The Hilltop Pre-AH Model™
In Brief
October 2019

1. Intended Use

The Hilltop Pre-AH Model™ risk scores are intended to add value to the primary care transformation process by facilitating improved efficiency in the allocation of scarce care coordination resources. Theoretically, if such resources are limited and the patients in a given practice panel differ in the benefit they would obtain through care coordination, then patient outcomes are optimized by focusing those care coordination resources on the patients for whom these resources will generate the most benefit.[1]

Hilltop conceptualizes benefit, in this context, as the avoidance of a patient-specific adverse event. Many distinct adverse events are possible (ranging from disease onset to institutionalization to death), but given the emphasis of the MDPCP on the reduction of unneeded utilization, the risk model focuses on *potentially avoidable* hospitalization or ED visits.[2]

It is crucial that the risk scores are as accurate as possible: ideally, the riskiest individuals as identified by the model have the highest actual likelihood of incurring an avoidable hospitalization in the next month, and the individuals identified by the model as lowest risk have the lowest actual likelihood of incurring an avoidable hospitalization in the next month.

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[1] There is some evidence to suggest that different patients receive different benefits from care coordination services. Researchers have found that proactive care coordination interventions for patients with a high risk of hospitalization have so far led to reductions in avoidable hospitalizations, ED utilization, and readmissions for the Medicaid population but not the Medicare population (Berkowitz et al., 2018).

[2] Potentially avoidable hospitalizations/ED visits are those incurred for medical conditions or diagnoses "for which timely and effective outpatient care can help to reduce the risks of hospitalization by either preventing the onset of an illness or condition, controlling an acute episodic illness or condition, or managing a chronic disease or condition" (Billings et al., 1993). This measure is discussed in greater detail in Section 3.2.1 of *Maryland Primary Care Program (MDPCP) Pre-AH Risk Score Specifications and Codebook, Version 1,* dated October 3, 2019.

a. Differentiation from CMS HCC Risk Scores

It is important to note that the Hilltop Pre-AH Model™ risk scores are conceptually distinct from the CMS Hierarchical Condition Category (HCC) risk scores that are currently presented in CRISP. The Hilltop Pre-AH Model™ risk scores use risk factors based on diagnoses, procedures, medications, utilization, demographics, and geographic factors in order to produce a practice-specific ranking of patient risk of avoidable hospital events within the next month. The CMS HCC risk scores are based on a model that uses diagnosis codes and a limited set of demographic information from a base year in order to predict *expenditures* over the following year. There is likely to be some overlap among individuals who incur an avoidable hospitalization and individuals who experience high medical spending, but the overlap is unlikely to be complete.[3] High medical expenditure can reflect a number of factors ranging from moderate utilization of high-cost procedures, high utilization of moderate-cost procedures, underlying morbidity, or geographic differences in treatment or referral practices.

The CMS HCC risk score was developed as a capitated payment risk adjustment methodology for Medicare Advantage participants in order to "address [the] issue of risk selection and to compensate Medicare Advantage health plans for accepting the risk of enrolling beneficiaries of varying health statuses" (CMS, 2018, pp. 9-10). Additionally, "the underlying risk assessment is designed to accurately explain the variation at the group level, not at the individual level, because risk adjustment is applied to large groups" (CMS, 2018, pp. 9-10). Note that "risk" for the CMS HCC risk model refers to *actuarial* risk: this model seeks to predict average expenditures over large groups of individuals. In contrast, the Hilltop Pre-AH Model™ risk score is designed to estimate, as closely as possible, event risk: that is, an *individual's* risk of an avoidable hospital event in the following month.

There are also differences in the time horizons of each risk score. CMS HCC "final risk scores are generally available 16-18 months after the close of the base year. For example, 2017 risk scores (based on 2016 diagnoses) will be available in the spring of 2018" (Center for Medicare & Medicaid Innovation, 2017, p. 26). The Hilltop Pre-AH Model™ risk scores, however, are updated monthly and use patient-level risk factor information current to the most recently available month of Medicare claims in order to generate risk scores. This is a strength of the Hilltop Pre-AH Model™: these risk scores reflect the underlying patient condition with a lag of only, at most, two months.[4] Finally, by definition, avoidable hospital events are preventable through timely

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[3] Internal testing shows a limited degree of substitutability between the two sets of risk scores. Specifically, we find that the Hilltop Pre-AH Model™ outperforms the CMS HCC risk score in predicting avoidable hospitalization in the following month: of the top 10 percent riskiest individuals ranked by each risk score, the Hilltop Pre-AH Model™ correctly identifies 45-50 percent of all avoidable hospital events, while the CMS HCC risk score identifies approximately 30 percent. Both concentration curves are presented in Section 4.2 of *Maryland Primary Care Program (MDPCP) Pre-AH Risk Score Specifications and Codebook, Version 1,* dated October 3, 2019.

[4] This lag depends on the timing of two factors: the receipt of CCLF claims by Hilltop, and the publication of the risk scores by CRISP. For example, claims data delivered to Hilltop in mid-August 2019 reflect utilization through mid-July 2019. Hilltop uses these July 2019 risk factors to generate risk scores that reflect the likelihood of incurring an avoidable hospital event in August 2019. These scores, then, will be vended to participating practices in the CRISP update in mid-September 2019.

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primary care and so, in principle, the identification and management of individuals at high risk of incurring an avoidable hospitalization may result in the avoidance of that particular hospitalization event. High medical expenditures, however, may reflect underlying morbidities that would necessitate utilization *regardless* of primary care intervention.

Hypothetical Patient Panel

Patient Name	Pre-AH Risk Score (%)	CMS Risk Tier
Patient 1	75%	Complex[5]
Patient 2	15%	Complex
Patient 3	5%	Tier 4
Patient 4	4%	Complex
Patient 5	2%	Tier 3
Patient 6	1%	Tier 3
Patient 7	Less than 1%	Tier 2
Patient 8	Less than 1%	Tier 2
Patient 9	Less than 1%	Tier 1
Patient 10	Less than 1%	Tier 2
Patient 11	Less than 1%	Tier 1
Patient 12	Less than 1%	Tier 1
Patient 13	Less than 1%	Tier 1

Patients in this practice are listed in descending order of risk. Based on the most recently available month of risk factors spanning diagnoses, procedures, medications, utilization, demographics, and geographic information, in conjunction with risk coefficients derived from training data, Patient 1 (or, equivalently, the ten patients represented by Patient 1) has a 75 percent chance of incurring an avoidable hospital event next month.[6] Patient 2 is the next riskiest, and has a 15 percent chance of incurring an avoidable hospital event. Patient 3 is the next riskiest, with a 5 percent chance. The distribution of risk is highly skewed: the majority of the practice's panel has less than 1 percent chance of incurring an avoidable hospitalization in

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[5] It is important to note that while the CMS risk tier is correlated with Hilltop Pre-AH Model™ risk scores, the correlation is not perfect for two reasons: first, CMS risk tiers are based on underlying HCC score, which is conceptually distinct from the Pre-AH risk score. Second, certain groups of patients are automatically assigned to certain CMS risk tiers, which further reduces the correlation between the two measures. In particular, beneficiaries without sufficiently long clinical histories are assigned to CMS risk tier 2, while beneficiaries with "a diagnosis of dementia, substance use disorder, or severe and persistent mental illness" are assigned to the Complex tier, regardless of their HCC score (CMMI, 2019). These individuals may, in turn, have relatively low (or high) risk of avoidable hospitalizations, meaning that an individual in, for example, the Complex CMS risk tier may have a low Pre-AH risk score. We highlight this point in this table by presenting a non-monotonic relationship between Pre-AH risk score and CMS risk tier.

[6] See Section 3.2 of *Maryland Primary Care Program (MDPCP) Pre-AH Risk Score Specifications and Codebook, Version 1,* dated October 3, 2019, for a more detailed discussion of the training and scoring process.

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the following month, and all but two of the patients have under a 6 percent event risk.[7]

Based on the MDPCP Care Management Fee (CMF) structure, this practice would receive $2,600 each month.[8] Distributing the CMF revenue equally across all 130 underlying patients would result in each patient receiving $20.00 of advanced primary care services each month. This distribution is unlikely to have a significant impact on patient outcomes: the low-risk individuals would be low-risk even without the advanced primary care intervention, and the high-risk individuals may require more resource-intensive interventions in order to experience improvement in outcomes.[9] Instead, if the practice concentrated the care management resources on the riskiest twenty patients, then it could devote $130 per month to each these patients, thus potentially allowing for weekly contact. Greater contact, in turn, may improve outcomes for these riskiest individuals who are in greatest need of assistance. The efficient allocation of resources requires that the distribution of care management resources match the distribution of risk.[10]

b. Business Process

Hilltop remains agnostic as to the particular types of interventions that are best-suited for the high-risk MDPCP population. Many interventions are possible, ranging from medication reconciliation to patient education to scheduling assistance, and patients are likely to respond best to different interventions based on their clinical and social needs. Interested readers should see published best practices in care coordination and care management.[11] Whatever the intervention strategy, Hilltop recommends that care managers and other users of the Hilltop Pre-AH Model™ risk score allocate their effort first to individuals with the highest risk of incurring an avoidable hospital event in the following month. For details on the user interface of the Hilltop Pre-AH Model™ risk scores, readers should see the CRISP user manual.[12]

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[7] While the data for this clinical vignette are hypothetical, the Hilltop Pre-AH Model™ risk scores are, in actuality, even more skewed: the average probability of incurring a future hospitalization is roughly 0.5 percent, while the maximum probability in the MDPCP cohort is greater than 99 percent.

[8] $50 for each of the 30 patients in the Complex tier; $30 for each of the 10 patients in Tier 4; $16 for each of the 20 patients in Tier 3; $8 for each of the 30 patients in Tier 2; and $6 for each of the 40 patients in Tier 1. For the purposes of this clinical vignette, we do not account for the Performance-Based Incentive Payment (PBIP), although this would potentially add $325 per month to this practice's MDPCP revenues.

[9] Liaw et al. (2015) conclude that, based on a review of four CMS-funded demonstrations involving care management fees, "to generate savings, resource allocation cannot be homogeneous. Instead, practices must focus more intensely on those at highest risk of utilization" (p. 557). Indeed, this may (partly) explain the varying effectiveness of care management, care coordination, and intensive primary care interventions as documented in the academic literature; many patients have low underlying risk of adverse outcomes, thus obviating the need for intervention, and the few high-risk patients may require significant intervention resources. For summaries of the literature on this subject, see Edwards et al. (2017) and Baker et al. (2018).

[10] Peikes et al. (2009) review the Medicare Coordinated Care Demonstration, in which 15 primary care practices implemented randomized controlled trials of coordinated care interventions from 2002 to 2006. The authors conclude that "programs with substantial in person contact that target moderate to severe patients can be cost-neutral and improve some aspects of care" (p. 603).

[11] See examples at Hong et al. (2014); McCarthy et al. (2015); and Anderson et al. (2015).

[12] https://crisphealth.org/resources/training-materials/

c. Reason for Risk

Currently, the Hilltop Pre-AH Model™ risk scores are individuals' probabilities of incurring an avoidable hospitalization in the following month. This probability is derived from a rich data set of risk factors—ranging from demographics to clinical diagnoses to geographical and social determinants of health—to which risk coefficients from a training model are applied. Each attributed MDPCP beneficiary will receive an updated score each month that reflects new risk factor information derived from Medicare claims in the previous month.

In a release planned for later this year, the Hilltop Pre-AH Model™ risk score will be accompanied by the three largest "reasons for risk" for each patient in a practice. The practice-specific risk score view on CRISP will be augmented to include those risk factors which contribute the most to each patient's risk of incurring an avoidable hospital event in the following month. For example, in the table above, Patient 1 might have "history of previous avoidable hospitalizations," "age," and "heart failure diagnosis" as the three most important reasons for risk. This information is intended to allow for the implementation of patient-specific, near-to-real-time, tailored interventions based on statistically validated risk factors. This functionality is currently in development.

2. Technical Implementation

This section presents details on data sources, risk factors, and methodology.

a. Data Sources

The Hilltop Pre-AH Model™ relies largely on data from Claim and Claim Line Feed (CCLF) Medicare claims files, supplemented with various publicly available environmental data sets used to generate the environmental risk factors. These data sources are detailed below.

i. CCLF Data

The majority of the risk factors in the Hilltop Pre-AH Model™ are derived from CCLF Medicare Parts A, B, and D claims files. Each month, Hilltop receives Part A claims, Part A revenue centers, Part A procedure codes, Part A diagnosis codes, Part B claim lines, Part B durable medical equipment claims, Part D claims, and patient demographic information (which also includes eligibility information) from CMS.[13] Additionally, Hilltop receives beneficiary attribution files and practice rosters each quarter.

Upon receipt of the monthly claims files, Hilltop first performs automated data validity checks in order to assess the integrity of the CCLF data files, followed by a data reduction step that subsets the claims files against the beneficiary attribution file. The resulting files retain the raw claims

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[13] For detailed documentation of these files, please see "Maryland Primary Care Program (MDPCP) CRISP Extract" (June 2019).

data that are inputs to the risk factor feature engineering process, but discard the claims for individuals that are not in the MDPCP population. The resulting data comprises approximately 220,000 individuals across almost 400 practices. These individuals incurred approximately 2.1 million part A claims, 16.8 million part B claims, and 12.4 million part D claims in the three-year period of February 2016 to January 2019.

Using SAS 9.4, Hilltop creates the model using risk factors identified in the literature review.[14] The risk factors are described in Section 3.2 and in greater detail in Appendix 1 in *Maryland Primary Care Program (MDPCP) Pre-AH Risk Score Specifications and Codebook, Version 1,* dated October 3, 2019.

ii. Social Determinants of Health Data Set

In order to control for environmental factors that may affect patients' probabilities of incurring avoidable hospitalizations, the risk model includes a rich set of area-level covariates derived from publicly available sources. Based on the "beneficiary ZIP code as per Medicare enrollment" (BENE_ZIP_CD), each attributed beneficiary is linked to environmental characteristics in his or her residential area.

- **USDA rural-urban commuting data** are Version 3.10 of the ZIP code Rural-Urban Commuting Areas (RUCA) taxonomy. Census tract level data and documentation are here: https://www.ers.usda.gov/data-products/rural-urban- commuting-area-codes/.
- **Neighborhood Atlas data** are from the University of Wisconsin School of Medicine. 2015 Area Deprivation Index (ADI) data were obtained at the Block Group level from https://www.neighborhoodatlas.medicine.wisc.edu/download.
- **CMS provider locations** are from the December 2018 Public Use Provider of Services file (https://www.cms.gov/Research-Statistics-Data-and-Systems/Downloadable-Public-Use-Files/Provider-of-Services/).
- **Veterans Affairs provider locations** are from the VA directory (https://www.va.gov/directory/guide/rpt_fac_list.cfm).
- **AMA data** are "Census tract layer attributes for American Medical Association Primary Care Physician Data, 2011," published by the Health Resources and Service Administration (HRSA) data warehouse. Specific source: https://data.hrsa.gov/DataDownload/PCSA/2010/t_ama2011_060614.dbf.
- **Land area** is from the 2018 Census Gazetteer (https://www.census.gov/geographies/reference-files/time-series/geo/gazetteer-files.html). Area is in square miles.
- **Area Health Resources File** (https://data.hrsa.gov/data/download) contains county-level data on a variety of health-related topics. Hilltop links this to ZCTAs using a ZCTA-county crosswalk (available from https://www2.census.gov/geo/docs/maps-data/data/rel/zcta_county_rel_10.txt).
- **ACS individual-level data** are from IPUMS (https://usa.ipums.org/usa/index.shtml).

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[14] Certain risk factors identified in the literature review were not ultimately operationalizable in Phase 1 of the Hilltop Pre-AH Model™. We will incorporate additional risk factors in future iterations of the model.

Individual-level microdata are filtered to retain only certain occupations and then aggregated to the county level. The variables derived from this data set—"Social Workers per 1,000 population" and "Percent Physician Diversity"—are populated only for a subset of counties covering approximately 1/3 of ZCTAs nationally.

b. Risk Factors

Based on the literature review, Hilltop identified and operationalized approximately 190 risk factors to be included in the risk model. While some of these risk factors are eliminated in the variable selection step due to high inter-variable correlation, this process is data-driven, and all risk factors are included in the pool of *potential* risk factors to be used in the model.

i. Literature Review

As a first step in the development process for the Hilltop Pre-AH Model™, Hilltop conducted a comprehensive literature review. The goal of the review was to find peer-reviewed academic journal articles that identified risk factors for potentially avoidable hospital events, thus providing a basis for risk factor extraction and feature creation. Identified risk factors were coded using CCLF and other publicly available data sources and included in the final risk model as potential predictors of avoidable hospitalization or ED use. The literature review provided the foundation for the risk model and was a crucial step in the modeling process. Using inclusion and exclusion criteria designed to reflect the MDPCP patient population, the Hilltop team screened over 3,300 articles in both a primary and secondary literature search, ultimately selecting 211 articles for risk factor extraction. For additional detail, see Pelser et al. (2019).

ii. Part A, B, and D Risk Factors

Risk factors based on Part A claims cover information on admissions over the past 12 months; nursing home stays over the past 12 months; and certain procedures. Additionally, the Part A claims are used in order to construct the avoidable hospital event outcome, as well as the diagnostic condition flags. These condition flags rely on diagnostic information from Part A and Part B claims in conjunction with Chronic Conditions Data Warehouse (CCW) coding specifications in order to generate beneficiary-level risk factors that represent underlying disease states.[15]

Risk factors based on Part B claims cover utilization of certain services (such as vaccinations, lab tests, or J-code procedures), place of service (for example, urgent care or rural health clinic), and provider specialty (for example, endocrinology or oncology). Hilltop also created risk factors to capture a beneficiary's primary care utilization and continuity of care. Finally, as above, the Part B claims are used in order to construct the avoidable hospital event outcome, as well as the diagnostic condition flags.

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[15] Additional detail on the CCW condition flag specifications can be found here: https://www.ccwdata.org/documents/10280/19139421/ccw-chronic-condition-algorithms.pdf, https://www.ccwdata.org/documents/10280/19139421/ccw-chronic-condition-algorithms-reference-list.pdf

Using Medicare Part D claims, Hilltop flags utilization of drugs identified in its literature review as potential risk factors for potentially avoidable hospital events. In order to capture compound drugs, which are drugs that contain multiple active ingredients, Hilltop relies largely on text-based, "contains"-type searches of the FDA's "National Drug Code Directory."[16]

i. Environmental Risk Factors

Several of the risk factors Hilltop identified during the literature review were individual-level demographic and socioeconomic factors that are unavailable in the CCLF data (for example, marital status). Consequently, corresponding area-level risk factors (for example, the percentage of the population aged 15+ that is currently married) are included in the risk model in order to proxy for the unobserved individual-level variables. Other environmental risk factors (for example, the area poverty rate) are intended to capture the social determinants of health: the neighborhood conditions in which people live and age that may affect health outcomes.

c. Modeling

Methodologically, Hilltop relies on a discrete time survival model that uses current values of procedural, diagnostic, utilization-based, pharmacy, demographic, and environmental risk factors to predict the likelihood that an individual incurs an avoidable hospitalization or ED visit in the *following* month. The parameter estimates generated in the model training are subsequently used to generate individual risk predictions in the scoring step. We assess the quality of our modeling using monthly concentration curves, which measure the cumulative share of all avoidable hospital events actually incurred by the riskiest (predicted) patients.

i. Avoidable Hospitalizations and Emergency Department Visits

The outcome measure in the Hilltop Pre-AH Model™ is a 0/1 indicator variable denoting whether an individual incurred an avoidable hospitalization or ED visit in a given month. In order to construct this measure, Hilltop relies on technical definitions provided by the Agency for Healthcare Research and Quality (AHRQ) as part of its prevention quality indicator (PQI) measures.[27] Diagnosis codes from Part A inpatient and ED claims are used to flag the following conditions, which are the basis for the composite PAH flag:[28]

- PQI #1: Diabetes Short-Term Complications
- PQI #3: Diabetes Long-Term Complications
- PQI #5: COPD or Asthma in Older Adults
- PQI #7: Hypertension
- PQI #8: Heart Failure
- PQI #10: Dehydration
- PQI #11: Bacterial Pneumonia
- PQI #12: Urinary Tract Infection

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[16] For example, "Simcor" contains two active substances: Simvastatin and Niacin. This is flagged as a statin because one of its active ingredients is a statin. Source for the FDA NDC directory: https://www.fda.gov/drugs/drug-approvals-and-databases/national-drug-code-directory

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- PQI #14: Uncontrolled diabetes
- PQI #15: Asthma in Younger Adults
- PQI #16: Lower-Extremity Amputation among Patients with Diabetes

This is implemented in the model as an indicator variable at the person-month level. If an individual incurs at least one avoidable hospitalization or ED visit in a given month, then that person receives a value of 1 for this variable—and 0 otherwise.

In order to estimate the concentration curve, the patient cohort is ordered from most to least risky (in terms of predicted risk) on the X axis, and the fraction of total avoidable hospital events captured by the riskiest patients on the Y axis. Note, for example, in the figure below that the top 10 percent riskiest patients account for approximately 50 percent of all avoidable hospitalizations in December 2018, and the top 20 percent riskiest patients account for approximately two-thirds of all avoidable hospitalizations. This figure shows the curve for December 2018.

Concentration Curve as of December 2018