CENTRACARE Health

Central MN Health Network (CMHN) Health Risk Assessment Instrument – Technical Guide

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Objectives:

1. Provide the technical specifications for the CentraCare Risk Assessment Instrument.

Overview

Risk assessment has important applications in healthcare. The level of available healthcare resources is not sufficient to handle demand. Therefore, there is a need for ranking individuals with respect to their need for healthcare so that preventive efforts can be focused on the patients with the highest need for care. Healthcare risk assessment instruments provide a method for creating a rank ordered list of patients in terms of their anticipated need for care.

The Central MN Health Network (CMHN) does not currently have a highly accurate healthcare risk assessment instrument. The currently available risk assessment methods such as the Epic General Risk Score, the Centers for Medicare and Medicaid Services Hierarchical Condition Classification (CMS-HCC) risk score, and the John Hopkins Adjusted Clinical Group (ACG) risk score do not appear to be very accurate at predicting future spending. Furthermore, these systems are either not available or not appropriate for the entire patient population. Expansion of these instruments to the entire patient population would appear to be a costly proposition. The purpose of this study was to develop an inexpensive, yet accurate, risk assessment instrument for the CMHN.

Before beginning development of a healthcare risk assessment instrument for the CMHN, a thorough exploration of existing health risk assessment models was conducted. This effort was hampered by the fact that many of the commercial risk assessment models are essentially "black box" models. That is, the specific mechanisms used are not published, and it is difficult to know how to recreate these commercial risk models.

Fortunately, two of the most popular and most thoroughly analyzed health risk assessment instruments are fully documented and can be recreated by anyone with a sufficient knowledge of data manipulation methods. The two publicly available risk assessment instruments that were used as templates for this project are the Centers for Medicare and Medicaid Services Hierarchical Condition Classification (CMS-HCC) scoring model, and the Health and Human Services Hierarchical Condition Classification (HHS-HCC) scoring model. Both models combine demographic factors with health condition groups to create a risk score. The risk groups are created using Hierarchical Condition Classification (HCC) diagnosis grouping systems that group International Classification of Disease (ICD) diagnoses into HCC categories. The HCCs are then put into a regression model predicting future spending.

To create the CMHN risk score, the CMS-HCC and HHS-HCC models were used as a base, and other data was added to the model to create a "hybrid" risk assessment model. The CMHN risk assessment instrument predicts future spending with a relatively high degree of accuracy by combining 1) demographic factors, 2) lab results, 3) previous spending, and 4) a combination of the CMS-HCC and HHS-HCC models to create a risk score.

The CMHN risk score can be created from existing data and implemented in the Electronic Health Records (EHR) and electronic data warehouse (EDW) systems using standard Structured Query Language (SQL). Therefore, the expected cost for implementation should be minimal. The accuracy of the CMHN risk score compares favorably with the best commercial models. In addition, the accuracy can be improved as additional data sources are identified.

The rest of this paper focuses on the on the development of CMHN risk assessment instrument, along with the methods for using this instrument. Possible directions for future research are suggested.

Risk Assessment at the Central MN Health Network

In general, the purpose of risk assessment is to predict the risk of a future outcome. Risk assessment is important in a healthcare context for tasks such as payment adjustment, care management, and panel assessment. The problem that must be overcome in predicting risk is that most of the important outcomes that we would like to predict are caused by many factors that are complex and intertwined. Therefore, accurate risk assessment requires the assessment of large numbers of factors, with attention to weighting the impacts of the individual factors in relation to the rest of the factors.

Several risk assessment methodologies have been developed in healthcare. These methodologies have been developed to predict future and estimated current healthcare spending. Four risk assessment methodologies currently available to subpopulations of patients in the CMHN are the Centers for Medicare and Medicaid Services-Hierarchical Condition Classification (CMS-HCC) score, a Count of total CMS-HCCs previously coded, the John Hopkins Adjusted Clinical Groups (ACG) score, and the Epic General Risk Score. These methodologies provide risk scores that predict future or current spending.

In a previous report (Arnold, 2017), a validation study was done to determine which of the five risk assessment methodologies was most predictive of future spending for various populations served by the CMHN. It was determined that the best predictor of future spending was the CMS-HCC score that had been computed by Optum for the Central MN ACO Medicare population. The second-best risk assessment instrument was a count of total HCCs previously coded. None of the risk assessment instruments currently available achieved a satisfactory level of predictive validity

Because the predictive validity of the existing risk instruments was unacceptably low, it was suggested that a CMHN risk assessment instrument should be developed. Initial tests of a preliminary CMHN risk assessment instrument suggest that it is possible to develop a fairly accurate “homegrown” healthcare risk assessment instrument using CMHN data. This report provides an overview of the development of the CMHN Health Risk Assessment Instrument, and the indications for its use. Future directions for research are discussed.

Risk assessment is a technical topic, and understanding the full complexity of this topic requires a deep understanding of statistics. Those interested in the basic underlying theory of risk assessment are invited to turn to Appendix A: A Deep Dive into Healthcare Risk Assessment. This Appendix provides a general overview of some of the underlying issues involved. The material in Appendix A can be briefly reviewed to get a sense of some of the challenges involved in risk assessment.

In a more general sense, the process of building a risk assessment instrument can be broken down into the following steps. 1) Collect data and build variables. 2) Put the variables in a linear regression model to generate a formula that predicts risk. 3) Adjust as needed. 4) Once a sufficiently accurate model is developed, use the regression formula to assign a risk score for every person in the population.

Chapter 1 provides an overview of the types of health risk assessment instruments. Some existing healthcare risk assessment models are reviewed. This is followed by a review of the validation study of the risk assessment instruments currently available to the CMHN.

Chapter 2 provides a description of how the CMHN risk assessment instrument is constructed. It also provides the results from initial validation analyses.

Chapter 1: Taking Stock of Healthcare Risk Assessment Methodologies

For those interested in the principles of risk assessment, it will be helpful to read the "deep dive into risk assessment" in Appendix A. This is intended to provide a general theoretical overview into the issues surrounding healthcare risk assessment. Chapter one will focus on the practical details.

The basic problem with risk assessment is that the future is hard to predict. We can be driving along in perfect health in one second, and in the next second, we can be critically injured by someone running a stop sign. These events are hard to predict, and they can have significant impacts on our health care costs. Because of the essential randomness in human life, there is a limit to the accuracy of any predictive model, and the best one can hope for is to get "reasonable accuracy."

The essential task of healthcare risk assessment is to create some method to rank people by their risk of some future outcome. In this project, the goal was to predict future healthcare spending. A good healthcare spending risk assessment instrument would create a low score for people who spend little and a high score for people who spend a lot.

Much of the practical work in healthcare risk assessment has been documented by the Society of Actuaries, and anyone interested in a detailed exploration of this topic should refer to the two recent articles listed below. The relevant issues brought up in these two articles will be briefly reviewed.

Recommended Reading on Healthcare Risk Assessment

Hileman, G. R., Rosenberg, M., & Mehmud, S. M. (2016). *Risk Scoring in Health Insurance: A Primer.* Society of Actuaries. https://www.soa.org/Files/Research/research-2016-risk-scoring-health-insurance.pdf

Hileman, G., & Steele, S. (2016). Accuracy of Claims-Based Risk Scoring Models. Technical report. Society of Actuaries. https://www.soa.org/Files/Research/research-2016-accuracy-claims-based-risk-scoring-models.pdf

Prospective vs. Concurrent Models

There are two primary types of predictive models used in healthcare risk assessment. These are "prospective" and "concurrent" models. Prospective models use past health history to predict future health outcomes. Concurrent models use present health status to predict present health outcomes. The purpose of a prospective model is to predict variation in future outcomes, while the purpose of a concurrent model is to assess variation in current outcomes.

The CMHN Healthcare Risk Assessment Instrument is based on a prospective risk assessment model. Past health history will be used to predict future health spending.

Risk Assessment Accuracy (Validity)

The accuracy of risk assessment instruments can be measured in a variety of ways. One of the most common methods for assessing the accuracy of a risk assessment instrument is to calculate the R squared value (R^2). R^2 is a variable that ranges from 0 to 1 and when it is multiplied by 100, it becomes a measure of the percentage of explained variation. The percent explained variation ($R^2 * 100$) provides a measure of the percentage of variation in outcome is explained by the measure. A risk assessment instrument with higher explained variation has greater validity.

The process involved in testing validity for prospective risk assessment instruments is to generate a set of risk scores in a previous period, and then measure the outcome in a later period. If the risk score is highly correlated with the outcome, we would say that the risk score is a valid measure of outcome.

The best prospective risk assessment instruments can explain about 20% of the variation in outcome. The explained variation for concurrent risk assessment instruments exceeds 40%, which is not surprising, because these instruments are explaining current variation with current data. For the purposes of testing the CMHN prospective risk scoring model, a goal of 20% explained variance will be set.

The State of The Art in HealthCare Risk Assessment

There are many healthcare risk assessment methodologies currently being used. The two biggest users of healthcare risk assessment are the Centers for Medicare and Medicaid Services (CMS) and Health and Human Services (HHS). Both have developed Hierarchical Condition Classification (HCC) systems for risk adjustment. The CMS-HCC model is designed to create risk adjusted payments for providers and the HHS-HCC model is designed to provide risk adjusted payments to insurance companies. Following these two systems, the next most popular health risk assessment system seems to be the John Hopkins Adjusted Clinical Group (ACG) system. This is followed by several types of commercial health risk assessment systems.

The CMS-HCC model is a prospective model that is designed to predict future spending for the Medicare population. The CMS-HCC model is based on the HCC, which is a group of ICD9 or ICD10 diagnosis codes representing a costly health condition such as diabetes, aids, etc. To calculate the CMS-HCC risk scores, a set of nine regression models based on age, gender, disability status, and 79 HCCs are developed using nationwide insurance data to predict future spending. The CMS-Models are designed to be hard to spoof, and are updated periodically. The age categories are limited to older ages and the HCCs tend to be limited to chronic conditions. The Central MN ACO gets historical CMS-HCC scores from CMS with its Medicare Shared Savings Program (MSSP) quarterly reports. Epic is now calculating CMS-HCC scores using the community model (one of nine models available). Optum is also providing CMS-HCC scores using the community model as part of its contract with the Central MN ACO.

The HHS-HCC model is a concurrent model that is designed to predict current spending with commercial insurance populations. The HHS-HCC model is used as part of the affordable care act (ACA) to equalize payments to insurance companies. The HHS-HCC models vary by insurance type (Bronze, Silver, Gold, Platinum, etc.) and, in addition to age and gender variable, include 127 HCCs. The HHS-HCCs tend to be a mixture of chronic and acute conditions. The age ranges are designed to capture risk for younger populations. The HHS-HCC model is not used directly by CentraCare, but the average scores for CentraCare patients would affect payments to commercial payors such as Blue Shield.

The John Hopkins Adjusted Clinical Group (ACG) model is a commercial model developed by John Hopkins University over several decades. It is based on the supposition that the number of separate types of problems is the best indicator of health risk. The problems are grouped by type into “adjusted diagnosis groups” (ADGs). For example, chronic health problems would be one ADG, and acute health problems would be another ADG. A person with five chronic problems might only be coded with 1 ADG. A person with both chronic and acute problems would have 2 ADGs. Each combination of ADGs is grouped into a ACG risk group, which each person fitting uniquely into only one ACG category. The ACG

is assigned a risk score and is also placed into a "resource utilization band" (RUB), which ranges from 0-5, with 0 being the lowest cost and 5 the highest. The Central MN Integrated Health Partnership (IHP) has licensed the John Hopkins ACG system and provides ACG risk scores to the IHP providers.

There are many other commercial risk assessment systems available. To get a sense of the number of possibilities, one might refer to the following review from 2013. The review provides information on 113 commercial health assessment systems. Many of these systems provide analytic tools for other purposes besides overall risk assessment.

Vigen, Greger, Duncan, Ian, & Coughlin, Sheryl (2013). Measurement of Healthcare Quality and Efficiency: Resources for Healthcare Professionals - Appendix D: Inventory of Programs and Organizations https://www.soa.org/Files/Research/Projects/research-quality-efficiency-inventory-2010-update.pdf

Accuracy of Risk Assessment Systems

There are two types of risk assessment systems. The first type is the prospective system, which is designed to predict the future. The best R Squared values, which are a measure of predictive accuracy, hover in the low 20% range for prospective risk assessment instruments. The second type is the concurrent system, which is designed to estimate risk for patients once their conditions have manifested themselves. A concurrent risk assessment system is simply a method for estimating what the costs of care should be, based on the national average costs for those conditions. The best R Squared values for concurrent risk assessment systems hover in the low 40% range. See page 28 of the CMS report listed below for an assessment of the accuracy for the HHS-HCC model, which is a concurrent model. The R Squared values range from 32.39% to 41.61%.

CMS (2017). 2018 Benefit Year Final HHS Risk Adjustment Model Coefficients https://www.cms.gov/CCIIO/Programs-and-Initiatives/Premium-Stabilization-Programs/Downloads/2018-Benefit-Year-Final-HHS-Risk-Adjustment-Model-Coefficients.pdf

The CMHN risk assessment system is a prospective system, and the accuracy should be compared against other prospective systems. There are several types of risk assessment algorithms, and the accuracy varies by the type of algorithm used. In general, risk assessment systems that rely on past spending patterns are more accurate that systems that rely on diagnoses.

For comparison purpose, it would be helpful to look at the CMS-HCC model, which is also a prospective risk assessment system. The accuracy of the CMS-HCC model is not extremely high. No accuracy data on the current CMS-HCC model (V22) could be found, but the accuracy for the previous two models (V12 & V21) was not particularly high. See page 65 of the report listed below. The accuracy ranges from a low of 1.51% for the New Enrollee V12 model to a high of 12.46% for the V21 Community model.

CMS (2011). Evaluation of the CMS-HCC Risk Adjustment Model: Final Report https://www.cms.gov/Medicare/Health-Plans/MedicareAdvtgSpecRateStats/downloads/evaluation_risk_adj_model_2011.pdf

Commercial prospective risk assessment systems tend to be more accurate than the CMS-HCC system. The table shown below provides the R^2 value for the prospective healthcare risk assessment instruments that are similar in nature to the risk assessment instrument being developed for the CMHN. The R Squared values range from 9.1% to 24.8%. The prior cost models outperform the diagnosis only models.

Table 1: R Squared Levels for Commercial Prospective Risk Models*

Risk Assessment Instrument	Type	R Squared
MARA	Prior Cost	24.8%
DxCG	Prior Cost	23.8%
Truven	Diagnosis Only	20.7%
MARA	Diagnosis Only	20.1%
Impact Pro	Diagnosis Only	18.9%
DxCG	Diagnosis Only	18.6%
John Hopkins ACG System	Prior Cost	17.8%
Wakely	Diagnosis Only	17.0%
John Hopkins ACG System	Diagnosis Only	16.2%
SCIO	Prior Cost	15.1%
CDPS	Diagnosis Only	9.1%

* Source: Hileman & Steele (2016: p.19)

Risk Assessment Accuracy for Currently Available Risk Assessment Instruments at CMHN

There are four prospective risk assessment tools that are currently available to CMHN providers. These include 1) the Epic General Risk Score, 2) the Centers for Medicare and Medicaid Services-Hierarchical Condition Classification (CMS-HCC) score, 3) a Count of total CMS-HCCs previously coded, and 4) the John Hopkins Adjusted Clinical Groups (ACG) score. Various sets of scores generated by these four risk assessment instruments were available for three separate populations.

The validation period was for the year immediately following the start date. The outcome variable was dollars spent. Three sets of risk scores were available.

The first set of CMS-HCC risk scores was downloaded from the CMS quarterly ACO report. CMS provided the HCC scores for 8,313 ACO beneficiaries in the first quarter of 2016. Costs were generated from the ACO claims data, and should have been as accurate as any available. The Epic General Risk scores were calculated from claims data available from Epic, using the model specification published by Epic. The count of CMS-HCC scores was created by cross-referencing all ICD9 and ICD10 diagnoses for each patient from 2010 onward with the 2016 CMS-HCC V21 (ICD9) and V22(ICD10) models published by CMS. Only one of each of the types of HCCs the person had ever been diagnosed with were counted.

The second set of risk scores consisted of John Hopkins ACG risk scores that were downloaded from the monthly IHP care management report from December of 2015. The state of Minnesota provides ACG scores and ACG Resource Utilization Bands (RUBs) for all patients participating in the Medicaid IHP program. The spending for the next year was calculated from claims data provided on those IHP clients during 2016. The Epic General Risk Score and the Count of CMS-HCCs were calculated for December 2015 and used as comparative risk score models.

The third set of risk scores was a set of CMS-HCCs created by Optum for the June 2016 assignable ACO population. Optum used the claims data provided by CMS with a two-month lag to calculate the risk scores. They used the 2016V22 CMS Community risk model. The Epic General Risk Score and the Count of CMS-HCC conditions were calculated to match the time of collection used by Optum. The outcome variable was calculated using one year of claims data provided by CMS.

Table 2: Risk Assessment Validation Samples

Population	Risk Scores Available
N=8,313 Medicare Patients Assigned to ACO Start Date: March 2016 Outcome: ACO claims data	CMS Generated CMS-HCC Scores Epic General Risk Score Count of Previously Coded CMS-HCCs
N=22,877 Medicaid Patients Assigned to IHP Start Date: January 2016	IHP Generated ACG Rescaled Risk Score IHP Generated ACG Resource Utilization Band Epic General Risk Score Count of Previously Coded CMS-HCCs
N = 14,969 Medicare Patients Assignable to ACO Start Date: June 2016	Optum Generated CMS-HCC Scores Epic General Risk Score Count of Previously Coded CMS-HCCs

Risk Assessment Validation Results

Results from CMS Model 2016Q2 (N=8,313 Medicare Patients)

Risk Assessment Method	**Explained Variance**
CMS HCC Score	4.8%
Epic General Risk Score	6.3%
Pre2016 HCC Count	8.5%

Results from IHP Model 2015 December (N=22,877 Medicaid Patients)

Risk Assessment Method	**Explained Variance**
ACG Rescaled Risk Score	5.9%
ACG Resource Utilization Band	3.8%
Epic General Risk Score	3.6%
Pre2016 HCC Count	8.0%

Results from Optum 201606 HCC Computations (N = 14,969 Medicare Patients)

Risk Assessment Method	**Explained Variance**
Optum HCC Score	11.7%
Epic General Risk Score	5.4%
Pre2016 HCC Count	8.9%

The conclusion to be drawn from these analyses was that none of the currently available risk scoring technologies available to the CMHN are sufficiently accurate for use as spend predictors. The most predictive model is the CMS-HCC score generated by Optum. The 11.7% explained variation in outcome falls short of the accuracy of commercial systems. A goal of 20% for a prospective risk assessment instrument does not seem to be unreasonable. A new healthcare risk scoring methodology seems to be needed in the CMHN.

Creating A Risk Assessment Model

The process of creating a risk assessment model can take many forms. For example, one might make a list of factors correlated with health risk, code each item a one if present and a zero if not, and use the resulting sum as a risk score. This is essentially how the Epic General Risk Score was developed. Another method is to use regression models to create weights for each risk factor. Most of the commercial models, as well as the CMS and HHS risk models appear to use a regression based method. In general, the accuracy of regression models would seem to be higher than item by item scores, and so the regression method was chosen.

The second issue was variable selection. In searching for a base model to work from in creating a CMHN risk scoring instrument, it became clear that the level of documentation for currently available healthcare risk assessment systems varied widely. The state of documentation regarding commercial healthcare risk assessment models appears to be very limited. A considerable amount of time and effort is spent developing commercial healthcare risk assessment instruments, and the methodologies involved appear to be closely guarded secrets.

At the other end of the spectrum, the ICD10 groupers used in the HCC models developed by CMS and HHS are completely documented and their use is open to anyone without charge. If one tried to resell the CMS-HCC and HHS-HCC models, there might be a problem, but CMS and HHS invite users to recreate their HCC models freely.

Given the availability of information on current risk assessment methodologies, it was decided to use the CMS and HHS risk assessment models as a base. These models have been developed over several decades, and have been thoroughly tested. Using these models as a starting point would appear to have definite advantages over starting from scratch.

In examining the CMS-HCC and HHS HCC risk assessment systems, it was determined that each is designed for different purposes and types of patients. The CMS-HCC model is prospective and designed for elderly populations. The HHS-HCC model is concurrent and designed for younger populations. Therefore, some type of combined model seemed to provide the most promise.

A Primer on Regression Models

The CMS and HHS HCC models are regression based models, where many variables are placed in a regression equation and the relative weights for each variable are calculated. The regression equation method was used in the calculation of the CMHN risk score.

Both the benefits and limitations of the regression method are that it tends to produce average scores that are based on historic factors. The averaging feature of regression is a benefit, since the average historic values tend to be good predictors of future events, but averaging can be a limitation since the

future often diverges from the past. In general, the benefits of the regression method outweigh the limitations, and this method tends to produce the most accurate predictors.

A regression model is essentially a formula. The basic form of the regression formula is as follows. The B values are weighting factors that are determined by the SPSS software, and the V values are the variables listed above. There were 42 demographic and historic variables such as Age, HCCCount, FY2015PaymentAmount, etc. + 148 HCC variables, for a total of N = 190 variables in the CMHN risk score model.

$$FY2016Payments = Constant + B_1*V_1 + B_2*V_2 + \ldots + B_N*V_N$$

Moving On

The following chapter describes the general form of the regression model used to calculate the CMHN risk score. The inputs and outputs produced are explained.

Chapter 2: Building and Testing a CMHN Risk Scoring Instrument

The basic principle behind the creation of an accurate risk assessment system is that the more data that one can accumulate, measured both in the length of time accumulated and in the variety of types of data, the more accurate the risk assessment system can be. First, as mentioned in the deep dive (Appendix A), health risk is fluctuating. Therefore, an extended period of measurement provides a better estimate of the average health of an individual than a single measurement. Second, health risk is affected by many factors, so as more types of health-related factors are assessed the accuracy of the instrument increases.

The accumulation of many sources of data is only helpful if the data sources are unrelated. Adding several sources of data that are essentially measuring the same thing has a negligible effect on model accuracy. Since many health factors are inter-related, it becomes challenging to create a health risk assessment instrument that exceeds the mid 20% range in R Squared values.

Many of the factors related to health risk are well known. These include age, gender, high blood pressure, high cholesterol, etc. In addition, it seems clear that a person with many health problems who had high costs in the past, would have high costs in the future. Finally, CMS and HHS have compiled two sets of diagnosis related HCCs that are related to higher cost conditions.

Using the knowledge of the most common health risk factors as a starting point, the work on the CMHN risk assessment system was begun. The following types of data were used as risk predictors.

Table 3: Types of Measures Used in the CMHN Risk Assessment System

Measurement Class	Detail
Demographics	Age by 10-year range Gender
Lab Results	Highest A1C Level Highest Systolic Blood Pressure (BP) Latest Body Mass Index (BMI) Highest Total Cholesterol level
Social Measures	Tobacco Use Alcoholic Drinks per Week
Prior Spending	Direct Spending from the previous 4 years Sum of Cost Categories from past 5 Years
Diagnoses	A merged set of 148 CMS and HHS HCCs
Health Score	Sum of Positive Health Indicators
Interaction Terms	Product of two or more other variables

In addition to the use of individual measures, “interaction” variables were created by multiplying two variables together. The theory behind interaction variables is that sometimes, there are factors that vary differently when they occur together. The interaction variables are marked with a X to signify the multiplicative effect. For example, AgeRangeXMale would indicate the product of the AgeRange and Male variables.

Method

The data for the CMHN risk assessment system was collected from the three CentraCare Electronic Data Warehouses (EDW, Star, Clarity), using SQL query scripts. The data was placed in a SQL "personal work area" (PWA) that had been provided by CentraCare's IT department. From there, it was downloaded into SPSS (IBM's Statistical Software Package) for regression analyses. Various regression models were created and tested until a fairly accurate risk assessment model with an R Squared of about 20% was produced. The model was then placed in an SQL script so that the CMHN risk score was available for use in the EDW.

The basic process involved was to either use variables collected from the data directly, or to create ordinal "scales" that were generated by 1) grouping ranges of values, or 2) adding other variables together. The scales were adjusted through trial and error to provide the most effective ranges.

Two types of data were collected (predictor and outcome). The predictor variables were collected by limiting the data to all data before July 1, 2016. The data extended back to 2011. The outcome data was the data from FY2016, which ranged from July 1, 2016 to June 30, 2017. The goal was to see if data collected before FY2016 could predict FY2016 spending.

Detailed descriptions of the variables used in the calculation of the risk score are provided in the Appendixes. The AgeRange was calculated in decades of life 0-9, 10-19, etc. Male was coded a one if Male and a zero if Female. The HCCCount was a count of the most significant HCCs truncated at 21+. CostWeight is the sum of the spending categories (0-$1,000, $1,001 to $10,000, $10,001 to $100,000, and $100,001 plus), for the past five years. The interaction terms were products of the preceding variables. A1CRange, BPRange, BMIRange, and CholesterolRange break the lab results for these four measures into levels of risk. TobaccoUser was coded a one for any type of tobacco use and a zero for no tobacco use. The DrinkRange variable broke the number of drinks per week into categories. The HealthScore variable was a sum of age less than 40 and zero risk factors from the other variables. FY2015 through FY2012 payment amounts were the direct dollars spent for care during the year, truncated to $450,000 if the care was more than $450,000 in that year.

The variables used are shown below, with the variable type listed and the individual correlations with the FY2016 spending levels. Note that some of the variables have correlations with the FY2016 payment amount of over r=.300. This would correspond with a R Squared of 9% or more. The fact that the combined R Squared for the CMHN risk score only approaches 20% provides an illustration that R Squared is not an additive phenomenon. One can put two variables with an R Squared of 9% in a model and if the two variables are highly related to each other the combined R Squared might still only be 9%. The only way to increase the R Squared of the final model is to include totally unrelated variables.

The other thing to note is that some of the variables, by themselves, had very little predictive power. For example, being male only has an r=.003 correlation with payment amount. This is not significant because it has a p value of p=.064, which is higher than p=.05. However, many of the interaction terms that are based on the Male variable are highly predictive. Therefore, the Male variable must be left in the model.

Please refer to the appendixes for more detailed descriptions of the variables.

Table 4: Variables included in the CMHN Risk Score Calculations

Variable	Description	Type	Correlation (r)
1	AgeRange	Ranges	.129
2	Male	Yes/No	.003
3	HCCCount	Ranges	.289
4	CostWeight	Sum of Variables	.275
5	AgeRangeXMale	Interaction	.064
6	AgeRangeXHCCCount	Interaction	.281
7	AgeRangeXCostWeight	Interaction	.292
8	MaleXHCCCount	Interaction	.208
9	MaleXCostWeight	Interaction	.178
10	HCCCountXCostWeight	Interaction	.333
11	AgeRangeXHCCCountXCostWeight	Interaction	.319
12	MaleXHCCCountXCostWeight	Interaction	.245
13	A1CRange	Ranges	.132
14	BPRange	Ranges	.163
15	BMIRange	Ranges	.065
16	CholesterolRange	Ranges	.114
17	TobaccoUser	Yes/No	.095
18	DrinkRange	Ranges	.075
19	HealthScore	Sum of Variables	-.206
20	FY2015PaymentAmount	Truncated Amount	.371
21	FY2014PaymentAmount	Truncated Amount	.233
22	FY2013PaymentAmount	Truncated Amount	.164
23	FY2012PaymentAmount	Truncated Amount	.167

The HCCs in the model

A set of 148 HCCs were constructed by combining the CMS and HHS HCC sets and were included as a group into the risk score model. The description of the combination process is provided in the Appendixes. The individual intercorrelations between the HCCs and the FY2016 payment amounts are provided below. Some of the HCCs have moderate correlations with payment amount. For example, Diabetes with Complications has a correlation with payments of r=.135.

Some of the HCCs, such as Autism Disorder are negatively correlated with payment amount. The reasons for the negative correlations are unknown, but the correlations could be negative because the condition is resolved, or because the person is cared for outside the CentraCare system. The negative correlations with the newborn conditions are most likely negative because the condition resolved itself as the child aged.

The variables with small and negative correlations are left in the risk model because they are part of the CMS and HHS HCC cost models and provide comparisons with other datasets. The insignificant variables also increase model accuracy. The values are so low (and insignificant) that one might guess that they probably have little or no impact on the overall accuracy of the risk score. However, taking out the insignificant values reduces the accuracy of the model by .1%, and so the small and insignificant HCC values are left in the CMHN risk score model.

Number	HCC	Description	Correlation (r)
1	HCC001	HIV/AIDS	.003
2	HCC002	Septicemia, Sepsis, Systemic Inflammatory Response Syndrome/Shock	.119
3	HCC006	Opportunistic Infections	.041
4	HCC008	Metastatic Cancer and Acute Leukemia	.138
5	HCC009	Lung and Other Severe Cancers	.095
6	HCC010	Lymphoma and Other Cancers	.113
7	HCC011	Colorectal, Bladder, and Other Cancers	.083
8	HCC012	Breast, Prostate, and Other Cancers and Tumors	.098
9	HCC017	Diabetes with Acute Complications	.046
10	HCC018	Diabetes with Chronic Complications	.135
11	HCC019	Diabetes without Complication	.124
12	HCC021	Protein-Calorie Malnutrition	.081
13	HCC022	Morbid Obesity	.089
14	HCC023	Other Significant Endocrine and Metabolic Disorders	.133
15	HCC027	End-Stage Liver Disease	.051
16	HCC028	Cirrhosis of Liver	.046
17	HCC029	Chronic Hepatitis	.020
18	HCC033	Intestinal Obstruction/Perforation	.077
19	HCC034	Chronic Pancreatitis	.026
20	HCC035	Inflammatory Bowel Disease	.051
21	HCC039	Bone/Joint/Muscle Infections/Necrosis	.073
22	HCC040	Rheumatoid Arthritis and Inflammatory Connective Tissue Disease	.076
23	HCC046	Severe Hematological Disorders	.042
24	HCC047	Disorders of Immunity	.126
25	HCC048	Coagulation Defects and Other Specified Hematological Disorders	.135
26	HCC054	Drug/Alcohol Psychosis	.032
27	HCC055	Drug/Alcohol Dependence	.040
28	HCC057	Schizophrenia	.019
29	HCC058	Major Depressive, Bipolar, and Paranoid Disorders	.056
30	HCC070	Quadriplegia	.027
31	HCC071	Paraplegia	.028
32	HCC072	Spinal Cord Disorders/Injuries	.032
33	HCC073	Amyotrophic Lateral Sclerosis and Other Motor Neuron Disease	.007
34	HCC074	Cerebral Palsy	.005
35	HCC075	Myasthenia Gravis/Myoneural Disorders and Guillain-Barre Syndrome/Inflammatory and Toxic Neuropathy	.068
36	HCC076	Muscular Dsytrophy	.000

37	HCC077	Multiple Sclerosis	.021
38	HCC078	Parkinson's and Huntington's Diseases	.023
39	HCC079	Seizure Disorders and Convulsions	.038
40	HCC080	Coma, Brain Compression/Anoxic Damage	.034
41	HCC082	Respirator Dependence/Tracheostomy Status	.041
42	HCC083	Respiratory Arrest	.019
43	HCC084	Cardio-Respiratory Failure and Shock	.106
44	HCC085	Congestive Heart Failure	.138
45	HCC086	Acute Myocardial Infarction	.061
46	HCC087	Unstable Angina and Other Acute Ischemic Heart Disease	.064
47	HCC088	Angina Pectoris	.063
48	HCC096	Specified Heart Arrhythmias	.108
49	HCC099	Cerebral Hemorrhage	.028
50	HCC100	Ischemic or Unspecified Stroke	.059
51	HCC103	Hemiplegia/Hemiparesis	.043
52	HCC104	Monoplegia, Other Paralytic Syndromes	.027
53	HCC106	Atherosclerosis of the Extremities with Ulceration or Gangrene	.080
54	HCC107	Vascular Disease with Complications	.089
55	HCC108	Vascular Disease	.146
56	HCC110	Cystic Fibrosis	.000
57	HCC111	Chronic Obstructive Pulmonary Disease	.109
58	HCC112	Fibrosis of Lung and Other Chronic Lung Disorder	.076
59	HCC114	Aspiration and Specified Bacterial Pneumonias	.051
60	HCC115	Pneumococcal Pneumonia, Empyema, Lung Abscess	.046
61	HCC122	Proliferative Diabetic Retinopathy and Vitreous Hemorrhage	.026
62	HCC124	Exudative Macular Degeneration	.004
63	HCC134	Dialysis Status	.166
64	HCC135	Acute Renal Failure	.155
65	HCC136	Chronic Kidney Disease (Stage 5)	.170
66	HCC137	Chronic Kidney Disease, Severe (Stage 4)	.126
67	HCC157	Pressure Ulcer of Skin with Necrosis Through to Muscle, Tendon, or Bone	.027
68	HCC158	Pressure Ulcer of Skin with Full Thickness Skin Loss	.041
69	HCC161	Chronic Ulcer of Skin, Except Pressure	.107
70	HCC162	Severe Skin Burn or Condition	.009
71	HCC166	Severe Head Injury	.012
72	HCC167	Major Head Injury	.019
73	HCC169	Vertebral Fractures without Spinal Cord Injury	.045
74	HCC170	Hip Fracture/Dislocation	.043
75	HCC173	Traumatic Amputations and Complications	.025

76	HCC176	Complications of Specified Implanted Device or Graft	.120
77	HCC186	Major Organ Transplant or Replacement Status	.047
78	HCC188	Artificial Openings for Feeding or Elimination	.070
79	HCC189	Amputation Status, Lower Limb/Amputation Complications	.067
80	HHSHCC003	Central Nervous System Infections, Except Viral Meningitis	.051
81	HHSHCC004	Viral or Unspecified Meningitis	.046
82	HHSHCC011	Colorectal, Breast (Age < 50), Kidney, and Other Cancers	.090
83	HHSHCC013	Thyroid Cancer, Melanoma, Neurofibromatosis, and Other Cancers and Tumors	.061
84	HHSHCC018	Pancreas Transplant Status/Complications	.028
85	HHSHCC027	Lipidoses and Glycogenosis	.011
86	HHSHCC028	Congenital Metabolic Disorders, Not Elsewhere Classified	.021
87	HHSHCC029	Amyloidosis, Porphyria, and Other Metabolic Disorders	.017
88	HHSHCC034	Liver Transplant Status/Complications	.007
89	HHSHCC038	Acute Liver Failure/Disease, Including Neonatal Hepatitis	.065
90	HHSHCC042	Peritonitis/Gastrointestinal Perforation/Necrotizing Enterocolitis	.063
91	HHSHCC047	Acute Pancreatitis/Other Pancreatic Disorders and Intestinal Malabsorption	.055
92	HHSHCC054	Necrotizing Fasciitis	.018
93	HHSHCC057	Systemic Lupus Erythematosus and Other Autoimmune Disorders	.050
94	HHSHCC061	Osteogenesis Imperfecta and Other Osteodystrophies	.010
95	HHSHCC062	Congenital/Developmental Skeletal and Connective Tissue Disorders	.002
96	HHSHCC063	Cleft Lip/Cleft Palate	.000
97	HHSHCC064	Major Congenital Anomalies of Diaphragm, Abdominal Wall, and Esophagus, Age < 2	.017
98	HHSHCC066	Hemophilia	.007
99	HHSHCC067	Myelodysplastic Syndromes and Myelofibrosis	.033
100	HHSHCC068	Aplastic Anemia	.028
101	HHSHCC069	Acquired Hemolytic Anemia, Including Hemolytic Disease of Newborn	.007
102	HHSHCC070	Sickle Cell Anemia (Hb-SS)	.001
103	HHSHCC071	Thalassemia Major	.004
104	HHSHCC073	Combined and Other Severe Immunodeficiencies	.003
105	HHSHCC074	Disorders of the Immune Mechanism	.060

106	HHSHCC075	Coagulation Defects and Other Specified Hematological Disorders	.068
107	HHSHCC081	Drug Psychosis	.015
108	HHSHCC082	Drug Dependence	.024
109	HHSHCC089	Reactive and Unspecified Psychosis, Delusional Disorders	.058
110	HHSHCC090	Personality Disorders	.028
111	HHSHCC094	Anorexia/Bulimia Nervosa	.009
112	HHSHCC096	Prader-Willi, Patau, Edwards, and Autosomal Deletion Syndromes	.004
113	HHSHCC097	Down Syndrome, Fragile X, Other Chromosomal Anomalies, and Congenital Malformation Syndromes	.005
114	HHSHCC102	Autistic Disorder	-.002
115	HHSHCC103	Pervasive Developmental Disorders, Except Autistic Disorder	-.002
116	HHSHCC108	Traumatic Complete Lesion Dorsal Spinal Cord	.001
117	HHSHCC112	Quadriplegic Cerebral Palsy	.007
118	HHSHCC114	Spina Bifida and Other Brain/Spinal/Nervous System Congenital Anomalies	.010
119	HHSHCC121	Hydrocephalus	.017
120	HHSHCC128	Heart Assistive Device/Artificial Heart	.014
121	HHSHCC129	Heart Transplant	.017
122	HHSHCC135	Heart Infection/Inflammation, Except Rheumatic	.048
123	HHSHCC137	Hypoplastic Left Heart Syndrome and Other Severe Congenital Heart Disorders	.002
124	HHSHCC138	Major Congenital Heart/Circulatory Disorders	.016
125	HHSHCC139	Atrial and Ventricular Septal Defects, Patent Ductus Arteriosus, and Other Congenital Heart/Circulatory Disorders	.022
126	HHSHCC149	Cerebral Aneurysm and Arteriovenous Malformation	.013
127	HHSHCC154	Vascular Disease with Complications	.059
128	HHSHCC156	Pulmonary Embolism and Deep Vein Thrombosis	.077
129	HHSHCC158	Lung Transplant Status/Complications	.010
130	HHSHCC161	Asthma	.058
131	HHSHCC183	Kidney Transplant Status	.055
132	HHSHCC203	Ectopic and Molar Pregnancy, Except with Renal Failure, Shock, or Embolism	.003
133	HHSHCC204	Miscarriage with Complications	.003
134	HHSHCC205	Miscarriage with No or Minor Complications	.010
135	HHSHCC207	Completed Pregnancy With Major Complications	.006
136	HHSHCC208	Completed Pregnancy With Complications	.005
137	HHSHCC209	Completed Pregnancy with No or Minor Complications	.002

138	HHSHCC226	Hip Fractures and Pathological Vertebral or Humerus Fractures	.057
139	HHSHCC227	Pathological Fractures, Except of Vertebrae, Hip, or Humerus	.049
140	HHSHCC242	Extremely Immature Newborns, Birthweight < 500 Grams	-.002
141	HHSHCC243	Extremely Immature Newborns, Including Birthweight 500-749 Grams	.003
142	HHSHCC244	Extremely Immature Newborns, Including Birthweight 750-999 Grams	-.001
143	HHSHCC245	Premature Newborns, Including Birthweight 1000-1499 Grams	-.001
144	HHSHCC246	Premature Newborns, Including Birthweight 1500-1999 Grams	-.006
145	HHSHCC247	Premature Newborns, Including Birthweight 2000-2499 Grams	-.009
146	HHSHCC248	Other Premature, Low Birthweight, Malnourished, or Multiple Birth Newborns	-.012
147	HHSHCC249	Term or Post-Term Singleton Newborn, Normal or High Birthweight	-.035
148	HHSHCC251	Stem Cell, Including Bone Marrow, Transplant Status/Complications	.033

Building the CMHN Risk Score Regression Model

The demographic and historic variables were entered one at a time into the regression software in 23 separate steps, and the HCC variables were entered as a group on Step 24. The R Squared values were calculated at each step, so that the stepwise improvements in predictive accuracy could be estimated. The final R Squared for the CMHN risk score model was 20.0%.

The t values are provided for a measure of predictive strength. A t value with magnitude over 3 tends to be highly significant. As the t value increases in magnitude, the predictive strength of that variable increases. Note that the prior year's payment amounts are some of the most strongly predictive variables for predicting this year's spending.

Note that the values for the variables included in the interaction terms must be interpreted carefully. HCCCount has a negative B coefficient because it is a highly positive predictor when combined with other variables such as the CostWeight. AgeRange is not significant because it is highly significant in combination with some of the interaction terms.

Step	Variable Added	R	R Square	B	t	p
0	Constant			1,641.757		
1	AgeRange	.129	.017	-2.862	-.188	.851
2	Male	.129	.017	-372.924	-4.241	.000
3	HCCCount	.292	.085	-2,353.863	-4.350	.000
4	CostWeight	.317	.101	-184.621	-4.451	.000
5	AgeRangeXMale	.318	.101	67.641	4.061	.000
6	AgeRangeXHCCCount	.318	.101	-32.526	-3.034	.002
7	AgeRangeXCostWeight	.321	.103	53.476	8.069	.000
8	MaleXHCCCount	.322	.103	82.378	2.028	.043
9	MaleXCostWeight	.322	.103	-108.534	-3.566	.000
10	HCCCountXCostWeight	.346	.120	180.366	12.651	.000
11	AgeRangeXHCCCountXCostWeight	.347	.120	-6.470	-3.359	.001
12	MaleXHCCCountXCostWeight	.347	.120	37.458	5.345	.000
13	A1CRange	.348	.121	170.096	7.137	.000
14	BPRange	.349	.122	230.415	7.992	.000
15	BMIRange	.349	.122	58.996	2.595	.009
16	CholesterolRange	.349	.122	117.416	4.176	.000
17	TobaccoUser	.349	.122	286.135	5.388	.000
18	DrinkRange	.350	.122	297.898	6.794	.000
19	HealthScore	.352	.124	-212.895	-9.843	.000
20	FY2015PaymentAmount	.425	.181	.258	140.177	.000
21	FY2014PaymentAmount	.429	.184	.070	34.148	.000
22	FY2013PaymentAmount	.429	.184	.023	10.966	.000
23	FY2012PaymentAmount	.430	.185	.039	15.803	.000
24	All HCCs	.447	.200			

The HCC Regression Coefficients

The HCC regression coefficients are listed below. All 148 of the HCC were included in the regression model. There are many negative coefficients, which might seem puzzling, but it is important to remember that some of these conditions can be acute, and the coding goes back to 2011. The reasons for a negative value are many and varied. If the condition is resolved, the person might be healthy again. Also, a person might have gotten so sick that they are placed in a nursing home. This would result in lower cost of treatment. Some patients may have received transplants, and the condition is resolved for the most part. Cancers can be cured. Low birth weight babies get healthy. Mothers are no longer present.

The only way to resolve the issues with individual conditions is to take the conditions and explore them, one at a time. This would seem to be a worthwhile project, but since the overall accuracy of the CMHN risk score is adequate for immediate use, the effort to explore the issues related to individual HCC conditions can be put on hold for now.

This is not meant to suggest that the effort to improve the coding should not proceed. It is just that the efforts to improve coding can proceed at a slower pace, now that the CMHN Risk Assessment instrument has been developed.

HCC	Description	B	t	p
HCC001	HIV/AIDS	-397.416	-.552	.581
HCC002	Septicemia, Sepsis, Systemic Inflammatory Response Syndrome/Shock	701.284	1.237	.216
HCC006	Opportunistic Infections	-1,140.810	-2.774	.006
HCC008	Metastatic Cancer and Acute Leukemia	7,037.527	11.681	.000
HCC009	Lung and Other Severe Cancers	2,906.996	4.902	.000
HCC010	Lymphoma and Other Cancers	3,648.424	6.270	.000
HCC011	Colorectal, Bladder, and Other Cancers	3,026.527	5.201	.000
HCC012	Breast, Prostate, and Other Cancers and Tumors	2,293.125	4.134	.000
HCC017	Diabetes with Acute Complications	2,880.607	4.350	.000
HCC018	Diabetes with Chronic Complications	2,985.600	5.336	.000
HCC019	Diabetes without Complication	-181.035	-1.845	.065
HCC021	Protein-Calorie Malnutrition	921.431	1.538	.124
HCC022	Morbid Obesity	2,144.200	3.877	.000
HCC023	Other Significant Endocrine and Metabolic Disorders	2,935.592	5.222	.000
HCC027	End-Stage Liver Disease	5,147.861	7.320	.000
HCC028	Cirrhosis of Liver	206.736	.533	.594
HCC029	Chronic Hepatitis	-456.166	-1.399	.162
HCC033	Intestinal Obstruction/Perforation	-785.299	-4.321	.000
HCC034	Chronic Pancreatitis	-80.879	-.158	.874
HCC035	Inflammatory Bowel Disease	5,071.177	8.745	.000
HCC039	Bone/Joint/Muscle Infections/Necrosis	-142.548	-.657	.511
HCC040	Rheumatoid Arthritis and Inflammatory Connective Tissue Disease	3,575.414	6.329	.000
HCC046	Severe Hematological Disorders	397.977	.381	.703

HCC047	Disorders of Immunity	3,573.184	5.995	.000
HCC048	Coagulation Defects and Other Specified Hematological Disorders	-172.805	-1.403	.161
HCC054	Drug/Alcohol Psychosis	-112.020	-.424	.672
HCC055	Drug/Alcohol Dependence	2,001.598	3.589	.000
HCC057	Schizophrenia	259.499	.944	.345
HCC058	Major Depressive, Bipolar, and Paranoid Disorders	2,059.710	3.764	.000
HCC070	Quadriplegia	3,786.014	4.536	.000
HCC071	Paraplegia	3,860.798	4.790	.000
HCC072	Spinal Cord Disorders/Injuries	-509.806	-1.597	.110
HCC073	Amyotrophic Lateral Sclerosis and Other Motor Neuron Disease	4,777.389	3.984	.000
HCC074	Cerebral Palsy	411.257	.917	.359
HCC075	Myasthenia Gravis/Myoneural Disorders and Guillain-Barre Syndrome/Inflammatory and Toxic Neuropathy	180.188	.528	.598
HCC076	Muscular Dsytrophy	6.138	.010	.992
HCC077	Multiple Sclerosis	3,232.266	5.118	.000
HCC078	Parkinson's and Huntington's Diseases	2,881.808	4.710	.000
HCC079	Seizure Disorders and Convulsions	112.802	.904	.366
HCC080	Coma, Brain Compression/Anoxic Damage	88.501	.142	.887
HCC082	Respirator Dependence/Tracheostomy Status	-3,258.653	-4.751	.000
HCC083	Respiratory Arrest	5,066.802	4.957	.000
HCC084	Cardio-Respiratory Failure and Shock	1,316.330	2.358	.018
HCC085	Congestive Heart Failure	2,958.095	5.361	.000
HCC086	Acute Myocardial Infarction	1,415.150	2.475	.013
HCC087	Unstable Angina and Other Acute Ischemic Heart Disease	611.780	1.076	.282
HCC088	Angina Pectoris	1,982.696	3.492	.000
HCC096	Specified Heart Arrhythmias	-119.228	-1.307	.191
HCC099	Cerebral Hemorrhage	641.940	1.038	.299
HCC100	Ischemic or Unspecified Stroke	-153.990	-.852	.394
HCC103	Hemiplegia/Hemiparesis	826.453	1.385	.166
HCC104	Monoplegia, Other Paralytic Syndromes	2,686.214	3.490	.000
HCC106	Atherosclerosis of the Extremities with Ulceration or Gangrene	4,394.019	6.114	.000
HCC107	Vascular Disease with Complications	2,295.918	3.832	.000
HCC108	Vascular Disease	3,254.833	5.881	.000
HCC110	Cystic Fibrosis	-477.533	-.355	.723
HCC111	Chronic Obstructive Pulmonary Disease	2,675.110	4.834	.000
HCC112	Fibrosis of Lung and Other Chronic Lung Disorder	2,470.495	4.382	.000
HCC114	Aspiration and Specified Bacterial Pneumonias	-292.857	-.488	.625
HCC115	Pneumococcal Pneumonia, Empyema, Lung Abscess	-1,058.155	-3.028	.002

HCC122	Proliferative Diabetic Retinopathy and Vitreous Hemorrhage	203.689	.312	.755
HCC124	Exudative Macular Degeneration	-2,994.583	-1.827	.068
HCC134	Dialysis Status	4,089.353	5.346	.000
HCC135	Acute Renal Failure	2,012.585	3.607	.000
HCC136	Chronic Kidney Disease (Stage 5)	10,969.227	14.203	.000
HCC137	Chronic Kidney Disease, Severe (Stage 4)	4,768.488	8.103	.000
HCC157	Pressure Ulcer of Skin with Necrosis Through to Muscle, Tendon, or Bone	119.067	.122	.903
HCC158	Pressure Ulcer of Skin with Full Thickness Skin Loss	-1,043.992	-1.897	.058
HCC161	Chronic Ulcer of Skin, Except Pressure	3,828.960	6.600	.000
HCC162	Severe Skin Burn or Condition	5,407.751	3.165	.002
HCC166	Severe Head Injury	8,358.916	4.834	.000
HCC167	Major Head Injury	-276.595	-1.704	.088
HCC169	Vertebral Fractures without Spinal Cord Injury	758.137	1.295	.195
HCC170	Hip Fracture/Dislocation	506.586	.838	.402
HCC173	Traumatic Amputations and Complications	-1,098.423	-2.997	.003
HCC176	Complications of Specified Implanted Device or Graft	1,708.648	3.002	.003
HCC186	Major Organ Transplant or Replacement Status	12,005.473	3.973	.000
HCC188	Artificial Openings for Feeding or Elimination	-553.247	-2.084	.037
HCC189	Amputation Status, Lower Limb/Amputation Complications	2,631.318	3.867	.000
HHSHCC003	Central Nervous System Infections, Except Viral Meningitis	63.857	.425	.671
HHSHCC004	Viral or Unspecified Meningitis	2,212.048	4.017	.000
HHSHCC011	Colorectal, Breast (Age < 50), Kidney, and Other Cancers	1,841.618	3.207	.001
HHSHCC013	Thyroid Cancer, Melanoma, Neurofibromatosis, and Other Cancers and Tumors	355.914	1.481	.138
HHSHCC018	Pancreas Transplant Status/Complications	-6,279.762	-2.054	.040
HHSHCC027	Lipidoses and Glycogenosis	1,557.001	1.294	.196
HHSHCC028	Congenital Metabolic Disorders, Not Elsewhere Classified	157.721	.273	.785
HHSHCC029	Amyloidosis, Porphyria, and Other Metabolic Disorders	-685.746	-.848	.396
HHSHCC034	Liver Transplant Status/Complications	-14,561.879	-4.748	.000
HHSHCC038	Acute Liver Failure/Disease, Including Neonatal Hepatitis	2,490.434	4.515	.000
HHSHCC042	Peritonitis/Gastrointestinal Perforation/Necrotizing Enterocolitis	847.756	1.392	.164
HHSHCC047	Acute Pancreatitis/Other Pancreatic Disorders and Intestinal Malabsorption	-278.778	-1.751	.080
HHSHCC054	Necrotizing Fasciitis	2,691.690	1.769	.077

HHSHCC057	Systemic Lupus Erythematosus and Other Autoimmune Disorders	1,199.007	2.029	.042
HHSHCC061	Osteogenesis Imperfecta and Other Osteodystrophies	2,037.164	1.915	.055
HHSHCC062	Congenital/Developmental Skeletal and Connective Tissue Disorders	-388.979	-.882	.378
HHSHCC063	Cleft Lip/Cleft Palate	364.484	.409	.682
HHSHCC064	Major Congenital Anomalies of Diaphragm, Abdominal Wall, and Esophagus, Age < 2	-614.797	-1.026	.305
HHSHCC066	Hemophilia	670.636	.399	.690
HHSHCC067	Myelodysplastic Syndromes and Myelofibrosis	7,686.455	6.334	.000
HHSHCC068	Aplastic Anemia	3,668.249	2.777	.005
HHSHCC069	Acquired Hemolytic Anemia, Including Hemolytic Disease of Newborn	-15.582	-.031	.975
HHSHCC070	Sickle Cell Anemia (Hb-SS)	-259.347	-.112	.911
HHSHCC071	Thalassemia Major	2,188.964	1.057	.291
HHSHCC073	Combined and Other Severe Immunodeficiencies	-512.669	-.338	.735
HHSHCC074	Disorders of the Immune Mechanism	2,618.122	3.949	.000
HHSHCC075	Coagulation Defects and Other Specified Hematological Disorders	1.819	.009	.993
HHSHCC081	Drug Psychosis	1,402.187	2.315	.021
HHSHCC082	Drug Dependence	1,385.806	2.419	.016
HHSHCC089	Reactive and Unspecified Psychosis, Delusional Disorders	-618.925	-3.706	.000
HHSHCC090	Personality Disorders	-404.256	-2.303	.021
HHSHCC094	Anorexia/Bulimia Nervosa	829.952	1.661	.097
HHSHCC096	Prader-Willi, Patau, Edwards, and Autosomal Deletion Syndromes	613.805	.670	.503
HHSHCC097	Down Syndrome, Fragile X, Other Chromosomal Anomalies, and Congenital Malformation Syndromes	326.341	.970	.332
HHSHCC102	Autistic Disorder	541.220	1.458	.145
HHSHCC103	Pervasive Developmental Disorders, Except Autistic Disorder	118.408	.280	.779
HHSHCC108	Traumatic Complete Lesion Dorsal Spinal Cord	-7,914.308	-1.793	.073
HHSHCC112	Quadriplegic Cerebral Palsy	653.269	.612	.540
HHSHCC114	Spina Bifida and Other Brain/Spinal/Nervous System Congenital Anomalies	3,332.665	4.377	.000
HHSHCC121	Hydrocephalus	389.251	.539	.590
HHSHCC128	Heart Assistive Device/Artificial Heart	-14,739.206	-4.503	.000
HHSHCC129	Heart Transplant	4,127.113	1.358	.175
HHSHCC135	Heart Infection/Inflammation, Except Rheumatic	36.634	.170	.865
HHSHCC137	Hypoplastic Left Heart Syndrome and Other Severe Congenital Heart Disorders	946.919	.599	.549
HHSHCC138	Major Congenital Heart/Circulatory Disorders	-56.528	-.205	.838

HHSHCC139	Atrial and Ventricular Septal Defects, Patent Ductus Arteriosus, and Other Congenital Heart/Circulatory Disorders	-183.878	-.868	.386
HHSHCC149	Cerebral Aneurysm and Arteriovenous Malformation	518.910	.751	.453
HHSHCC154	Vascular Disease with Complications	620.655	.952	.341
HHSHCC156	Pulmonary Embolism and Deep Vein Thrombosis	910.131	1.558	.119
HHSHCC158	Lung Transplant Status/Complications	-2,926.272	-.805	.421
HHSHCC161	Asthma	2,221.020	4.072	.000
HHSHCC183	Kidney Transplant Status	-258.817	-.350	.726
HHSHCC203	Ectopic and Molar Pregnancy, Except with Renal Failure, Shock, or Embolism	-266.746	-.483	.629
HHSHCC204	Miscarriage with Complications	-405.284	-.538	.591
HHSHCC205	Miscarriage with No or Minor Complications	3,122.698	5.280	.000
HHSHCC207	Completed Pregnancy With Major Complications	231.746	.593	.553
HHSHCC208	Completed Pregnancy With Complications	-205.305	-1.137	.256
HHSHCC209	Completed Pregnancy with No or Minor Complications	-255.505	-1.755	.079
HHSHCC226	Hip Fractures and Pathological Vertebral or Humerus Fractures	3,361.053	5.375	.000
HHSHCC227	Pathological Fractures, Except of Vertebrae, Hip, or Humerus	7,379.677	8.686	.000
HHSHCC242	Extremely Immature Newborns, Birthweight < 500 Grams	1,914.387	1.060	.289
HHSHCC243	Extremely Immature Newborns, Including Birthweight 500-749 Grams	-2,583.438	-1.511	.131
HHSHCC244	Extremely Immature Newborns, Including Birthweight 750-999 Grams	-5,307.418	-3.523	.000
HHSHCC245	Premature Newborns, Including Birthweight 1000-1499 Grams	-1,922.383	-1.959	.050
HHSHCC246	Premature Newborns, Including Birthweight 1500-1999 Grams	-549.781	-.693	.488
HHSHCC247	Premature Newborns, Including Birthweight 2000-2499 Grams	-281.108	-.722	.470
HHSHCC248	Other Premature, Low Birthweight, Malnourished, or Multiple Birth Newborns	119.536	.467	.640
HHSHCC249	Term or Post-Term Singleton Newborn, Normal or High Birthweight	227.388	2.235	.025
HHSHCC251	Stem Cell, Including Bone Marrow, Transplant Status/Complications	-4,925.871	-1.624	.104

Conclusion

The CMHN risk assessment project appears to have produced a fairly accurate risk model. The risk model is a hybrid model that combines demographics, diagnoses, lab results, and prior cost to predict

future health care costs. The table shown below provides a ranking of commercial models, the CMHN risk score, and the current risk assessment instruments available to CentraCare.

Risk Assessment Instrument	Type	R Squared
MARA	Prior Cost	24.8%
DxCG	Prior Cost	23.8%
Truven	Diagnosis Only	20.7%
MARA	Diagnosis Only	20.1%
CMHN Risk Assessment Instrument	**Hybrid Prior Cost & Diagnosis**	**20.0%**
Impact Pro	Diagnosis Only	18.9%
DxCG	Diagnosis Only	18.6%
John Hopkins ACG System	Prior Cost	17.8%
Wakely	Diagnosis Only	17.0%
John Hopkins ACG System	Diagnosis Only	16.2%
SCIO	Prior Cost	15.1%
CMS-HCC with Central MN ACO	Diagnosis Only	11.7%
CDPS	Diagnosis Only	9.1%
Count of CMS-HCCs	Diagnosis Only	8.0% to 8.5%
ACG with CCH IHP Population	Diagnosis Only	5.9%
Epic General Risk Score	Diagnosis Only	3.6% to 6.3%
CMS-HCC with Central MN ACO	Diagnosis Only	4.8%

The regression formula generated from SPSS was copied back up into the CentraCare EDW using a SQL script and the risk scores are available for use.

Appendix A: Deep Dive into Healthcare Risk Assessment

There are a series of basic issues that need to be resolved if one is to accurately predict future healthcare spending. These are as follows.

1. Health risk is a massively multivariate phenomenon
2. Health risk is highly dynamic and highly stable at the same time
3. Health risk changes systematically over the life course
4. Population health risk is normally distributed with mixing
5. Cumulative health risk is an area under a curve
6. A change in mean risk levels produces a nonlinear sigmoid "S-Shaped" response in participation
7. Costs increase exponentially with health risk

Health Risk is a Massively Multivariate Phenomenon

There are many factors that influence health. A short list would include,

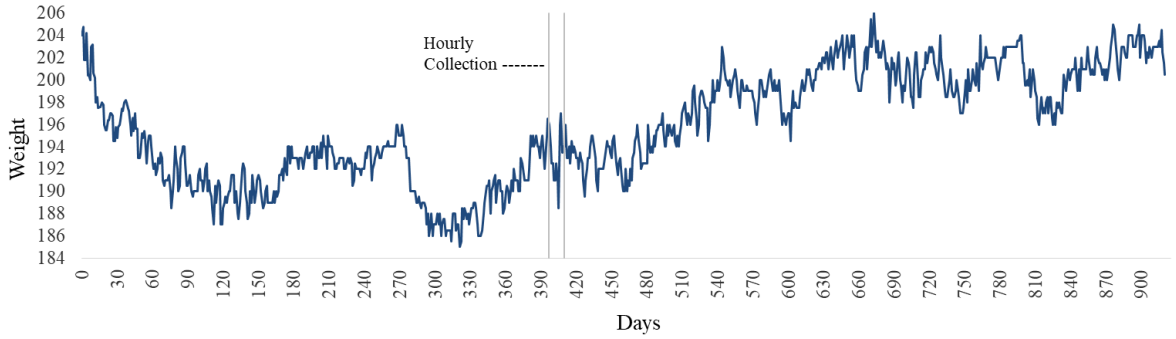
- Genetic
- Developmental
- Situational
- Historical
- Social

Because there are a massive number of variables that affect health, it is important to develop a sample of as many measurable factors as possible. By aggregating a large number of factors, it is possible to improve prediction accuracy.

Health risk is highly dynamic and highly stable at the same time

There are two things to remember about risk assessment. First, people are constantly changing. Change occurs at all time frames, from seconds, to minutes, hours, months, years, and decades. The result of this variation is that, in general, only about 16% of the variation in outcome can be easily explained. The chart below provides a general sample of how risk changes over time. This is a plot of daily weight over a period of three years. Although health is much harder to measure than weight, we can assume that it has similar dynamics fluctuation over time.

Figure 1: Risk Over Time



The second factor to consider is that health is relatively stable over time. In the chart shown above, there is fluctuation, but the fluctuation has remained within a 20-pound weight band. In general, it would be difficult to predict an exact weight, but relatively easy to predict a weight range. Similarly, it is difficult to predict an exact health level, but relatively easy to predict a health range.

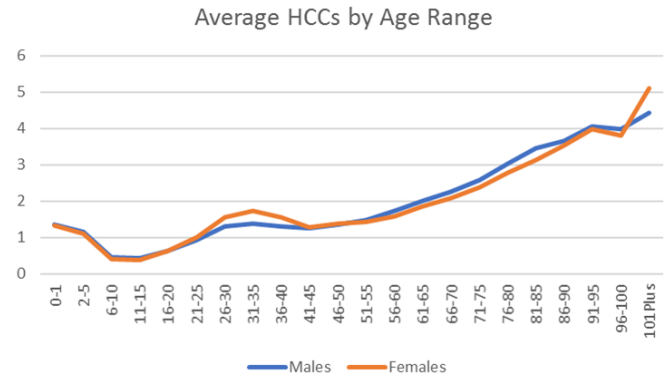
Health risk changes systematically over the life course

The third factor to consider is that health changes systematically over the life course. If we plot the total number of HCCs by age, as in Figure 2 below, we find that there is a higher level of risk for infants, health risk is low for toddlers and young children, and then risk rises steadily over the life course.

Note that females have a slightly higher number of HCCs during the child bearing years, which is not necessarily a measure of poor health, but since having children is a predictor of healthcare spending, and pregnancy is included in the HCC lists.

This fact is important from a predictive standpoint. Because health risks rise over the life course, it is important to include age as a factor in healthcare risk assessment. We can predict a certain probability of spending simply by knowing a person's age.

Figure 2: Average HCCs by Age Range

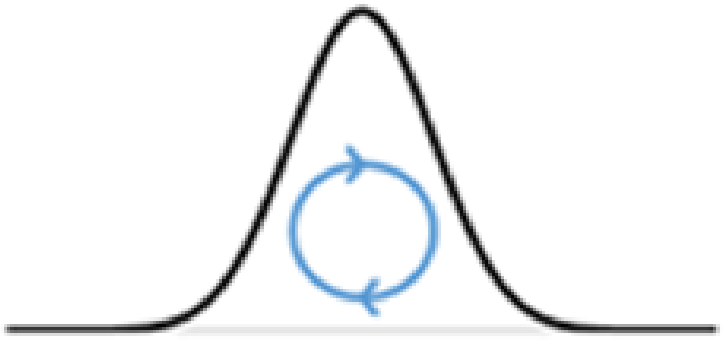


Population health risk is normally distributed with mixing

The distribution of health risk is not immediately apparent. We really can't measure health risk exactly, and our measures of health risk, like healthcare spending or death rates, are not evenly distributed in the population. However, it can be assumed that health risk is normally distributed in populations. This is a statistical property that flows from the central limit theorem and the joint probability when large numbers of factors interact.

Since we know that health risk is fluctuating, we can assume that the normal distribution of health risk is mixing. That is, people at the low and high ends of the health risk distribution can be moving to the middle, and people at the middle can be moving up or down. This can be visualized by the following model.

Figure 3: A Population Health Risk Model

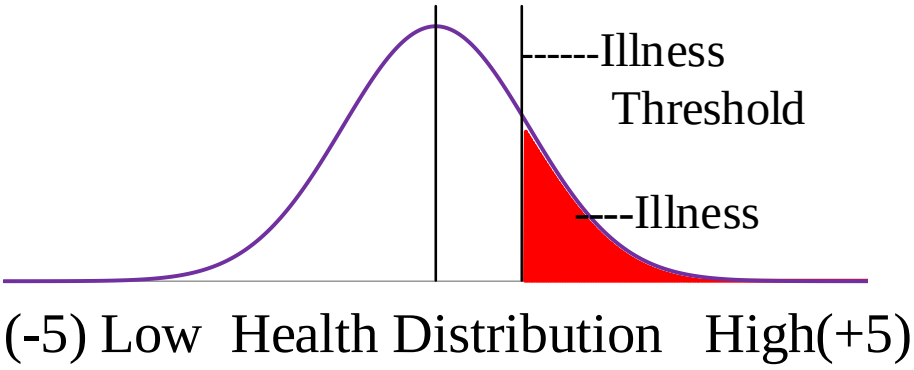


Cumulative health risk is an area under a curve

The next item is probably difficult to imagine, since people tend to think in a linear fashion, but health outcomes tend to be highly nonlinear in nature. People tend to spend money on healthcare when the illness or condition exceeds a certain level, and not before. Therefore, a threshold model is needed to model health risk. People to the right of the threshold shown below will be likely to spend money on healthcare, while people to the left will not.

This model has some interesting implications. One implication is that slight changes in the level of health can have large impacts on participation levels. Conversely, sometimes, large changes in health levels may have little or no effect on participation levels. We measure the participation levels by assessing changes in the area under the curve to the right of the normal distribution.

Figure 4: Measuring the Area Under the Curve

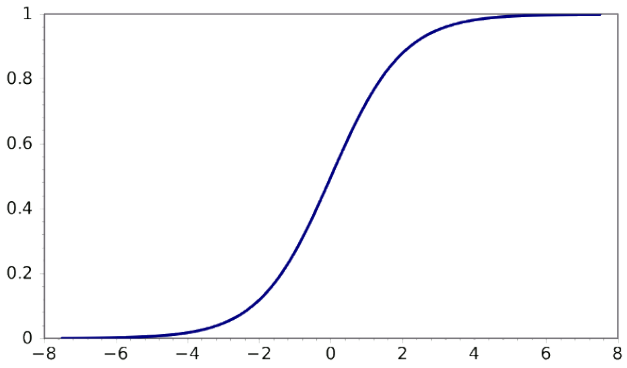


A change in mean health risk levels produces a nonlinear sigmoid "S-Shaped" response in participation

Another basic consideration for risk assessment is that participation rates in healthcare follow a nonlinear sigmoid, or "S-Shaped," response curve. For those who have studied dose-response relationships, this will probably seem familiar. The initial effects on an organism of low doses of a poison are small. However, as the dose goes up, the effect rises rapidly. However, there are always small numbers of people who can handle elevated levels of a poison with small effect. The response

curve illustration the relationship between health risk and healthcare participation looks like the one shown below.

Figure 6: The Dose-Response Model of Healthcare Risk Vs. Healthcare Participation



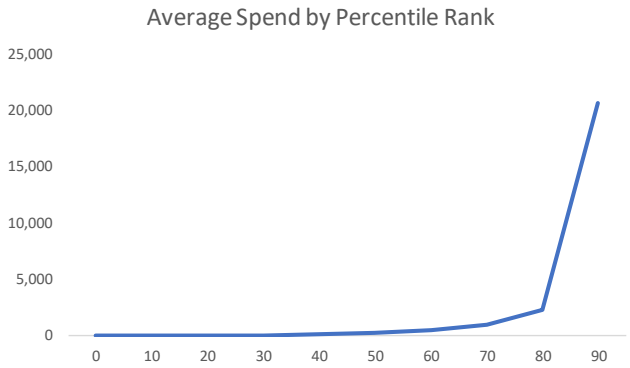
Costs Increase Exponentially with Health Risk

The final consideration is that spending on healthcare increases exponentially with health risk. Most patients incur either no costs or very small costs, while some patients incur very high costs. Almost half of the current CentraCare Health patients at the beginning of 2016 (47.3%) had no charges at all in 2016. By plotting the average cost per patient by percentile rank of risk, one finds that the patients in the 90th percentile of risk, spend almost ten times more than the patients in the 80th risk percentile.

The plot of average spending by percentile rank is shown below. The nonlinear nature of healthcare spending creates challenges for the creation of healthcare risk scores (See Jones, A.M. (2010). Models for Healthcare. https://www.york.ac.uk/media/economics/documents/herc/wp/10_01.pdf). The net result is that the risk scores are not normally distributed like risk itself. The risk scores tend to cluster around zero and become highly inflated for high-risk patients.

Note that the 80/20 rule does not apply in this case. In the case of healthcare spending, the top 10% of patients spent 84% of the total dollars in 2016. The top 20% of patients spent 93.7% of the total dollars spent. The rule is inflated to 94/20, not 80/20.

Figure 7: The Exponential Increase in Healthcare Spending by Risk Level



Appendix B: Historic Variables

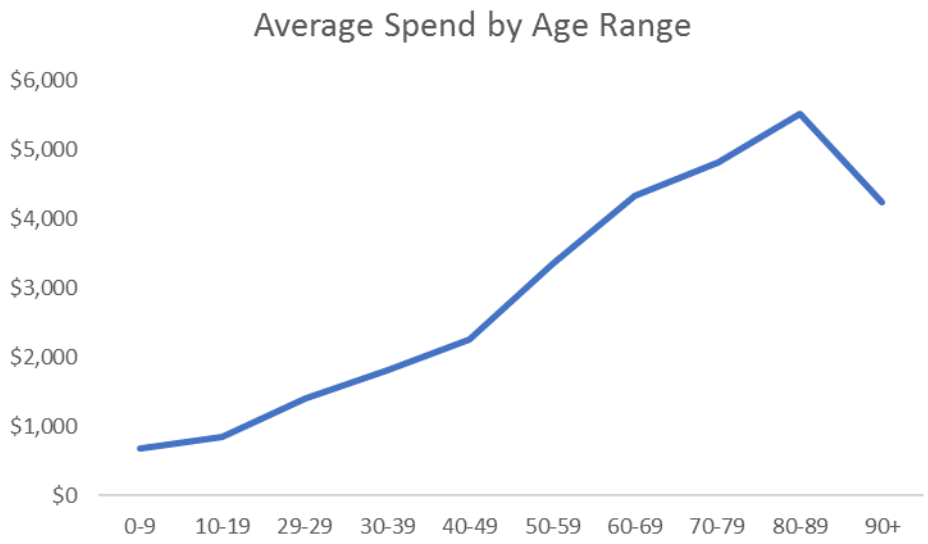
AgeRange

The AgeRange variable began at 1 and increased by one for each decade of life. People over 101 were grouped with people in their 90s. Average spend increased almost linearly with AgeRange.

Table B1: AgeRange Variable Groupings

AgeRange	Ages	N	Mean Spend	SD
1	0-9	38,385	$684	$2,427
2	10-19	32,621	$846	$4,759
3	29-29	38,425	$1,399	$6,807
4	30-39	36,467	$1,819	$7,933
5	40-49	32,326	$2,263	$11,533
6	50-59	43,853	$3,342	$15,535
7	60-69	40,963	$4,328	$16,872
8	70-79	29,757	$4,805	$15,460
9	80-89	16,802	$5,519	$15,368
10	90+	4,454	$4,232	$12,456
Total		**314,053**	**$2,629**	**$11,853**

Figure B1: Average Spend by Age Range



HCCCount

The HCCCount variable was the sum of the most significant HCC contributors to total cost. When the total count of all of the HCCs was used, the model became less accurate. Therefore, only the following HCCs were summed to create the HCCCount variable.

Table B2: HCCs used in the HCCCount Variable

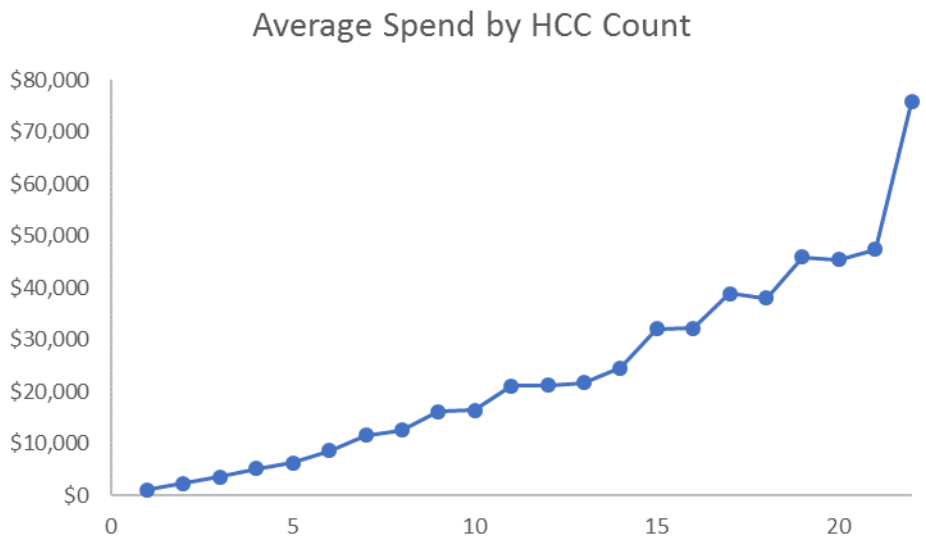
HCC002	HCC046	HCC086	HCC136	HHSHCC034	HHSHCC154
HCC008	HCC047	HCC087	HCC137	HHSHCC038	HHSHCC156
HCC009	HCC055	HCC088	HCC161	HHSHCC042	HHSHCC161
HCC010	HCC058	HCC099	HCC162	HHSHCC057	HHSHCC183
HCC011	HCC070	HCC103	HCC166	HHSHCC067	HHSHCC205
HCC012	HCC071	HCC104	HCC169	HHSHCC068	HHSHCC226
HCC017	HCC073	HCC106	HCC170	HHSHCC074	HHSHCC227
HCC018	HCC077	HCC107	HCC176	HHSHCC081	HHSHCC244
HCC021	HCC078	HCC108	HCC186	HHSHCC082	HHSHCC245
HCC022	HCC080	HCC111	HCC189	HHSHCC108	HHSHCC246
HCC023	HCC082	HCC112	HHSHCC004	HHSHCC114	HHSHCC251
HCC027	HCC083	HCC114	HHSHCC011	HHSHCC121	
HCC035	HCC084	HCC134	HHSHCC018	HHSHCC128	
HCC040	HCC085	HCC135	HHSHCC029	HHSHCC149	

Table B3: Counts, Average Spend, and SD by HCCCount

HCCCount	N	Mean Spend	SD
0	189,754	$1,140	$5,756
1	57,064	$2,417	$9,689
2	27,178	$3,587	$12,381
3	14,396	$5,214	$15,755
4	8,493	$6,403	$18,055
5	5,346	$8,735	$24,752
6	3,604	$11,661	$30,406
7	2,380	$12,643	$30,729
8	1,644	$16,258	$35,667
9	1,167	$16,500	$31,132
10	902	$21,089	$39,426
11	618	$21,298	$42,154
12	427	$21,758	$42,288
13	293	$24,653	$37,724
14	250	$32,162	$44,311
15	172	$32,290	$41,402
16	104	$38,908	$59,876
17	84	$38,075	$66,180

18	52	$45,930	$59,834
19	33	$45,414	$51,457
20	28	$47,372	$55,532
21 +	64	$75,802	$83,735
Total	**314,053**	**$2,629**	**$11,853**

Figure B2: Average Spend by HCCCount



CostWeight

The CostWeight variable was the sum of the annual spending range category values for the previous 5 years (2011-2015). The annual spending range category values were assigned as follows. The net result was a variable that ranged from 0-15, and was correlated with spend at r = .275.

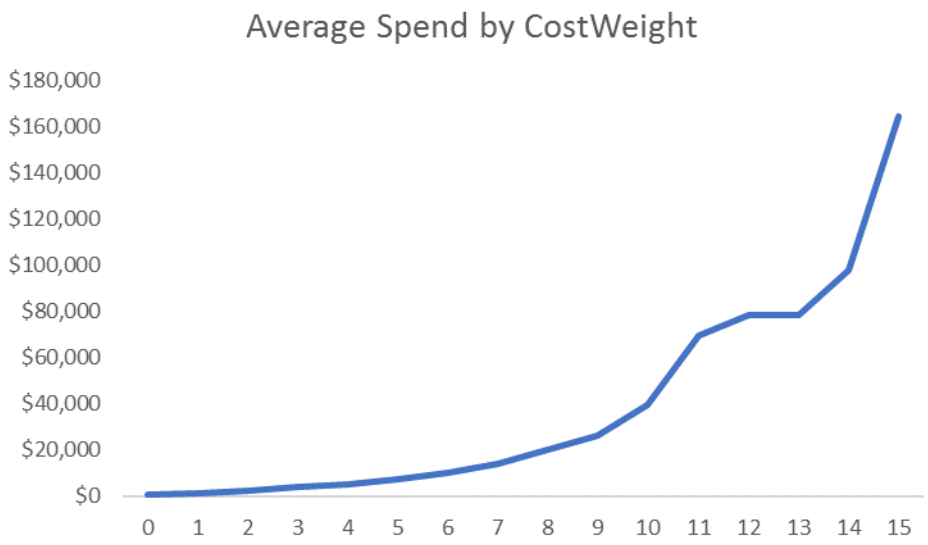
Table B4: Spending Range Crosswalk

Spending Range	Annual Spending Range Category Value
0-$999.99	0
$1,000-$9,999.99	1
$10,000-$199,999.99	2
$100,000 Plus	3

Table B5: Counts, Average Spend, and SD by CostWeight

CostWeight	N	Mean Spend	SD
0	115,100	$871	$5,505
1	80,709	$1,481	$7,354
2	52,808	$2,593	$10,410
3	26,108	$4,034	$14,994
4	16,735	$5,140	$15,286
5	10,353	$7,475	$20,938
6	5,917	$10,018	$22,363
7	3,040	$13,851	$27,642
8	1,576	$19,959	$35,622
9	800	$26,174	$40,908
10	668	$39,705	$38,161
11	120	$69,691	$85,959
12	59	$78,621	$81,889
13	23	$78,324	$62,959
14	17	$97,982	$77,592
15	20	$164,483	$70,351
Total	**314,053**	**$2,629**	**$11,853**

Figure B3: Average Spend by CostWeight

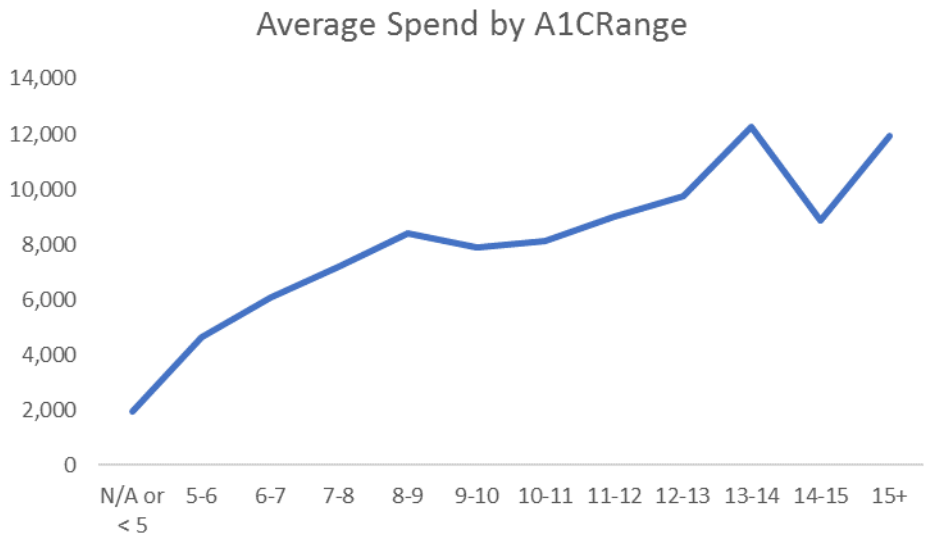


A1CRange

Table B5: Counts, Average Spend, and SD by A1CRange

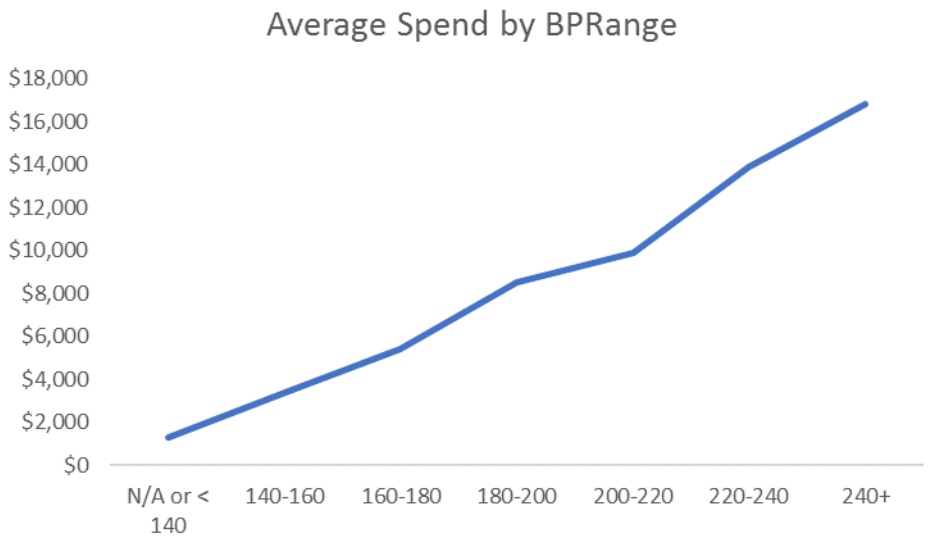
A1CRange	Highest A1C	N	Mean Spend	SD
0	N/A or < 5	263,881	1,959	9,677
1	5-6	20,817	4,628	14,812
2	6-7	13,668	6,077	18,312
3	7-8	5,248	7,207	20,728
4	8-9	3,328	8,380	25,434
5	9-10	2,324	7,890	23,364
6	10-11	1,655	8,128	23,812
7	11-12	1,166	8,992	26,006
8	12-13	810	9,745	27,442
9	13-14	605	12,276	39,584
10	14-15	270	8,844	23,185
11	15+	281	11,921	31,701
Total		**314,053**	**2,629**	**11,853**

Figure B4: Average Spend by A1CRange



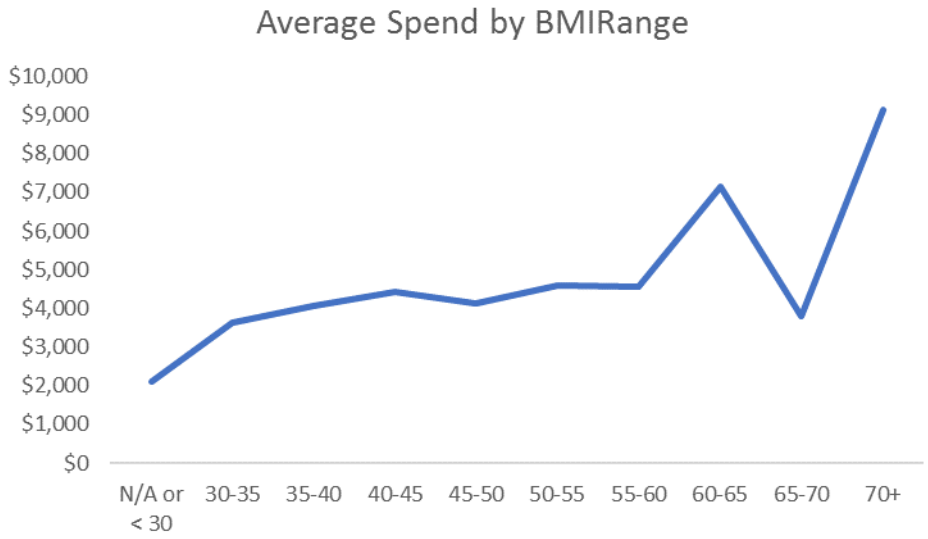
BPRange

BPRange	Highest BP	N	Mean Spend	SD
	N/A or <			
0	140	185,419	$1,321	$7,147
1	140-160	80,143	$3,387	$13,427
2	160-180	35,005	$5,412	$17,128
3	180-200	11,176	$8,489	$24,293
4	200-220	1,869	$9,889	$28,362
5	220-240	367	$13,868	$36,223
6	240+	74	$16,823	$48,957
Total		**314,053**	**$2,629**	**$11,853**



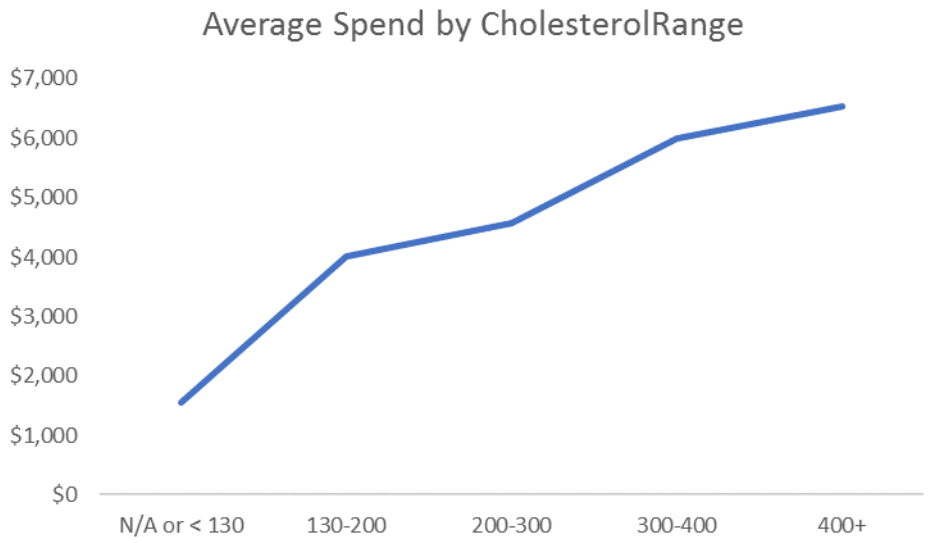
BMIRange

BMIRange	Highest BMI	N	Mean Spend	SD
0	N/A or < 30	222,272	$2,102	$10,291
1	30-35	50,260	$3,635	$14,109
2	35-40	24,203	$4,070	$15,668
3	40-45	10,404	$4,441	$16,440
4	45-50	4,179	$4,144	$13,582
5	50-55	1,644	$4,596	$16,293
6	55-60	629	$4,558	$15,183
7	60-65	248	$7,141	$21,980
8	65-70	106	$3,806	$10,474
9	70+	108	$9,122	$33,035
Total		**314,053**	**$2,629**	**$11,853**



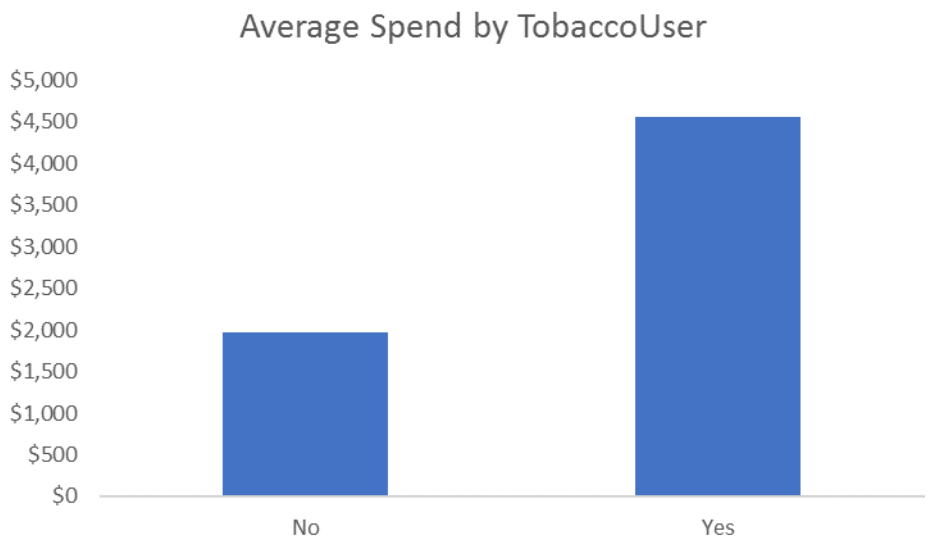
CholesterolRange

CholesterolRange	Highest Cholesterol	N	Mean Spend	SD
0	N/A or < 130	194,606	$1,553	$9,086
1	130-200	51,176	$4,007	$14,097
2	200-300	64,197	$4,573	$15,641
3	300-400	3,772	$6,005	$19,948
4	400+	302	$6,536	$15,079
Total		**314,053**	**$2,629**	**$11,853**



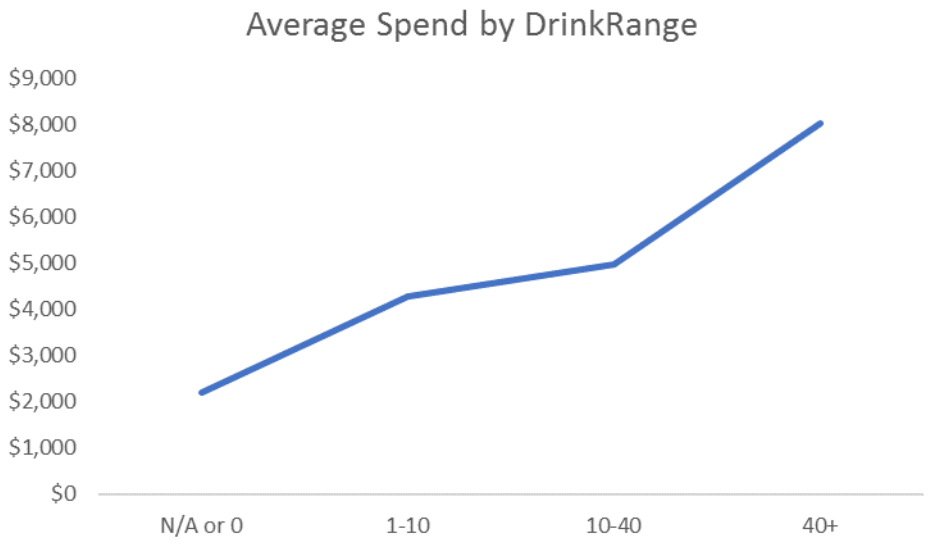
Cc

TobaccoUser	N	Mean Spend	SD
No	235,001	$1,976	$9,756
Yes	79,052	$4,568	$16,437
Total	**314,053**	**$2,629**	**$11,853**



DR

DrinkRange	Max Drinks/Week	N	Mean Spend	SD
0	N/A or 0	254,882	$2,204	$10,685
1	1-10	48,095	$4,290	$15,491
2	10-40	10,295	$4,964	$16,604
3	40+	781	$8,036	$22,148
Total		**314,053**	**$2,629**	**$11,853**



HealthScore

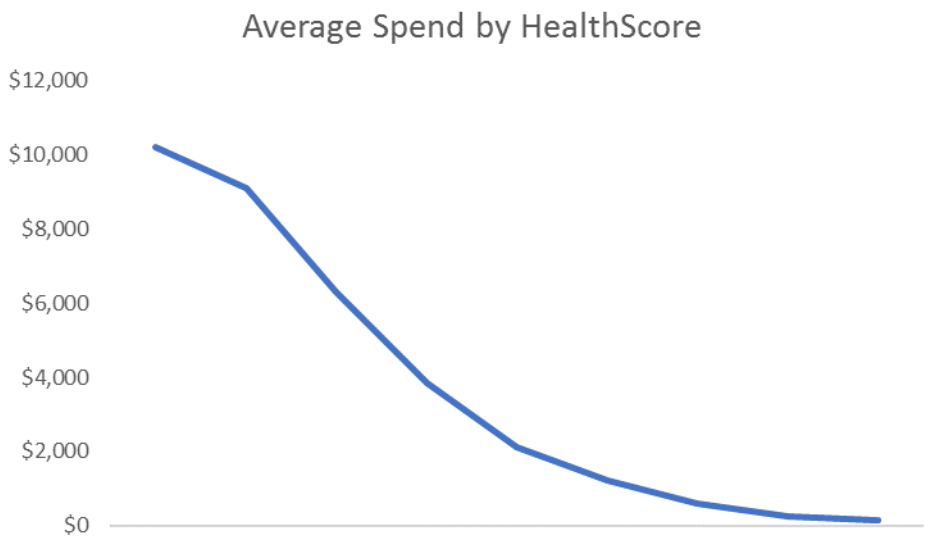
Healthscore is set to zero and then 1 is added for each of the following conditions that are met.

1. Age < 40
2. HCCTotalCount = 0
3. A1CRange = 0
4. BPRange = 0
5. TobaccoUser = 0
6. DrinkRange = 0
7. FY2015Payments = 0
8. FY2015Payments = 0 AND FY2014Payments = 0
9. FY2015Payments = 0 AND FY2014Payments = 0 AND FY2013Payments = 0
10. FY2015Payments = 0 AND FY2014Payments = 0 AND FY2013Payments = 0 AND FY2012Payments = 0

Table B6: Counts, Average Spend, and SD by HealthScore

HealthScore	N	Mean Spend	SD
0	4,402	$10,211	$23,294
1	17,686	$9,113	$24,193
2	34,491	$6,315	$19,530
3	44,311	$3,851	$14,039
4	49,036	$2,118	$9,661
5	68,933	$1,206	$5,439
6	58,996	$604	$3,296
7	26,682	$254	$1,846
8	9,516	$157	$1,132
Total	**314,053**	**$2,629**	**$11,853**

Figure B4: Average Spend by HealthScore



Appendix C: ***HCC Methodology: Combining HCCs***

HCCs are groups of ICD9 and ICD10 codes that relate to a category of illnesses. For example, the HCC001 classification includes all patients with a diagnosis of HIV/AIDS. CMS has 79 current HCC categories (Table B1) and HHS has 127 HCC categories (Table B2).

There is some general overlap between the CMS and HHS HCC categories, and it seemed that a reduction in total HCCs was possible by combining the two systems. Both CMS and HHS publish their ICD9 and ICD10 to HCC crosswalk files. Therefore, it was a relatively simple matter to collect the CCH ICD9 and ICD10 diagnoses from 2010 onwards and create a set of CMS-HCC and HHS-HCC classifications for each patient. Then, it was possible to look at the correlations between the two systems. Several HCC classifications were found to be either the same ($r = 1$) or very highly correlated ($r > .7$). For example, CMS-HCC 001 (HIV/AIDS) is the same as HHS-HCC 001 (HIV/AIDS).

The categories that were most highly correlated were grouped together, and 148 CMHN HCCs remained (Table B3). Note that the CMS and HHS HCC numbers did not always match exactly. For example, CMHN-HCC 026 is derived from CMS-HCC 029 (Chronic Hepatitis) and HHS-HCC 037 (Chronic Hepatitis). The correlation between the CMS-HCC and HHS-HCC classification systems is not perfect at $r=.744$. Even though CMS-HCC 029 and HHS-HCC 037 are both called the same thing (Chronic Hepatitis), the use slightly different ICD diagnoses in their definitions. Otherwise the correlation would be $r=1.000$. The method used to combine the closely related CMS and HHS HCCs is to set CMHN-HCC 026 = 1 if CMS-HCC 029 or HHS-HCC 037 is equal to 1.

Appendix C - Table C1: The CMS-HCC Definitions

HCC	Number	Description
HCC001	1	HIV/AIDS
HCC002	2	Septicemia, Sepsis, Systemic Inflammatory Response Syndrome/Shock
HCC006	6	Opportunistic Infections
HCC008	8	Metastatic Cancer and Acute Leukemia
HCC009	9	Lung and Other Severe Cancers
HCC010	10	Lymphoma and Other Cancers
HCC011	11	Colorectal, Bladder, and Other Cancers
HCC012	12	Breast, Prostate, and Other Cancers and Tumors
HCC017	17	Diabetes with Acute Complications
HCC018	18	Diabetes with Chronic Complications
HCC019	19	Diabetes without Complication
HCC021	21	Protein-Calorie Malnutrition
HCC022	22	Morbid Obesity
HCC023	23	Other Significant Endocrine and Metabolic Disorders
HCC027	27	End-Stage Liver Disease
HCC028	28	Cirrhosis of Liver
HCC029	29	Chronic Hepatitis
HCC033	33	Intestinal Obstruction/Perforation
HCC034	34	Chronic Pancreatitis
HCC035	35	Inflammatory Bowel Disease
HCC039	39	Bone/Joint/Muscle Infections/Necrosis
HCC040	40	Rheumatoid Arthritis and Inflammatory Connective Tissue Disease
HCC046	46	Severe Hematological Disorders
HCC047	47	Disorders of Immunity
HCC048	48	Coagulation Defects and Other Specified Hematological Disorders
HCC054	54	Drug/Alcohol Psychosis
HCC055	55	Drug/Alcohol Dependence
HCC057	57	Schizophrenia
HCC058	58	Major Depressive, Bipolar, and Paranoid Disorders
HCC070	70	Quadriplegia
HCC071	71	Paraplegia
HCC072	72	Spinal Cord Disorders/Injuries
HCC073	73	Amyotrophic Lateral Sclerosis and Other Motor Neuron Disease
HCC074	74	Cerebral Palsy
HCC075	75	Myasthenia Gravis/Myoneural Disorders and Guillain-Barre Syndrome/Inflammatory and Toxic Neuropathy
HCC076	76	Muscular Dsytrophy
HCC077	77	Multiple Sclerosis
HCC078	78	Parkinson's and Huntington's Diseases
HCC079	79	Seizure Disorders and Convulsions

HCC080	80	Coma, Brain Compression/Anoxic Damage
HCC082	82	Respirator Dependence/Tracheostomy Status
HCC083	83	Respiratory Arrest
HCC084	84	Cardio-Respiratory Failure and Shock
HCC085	85	Congestive Heart Failure
HCC086	86	Acute Myocardial Infarction
HCC087	87	Unstable Angina and Other Acute Ischemic Heart Disease
HCC088	88	Angina Pectoris
HCC096	96	Specified Heart Arrhythmias
HCC099	99	Cerebral Hemorrhage
HCC100	100	Ischemic or Unspecified Stroke
HCC103	103	Hemiplegia/Hemiparesis
HCC104	104	Monoplegia, Other Paralytic Syndromes
HCC106	106	Atherosclerosis of the Extremities with Ulceration or Gangrene
HCC107	107	Vascular Disease with Complications
HCC108	108	Vascular Disease
HCC110	110	Cystic Fibrosis
HCC111	111	Chronic Obstructive Pulmonary Disease
HCC112	112	Fibrosis of Lung and Other Chronic Lung Disorder
HCC114	114	Aspiration and Specified Bacterial Pneumonias
HCC115	115	Pneumococcal Pneumonia, Empyema, Lung Abscess
HCC122	122	Proliferative Diabetic Retinopathy and Vitreous Hemorrhage
HCC124	124	Exudative Macular Degeneration
HCC134	134	Dialysis Status
HCC135	135	Acute Renal Failure
HCC136	136	Chronic Kidney Disease (Stage 5)
HCC137	137	Chronic Kidney Disease, Severe (Stage 4)
HCC157	157	Pressure Ulcer of Skin with Necrosis Through to Muscle, Tendon, or Bone
HCC158	158	Pressure Ulcer of Skin with Full Thickness Skin Loss
HCC161	161	Chronic Ulcer of Skin, Except Pressure
HCC162	162	Severe Skin Burn or Condition
HCC166	166	Severe Head Injury
HCC167	167	Major Head Injury
HCC169	169	Vertebral Fractures without Spinal Cord Injury
HCC170	170	Hip Fracture/Dislocation
HCC173	173	Traumatic Amputations and Complications
HCC176	176	Complications of Specified Implanted Device or Graft
HCC186	186	Major Organ Transplant or Replacement Status
HCC188	188	Artificial Openings for Feeding or Elimination
HCC189	189	Amputation Status, Lower Limb/Amputation Complications

Appendix C - Table C2: The HHS-HCC Definitions

HHSHCC	Number	HHSHCC Description
HHSHCC001	1	HIV/AIDS
HHSHCC02	2	Septicemia, Sepsis, Systemic Inflammatory Response Syndrome/Shock
HHSHCC003	3	Central Nervous System Infections, Except Viral Meningitis
HHSHCC004	4	Viral or Unspecified Meningitis
HHSHCC006	6	Opportunistic Infections
HHSHCC008	8	Metastatic Cancer
HHSHCC009	9	Lung, Brain, and Other Severe Cancers, Including Pediatric Acute Lymphoid Leukemia
HHSHCC010	10	Non-Hodgkin's Lymphomas and Other Cancers and Tumors
HHSHCC011	11	Colorectal, Breast (Age < 50), Kidney, and Other Cancers
HHSHCC012	12	Breast (Age 50+) and Prostate Cancer, Benign/Uncertain Brain Tumors, and Other Cancers and Tumors
HHSHCC013	13	Thyroid Cancer, Melanoma, Neurofibromatosis, and Other Cancers and Tumors
HHSHCC018	18	Pancreas Transplant Status/Complications
HHSHCC019	19	Diabetes with Acute Complications
HHSHCC020	20	Diabetes with Chronic Complications
HHSHCC021	21	Diabetes without Complication
HHSHCC023	23	Protein-Calorie Malnutrition
HHSHCC026	26	Mucopolysaccharidosis
HHSHCC027	27	Lipidoses and Glycogenosis
HHSHCC028	28	Congenital Metabolic Disorders, Not Elsewhere Classified
HHSHCC029	29	Amyloidosis, Porphyria, and Other Metabolic Disorders
HHSHCC030	30	Adrenal, Pituitary, and Other Significant Endocrine Disorders
HHSHCC034	34	Liver Transplant Status/Complications
HHSHCC035	35	End-Stage Liver Disease
HHSHCC036	36	Cirrhosis of Liver
HHSHCC037	37	Chronic Hepatitis
HHSHCC038	38	Acute Liver Failure/Disease, Including Neonatal Hepatitis
HHSHCC041	41	Intestine Transplant Status/Complications
HHSHCC042	42	Peritonitis/Gastrointestinal Perforation/Necrotizing Enterocolitis
HHSHCC045	45	Intestinal Obstruction
HHSHCC046	46	Chronic Pancreatitis
HHSHCC047	47	Acute Pancreatitis/Other Pancreatic Disorders and Intestinal Malabsorption
HHSHCC048	48	Inflammatory Bowel Disease
HHSHCC054	54	Necrotizing Fasciitis
HHSHCC055	55	Bone/Joint/Muscle Infections/Necrosis
HHSHCC056	56	Rheumatoid Arthritis and Specified Autoimmune Disorders
HHSHCC057	57	Systemic Lupus Erythematosus and Other Autoimmune Disorders
HHSHCC061	61	Osteogenesis Imperfecta and Other Osteodystrophies
HHSHCC062	62	Congenital/Developmental Skeletal and Connective Tissue Disorders
HHSHCC063	63	Cleft Lip/Cleft Palate

HHSHCC064	64	Major Congenital Anomalies of Diaphragm, Abdominal Wall, and Esophagus, Age < 2
HHSHCC066	66	Hemophilia
HHSHCC067	67	Myelodysplastic Syndromes and Myelofibrosis
HHSHCC068	68	Aplastic Anemia
HHSHCC069	69	Acquired Hemolytic Anemia, Including Hemolytic Disease of Newborn
HHSHCC070	70	Sickle Cell Anemia (Hb-SS)
HHSHCC071	71	Thalassemia Major
HHSHCC073	73	Combined and Other Severe Immunodeficiencies
HHSHCC074	74	Disorders of the Immune Mechanism
HHSHCC075	75	Coagulation Defects and Other Specified Hematological Disorders
HHSHCC081	81	Drug Psychosis
HHSHCC082	82	Drug Dependence
HHSHCC087	87	Schizophrenia
HHSHCC088	88	Major Depressive and Bipolar Disorders
HHSHCC089	89	Reactive and Unspecified Psychosis, Delusional Disorders
HHSHCC090	90	Personality Disorders
HHSHCC094	94	Anorexia/Bulimia Nervosa
HHSHCC096	96	Prader-Willi, Patau, Edwards, and Autosomal Deletion Syndromes
HHSHCC097	97	Down Syndrome, Fragile X, Other Chromosomal Anomalies, and Congenital Malformation Syndromes
HHSHCC102	102	Autistic Disorder
HHSHCC103	103	Pervasive Developmental Disorders, Except Autistic Disorder
HHSHCC106	106	Traumatic Complete Lesion Cervical Spinal Cord
HHSHCC107	107	Quadriplegia
HHSHCC108	108	Traumatic Complete Lesion Dorsal Spinal Cord
HHSHCC109	109	Paraplegia
HHSHCC110	110	Spinal Cord Disorders/Injuries
HHSHCC111	111	Amyotrophic Lateral Sclerosis and Other Anterior Horn Cell Disease
HHSHCC112	112	Quadriplegic Cerebral Palsy
HHSHCC113	113	Cerebral Palsy, Except Quadriplegic
HHSHCC114	114	Spina Bifida and Other Brain/Spinal/Nervous System Congenital Anomalies
HHSHCC115	115	Myasthenia Gravis/Myoneural Disorders and Guillain-Barre Syndrome/Inflammatory and Toxic Neuropathy
HHSHCC117	117	Muscular Dystrophy
HHSHCC118	118	Multiple Sclerosis
HHSHCC119	119	Parkinson's, Huntington's, and Spinocerebellar Disease, and Other Neurodegenerative Disorders
HHSHCC120	120	Seizure Disorders and Convulsions
HHSHCC121	121	Hydrocephalus
HHSHCC122	122	Non-Traumatic Coma, Brain Compression/Anoxic Damage
HHSHCC125	125	Respirator Dependence/Tracheostomy Status
HHSHCC126	126	Respiratory Arrest
HHSHCC127	127	Cardio-Respiratory Failure and Shock, Including Respiratory Distress Syndromes

HHSHCC128	128	Heart Assistive Device/Artificial Heart
HHSHCC129	129	Heart Transplant
HHSHCC130	130	Congestive Heart Failure
HHSHCC131	131	Acute Myocardial Infarction
HHSHCC132	132	Unstable Angina and Other Acute Ischemic Heart Disease
HHSHCC135	135	Heart Infection/Inflammation, Except Rheumatic
HHSHCC137	137	Hypoplastic Left Heart Syndrome and Other Severe Congenital Heart Disorders
HHSHCC138	138	Major Congenital Heart/Circulatory Disorders
HHSHCC139	139	Atrial and Ventricular Septal Defects, Patent Ductus Arteriosus, and Other Congenital Heart/Circulatory Disorders
HHSHCC142	142	Specified Heart Arrhythmias
HHSHCC145	145	Intracranial Hemorrhage
HHSHCC146	146	Ischemic or Unspecified Stroke
HHSHCC149	149	Cerebral Aneurysm and Arteriovenous Malformation
HHSHCC150	150	Hemiplegia/Hemiparesis
HHSHCC151	151	Monoplegia, Other Paralytic Syndromes
HHSHCC153	153	Atherosclerosis of the Extremities with Ulceration or Gangrene
HHSHCC154	154	Vascular Disease with Complications
HHSHCC156	156	Pulmonary Embolism and Deep Vein Thrombosis
HHSHCC158	158	Lung Transplant Status/Complications
HHSHCC159	159	Cystic Fibrosis
HHSHCC160	160	Chronic Obstructive Pulmonary Disease, Including Bronchiectasis
HHSHCC161	161	Asthma
HHSHCC162	162	Fibrosis of Lung and Other Lung Disorders
HHSHCC163	163	Aspiration and Specified Bacterial Pneumonias and Other Severe Lung Infections
HHSHCC183	183	Kidney Transplant Status
HHSHCC184	184	End Stage Renal Disease
HHSHCC187	187	Chronic Kidney Disease, Stage 5
HHSHCC188	188	Chronic Kidney Disease, Severe (Stage 4)
HHSHCC203	203	Ectopic and Molar Pregnancy, Except with Renal Failure, Shock, or Embolism
HHSHCC204	204	Miscarriage with Complications
HHSHCC205	205	Miscarriage with No or Minor Complications
HHSHCC207	207	Completed Pregnancy With Major Complications
HHSHCC208	208	Completed Pregnancy With Complications
HHSHCC209	209	Completed Pregnancy with No or Minor Complications
HHSHCC217	217	Chronic Ulcer of Skin, Except Pressure
HHSHCC226	226	Hip Fractures and Pathological Vertebral or Humerus Fractures
HHSHCC227	227	Pathological Fractures, Except of Vertebrae, Hip, or Humerus
HHSHCC242	242	Extremely Immature Newborns, Birthweight < 500 Grams
HHSHCC243	243	Extremely Immature Newborns, Including Birthweight 500-749 Grams
HHSHCC244	244	Extremely Immature Newborns, Including Birthweight 750-999 Grams
HHSHCC245	245	Premature Newborns, Including Birthweight 1000-1499 Grams
HHSHCC246	246	Premature Newborns, Including Birthweight 1500-1999 Grams

HHSHCC247	247	Premature Newborns, Including Birthweight 2000-2499 Grams
HHSHCC248	248	Other Premature, Low Birthweight, Malnourished, or Multiple Birth Newborns
HHSHCC249	249	Term or Post-Term Singleton Newborn, Normal or High Birthweight
HHSHCC251	251	Stem Cell, Including Bone Marrow, Transplant Status/Complications
HHSHCC253	253	Artificial Openings for Feeding or Elimination
HHSHCC254	254	Amputation Status, Lower Limb/Amputation Complications

Appendix C - Table C3: The CMHN-HCC Definitions

CMHN-HCC	CMHN-HCC Description	CMS-HCC	HHS-HCC	Correlation
1	HIV/AIDS	1	1	.922
2	Septicemia, Sepsis, Systemic Inflammatory Response Syndrome/Shock	2	2	.967
3	Central Nervous System Infections, Except Viral Meningitis		3	
4	Viral or Unspecified Meningitis		4	
5	Opportunistic Infections	6	6	.896
6	Metastatic Cancer and Acute Leukemia	8	8	.927
7	Lung and Other Severe Cancers	9	9	.928
8	Lymphoma and Other Cancers	10	10	.753
9	Colorectal, Bladder, and Other Cancers	11	11	
10	Breast, Prostate, and Other Cancers and Tumors	12	12	.845
11	Thyroid Cancer, Melanoma, Neurofibromatosis, and Other Cancers and Tumors		13	
12	Pancreas Transplant Status/Complications		18	
13	Diabetes with Acute Complications	17	19	1.000
14	Diabetes with Chronic Complications	18	20	1.000
15	Diabetes without Complication	19	21	1.000
16	Protein-Calorie Malnutrition	21	23	1.000
17	Mucopolysaccharidosis		26	
18	Lipidoses and Glycogenosis		27	
19	Congenital Metabolic Disorders, Not Elsewhere Classified		28	
20	Morbid Obesity	22		
21	Amyloidosis, Porphyria, and Other Metabolic Disorders		29	
22	Other Significant Endocrine and Metabolic Disorders	23	30	.940
23	Liver Transplant Status/Complications		34	
24	End-Stage Liver Disease	27	35	1.000
25	Cirrhosis of Liver	28	36	1.000
26	Chronic Hepatitis	29	37	.744
27	Acute Liver Failure/Disease, Including Neonatal Hepatitis		38	
28	Intestine Transplant Status/Complications		41	
29	Peritonitis/Gastrointestinal Perforation/Necrotizing Enterocolitis		42	
30	Intestinal Obstruction/Perforation	33	45	.871
31	Chronic Pancreatitis	34	46	1.000
32	Acute Pancreatitis/Other Pancreatic Disorders and Intestinal Malabsorption		47	
33	Inflammatory Bowel Disease	35	48	.999

34	Necrotizing Fasciitis		54	
35	Bone/Joint/Muscle Infections/Necrosis	39	55	.798
36	Rheumatoid Arthritis and Inflammatory Connective Tissue Disease	40	56	.767
37	Severe Hematological Disorders	46		
38	Disorders of Immunity	47		
39	Coagulation Defects and Other Specified Hematological Disorders	48		
40	Drug/Alcohol Psychosis	54		
41	Drug/Alcohol Dependence	55		
42	Systemic Lupus Erythematosus and Other Autoimmune Disorders		57	
43	Osteogenesis Imperfecta and Other Osteodystrophies		61	
44	Congenital/Developmental Skeletal and Connective Tissue Disorders		62	
45	Cleft Lip/Cleft Palate		63	
46	Major Congenital Anomalies of Diaphragm, Abdominal Wall, and Esophagus, Age < 2		64	
47	Hemophilia		66	
48	Myelodysplastic Syndromes and Myelofibrosis		67	
49	Aplastic Anemia		68	
50	Acquired Hemolytic Anemia, Including Hemolytic Disease of Newborn		69	
51	Sickle Cell Anemia (Hb-SS)		70	
52	Thalassemia Major		71	
53	Combined and Other Severe Immunodeficiencies		73	
54	Disorders of the Immune Mechanism		74	
55	Coagulation Defects and Other Specified Hematological Disorders		75	
56	Drug Psychosis		81	
57	Drug Dependence		82	
58	Schizophrenia	57	87	1.000
59	Major Depressive, Bipolar, and Paranoid Disorders	58	88	.949
60	Reactive and Unspecified Psychosis, Delusional Disorders		89	
61	Personality Disorders		90	
62	Anorexia/Bulimia Nervosa		94	
63	Prader-Willi, Patau, Edwards, and Autosomal Deletion Syndromes		96	
64	Down Syndrome, Fragile X, Other Chromosomal Anomalies, and Congenital Malformation Syndromes		97	
65	Autistic Disorder		102	
66	Pervasive Developmental Disorders, Except Autistic Disorder		103	
67	Traumatic Complete Lesion Cervical Spinal Cord		106	

68	Quadriplegia	70	107	.997
69	Traumatic Complete Lesion Dorsal Spinal Cord		108	
70	Paraplegia	71	109	.998
71	Spinal Cord Disorders/Injuries	72	110	.756
72	Amyotrophic Lateral Sclerosis and Other Motor Neuron Disease	73	111	.816
73	Quadriplegic Cerebral Palsy		112	
74	Cerebral Palsy	74	113	.977
75	Spina Bifida and Other Brain/Spinal/Nervous System Congenital Anomalies		114	
76	Myasthenia Gravis/Myoneural Disorders and Guillain-Barre Syndrome/Inflammatory and Toxic Neuropathy	75	115	1.000
77	Muscular Dsytrophy	76	117	1.000
78	Multiple Sclerosis	77	118	.980
79	Parkinson's and Huntington's Diseases	78	119	.924
80	Seizure Disorders and Convulsions	79	120	.999
81	Hydrocephalus		121	
82	Coma, Brain Compression/Anoxic Damage	80	122	.985
83	Respirator Dependence/Tracheostomy Status	82	125	1.000
84	Respiratory Arrest	83	126	.955
85	Cardio-Respiratory Failure and Shock	84	127	.919
86	Heart Assistive Device/Artificial Heart		128	
87	Heart Transplant		129	
88	Congestive Heart Failure	85	130	1.000
89	Acute Myocardial Infarction	86	131	1.000
90	Unstable Angina and Other Acute Ischemic Heart Disease	87	132	1.000
91	Angina Pectoris	88		
92	Heart Infection/Inflammation, Except Rheumatic		135	
93	Hypoplastic Left Heart Syndrome and Other Severe Congenital Heart Disorders		137	
94	Major Congenital Heart/Circulatory Disorders		138	
95	Atrial and Ventricular Septal Defects, Patent Ductus Arteriosus, and Other Congenital Heart/Circulatory Disorders		139	
96	Specified Heart Arrhythmias	96	142	1.000
97	Cerebral Hemorrhage	99	145	.983
98	Ischemic or Unspecified Stroke	100	146	.940
99	Cerebral Aneurysm and Arteriovenous Malformation		149	
100	Hemiplegia/Hemiparesis	103	150	1.000
101	Monoplegia, Other Paralytic Syndromes	104	151	.997
102	Atherosclerosis of the Extremities with Ulceration or Gangrene	106	153	.986
103	Vascular Disease with Complications	107		

104	Vascular Disease	108		
105	Vascular Disease with Complications		154	
106	Pulmonary Embolism and Deep Vein Thrombosis		156	
107	Lung Transplant Status/Complications		158	
108	Cystic Fibrosis	110	159	1.000
109	Chronic Obstructive Pulmonary Disease	111	160	.987
110	Asthma		161	
111	Fibrosis of Lung and Other Chronic Lung Disorder	112	162	.940
112	Aspiration and Specified Bacterial Pneumonias	114	163	.853
113	Pneumococcal Pneumonia, Empyema, Lung Abscess	115		
114	Proliferative Diabetic Retinopathy and Vitreous Hemorrhage	122		
115	Exudative Macular Degeneration	124		
116	Kidney Transplant Status		183	
117	Dialysis Status	134	184	.858
118	Acute Renal Failure	135		
119	Chronic Kidney Disease (Stage 5)	136	187	.935
120	Chronic Kidney Disease, Severe (Stage 4)	137	188	.999
121	Pressure Ulcer of Skin with Necrosis Through to Muscle, Tendon, or Bone	157		
122	Pressure Ulcer of Skin with Full Thickness Skin Loss	158		
123	Ectopic and Molar Pregnancy, Except with Renal Failure, Shock, or Embolism		203	
124	Miscarriage with Complications		204	
125	Miscarriage with No or Minor Complications		205	
126	Completed Pregnancy With Major Complications		207	
127	Completed Pregnancy With Complications		208	
128	Completed Pregnancy with No or Minor Complications		209	
129	Chronic Ulcer of Skin, Except Pressure	161	217	.981
130	Severe Skin Burn or Condition	162		
131	Severe Head Injury	166		
132	Major Head Injury	167		
133	Vertebral Fractures without Spinal Cord Injury	169		
134	Hip Fracture/Dislocation	170		
135	Traumatic Amputations and Complications	173		
136	Complications of Specified Implanted Device or Graft	176		
137	Major Organ Transplant or Replacement Status	186		
138	Hip Fractures and Pathological Vertebral or Humerus Fractures		226	
139	Pathological Fractures, Except of Vertebrae, Hip, or Humerus		227	
140	Extremely Immature Newborns, Birthweight < 500 Grams		242	

141	Extremely Immature Newborns, Including Birthweight 500-749 Grams		243	
142	Extremely Immature Newborns, Including Birthweight 750-999 Grams		244	
143	Premature Newborns, Including Birthweight 1000-1499 Grams		245	
144	Premature Newborns, Including Birthweight 1500-1999 Grams		246	
145	Premature Newborns, Including Birthweight 2000-2499 Grams		247	
146	Other Premature, Low Birthweight, Malnourished, or Multiple Birth Newborns		248	
147	Term or Post-Term Singleton Newborn, Normal or High Birthweight		249	
148	Stem Cell, Including Bone Marrow, Transplant Status/Complications		251	
149	Artificial Openings for Feeding or Elimination	188	253	1.000
150	Amputation Status, Lower Limb/Amputation Complications	189	254	1.000