Healthcare Cost Analyses of Older Patients Explore Cost Savings Opportunities: a Longitudinal Retrospective Study

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Abstract

Background: Half of Medicare reimbursement goes towards caring for the top 5% of the most expensive patients. However, little is known about these patients prior to reaching the top or how their cost changes annually. To address these gaps we analyzed patient flow and associated healthcare cost trends over 5 years period.

Objective: To evaluate the cost of healthcare utilization of older patients by analyzing changes in their expenditure long term.

Methods: This is a retrospective, longitudinal, multicenter study to evaluate healthcare cost of 2,643 older patients over the period 2011-2015. All patients had at least one episode of home healthcare during the study period and used a Personal Emergency Response Service (PERS) at home for any length of time during the observation period. We segmented all patients into Top-(5%), Middle-(6-50%) and Bottom-(51-100%) segments by their annual expenditures and built cost pyramids based thereon. The longitudinal healthcare expenditure trends of the complete study population as well as each segment were assessed by linear regression models. Patient flows throughout the segments of the cost acuity pyramids from year to year were modeled by Markov chains.

Results: Total healthcare cost of the study population nearly doubled from $17.7M in 2011 to $33.0M in 2015 with an expected yearly cost increase of $3.6M (p=0.003). This grow was driven by significantly higher cost increase in the Middle-segment ($2.3M, p=0.002). The expected yearly costs increase of the Top- and Bottom-segments was $1.2M (p=0.008) and $0.1M (p=0.003), respectively. The patients and cost flow analyses showed that 18% of patients moved up the cost acuity pyramid yearly and their cost increased by 672% in contrast to 22% of patients that moved down with a cost decreased by 86%. The remaining 60% of patients stayed at the same segment from year to year but their cost increased by 18%.

Conclusions: While many healthcare organizations target costly intensive interventions at their most expensive patients (Top-segment), this analysis unveiled potential cost savings opportunities by managing the patients in the lower cost segments that are at risk of moving up the cost acuity pyramid. To achieve this, data analytics that integrate longitudinal data from the EHRs and home monitoring devices like PERS may help healthcare organizations to optimize resources by enabling clinicians to proactively manage patients in their home or community environments, beyond institutional settings and 30-60 day telehealth services.
**Keywords:** healthcare cost analysis; cost acuity pyramid; patient segmentation; annual cost changes of each segment; patient and cost flow through the segments
Introduction

The United States (US) spends more on healthcare per person than any other country in the world []. National healthcare expenditure increased by 5.8% to $3.2 trillion from 2014 to 2015, or $9,990 per person, and accounted for 17.8% of gross domestic product []. A recent study [] on factors associated with increases in US healthcare spending found that changes in healthcare service price and intensity were associated with a 50% spending increase. Population growth and aging were also positively associated with increasing in healthcare cost, while disease prevalence or incidence were negatively associated.

A sizeable proportion (20%) of all national healthcare expenditure is due to Medicare spending, a federal health insurance program for US citizens who are 65 years and older, younger people with certain disabilities, and those who suffer from end stage renal disease []. Among Medicare beneficiaries, older patients are among the groups that spend the most, largely driven by inpatient (including emergency care) and post-acute care costs []. In fact, the average Medicare expenditure per patient on emergency care, including emergency department (ED) visits (treat-and-release) and unplanned emergency hospitalizations, doubled from $700 in 2003 to $1,390 in 2012 []. Medicare beneficiaries are nearly twice as likely as the privately insured to be admitted four or more times per year to the ED []. Further, readmissions are common among Medicare patients and cost $26 billion annually, as estimated by the Agency for Healthcare Research and Quality (AHRQ) []. Nearly a quarter of these Medicare readmissions are considered potentially avoidable [], [] by the Centers for Medicare & Medicaid Services (CMS), the federal agency that administers Medicare.

Unsustainable healthcare costs and the need to improve overall efficiency is the driving force for the introduction of value-based care, where clinicians need to cost-effectively monitor, diagnose and treat patients. Many healthcare organizations (HCOs) now use value-based care strategies [], involving connected solutions that seamlessly integrate big data and use data analytics to identify and manage high-risk and high-cost patients []. For example, a technology used worldwide for older patients is the Personal Emergency Response Service (PERS). PERS is designed to promote independent living in older adults by providing help in case of medical emergencies that could lead to costly ED visits and/or hospitalizations. While PERS has been widely used for many years to monitor older patients, only recently PERS data has been utilized to develop CareSage [], a data analytics engine that identifies older patients at risk of ED transports/visits. Further, the unique combination of electronic health record (EHR) and PERS data improved the existing ED transports predictive model and facilitated the development of new models predicting emergency care []. To enable the development of cost-effective population health programs for older patients utilizing PERS, there is a need to better understand their healthcare utilization cost.
Healthcare expenditure in the US is unevenly distributed among individuals and different segments of the population. Stanton et. al. [] used several segments to classify the US population based on their healthcare expenditure, e.g. top 1%, 5%, 10%, 20%, 50%, etc. These segments are also utilized in literature []-[] and show high cost concentration in a small group of individuals, particularly in the CMS population in a single year. For example, the bottom 50% of the population (B-segment) spends little (3-4%) on healthcare, while the top 5% of the population (T-segment) spends almost half of the total expenditure[]. Accordingly, most HCOs focus on developing population health management programs targeting the T-segment of most expensive patients. However, prior studies have not yet explored the full dynamics of patient and cost flows between the different segments from year to year. Furthermore, little is known about patient and cost flow prior to reaching the top 5%. To address these gaps and enable HCOs to deliver targeted and cost-effective interventions, we analyzed patient flow throughout the cost segments and associated yearly healthcare cost changes.

**Methods**

**Aims**

The primary aim of this study was to evaluate healthcare costs of older patients using PERS over a period of 5 years. Specifically, to answer the following questions:

- What is the total healthcare cost of the study population from 2011 to 2015 and its distribution across specific cost segments?

- Are there longitudinal trends in healthcare cost across the cost segments?

- How does the number of the patients and their cost vary from year to year throughout the cost segments?

**Design**

This is a retrospective, longitudinal, multicenter study to evaluate healthcare cost of inpatient and outpatient hospital encounters in patients using PERS for any length of time during the study period. The study was approved by the Partners Human Research Committee, the Institutional Review Board for Partners Healthcare hospitals.

**Settings**

Study participants were identified from Partners Healthcare at Home (PHH) - a home health agency that offers general care as well as specialized services to help patients within the Partners Healthcare System (PHS) network of hospitals manage chronic conditions while at home. Patients are usually referred to the PHH service by their care providers after discharge from the hospital. In addition to in-person home visits, PHH utilizes a variety of healthcare technologies to manage their patients. One of these technologies is the Lifeline PERS, which PHH care providers routinely recommend to chronically ill patients who are at
risk of falls or other health-related emergencies. Detailed descriptions of PHH and PERS are described in a previous paper [1].

Subject selection
Patients included in this study received healthcare at any of 5 PHS affiliated hospitals and had at least one inpatient and/or outpatient encounter. Study subjects had at least one episode of PHH care with average duration of 2-3 months and were enrolled to PERS through PHH for any length of time during 2011-2015. Initially, there were 4,290 patients identified as PERS users from the Lifeline database (Figure 1). We excluded patients that were unmatched (by first name, last name, and date of birth) in the PHS data warehouse and those without any healthcare utilization record in the study period since their healthcare costs were zero in 5 years and did not vary from year to year. This resulted in 2,643 patients included in the data analysis. All data were de-identified before analyses.

Data Sources
The primary data sources for this study were the Enterprise Data Warehouse (EDW) and Research Patient Data Registry (RPDR) – both are electronic medical record data repositories of hospitals within the PHS network, which include data such as demographics, medical conditions, clinical encounters, and healthcare cost. The PERS database included patient’s demographics, patients’ living situation and care giver network, self-reported medical conditions, and medical alert data. The latter includes all information gathered during the interactions of the patients with the Lifeline response center associates, including the reason the personal help button was pressed and the outcome of the patient-response center interaction.

Subject segmentation
We ranked subjects by their yearly healthcare expenditure from highest to lowest and then grouped them into the following segments: T – segment constitutes the top 5% (0%, 5%) most expensive patients; M – segment comprises the middle 45% (5%, 50%) of all patients;
B – segment includes the bottom 50% (50%, 100%) less expensive patients. We utilized these three segments to build a cost acuity pyramid (Figure 2) that is a core visual component in the healthcare cost analysis performed in this paper.

Outcomes
To address the aforementioned study objectives, our primary outcomes were a) to quantify patients who moved up, down or stayed at the same segment of cost acuity pyramids over a 2-year period, and b) to evaluate the cost associated with these flows.

Prior to analyzing the primary outcomes, we conducted exploratory analyses to evaluate a secondary outcome - the total healthcare cost of the study population and its distribution across the segments of the cost acuity pyramids for each available fiscal year. In addition, we performed inferential analysis to identify longitudinal trends in total healthcare cost of the complete study population as well as of each segments of the cost acuity pyramids, which is another secondary outcome.

Statistical Analysis
Demographic and healthcare utilization data for the fiscal years 2011-2015 were extracted from the EDW using Microsoft Structured Query Language (SQL) Server Management Studio (SSMS) 2014. Data management and de-identification were achieved through SSMS and Microsoft Excel 2007. The statistical analysis described below was performed in R version 3.2.2 [].

To evaluate our primary outcomes we applied 3-step analyses: 1) model the patients’ flows between the T-, M- and B-segments of cost acuity pyramid over 2-year period, 2) group these flows to quantify patients moving up, down, or staying at the same segment of the cost acuity pyramid, and 3) estimate the cost flows associated with the patient flows.

To model the patients’ flow in step 1) above we created a Markov model of the flows from each segment to all others over 2 successive years. The availability of longitudinal data for building a robust Markov chain was crucial in this study. Markov chains have been used in the economic evaluation of healthcare [], but not to examine the flow between the T-, M- and B-segments of the cost acuity pyramid. The Markov chain we built in this study included 3 states (B-, M-, or T-segment) and 9 transitions (B-to-B, B-to-M, B-to-T, M-to-B, M-to-M, M-to-T, T-to-B, T-to-M, T-to-T). The states represent the patient segments of the cost acuity pyramid, while the transitions indicate the probability that a patient will move from one segment to another over a 2-year period. Each probability is an average of the flow percentages over 4 pairs of fiscal years (FY), i.e., FY11-FY12, FY12-FY13, FY13-FY14, FY14-FY15. The 9 probabilities constitute a 3x3 transition matrix associated with the Markov chain. This transition matrix is used in step 2) of the analysis described above. Namely, the probabilities in the lower triangular, upper triangular and diagonal of this matrix are
multiplied by the size of the corresponding segments and summed up to quantify patient movements throughout the segments of the cost acuity pyramid.

To evaluate healthcare expenditure trends we carried out linear regression analysis. Four linear regression models were built with healthcare cost of the total study population, T-, M-, and B-segment as dependent variables, respectively, and each available fiscal year as an independent variable. Each model provides an estimate of expected yearly cost increase/decrease.

**Results**

**Characteristics of Study Population**

The study population was on average 79 years old, predominately female (75%), white (93%), living alone (94%), without family caregivers (99.5%) and at least 86% had a high school education (Table 1). The majority of the patients (77%) had multiple medical conditions and top 5 inpatient principal diagnosis groups were: Chronic Heart Failure (5.7%), Chronic Obstructive Pulmonary Disease (4.6%), Dysrhythmias (4.3%), Septicemia (4.1%) and Pneumonia (4.1%).

**Healthcare Cost Distribution and Trends**

The healthcare costs were unevenly distributed across the segments of the cost acuity pyramid of each fiscal year. For example, there were 2,206 patients with any healthcare utilization in 2015 (Figure 2). Their total healthcare cost was $33.0M and the average cost per patient was $14,950 (SD=$31,722). The T-segment in 2015 (in total 110 patients with annual cost above $65,117) constitutes 39% ($12.9M) of the total healthcare expenditures and the average cost per patient was $117,201 (SD=$75,976). The M-segment (in total 993 patients with annual cost above $3,670) accounts for 57% ($18.9M) of the total healthcare expenditures and the average cost per patient was $19,037 (SD=$14,534). The B-segment (in total 1,103 patients) comprises only 4% ($1.2M) of the total healthcare expenditure and the average cost per patient was $1,072 (SD=$985).
Table 1: Characteristics of Study Population

<table>
<thead>
<tr>
<th>Variables</th>
<th>Study Population % (N=2,643)</th>
<th>Variables</th>
<th>Study Population % (N=2,643)</th>
</tr>
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<tbody>
<tr>
<td><strong>Age, mean (SD)</strong></td>
<td>79 (11)</td>
<td><strong>Education, % (N)</strong></td>
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<td><strong>Age Cat., % (N)</strong></td>
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<tr>
<td>≥ College</td>
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<td></td>
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<tr>
<td>&lt;65</td>
<td>11% (303)</td>
<td>Some college</td>
<td>7% (102)</td>
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<td>65+</td>
<td>89% (2,340)</td>
<td>High-school</td>
<td>43% (657)</td>
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<td><strong>Gender, % (N)</strong></td>
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<tr>
<td>Married</td>
<td>29% (695)</td>
<td>Divorced</td>
<td>13% (317)</td>
</tr>
<tr>
<td>Race, % (N)</td>
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<tr>
<td>Hispanic</td>
<td>93% (2,312)</td>
<td>Divorced</td>
<td>13% (317)</td>
</tr>
<tr>
<td>White</td>
<td>0% (9)</td>
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<td>5% (128)</td>
<td>Widowed</td>
<td>37% (887)</td>
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<tr>
<td>Other</td>
<td>1% (26)</td>
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<td>37% (887)</td>
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<td>n = 168</td>
<td>Unknown</td>
<td>n = 269</td>
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<tr>
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<td></td>
<td><strong>Medical Cond., % (N)</strong></td>
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<td>99.5% (2,629)</td>
<td>1</td>
<td>23% (608)</td>
</tr>
<tr>
<td>1</td>
<td>0.5% (14)</td>
<td>2</td>
<td>25% (661)</td>
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<tr>
<td><strong>Live Alone, % (N)</strong></td>
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<td>94% (2,483)</td>
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<td>31% (819)</td>
</tr>
<tr>
<td>No</td>
<td>6% (160)</td>
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</tbody>
</table>
The total healthcare expenditure of the study population nearly doubled from $17.7M in FY11 to $33.0M in FY15 although the number of patients per year having any costs remained similar (Figure 3). About two thirds of these total expenditure (ranging from 63% to 71% throughout FY11-FY15) were hospital admissions cost, which doubled from $11.4M in FY11 to $23.4M in FY15. The remaining one third of total expenditure was outpatient encounters cost, which also increased from $6.3M in FY11 to $9.6M in FY15.

The M-segment was the most expensive with cost increased from $9.1M in FY11 to $18.9M in FY15 (Figure 3). Moreover, the relative contribution of the M-segment to the total cost increased from 51% in FY11 to 57% in FY15. Next was the T-segment with cost increased from $8.0M in FY11 to $12.9M in FY15. The relative contribution of the T-segment to the total cost decreased from 45% in FY11 to 39% in FY15 in contrast to the M-segment. The cost of the B-segment increased from $0.6M in FY11 to $1.2M in FY15. However, the relative contribution of the B-segment to the total cost remain steady 3-4% over the 5 years. Further, the linear regression analysis (Figure 3) shows that the increasing trend in total healthcare cost of the study population is statistically significant (p=0.003) with an expected yearly cost increase of $3.6M. This growth was driven by significantly high cost increase of $2.3M in the M-segment (p=0.002). The expected yearly cost also increased significantly in the T- and B- segments with $1.2M (p=0.008) and $0.1M (p=0.003), respectively.

Figure 2: Cost acuity pyramid based on healthcare expenditure in 2015
Patients and Cost Flows throughout the Segments of the Cost Pyramids
The Markov model of the patient flow throughout the segments of the cost acuity pyramids is illustrated below (Figure 4).
An alternative visualization using the cost acuity pyramids is shown in the upper part of Figure 5. Both figures highlight several important insights. First, the B-segment is the most stable of all 3 segments: majority (69%) of the patients in the B-segment stay at the same segment next fiscal year; 2% move up to the T-segment while the remaining 29% of the patients move up to the M-segment of the cost acuity pyramid next fiscal year. Second, the M-segment is more dynamic than the B-segment: majority (55%) of the patients in the M-segment stay at the same segment next fiscal year; 5% move up to the T-segment and the remaining 40% move down to the B-segment of the cost acuity pyramid next fiscal year. Third, it is evident that the T-segment is the most dynamic of all 3 segments: only 24% of the patients in the T-segment stay at the same segment next fiscal year; while 54% and 22% of the patients move down to the M- and B-segments of the cost acuity pyramid next fiscal year, respectively.

The cost flow associated with the patient flow is depicted in the lower part of Figure 5, specifically for the two most recent years in our data FY14-FY15. It illustrates that the cost of 1,112 patients in the B-segment increased from $1M in FY14 to $8.7M in FY15 (+770%) due to their movement up to the M- and T-segments depicted in the upper part of Figure 5. Similarly, the cost of 1,000 patients in the M-segment increased from $15.7M in FY14 to

![Figure 5: Patient and cost flows of T-, M- and B-segments of cost acuity pyramid](image-url)
$16.5M in FY15 (+5%) due to their movements to the B- and T-segments. The cost of 111 patients in the T-segment decreased from $12.1M in FY14 to $5.4M in FY15 (-55%) due to their movement down to the lower segments.

After quantifying the patient and cost flows throughout the segments of the cost acuity pyramids, we evaluated our primary outcome, namely, how many patients moved up, down, or stayed at the same segment the following year (Figure 6). In total, 22% of the patients moved at least one segment down the cost acuity pyramid yearly and their cost decreased from $14.5M in FY14 to $2.0M in FY15 (-86%). Another 18% (403) of the patients moved at least one segment up the cost acuity pyramid yearly and their cost increased from $1.8M in FY14 to $13.9M in FY15 (+672%). The majority (60%) of the patients stayed at the same segment of the cost acuity pyramid yearly, however their cost increased from $12.5M in FY14 to $14.8M in FY15 (+18%).

Figure 6: Patients moving up/down the cost acuity pyramid and their cost flow
Discussion

This study is the first to quantify patients’ annual movements through segments of the cost acuity pyramid and associated changes in healthcare costs. We discovered three main findings. First, total healthcare cost of study population doubled from $17.7M to $33.0M (2011-2015) with an expected increase of $3.6M/year \( p=0.003 \). Second, patients in the M-segment were major contributors to the increased cost with an expected increase of $2.3M/year \( p=0.002 \). The M-segment was persistently the costliest throughout all 5 years. Third, the patients and cost flow analysis showed that 18% of patients moved up the cost acuity pyramid yearly and their cost increased by 672% in contrast to 22% of patients that moved down with a cost decreased by 86%. The remaining 60% of patients stayed at the same segment from year to year but their cost increased by 18%.

Our first finding is consistent with prior studies characterizing high cost users as predominantly older patients with functional limitations and multiple chronic conditions \cite{[76x468]}\cite{[89x468]}. Yet, the magnitude of this annual increase of 20% ($3.6 M) is notably three times higher than the national average of 6% per year, as projected by CMS \cite{[442x452]}. This discrepancy can be explained, in part, by the fact that our population is significantly older than the national CMS population (79 vs. 71 years old) \cite{[318x419]}. Nevertheless, we found in \cite{[471x419]} that 37% of all costly admissions were due to medical conditions leading to potentially avoidable admissions \cite{[139x387]}, \cite{[155x387]}. This suggests that interventions targeting these conditions may be an effective strategy for cost reduction in older adults.

The second finding that the M-segment (not the T-segment) of the cost acuity pyramid is the most expensive each year is a new insight that reveals the importance of the M-segment for cost management. Currently, most HCOs develop population health management programs targeting the T-segment of the cost acuity pyramid \cite{[399x296]}\cite{[411x296]}. While these programs have demonstrated improvement in clinical outcomes, evidence supporting their impact on healthcare cost is inconclusive \cite{[236x264]}. Often these studies compare healthcare expenditure pre- and post-program introduction. The lack of randomized control trials raises the question of whether the reported cost savings can be attributed to the effect of the interventions or a statistical phenomenon known as regression to the mean \cite{[383x216]}. Figure 5 supports the latter illustrating that a majority (76%) of patients in the T-segment tend to move to the M- and B-segments the following year and, consequently, their cost drops by $6.7M (-55%). However, this cost reduction can be completely phased out by the cost increase of the B-segment by $7.7M (770%) due to patients moving up. Therefore, for all cost-reduction initiatives, the unforeseen costs of patients moving up the cost acuity pyramid, which are hidden within an overall budget, may seem to invalidate the work being done to manage the cost of the T-segment.
The third finding illustrates how healthcare expenditure of the different segments of the cost acuity pyramid change over 2-year period. Previous work [], [] analyzing the persistence of expenditure over a 2-year period reported a slightly higher percentage of patients remaining in the top 5%- (34% vs. 24%) and bottom 50%-segments (73% vs. 69%) compared to our results. However, these studies involved the general US population which is much younger than the older population in our study. Our study is the first one that quantifies not only the patients staying at the same cost segment but also those moving up and down throughout the segments of the cost acuity pyramid over a 2-year period as well as their cost changes.

Summing up, our findings demonstrate that a holistic cost management approach, taking into account the dynamic flows between all segments of the cost acuity pyramid rather than the T-segment only, is needed to reverse the increase in total healthcare cost. This approach would target interventions to patients moving up the cost acuity pyramid.

Limitations
This study has two main limitations. First, the PERS used by this population was self-paid and may limit the study generalizability to patients that can afford the service. Second, our analyses do not included cost of patients’ clinical encounters that may have occurred outside the Partners Healthcare network.

Future studies
Future studies will examine which patients’ characteristics impact the patients move through the cost acuity pyramid and use them to predict these movements. Additionally, we will conduct a prospective study to evaluate the cost savings of disease management programs for older patients using PERS and CareSage as a long term home monitoring service [].

Conclusions
While many HCOs target costly intensive interventions at their most expensive patients, this analysis unveiled potential cost savings opportunities by managing the patients in the lower cost segments that are at risk of moving up the cost acuity pyramid. Accordingly, HCOs should prioritize population health management programs able to identify patients at risk of moving up the cost acuity pyramid and provide interventions tailored to a patient’s specific problem, which might be related to frequent ED transports/visits, medication non-adherence, or lack of social support. To achieve this, data analytics that integrate longitudinal data from the EHRs and home monitoring devices may help HCOs to optimize resources by enabling clinicians to proactively manage patients in their home or community environments, beyond institutional settings and 30-60 day telehealth services.
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Conflict of interests
Philips provided funding for this study and four Philips employees (MS, JB, LS and AO) played a role in the design of the study, data collection, analysis, interpretation and writing of the manuscript.

Abbreviations
AHRQ: Agency for Healthcare Research and Quality
CMS: Centers for Medicaid and Medicare Services
ED: emergency department
EDW: enterprise data warehouse
EHR: electronic health record
FY: fiscal year
HCO: health care organizations
PERS: personal emergency response service
PHH: Partners Healthcare at home
PHS: Partners Healthcare system
RPDR: research patient data registry
SD: standard deviation
SQL: structured query language
SSMS: SQL server management studio

References