130, 130-135, 145-150, 150-155, and greater than 155. The standardized normal and abnormal test result ranges for each of the clinical laboratory data elements is detailed in Appendix E.

We hypothesized that the test ranges that deviated most from normal would tend to correlate with higher mortality rates. We tested this hypothesis by examining the ability of TRRs for each laboratory test to predict mortality when combined with APR DRGs.

We agreed with the overall philosophical approach of prior research that used laboratory values for improved risk of mortality prediction based on diagnoses/procedures present on admission, the challenge was in operationalizing this approach. There are several possible methods for selecting an admission laboratory value, including 1) the first test result value available; 2) the first test result available as long as it occurs in the first 48 hrs; or 3) the nearest normal or the most abnormal result in the first 48 hrs if more than one laboratory result is available.

Since the admission date was not provided as a data element in the administrative dataset, we did not know if a test was performed within 48 hours of admission. Therefore, for patient discharges

[2] Abt Associates, Inc. Adding Clinical Data Elements to Administrative Data for Hospital-level Reporting: Final Report AHRQ Contract # 233-02-0088, Task Order 13. July 3, 2006

[3] Pine M, Jordan HS, Elixhauser A, et. al. Enhancement of Claims Data to Improve Risk Adjustment of Hospital Mortality. JAMA 297 (1): 71-76; January 3, 2007.

[4] Pine M, Jordan HS, Elixhauser A, et al. Modifying ICD-9 Coding of secondary diagnoses to improve the risk adjustment of inpatient mortality rates. Medical Decision Making 2009 Jan-Feb; 29 (1): 69-81

with multiple test results for the same clinical laboratory data element, we selected the first test result available to be included in the clinical laboratory data analysis file.

This strategy of selecting only a single result from each hospitalization for each of the laboratory tests yielded at total of 6,506,941 (from the total file of over 11 million) records from 16 Florida hospitals in the final clinical laboratory data analysis file. If a patient did not have a specific laboratory test performed during the hospitalization, the patient was assigned to the "No Data" test result range category for purposes of the analysis for that specific laboratory data element. By creating this "No Data" test result range category, all the administrative data could be used in the analysis and the results would be more consistent across the various clinical laboratory data elements.

Step 4: Identify the subset of clinical laboratory test results that improve the performance of APR DRGs for predicting inpatient mortality

The next step was to determine which of the laboratory tests and their test result ranges added predictive value to the existing APR DRGs, and to incorporate them into the APR DRG logic. Risk adjusted models were created and analyzed using the following hospital administrative and clinical laboratory dataset models:

- Model A – the Discharge APR DRG and risk of mortality subclass assignment based on administrative data elements including principal and all secondary diagnosis, procedures, age, gender, and patient discharge status; no clinical laboratory data
- Model B - the Admission APR DRG and risk of mortality subclass assignment based on the same administrative data elements for Model A plus the present on admission (POA) indicator for each secondary diagnosis and the number of days after admission each procedure is performed; no clinical laboratory data
- Model C – the Admission APR DRG and risk of mortality subclass used in Model B data plus test results for each of the selected laboratory clinical data elements

We used the APR DRG version 26.1 software to assign each discharge in the administrative dataset both a Discharge APR DRG and risk of mortality subclass, as well as an Admission APR DRG and risk of mortality subclass. Because we were primarily interested in the impact of adding clinical laboratory data elements to the risk of mortality at the time of admission, we used

Admission APR DRG and risk of mortality ("Model B") as the basic risk adjustment model for the development of model "C". We then examined the effect of individual laboratory tests and test result ranges within various patient groups, including individual APR DRGs, entire Major Diagnostic Categories (MDC), all surgical APR DRGs or all medical APR DRGs, or the entire patient population, in order to identify those laboratory tests associated with of higher risk of mortality. Indirect rate standardization was used to generate a set of reports that were used to evaluate the impact of clinical laboratory data on the four risk of morality subclasses. (Technical specifications for the indirect rate standardization are found in Appendix F.) The clinical hypothesis tested was that for certain categories of patients the risk of mortality subclass could be increased based on the value of specific clinical laboratory results.

We developed separate clinical models for each of the laboratory data elements by calculating the mortality rate for each TRR within each ROM subclass for each category of cases. In addition we calculated an "impact factor" index for each TRR on each of the 4 ROM subclasses. The impact factor index was a generated by interpolating the mortality rate created by TRR in each ROM subclass between the mortality rate of the ROM subclass that would be expected without using laboratory data (e.g. the mortality rate resulting from Model "B") and the expected mortality rate of the next highest ROM subclass. For example, if the mortality rate calculation for the TRR for pH < 7.10 in ROM subclass 1 was 15%, and the expected mortality rate derived from Model "B" for ROM 1 was 10%, and the expected mortality rate for ROM 2 was 20%, the impact factor would be 1.5, since the mortality rate increase due to the TRR for the low pH was 50% of the way between ROM 1 and ROM 2. The clinical panel then reviewed the resulting reports to determine which specific laboratory TRRs should be used to alter the risk of mortality subclass for specific type of cases.

The clinical panel focused on those TRR and ROM subclass combinations with at least 20 cases and with an impact factor that was at least 50% higher than the expected value derived from Model "B" (e.g., >1.5 for ROM 1, >2.5 for ROM 2, etc).

The following format was used to evaluate each clinical laboratory abnormal test result ranges:

Test Result Range	Ocurrence ROM 1	Mortality Rate ROM 1	Impact Measure ROM 1	Ocurrence ROM 2	Mortality Rate ROM 2	Impact Measure ROM 2	Ocurrence ROM 3	Mortality Rate ROM 3	Impact Measure ROM 3	Ocurrence ROM 4	Mortality Rate ROM 4	Impact Measure ROM 4

where "Occurrence" is the number of patients in each risk of mortality subclass, "Mortality Rate" is the percent of patients who died in each APR DRG risk of mortality subclass and "Impact Measure" is a relative measure of the impact on the likelihood of dying of patients assigned to each of the four APR DRG risk of mortality subclasses. The Impact Measure is in the format of X.Y where X is the estimated risk of mortality subclass value from the data and Y is an interpolation of the estimated risk of mortality subclass value and the next higher risk of mortality subclass value (e.g., a 3.2 means that the subset patients with the laboratory test result in the specified range have a risk of mortality that is 20 percent of the way between the risk of mortality for patients in APR DRG subclass 3 and APR DRG subclass 4). The rows in the analysis are the different ranges of the laboratory test result being examined.

Reports for each clinical laboratory data element were generated in the form at described above with the test result range categories in the rows of the reports. The rows on the reports were summarized by four specific case type aggregation levels: 1) overall, 2) cases defined as medical or surgical based on the APR DRG assignment, 3) MDC, and 4) base Admission APR DRG. By aggregating the reports by the various types of cases, the clinical review of the results can determine if the laboratory test result range related adjustments to the APR DRG risk of mortality algorithm should be made for specific risk of mortality levels, for specific test result range categories, or diseases specific at either the MDC or base Admission APR DRG level.

Step 5: Assess the overall incremental improvement due to the addition of the clinical laboratory test results on the performance of APR DRGs for predicting inpatient mortality

The literature which assesses the ability of various models to predict mortality relies on two basic statistics, reduction of variance (R^2) and the area under the receiver operating characteristics (ROC) curve. In order to be consistent with this literature, the same two statistics were used for evaluating the ability of the APR DRG system to predict inpatient mortality with Florida data.

Case-level comparison of the baseline model A (using only administrative data) to model "B" (including the secondary diagnosis present on admission indicator) and model "C" (combining model B with laboratory test results) were performed using the c-statistic and R^2. The c-statistic summarizes the ability of the Admission APR DRG and risk of mortality models to discriminate between patients that were discharged alive or dead. The R^2 also summarizes the degree of error

inherent in the Admission APR DRG and risk of mortality models' ability to predict individual deaths. The statistical formulas for the R^2 and c-statistic calculations are shown in Appendix G.

In order to understand the interpretation of the c-statistic, assume that patients are separated into two groups comprising those who died and those who survived. If a patient is drawn from each group at random, then each of these patients will have an associated APR DRG and each APR DRG will have an associated mortality rate (i.e., fraction of patients who die). The c-statistic is the probability that the mortality rate in the APR DRG assigned to the patient who died is higher than the mortality rate in the APR DRG assigned to the patient who lived

The research team next incorporated the results of the analysis into an APR DRG research prototype grouper. Each model was run against the Florida analysis dataset. Case level c-statistics and R^2 were computed for each model separately. These reports and statistics were reviewed by the clinical panel to determine which clinical laboratory attributes should be recommend for incorporation into the APR DRG risk of mortality model. Once the individual clinical laboratory data element models for inclusion into the APR DRG model were identified, the APR DRG research prototype was developed to include all the additional recommended clinical laboratory modifications for a final evaluation of Model "C", and case level statistics were recomputed.

RESULTS

APR DRG Classification of the Florida Administrative Discharge Analysis Dataset

The 188, 555 administrative records in the analysis file were grouped and assigned an Admission and Discharge APR DRG and risk of mortality subclass. The administrative data is a full abstract of nine months of hospital inpatient acute care discharge data and represents the complete diversity of conditions, diseases and procedures encountered at these facilities. Table 4 contains ten examples of high volume base APR DRGs from the administrative discharge analysis dataset that have relatively high mortality rates. The mortality rates for each risk of morality level 1 through 4 are also shown in Table 4 along with the percent of discharges for that base APR DRG that had one or more linked laboratory test record. The morality rates increase monotonically as the risk of mortality level increases from 1 (minor) to 4 (extreme), as would be expected based on results obtained previously from national databases.

Table 4: Number of Deaths for High Volume APR DRGs

Base APR DRG	APR DRG description	Number of Discharges	Number of Discharges Died	Mortailty Rate	Mortality Rate for ROM=1 Minor	Mortality Rate for ROM=2 Moderate	Mortality Rate for ROM=3 Major	Mortality Rate for ROM =4 Extreme	Percent of Discharges with At Least One Lab Record
720	Septicemia & disseminated infections	2211	361	16.3%	0.4%	4.0%	9.5%	33.0%	87.3%
133	Pulmonary edema & respiratory failure	1534	218	14.2%	1.0%	5.8%	11.8%	39.8%	85.8%
137	Major respiratory infections & inflammations	1072	90	8.4%	0.0%	4.5%	9.2%	25.5%	90.9%
190	Acute myocardial infarction	1975	100	5.1%	0.5%	0.8%	4.1%	25.6%	88.7%
045	CVA & precerebral occlusion w infarct	1903	69	3.6%	1.2%	2.6%	6.3%	32.4%	91.2%
221	Major small & large bowel procedures	1751	57	3.3%	0.6%	2.2%	8.7%	21.9%	90.3%
460	Renal failure	2455	79	3.2%	0.0%	1.4%	5.6%	21.5%	91.8%
248	Major gastrointestinal & peritoneal infections	1187	34	2.9%	0.4%	1.7%	6.2%	23.5%	79.0%
174	Percutaneous cardiovascular procedures w AMI	1261	30	2.4%	0.0%	0.5%	4.1%	27.3%	86.6%
194	Heart failure	4426	99	2.2%	0.0%	1.0%	4.0%	12.8%	92.3%

Step 4: Identify the subset of clinical laboratory test results that improve the performance of APR DRGs for predicting inpatient mortality

The administrative and clinical laboratory data was used to test and validate the clinical hypothesis that for certain types of patients, the risk of mortality subclass could be increased based on the value of specific clinical laboratory results. Using the indirect rate standardization reports described above, each clinical laboratory test result range was evaluated to determine if a laboratory test result in the specified range impacted the likelihood of dying and if the specified laboratory test result range should be used to alter the risk of mortality level for specific types of cases.

For example, Table 5 shows the section of this report for pH, aggregated by Medical (M) and Surgical (S) case types. The clinical laboratory data element pH has six abnormal test result range categories plus a normal test result range. Patients who did not have a pH test were assigned to the "NoLab" test result range category. For pH < 7.10 medical cases in Table 5 below, there are 77 cases assigned to a risk of mortality subclass 1 (minor) with a mortality rate of 1.3%. The mortality impact measure for these cases in risk of mortality subclass 1 is 2.61 indicating that these cases expected mortality rate is 61 percent of the difference between risk of mortality subclass 2 (moderate) and 3 (major). The actual risk of mortality for these cases is more like the expected mortality for subclass 2 or 3. As a result of this data medical patient assigned to risk of mortality subclass 1 who had a PH<7.10 were promoted to a risk of mortality subclass of 2. This pattern is consistent with the surgical cases as well even though the volume of cases was lower for surgical cases.

Table 5: Impact Report for pH Medical Surgical aggregation

Case Type Aggregation	Test Result Range Category	Test Result Range	Ocurrence ROM 1	Mortality Rate ROM 1	Impact Measure ROM 1	Ocurrence ROM 2	Mortality Rate ROM 2	Impact Measure ROM 2	Ocurrence ROM 3	Mortality Rate ROM 3	Impact Measure ROM 3	Ocurrence ROM 4	Mortality Rate ROM 4	Impact Measure ROM 4	Total Occrrence Across ROM Subclasses
Medical	ABNTRR1	< 7.10	77	0.013	2.61	74	0.162	3.67	88	0.261	3.88	172	0.657	5.00	411
	ABNTRR2	7.10 - 7.15	52	0.019	2.77	47	0.021	1.91	57	0.228	3.66	64	0.391	4.48	220
	ABNTRR3	7.15 - 7.20	83	0.000	0.00	62	0.145	3.53	117	0.179	3.46	97	0.371	4.22	359
	ABNTRR4	7.20 - 7.35	1,001	0.006	1.30	787	0.051	2.76	912	0.128	3.28	612	0.320	4.12	3,312
	ABNTRR5	7.45 - 7.55	675	0.015	2.20	1,093	0.030	2.38	876	0.103	3.23	391	0.304	3.97	3,035
	ABNTRR6	> 7.55	61	0.016	2.43	86	0.035	2.51	63	0.159	3.53	42	0.381	4.24	252
	NTRR	7.35 - 7.45	2,337	0.003	1.15	2,204	0.032	2.50	1,526	0.088	3.15	788	0.280	3.97	6,855
	NoLab		87,107	0.001	1.00	29,198	0.007	1.68	9,407	0.030	2.48	1,220	0.177	3.62	126,932
Surgical	ABNTRR1	< 7.10	23	0.043	2.23	18	0.278	4.22	16	0.375	4.37	23	0.435	4.72	80
	ABNTRR2	7.10 - 7.15	15	0.067	2.68	19	0.316	4.34	22	0.136	3.14	16	0.438	4.57	72
	ABNTRR3	7.15 - 7.20	37	0.054	2.47	13	0.077	3.06	33	0.273	4.20	23	0.217	3.61	106
	ABNTRR4	7.20 - 7.35	520	0.002	0.45	463	0.052	2.68	333	0.153	3.48	209	0.292	4.22	1,525
	ABNTRR5	7.45 - 7.55	206	0.034	2.23	321	0.078	3.03	249	0.137	3.30	88	0.273	4.07	864
	ABNTRR6	> 7.55	15	0.000	0.00	19	0.053	2.48	19	0.158	3.24	10	0.600	4.53	63
	NTRR	7.35 - 7.45	795	0.008	1.19	936	0.031	2.20	571	0.114	3.23	223	0.242	4.09	2,525
	NoLab		32,225	0.000	0.67	7,499	0.005	1.36	2,002	0.025	2.32	218	0.133	3.76	41,944

Our clinical panel reviewed the impact reports and determined potential modifications to the APR DRG risk of mortality subclass assignment algorithm. The mortality impact reports for each clinical laboratory data element are available from the authors upon request in an Excel file.

Based on a review of the mortality impact reports, the final clinical laboratory model ("Model C") included adjustments based on eleven clinical laboratory data elements. The adjustments to the risk of mortality assignment were specific to selected abnormal test result ranges and applied overall to all cases, or cases that belonged to specific clinical subgroups, including medical DRGs, surgical DRGs, or a specific MDC. The presence of a specified abnormal test result range category increased the risk of mortality level by one subclass to a specified maximum risk of mortality subclass.

Table 6 shows the final specifications for thirty-two adjustments to the risk of mortality subclass algorithm. For each selected clinical laboratory abnormal test result range, an increase of one risk of morality subclass is applied to the baseline Admission APR DRG risk of mortality assignment. A maximum risk of mortality subclass value from two (moderate) to four (extreme) is also defined. The type of case for which the adjustment is to be applied is specified by "M" for medical DRG cases, "S" for surgical DRG cases, or "MS" for both medical and surgical cases. If the adjustment is to be applied for only cases assigned to a specific MDC, the MDC number is specified in the column "MDC Specific". For example, MDC 05 is the Diseases & Disorders of the Circulatory System. The complete list of the twenty-five MDC numbers and descriptions are shown in Appendix H.

Table 6: Clinical Laboratory Model Adjustment Specifications

Clinical Laboratory Model Adjustment	TRR Description	Max ROM	Medical / Sugical Type	MDC Specific	Number of ROM Impacted Cases	Percent of Cases with ROM Impacted
SGOT	300 - 2000	3	MS		1,057	0.56%
SGOT	> 2000	3	MS		68	0.04%
Sodium	150 - 155	2	MS		160	0.08%
Sodium	> 155	2	MS		37	0.02%
Sodium	< 130	3	M	05	416	0.22%
pH	< 7.10	4	MS		454	0.24%
pH	7.10 - 7.15	3	S		65	0.03%
pCO2	< 27	3	S		246	0.13%
pCO2	< 27	3	M	01	25	0.01%
pCO2	< 27	3	M	04	106	0.06%
pCO2	< 27	3	M	05	53	0.03%
pCO2	< 27	4	M	06	71	0.04%
pCO2	< 27	4	M	07	60	0.03%
pCO2	< 27	4	M	18	61	0.03%
pCO2	60 - 65	3	MS		612	0.32%
pCO2	> 65	3	MS		755	0.40%
Albumin	< 2.4	3	MS		6,655	3.53%
Total bilrubin fractions	10 - 20	3	MS		1,078	0.57%
Total bilrubin fractions	> 20	3	MS		99	0.05%
Blood urea nitrogen	40 - 50	3	MS		4,912	2.61%
Blood urea nitrogen	> 50	3	MS		3,745	1.99%
Platelets	< 20	3	MS		579	0.31%
Platelets	20 - 60	3	S		240	0.13%
White blood cell count	< 1	3	MS		468	0.25%
White blood cell count	40 - 100	4	MS		545	0.29%
White blood cell count	> 100	4	MS		56	0.03%
Bicarbonate	< 10	4	MS		393	0.21%
Bicarbonate	10 - 15	4	MS		766	0.41%
Bicarbonate	35 - 45	3	MS		556	0.29%
Bicarbonate	> 45	3	MS		72	0.04%
SGPT	300 - 2000	3	MS		1,246	0.66%
SGPT	> 2000	3	MS		98	0.05%

From Table 6, patients with a sodium test result less than 130 would have their admission risk of mortality subclass increased one level up to a maximum risk of mortality subclass of 3, applied only to those cases assigned to a medical APR DRG in MDC 5. This specific adjustment for sodium less than 130 increased the risk of mortality by one subclass for 416 (0.22%) patients.

Overall, 18,057 (9.58%) patients were impacted by the addition of clinical laboratory data elements in the Admission APR DRG risk of mortality assignment. Blood urea nitrogen, Albumin and pCO2 made up the vast majority of changes to the Admission APR DRG risk of mortality assignment representing 8,657, 6,655, and 1,989 patients, respectively.

Step 5: Assess the overall incremental improvement due to the addition of the clinical laboratory test results on the performance of APR DRGs for predicting inpatient mortality

The c-statistic and R^2 for mortality was computed based on the APR DRG and risk of mortality classification as defined by the three clinical models A, B and C as described in the methods section. The third clinical model "C" incorporates the selected clinical laboratory data adjustments specified above in Table 6. Table 7 shows the c-statistic and R^2 for mortality for the three clinical models. The removal of post-admission complications from the APR DRG and ROM assignment in clinical model "A" to clinical model "B" results in a percent decrease of 1.23% and 12.66% in the c-statistic and R^2, respectively. The addition of the clinical laboratory data to the assignment of the Admission APR DRG and ROM subclass in model "C" relative to model "B" resulted in a percent increase of 0.574% and 4.53% in the c-statistic and R^2 respectively.

Table 7: Clinical Model C-Statistic and R^2 Results

Clinical Model	C Statistic	R^2
A. Discharge APR DRG ROM	0.9652	0.2290
B. Admission APR DRG ROM	0.9532	0.2000
C. Lab Adjusted Admission APR DRG ROM	0.9587	0.2091

For each of the clinical laboratory adjustment contained in Table 6, the c-statistic and R^2 was independently calculated and the results for each clinical laboratory adjustment for the final

clinical laboratory model ("Model C") are shown in Table 8. The percent change in c-statistic and R^2 from the Admission APR DRG ROM clinical model ("Model B") were reviewed. Four clinical laboratory data element abnormal TRR category adjustment specifications had the largest impact on the overall increase in the results. pH < 7.1, Bicarbonate 10-15 and < 10, and Blood urea nitrogen had a percent increase in R^2 of 4.41, 3.16, 2.86 and 1.07 respectively.

Table 8 Final Simulation Results C-Statistic and R^2

Clinical Laboratory Model Adjustment	TRR Description	Max ROM	Medical / Sugical Type	MDC Specific	C Stat	R2	Percent Change from Admission APR DRG C Stat	Percent Change from Admission APR DRG R2
SGOT	300 - 2000	3	MS		0.9542	0.2015	0.105	0.731
SGOT	> 2000	3	MS		0.9535	0.2004	0.023	0.204
Sodium	150 - 155	2	MS		0.9533	0.2001	0.002	0.029
Sodium	> 155	2	MS		0.9533	0.2000	0.011	0.022
Sodium	< 130	3	M	05	0.9534	0.2000	0.012	0.006
pH	< 7.10	4	MS		0.9556	0.2088	0.247	4.406
pH	7.10 - 7.15	3	S		0.9538	0.2010	0.062	0.523
pCO2	< 27	3	S		0.9546	0.2016	0.138	0.782
pCO2	< 27	3	M	01	0.9533	0.2001	0.003	0.049
pCO2	< 27	3	M	04	0.9534	0.2001	0.012	0.033
pCO2	< 27	3	M	05	0.9533	0.2000	0.005	0.017
pCO2	< 27	4	M	06	0.9535	0.2006	0.025	0.313
pCO2	< 27	4	M	07	0.9534	0.2009	0.011	0.434
pCO2	< 27	4	M	18	0.9534	0.2008	0.011	0.390
pCO2	60 - 65	3	MS		0.9539	0.2007	0.070	0.361
pCO2	> 65	3	MS		0.9550	0.2017	0.182	0.847
Albumin	< 2.4	3	MS		0.9562	0.2017	0.309	0.869
Total bilrubin fractions	10 - 20	3	MS		0.9539	0.2005	0.067	0.268
Total bilrubin fractions	> 20	3	MS		0.9536	0.2002	0.036	0.118
Blood urea nitrogen	40 - 50	3	MS		0.9550	0.2015	0.185	0.734
Blood urea nitrogen	> 50	3	MS		0.9556	0.2021	0.242	1.067
Platelets	< 20	3	MS		0.9539	0.2009	0.072	0.446
Platelets	20 - 60	3	S		0.9537	0.2009	0.044	0.468
White blood cell count	< 1	3	MS		0.9537	0.2001	0.047	0.035
White blood cell count	40 - 100	4	MS		0.9543	0.2015	0.106	0.754
White blood cell count	> 100	4	MS		0.9532	0.2000	0.000	0.025
Bicarbonate	< 10	4	MS		0.9547	0.2057	0.154	2.858
Bicarbonate	10 - 15	4	MS		0.9558	0.2063	0.267	3.158
Bicarbonate	35 - 45	3	MS		0.9538	0.2004	0.059	0.186
Bicarbonate	> 45	3	MS		0.9534	0.2001	0.014	0.031
SGPT	300 - 2000	3	MS		0.9545	0.2017	0.131	0.866
SGPT	> 2000	3	MS		0.9539	0.2007	0.065	0.338

DISCUSSION

Because of the increasing importance and scrutiny of public reporting of inpatient outcomes and pay-for-performance initiatives, the risk adjustment method used in the comparison hospital outcome rates such as mortality must accurately describe a hospital's case mix. Applications of risk adjusted mortality rates currently use the discharge APR DRG and risk of mortality subclass that includes all secondary diagnosis including those that develop during the hospital stay. However, the assessment of inpatient risk of mortality should ideally be based on a patient's condition at the time of admission. The challenge is to give hospitals credit for diseases and conditions that represent a natural progression of the patient's underlying problem, but not to give credit for preventable complications. In this study, to partially address this issue, the Admission APR DRG and risk of mortality subclass was computed using the present on admission indicator in order to remove any bias introduced by the inclusion of preventable complications in the risk assessment (partially in the sense that there may be some secondary diagnoses that occur after admission that should be included in the ROM assessment). While the statistical performance of the Admission APR DRG is lower than the Discharge APR DRG, the decrease in predictive power is relatively small and the APR DRG risk of mortality adjustment remained high even when the confounding effect of post admission complications was removed. In large measure this is due to the fact that the APR DRGs are a detailed clinical model and, for example, take into account the interaction between secondary diagnoses. The slight reduction in predictive power for the Admission APR DRG risk of mortality demonstrates that the models based on APR DRG risk of mortality derive their predictive power primarily from the diagnostic information present at admission and clinical stratification, and not from post admission complications. An important evaluation criteria for any risk of mortality system, is the extent to which the statistical performance of the system is dependent on the inclusion of post admission complications.

Since laboratory test results are not currently collected in administrative data, there will be considerable effort and cost associated with any mandate to report laboratory test results. To justify such costs the operational value of the laboratory test results must be demonstrated. This study demonstrated the value of selected laboratory results for enhancing the prediction of patient mortality. This preliminary study identified laboratory tests that are relevant for APR DRG Risk of Morality prediction and therefore should constitute the minimum scope of

laboratory test results that are included in any mandated collection of selected laboratory test results.

In order to facilitate the collection of selected laboratory test results, this type of additional information could be collected in a manner more consistent with the existing ICD-9-CM diagnosis coding and reporting practices. A discrete set of "codes" could be defined for a select set of laboratory test results to provide a means for collecting additional patient characteristics in a way that does not require existing claims forms or claims processing systems to be modified.

Limitations

Although the study database included 188,555 patients with both administrative and clinical laboratory test results, some laboratory tests are relatively infrequently performed. To fully evaluate such laboratory test results, a larger data sample would be required. The evaluation of the use of laboratory data for mortality prediction was done in the context of APR DRGs and the conclusions may not apply to other methods of mortality risk adjustment. However, given the comprehensive logic of APR DRGs the laboratory results found to provide additional explanatory power are likely to apply to any risk of mortality model based on administrative data. However, the converse is not necessarily true. Laboratory results found not to provide additional explanatory power in the context of APR DRGs may add additional explanatory power to less comprehensive models of risk of mortality based on administrative data. As with any analysis based on administrative data, the study results are affected by the accuracy and completeness of the diagnosis, procedure, and POA coding. In order to use laboratory data to identify risk of mortality at admission, the computerized record will need to contain information about when during the hospitalization the lab test was performed. A lab value obtained in the first 1 or 2 days of hospitalization should adequately reflect the patient's condition at the time of admission. If the test was first obtained later in the stay, however, it may mean that it was ordered in response to a post-admission complication or deterioration, and would not reflect the patient's risk of mortality at admission.

Although our goal was to enhance the performance of the Admission APR DRG and risk of mortality and to therefore use laboratory tests obtained near the time of admission, this could not always be the case. Although some types of laboratory tests are done routinely on admission (sodium, creatinine, hematocrit), others, such as pH or pO2 may be done only in patients who are

either seriously ill at the time of admission or who became ill during the hospitalization. In the former case, the fact that a particular lab test was ordered at all may be an indicator that the patient was thought to be seriously ill, and the fact that the test was obtained in the first place could have as much significance as if it were abnormal. In the latter case (lab test ordered after admission), the abnormal lab test may be a marker for hospital acquired complications rather than a reflection of the clinical state at the time of admission. This situation can be rectified if the number of days (hours) between when the patient is admitted and when each lab test was obtained are made available.

CONCLUSIONS

The results of this study demonstrate that selected clinical laboratory data elements added to administrative data can improve the accuracy of the risk adjustment models for comparing hospital mortality rates. The laboratory test results that were found to contribute to increased predictive power were consistent with clinical expectations and constitute a relatively small number of laboratory test results that are indicative of acute disease. The addition of eleven clinical laboratory test results to the assignment of the admission APR DRG risk of mortality increased the c-statistic and R^2 by 0.574 percent and 4.53 percent, respectively. Risk of mortality models are in the midst of significant evolution. The emergence of the POA indicator in the past year along with the incorporation of selected clinical data elements such as laboratory test results can lead to more valid and stable assessments of risk of mortality at admission.

Appendix A
Frequency of Laboratory Test Records Provided by Health System/Children's Hospital

			Number of Laboratory Test Records					
LOINC Code	LOINC Description	Clinical Laboratory Data Element	Total	All Childrens	Bay Care	Broward Health	Memorial	Miami Childrens
1742-6	Alanine Aminotransferase	SGOT	184,819	0	117,262	58,449	9,099	7
13969-1	Creatine Kinase MB	CPK MB	95,094	57	59,988	35,027	22	0
2823-3	Potassium	Potassium	460,268	21,708	261,075	151,247	23,898	1,373
2951-2	Sodium	Sodium	448,449	21,756	256,223	146,276	23,423	452
48425-3	Troponin T, Blood	Troponin T						
6598-7	Troponin T, Serum or Plasma	Troponin T	14,012	0	0	0	14,012	0
10839-9	Troponin I	Troponin I	100,017	406	62,138	37,420	53	0
2744-1	pH, Arterial Blood	pH	71,652	1,426	43,659	22,599	3,968	0
2745-8	pH, Capillary Blood	pH	2,350	2,350	0	0	0	0
2746-6	pH, Venous Blood	pH	141	141	0	0	0	0
2708-6	Oxygen Saturation, Arterial Blood	PO2.sat	33,639	1,390	14,336	17,913	0	0
2709-4	Oxygen Saturation, Capillary Blood	PO2.sat	1,795	1,795	0	0	0	0
2711-0	Oxygen Saturation, Venous Blood	PO2.sat	67	67	0	0	0	0
2713-6	Oxygen Saturation, Calculated	PO2.sat	0	0	0	0	0	
2019-8	Carbon Dioxide, Arterial Blood	pCO2	72,616	1,398	43,640	23,612	3,966	0
2020-6	Carbon Dioxide, Capillary Blood	pCO2	2,341	2,341	0	0	0	0
2021-4	Carbon Dioxide, Venous Blood	pCO2	85	85	0	0	0	0
5902-2	Prothrombin Time	Prothrombin Time	58,144	2,305	0	43,694	11,002	646
1751-7	Albumin	Albumin	198,307	10,072	118,027	60,020	9,124	647
11555-0	Base Excess, Blood	Base Excess	0	0	0	0	0	
1925-7	Base Excess, Arterial Blood	Base Excess	29,022	1,459	0	23,598	3,965	0
1926-5	Base Excess, Capillary Blood	Base Excess	2,354	2,354	0	0	0	0
1927-3	Base Excess, Venous Blood	Base Excess	141	141	0	0	0	0
1975-2	Bilirubin	Total bilrubin fractions	198,395	10,889	118,964	57,897	9,104	936
17861-6	Calcium	Calcium (total)	445,370	21,166	254,625	145,965	23,455	90
17863-2	Ionized Calcium, Serum grams	Calcium (ionized)	6,560	0	5,191	1,369	0	0
1994-3	Ionized Calcium, Blood moles	Calcium (ionized)	14,406	14,347	0	0	0	40
1995-0	Ionized Calcium, Serum moles	Calcium (ionized)	0	0	0	0	0	
34581-9	Ionized Calcium, Arterial Blood moles	Calcium (ionized)	430	0	0	0	430	0
2160-0	Creatinine	Creatinine	446,598	21,276	255,025	145,859	23,418	580
2345-7	Glucose	Glucose	446,099	21,087	253,255	146,722	23,652	782
6768-6	Alkaline Phosphatase	Alkaline phosphatase	202,134	8,475	117,174	58,299	18,160	15
3094-0	Urea Nitrogen	Blood urea nitrogen	444,397	21,196	253,677	145,680	23,421	253
4544-3	Hematocrit	Hematocrit	504,595	19,531	293,606	158,486	32,566	220
785-6	Mean Cell Hemoglobin	Mean cell Hemoglobin	466,044	17,904	264,996	154,009	29,130	3
787-2	Mean Cell Volume	Mean Cell volume	466,045	17,904	264,995	154,012	29,130	2
777-3	Platelets, automated count	Platelets	471,195	18,537	266,496	154,675	29,363	1,148
778-1	Platelets, manual count	Platelets	103	0	0	0	3	60
6690-2	Leukocytes, automated count	White blood cell count	469,471	17,905	265,106	154,877	29,125	1,295
804-5	Leukocytes, manual count	White blood cell count						
2075-0	Chloride	Chloride	447,104	21,224	255,787	146,019	23,380	385
14627-4	Bicarbonate, Venous Blood	Bicarbonate	140	140	0	0	0	0
1959-6	Bicarbonate, Blood	Bicarbonate	0	0	0	0	0	
1960-4	Bicarbonate, Arterial Blood	Bicarbonate	74,661	1,458	45,639	23,599	3,965	0
1961-2	Bicarbonate, Capillary Blood	Bicarbonate	2,085	2,085	0	0	0	0
2324-2	Gamma Glutamyl Transferase	Gamma Glutamyl Transferase	2,470	121	717	1,572	60	0
1920-8	Aspartate Aminotransferase	SGPT	184,886	0	117,269	58,514	9,096	4
2777-1	Phosphorous	Phosphorous	55,088	7,173	27,729	18,706	1,129	193
718-7	Hemoglobin	Total Hemoglobin	485,406	0	293,373	158,698	32,482	472
14979-9	Partial Thromboplastin Time	Partial thromboplastin time	98,731	2,813	55,356	30,496	8,979	560
533-0	Mycobacterium species, Blood by Culture	Blood/Lymph Culture-Positive	0	0	0	0	0	
600-7	Bacteria, Blood by Culture	Blood/Lymph Culture-Positive	2,758	591	0	0	2,167	
601-5	Fungus, Blood by Culture	Blood/Lymph Culture-Positive	0	1	0	0	0	
2703-7	Oxygen		43,637	0	43,637	0	0	0
664-3	Gram Stain							
Unknown	Unknown		65,267	0	65,267	0	0	0
Blank	Blank		175	0	0	0	0	175

Appendix B
Frequency of Discharges with One or More Laboratory Data Records by Health System/Children's Hospital

All Children's Hospital

Year	Quarter	Number of Administrative Discharges	Number of Discharges with One or More Laboratory Data Record	Percent of Discharges with One or More Laboratory Data Record
All Children's Hospital				
2007	2	1,961	1,603	81.7
2007	3	1,885	1,572	83.4
2007	4	2,101	1,686	80.2

Memorial Health System

Year	Quarter	Number of Administrative Discharges	Number of Discharges with One or More Laboratory Data Record	Percent of Discharges with One or More Laboratory Data Record
Memorial - Memorial Hospital Miramar				
2007	2	2,256	1,723	76.4
2007	3	2,850	2,114	74.2
2007	4	3,036	775	25.5
Memorial - Memorial Hospital Pembroke				
2007	2	1,678	1,565	93.3
2007	3	1,757	1,646	93.7
2007	4	1,750	630	36.0
Memorial - Memorial Hospital West				
2007	2	6,666	5,230	78.5
2007	3	6,944	5,444	78.4
2007	4	6,795	2,051	30.2
Memorial - Memorial Regional Hospital				
2007	2	8,750	6,090	69.6
2007	3	9,663	6,892	71.3
2007	4	9,988	2,814	28.2

Bay Care Health System

Year	Quarter	Number of Administrative Discharges	Number of Discharges with One or More Laboratory Data Record	Percent of Discharges with One or More Laboratory Data Record
BayCare - Mease Countryside Hospital				
2007	2	4,274	3,854	90.2
2007	3	4,168	3,734	89.6
2007	4	4,487	4,055	90.4
BayCare - Mease Dunedin Hospital				
2007	2	1,598	1,544	96.6
2007	3	1,571	1,515	96.4
2007	4	1,624	1,543	95.0
BayCare - Morton Plant Hospital				
2007	2	7,895	6,938	87.9
2007	3	7,803	6,921	88.7
2007	4	7,964	7,092	89.1
BayCare - Morton Plant North Bay Hospital				
2007	1	1,262	0	0.0
2007	2	1,209	1,130	93.5
2007	3	1,181	1,171	99.2
2007	4	1,186	1,178	99.3
BayCare - South Florida Baptist Hospital				
2007	2	1,451	1,362	93.9
2007	3	1,425	1,342	94.2
2007	4	1,648	1,550	94.1
BayCare - St. Anthony's Hospital				
2007	2	2,512	2,398	95.5
2007	3	2,840	2,697	95.0
2007	4	2,806	2,671	95.2
BayCare - St. Joseph's Hospital				
2007	2	11,653	10,081	86.5
2007	3	12,533	10,919	87.1
2007	4	13,028	11,300	86.7

Broward Health System

Year	Quarter	Number of Administrative Discharges	Number of Discharges with One or More Laboratory Data Record	Percent of Discharges with One or More Laboratory Data Record
Broward - Broward General Medical Center				
2007	2	6,861	6,324	92.2
2007	3	7,243	6,606	91.2
2007	4	7,792	7,103	91.2
Broward - Coral Springs Medical Center				
2007	2	3,089	2,705	87.6
2007	3	3,378	2,928	86.7
2007	4	3,409	2,929	85.9
Broward - Imperial Point Medical Center				
2007	2	1,694	1,595	94.2
2007	3	1,781	1,677	94.2
2007	4	1,843	1,774	96.3
Broward - North Broward Medical Center				
2007	2	3,250	3,188	98.1
2007	3	3,429	3,362	98.0
2007	4	3,441	3,388	98.5

Miami Children's Hospital

Year	Quarter	Number of Administrative Discharges	Number of Discharges with One or More Laboratory Data Record	Percent of Discharges with One or More Laboratory Data Record
Miami Children's Hospital				
2008	1	3,042	0	0.0
2008	2	3,107	394	12.7
2008	3	2,776	408	14.7
2008	4	3,135	443	14.1

Appendix C
Present on Admission Data Quality Screening Criteria

The diagnosis present on admission indicator is a key data element for assigning an admission APR DRG for risk adjustment at the time of admission. To evaluate the appropriateness of the use of the POA coding, the Florida administrative dataset needs to be reviewed and hospitals with questionable POA data removed. To assist in developing a methodology for data cleansing a data set, statistical analysis was performed on the 2005/2006 California data. From this analysis of the California data, a set of POA screening criteria was developed and applied to the Florida administrative data to ensure POA coding accuracy.

The POA screening criteria required the use of four different list of diagnosis codes. The first set of codes contains a list of all secondary diagnosis codes identified as pre-existing and should always or nearly always be coded as present on admission. Hospitals with a low present on admission rate for these secondary diagnosis codes would be in question. The second set of codes contains a list of all secondary diagnosis codes identified as exempt defined in the national POA coding guidelines. These codes are usually either present on admission or their present on admission status is not an important distinction such as the V codes for need for vaccination, observe newborn, circumcision, sterilization, et.al. Some of the exempt V codes provide information about the circumstances of treatment such as no proc/contraindicated, lap surgery converted to open surgery and POA would not have the same meaning as for diagnoses. The third list of secondary diagnosis codes are perinatal codes 7600x-7799x. The fourth list of secondary diagnosis codes contains codes that should have a relatively lower percentage rate for being present on admission when they occur for elective surgical cases and surgical cases that may be urgent but usually aren't emergency situations. Hospitals with a high present on admission percentage rate for these secondary diagnosis codes for these surgical DRG cases would be in question. The codes contained in these four list are available from the authors upon request.

Discharges from the administrative dataset for hospitals with poor quality coding of the present on admission indicator were excluded from the administrative analysis dataset if:

- Hospitals with excessive numbers of pre-existing secondary diagnoses labeled Not POA greater than or equal to 7.5%. This criterion identifies hospitals with a high not POA rate for pre-existing secondary diagnosis codes. For example, chronic conditions that could not have arisen after hospital admission such as diabetes, chronic lung disease and malignancy.
- Hospitals with excessive numbers of secondary diagnoses with a POA designation of "uncertain" greater than or equal to 10%. This criterion identifies hospitals with a high uncertain present on admission rate for secondary diagnosis codes (excluding exempt and pre-existing codes).
- Hospitals with a high percent of secondary diagnosis coded POA greater than or equal to 96%. This criterion identifies hospitals with an extremely high percent present on admission rate for secondary diagnosis codes (excluding exempt, pre-existing, and OB 7600x-7799x codes).
- Hospitals with a low percent of secondary diagnosis coded POA less than or equal to 70%. This criterion identifies hospitals with a low percent present on admission rate for secondary diagnosis codes (excluding exempt, pre-existing, and OB 7600x-7799x codes).
- Hospitals with excessive numbers of potential "false negatives" greater than or equal to 40%. This criterion identifies hospitals with a high present on admission percentage rate among secondary diagnosis codes from a list of codes that were likely to be complications of surgery during the current admission. A hospital was considered to have failed this criterion if the percentage of secondary diagnoses from the following list of diagnosis codes labeled POA was greater than or equal to 40%.

Appendix D
List of Extreme Laboratory Test Results

Clinical Laboratory Data Element	Laboratory Test Result Value	Number of Laboratory Test Records
SGOT	0.00	2
CPK MB	0.00	9
	0.00	2
Potassium	1.00	1
	1.20	1
Sodium	0.00	2
	201.00	1
	240.00	1
pH	0.00	23
	0.30	1
PO2.sat	0.00	2
	0.00	21
	875.00	1
	988.00	1
	993.00	1
pCO2	0.00	29
Prothrombin Time	0.00	1
	1.00	1
	1.20	2
Albumin	0.00	2
	0.50	1
	0.80	2
	0.90	4
	30.00	1
Base Excess	100.00	1
Total bilrubin fractions	0.00	47
Calcium (total)	0.00	2
	147.10	1
Creatinine	0.00	2
	86.00	1
	96.90	1

Clinical Laboratory Data Element	Laboratory Test Result Value	Number of Laboratory Test Records
Glucose	0.00	2
	2061.00	1
	2294.00	1
	3063.00	1
	3970.00	1
Alkaline phosphatase	0.00	2
	3038.00	1
	3128.00	1
	3170.00	1
	3308.00	2
	3466.00	1
	3536.00	1
	3573.00	1
	3687.00	1
	3697.00	1
	3740.00	1
	3830.00	1
	4270.00	1
	4610.00	1
Blood urea nitrogen	0.00	2
	310.00	1
	314.00	1
	320.00	1
	326.00	1
Hematocrit (male)	0.00	3
	0.80	1
	1.10	1
Hematocrit (female)	0.20	1
	0.70	2
Bicarbonate	-5.00	1
	-3.00	1
	-2.00	1
	-0.70	1
	0.00	2
	0.00	29
	0.20	1
	0.30	1
	0.90	1
	96.10	1

Clinical Laboratory Data Element	Laboratory Test Result Value	Number of Laboratory Test Records
SGPT	0.00	2
Phosphorous	0.00	1
	46.00	1
	72.00	1
Total Hemoglobin (male)	0.00	2

Appendix E
Clinical Laboratory Data Element Normal and Abnormal Test Result Range Categories

Clinical Laboratory Data Element	Normal Test Result Range Category (NTRR)	Abnormal Test Result Range Category 1 (ABNTRR1)	Abnormal Test Result Range Category 2 (ABNTRR2)	Abnormal Test Result Range Category 3 (ABNTRR3)	Abnormal Test Result Range Category 4 (ABNTRR4)	Abnormal Test Result Range Category 5 (ABNTRR5)	Abnormal Test Result Range Category 6 (ABNTRR6)
SGOT	< 60	60 - 100	100 - 300	300 - 2000	> 2000		
CPK MB	< 5	5 - 6	6 - 8	> 8			
Potassium	3.5 - 5.5	< 3	3 - 3.5	5.5 - 6	> 6		
Sodium	135 - 145	< 130	130 - 135	145 - 155	> 155		
Troponin T	< 0.5	0.5 - 2	2 - 5	5 - 10	> 10		
pH	7.45 - 7.55	< 7.15	7.15 - 7.3	7.3 - 7.45	> 7.55		
PO2.sat	> 94	< 50	50 - 60	60 - 70	70 - 88	88 - 92	92 - 94
pCO2	36 - 50	< 27	27 - 36	50 - 65	> 65		
Prothrombin Time	< 20	20 - 50	> 50				
Albumin	> 3.5	< 2.4	2.4 - 2.7	2.7 - 3.5			
Base Excess	-3 - 3	< -7	-7 - -3	3 - 7	> 7		
Total bilrubin fractions	< 4	4 - 10	10 - 20	> 20			
Calcium	8 - 11	< 6	6 - 7	7 - 8	11 - 13	13 - 15	> 15
Creatinine	< 1.2	1.2 - 1.5	1.5 - 2.5	2.5 - 3.5	3.5 - 5	> 5	
Glucose	50 - 200	< 50	200 - 350	350 - 500	500 - 750	750 - 1000	> 1000
Alkaline phosphatase	< 350	350 - 500	500 - 1000	> 1000			
Blood urea nitrogen	< 20	20 - 30	30 - 40	40 - 50	> 50		
Hematocrit (male)	40 - 55	< 20	20 - 30	30 - 40	> 55		
Hematocrit (female)	35 - 50	< 20	20 - 30	30 - 35	> 50		
Platelets	60 - 450	< 20	20 - 60	450 - 800	> 800		
White blood cell count	2 - 14	< 1	1 - 2	14 - 20	20 - 50	50 - 100	> 100
Bicarbonate	15 - 35	< 10	10 - 15	35 - 45	> 45		
Gamma glutamyl transferase	< 60	60 - 100	100 - 300	300 - 2000	> 2000		
SGPT	< 60	60 - 100	100 - 300	300 - 2000	> 2000		
Phosphorous	2.5 - 6	< 1	1 - 1.5	1.5 - 2.5	6 - 9	> 9	
Total hemoglobin	10 - 17	< 5	5 - 6.7	6. 7 - 10	> 17		

Appendix F
Indirect Rate Standardization Calculation

Steps for calculating the indirect rate standardization mortality impact measure for each Clinical Laboratory Data Element (CLDE) Test Results Range (TRR) category.

1) Group the data under admission APR Grouper 26. Use the risk of mortality level as the subclass value: level 1 (minor), level 2 (moderate), level 3 (major), and level 4 (extreme).

2) Compute the mortality rate for all APR DRGs

i	= patient subclass (ROM level) where 1=minor, 2=moderate, 3=major, and 4=extreme
g	= APR DRG
s	= subset of patients
N(i,g)	= number of patients in DRG g in subclass I
C(i,g,p)	= died status (0=alive, 1=died) of the pth patient in DRG g in subclass i
C(i,g)	= mortality rate of patients in DRG g in subclass I

$$C(i,g) = \frac{\sum_{g} C(i,g,p)}{N(i,g)}$$

3) Normalize the C(i,g) mortality rate for each DRG to make sure they are monotonically increasing. Fix any APR DRGs that the mortality rate not monotonically increasing from C(1,g) to C(2,g) to C(3, g) to C(4,g).

4) Define the subset of patients and compute the mortality rate for the patients in the subset. The subset of patients is defined as

Subset 1 = contain the set of patients who have the specific APR DRG and CLDE - TRR category w/ ROM level 1
Subset 2 = contain the set of patients who have the specific APR DRG and CLDE - TRR category w/ ROM level 2
Subset 3 = contain the set of patients who have the specific APR DRG and CLDE - TRR category w/ ROM level 3
Subset 4 = contain the set of patients who have the specific APR DRG and CLDE - TRR category w/ ROM level 4

s	= subset of patients
A(s)	= mortality rate for patients in subset s
N(s)	= number of patients in subset s

$$A(s) = \frac{\sum_{i,g,p \in s} C(i,g,p)}{N(s)}$$

5) Calculate the estimated mortality rate for patients in subset s. For each CLDE - TRR in each APR DRG g E(1,s), E(2,s), E(3,s) and E(4,s) will be computed separately.

N(g,s) = number of patients in APR DRG g in subset s
E(i,s) = expected mortality rate for patients in subset s if the patients are assigned to subclass i

$$E(i,s) = \frac{\sum_{g} N(g,s)C(i,g)}{N(s)}$$

6) By comparing A(s) to E(1,s), E(2,s), E(3,s) and E(4,s) for each subset the estimated subclass for the CLDE - TRR category in the APR DRG g can be computed in the following form

X.Y

X is the estimated subclass value from the data. If A(s) is within the range in the table then the estimated subclass (i.e., X) for the CLDE - TRR category in the APR DRG g will have the value shown in the following table

X	Low	High
0	0	<E(1,s)
1	E(1,s)	<E(2,s)
2	E(2,s)	<E(3,s)
3	E(3,s)	<E(4,s)
4	E(4,s)	<2E(4,s)
5	>= 2E(4,s)	-

Y is an interpolation of the value of A(s) between the estimated subclass value and the next higher subclass value.

Appendix G
Model Validation Statistics

Reduction of Variance

The reduction of variance (R^2) measures the proportion of variation that is explained by the APR DRG system. R^2 provides a summary measure of the extent to which the APR DRG system is able to predict the value of an outcome variable based on the characteristics of individual patients. For a categorical variable such as APR DRGs, R^2 is computed as

$$\frac{\sum_i (y_i - A)^2 - \sum_i (y_i - A_g)^2}{\sum_i (y_i - A)^2}$$

where y_i is the value of the variable for the ith patient, A is the average value of the variable in the database and Ag is the average value of the variable in DRG g. The square of the difference between the actual value (i.e., yi) and the predicted value (i.e., A or Ag) is a measure of the variation in the data. The term

$$\sum_i (y_i - A)^2$$

is the amount of variation before subdividing the data into DRGs and the term

$$\sum_i (y_i - A_g)^2$$

is the amount of variation after subdividing the data into APR DRGs. The difference between these two terms is the reduction in variation resulting from the subdivision of the data into APR DRGs.

R^2 is the ratio of the reduction in variation to the amount of variation before subdividing into APR DRGs. R^2 ranges between zero and one and measures the fraction of variation explained by the APR DRGs. Thus, an R^2 of 0.415 would mean that subdividing the data into APR DRGs reduces the amount of variation in the data by 41.5 percent.

The R^2 for mortality is computed by assigning each patient a value of zero or one indicating whether they were discharged alive or dead, respectively. The predicted mortality for the patient is equal to the average value of the zero/one variable in the DRG to which the patient is assigned. The average value of the zero/one value is equivalent to the fraction of patients who died in the APR DRG. Based on the zero/one variable, the R^2 for mortality is computed in the same manner as the R^2 for cost or length of stay described above.

C-Statistics

The area under the receiver operating characteristics (ROC) curve, is commonly used to evaluate alternative methods for predicting a zero/one outcome. The area under the ROC curve is typically used for evaluating the efficacy of a method which predicts that a given patient will or will not experience the event of interest. The basis of the ROC curve is sensitivity and specificity. In this context, sensitivity is the probability that someone who died was classified as likely to have died, while specificity is the probability that someone who did not die was classified as not likely to die. Sensitivity and specificity are computed as follows:

$$\text{Sensitivity} = \sum n_i p_i \, I(p_i \geq P) \,/\, \sum n_i p_i$$

$$\text{Specificity} = \sum n_i (1-p_i) \, I(p_i < P) \,/\, \sum n_i (1-p_i)$$

where n_i is the number of patients in APR DRG i, p_i is the fraction of patients who died in APR DRG i and $I(p_i)$ is an indicator that takes the value 1.0 if, in a particular APR DRG, the proportion of dead is at least P for sensitivity and less than P for specificity. The computation of the sensitivity and specificity assumes that all patients in an APR DRG died if $p_i \geq P$ and conversely that all patients in an APR DRG lived if $p_i < P$.

The ROC curve plots sensitivity against one minus specificity as the value of P varies. The area under the ROC curve is referred to as the c-statistic. The c-statistic measures how well the APR DRG system discriminates between patients who lived and those who died. A c-statistic value of 0.5 indicates no ability to discriminate while a value of 1.0 indicates perfect discrimination.

Appendix H

List of Major Diagnostic Categories

1 Diseases and Disorders of the Nervous System

2 Diseases and Disorders of the Eye

3 Ear, Nose, Mouth, Throat, and Craniofacial Diseases and Disorders

4 Diseases and Disorders of the Respiratory System

5 Diseases and Disorders of the Circulatory System

6 Diseases and Disorders of the Digestive System

7 Diseases and Disorders of the Hepatobiliary System and Pancreas

8 Diseases and Disorders of the Musculoskeletal System and Connective Tissue

9 Diseases and Disorders of the Skin, Subcutaneous Tissue and Breast

10 Endocrine, Nutritional and Metabolic Diseases and Disorders

11 Diseases and Disorders of the Kidney and Urinary Tract

12 Diseases and Disorders of the Male Reproductive System

13 Diseases and Disorders of the Female Reproductive System

14 Pregnancy, Childbirth and the Puerperium

15 Newborns and Other Neonates with Conditions Originating in the Perinatal Period

16 Diseases and Disorders of Blood, Blood Forming Organs and Immunological Disorders

17 Lymphatic, Hematopoietic, Other Malignancies, Chemotherapy and Radiotherapy

18 Infectious and Parasitic Diseases, Systemic or Unspecified Sites

19 Mental Diseases and Disorders

20 Alcohol/Drug Use and Alcohol/Drug Induced Organic Mental Disorders

21 Poisonings, Toxic Effects, Other Injuries and Other Complications of Treatment

22 Burns

23 Rehabilitation, Aftercare, Other Factors Influencing Health Status and Other Health Service Contacts

24 Human Immunodeficiency Virus (HIV) Infections

25 Multiple Significant Trauma