DOI: 10.1111/1475-6773.13709

METHODS ARTICLE

HSR Health Services Research

Methods for estimating the cost of treat-and-release emergency department visits

Gary T. Pickens PhD[1] | Brian Moore PhD[3] | Mark W. Smith PhD[2] | Kimberly W. McDermott PhD[3] | Amanda Mummert PhD[1] | Zeynal Karaca PhD[4]

[1]IBM Watson Health, Santa Barbara, California, USA

[2]CATHEXIS, Falls Church, Virginia, USA

[3]IBM Watson Health, Cambridge, Massachusetts, USA

[4]Agency for Healthcare Research and Quality, Rockville, Maryland, USA

Correspondence
Zeynal Karaca, PhD, Agency for Healthcare Research and Quality, 5600 Fishers Lane, Rockville, MD 20857, USA.
Email: zeynal.karaca@ahrq.hhs.gov

Funding information
Agency for Healthcare Research and Quality, Grant/Award Number: Contract No HHSA-290-2018-00001-C; Healthcare Cost and Utilization Project (HCUP); Center for Financing, Access and Cost Trends (CFACT)

Abstract

Objective: To evaluate and compare approaches to estimating the service delivery cost of emergency department (ED) visits from total charge data only.

Data Sources: The 2013–2017 Healthcare Cost and Utilization Project's (HCUP) State Emergency Department Databases (SEDD) and the Centers for Medicare and Medicaid Services Healthcare Cost Report Information System (HCRIS) public use files.

Study Design: Compare a baseline approach (requiring cost-center-level charge detail) and four alternative methods (relying on total charges only) for estimating ED visit costs. Estimation errors are calculated after applying each method to a sample of ED visits, treating estimates from the baseline approach as the "true" cost. Performance metrics are calculated at the visit and hospital levels.

Data Collection/Extraction Methods: The charges, revenue center codes, and patient/hospital characteristics were extracted from the SEDD. Detailed costs and charges were extracted from HCRIS public use files.

Principal Findings: Baseline ("true") ED visit costs increased from $383 to $420 per visit between 2013 and 2017. Three methods performed comparatively well estimating mean cost per visit. The method using an overall cost-to-charge ratio (CCR) for all ancillary cost centers without regression adjustment (ANC-CCR) performed the worst, overestimating "true" costs by $63–$113 per visit. The other three methods, which used CCRs computed from selected cost centers, exhibited much smaller bias, with two of the methods yielding estimates within $2 of the "true" cost in 2017. Compared with ANC-CCR, the other three methods had more compact estimation error distributions. The estimated mean visit costs from all four methods have relatively small statistical variance, with 95% confidence intervals for mean cost in a hospital with 25,000 ED visits ranging between $4 and $7.

Conclusions: When cost-center-level charge detail for ED visits is unavailable, alternative methods relying on total ED charges can estimate ED service costs for patient and hospital segments.

KEYWORDS
costs and cost analysis, direct service costs, emergency medical services, emergency service, fees and charges, hospital charges, hospital costs

What is known on this topic

- Sophisticated cost accounting methods can be used to estimate emergency department (ED) treatment costs for individual facilities, but these methods cannot be applied to most multihospital or nationwide databases.
- An approach that requires ED visit charges and cost-to-charge ratios reported by cost center is likely the most accurate costing method that can be applied to multihospital databases.
- Not all data sources provide cost-center-level charge detail; alternative estimation methods are needed for treatment cost of ED services.

What this study adds

- The cost estimation methods presented here allow hospitals to compare their ED service delivery costs with other organizations' costs and benchmarks using total charge data available in most hospital ED administrative databases.
- Health services researchers can apply these cost estimation methods to identify key drivers of ED cost growth and inform policies aimed at reducing ED costs.

1 | INTRODUCTION

Spending on emergency department (ED) care in the United States has been rising rapidly. From 1996 through 2013, spending on emergency care increased at an annual growth rate of 6.4%, compared with 2.8% for inpatient care.[1] From 2010 to 2016, the mean charge per ED visit increased from $2061 to $3516, a compound annual growth rate of 9.3%.[2]

Many patients present to the ED with nonurgent medical problems that could be addressed in other settings for a substantially lower cost.[3,4] Reasons that patients use the ED for nonurgent care include a lack of access to other providers[5] and the perception of low-quality primary care options.[6] These "avoidable" visits constitute 4.8%–90% of ED encounters, depending on the definition of *avoidable*.[7]

Understanding the drivers of ED cost growth is the first step toward developing health policies to slow it. In addition to policy considerations, individual hospitals and health systems have strong incentives to understand and control ED service delivery costs. The ED is an important source of outpatient revenue and cost for most hospitals, so controlling ED costs is important for economic viability.[8] In addition, the Medicare Hospital Outpatient Prospective Payment System provides fixed reimbursement to hospitals for ED services. This means hospitals need to track costs and identify opportunities, including comparison to other organizations, for more cost-efficient delivery of services.

Billing charges do not reflect the true cost of providing services, in part because hospitals do not apply a fixed mark-up to costs.[9] The traditional approach is to apply a hospital-level cost-to-charge ratio (CCR) to convert ED charges into estimated costs, but hospital-wide CCRs may be inaccurate for individual departments such as the ED.[10] The Medicare Hospital Outpatient Prospective Payment System implements the most prevalent application of CCR methods in use today to estimate the cost of providing ED services at different levels of visit intensity.[11] Some studies have compared CCRs with other cost estimation methods, such as Relative Value Units or other cost accounting methods.[12–16] None of these studies used large comparative databases, however, nor did any focus exclusively on the ED.

This study evaluated four methods for estimating the service delivery cost of hospital ED visits using data on total charges from a large, multiyear dataset. These estimates were compared with cost estimates calculated using individual cost-center charges for the same visits. A method that relies only on total charges is valuable because many hospital ED databases do not feature charges for individual cost centers.

2 | METHODS

2.1 | Study design and data sources

We obtained ED data from the Agency for Healthcare Research and Quality Healthcare Cost and Utilization Project (HCUP) State Emergency Department Databases (SEDD) for data years 2013–2017. The SEDD capture all-payer visits at hospital-affiliated EDs that do not result in hospitalization (*treat-and-release visits*).[17] Data for this study come from 24 states (see Appendix A1). These states provided billed charges at the level of UB-04 (CMS-1450 claim form) revenue codes for accommodation and ancillary services (*line-item detail*), enabling us to test alternative costing methods.[18] Measures derived from the SEDD include charge amounts, associated UB-04 revenue center codes, patient characteristics, and hospital characteristics.

We extracted detailed costs and charges from the Centers for Medicare and Medicaid Services (CMS) Healthcare Cost Report Information System (HCRIS) public use files, which contain annual cost reports for Medicare-certified institutional providers.[19] HCRIS captures all costs and charges reported by participating institutions for a given year, grouped into CMS-defined cost centers. Our analysis matched treat-and-release visits in the SEDD with HCRIS cost reports by

hospital and year. We used the Medicare Provider Number from the American Hospital Association Annual Survey to link hospital information between the HCRIS and the SEDD.

Because of differences in how hospitals assemble detailed costs and charges, we grouped cost centers (i.e., HCRIS) and UB-04 revenue codes (i.e., SEDD) into clusters. We started with the cost-center clusters defined by Sun and Friedman[20] and then incorporated refinements to take advantage of the more detailed cost centers supplied in recent HCRIS public use files. Appendix A2 contains the mapping of CMS cost centers to cost-center clusters used in this study. Appendix A3 contains the mapping of UB-04 revenue codes to cost-center clusters.

Using the HCRIS data, we calculated CCRs for each hospital and cost-center cluster. For a given hospital and year, we summarized total costs, inpatient charges, and outpatient charges by the cost-center clusters described in Table 1. Total costs included direct costs (e.g., laboratory or radiology) and indirect costs (e.g., general/administrative or housekeeping) as reported in HCRIS. Most physician costs associated with ED service delivery are not included in hospital submissions to HCRIS. Inpatient and outpatient charges are gross charges, namely those before contractual allowances are applied. Finally, a CCR for each cost-center cluster was calculated as the ratio of total costs to charges.

We imposed several data cleaning steps on the SEDD source data and excluded visits with questionable charges, costs, or other data quality and consistency issues. We excluded ED visit records meeting any of these criteria (percentage of visits excluded in parentheses):

- Missing data for source of payment (0.22%), sex (0.01%), or age (0.00%)
- Missing data for any cost-center cluster CCR associated with the visit record (6.71%)
- Detailed charges sum to zero (8.87%)
- A total charge differing from the sum of detailed charges by more than $2.00 (10.61%)
- Presence of a cost-center cluster indicating inpatient accommodations on a visit record (0.27%)

TABLE 1 Cost centers associated with ancillary and emergency department cost-to-charge ratios[a]

Cost-center cluster	2017 HCRIS national median hospital CCR	2017 SEDD detailed charge distribution (%)	2017 HCRIS OP charge distribution (%)	2017 HCRIS IP charge distribution (%)	2017 HCRIS IP + OP charge distribution (%)	Included in ancillary CCR	Included in ED-CCR-N	Included in ED-CCR-B
Routine bed unit	0.74	1.2	0.0	18.2	9.6			
Special care unit	0.53	0.0	0.0	7.2	3.8			
Nursery + labor and delivery	0.51	0.0	0.3	2.6	1.5			
Subacute/long-term care	1.04	0.0	0.0	0.3	0.2			
Operating room and related	0.26	2.2	12.9	11.9	12.4	X		
Radiology and related	0.20	9.1	16.8	6.4	11.3	X	X	X
Laboratory	0.20	14.3	11.7	10.3	11.0	X	X	X
Therapies	0.33	3.9	3.3	7.1	5.3	X		
Pharmacy	0.29	4.0	12.4	11.6	12.0	X		X
Clinic and related high CCR centers	0.64	0.9	5.0	0.1	2.4	X		
All other ancillary	0.19	1.4	2.4	2.6	2.5	X		
MRI	0.09	1.2	2.2	0.9	1.5	X		
Emergency department	0.25	37.5	13.6	3.9	8.5	X	X	X
CT scans	0.04	18.9	7.3	3.4	5.3	X	X	X
Medical/surgical supplies	0.39	1.1	3.0	4.5	3.8	X		
Cardiac catheterization	0.13	0.6	3.0	2.3	2.6	X		
Implants	0.39	0.3	3.2	0.4	1.8	X		
Observation beds	0.17	4.5	2.0	6.0	4.1	X		X
Ambulatory surgery center	0.34	0.0	0.8	0.1	0.4	X		
Durable medical equipment	0.58	0.0	0.0	0.0	0.0	X		

[a]The source for data in this table is the Agency for Healthcare Research and Quality, Healthcare Cost and Utilization Project, State Emergency Department Databases, 2017; Centers for Medicare and Medicaid Services, and Healthcare Cost Report Information System public use files, 2017.
Abbreviations: CCR, cost-to-charge ratio; CT, computed tomography; ED, emergency department; ED-CCR-B, ratio estimate with six cost centers; ED-CCR-N, ratio estimate with four cost centers; HCRIS, Healthcare Cost Report Information System; IP, inpatient; MRI, magnetic resonance imaging; OP, outpatient; SEDD, State Emergency Department Databases.

- Three or more cost-center clusters with CCRs that were identified as outliers using the empirically derived fifth and 95th CCR percentiles (10.74%)

After the exclusions noted above, two additional requirements related to outlier estimated costs were applied to visits qualifying for our study sample. First, visits with costs estimated from detailed cost centers (see the DETAIL-CCR method) below the first or above the 99th percentile were excluded. Second, any visit with a negative estimated cost using the Ancillary CCR Ratio Estimate (ANC-CCR) method (see below) was excluded because such visits are not admissible for the Ancillary CCR Regression Estimate (ANC-REG) method (requires a log transformation of the of the ANC-CCR estimated cost, see below). The second exclusion was imposed to ensure the same sample of visits was present when evaluating alternative cost estimation methods.

Over the 2013–2017 study period, 28.2% of visit records were excluded in total due to data quality, consistency, or outlier issues.

2.2 | Analytic approach/statistical strategy

We compared a baseline approach and four alternative methods for estimating costs of treat-and-release ED visits. The baseline approach (i.e., DETAIL-CCR) requires ED visit charges reported by cost-center cluster and is likely the most accurate costing method that can be applied to large multihospital databases. However, not all data sources provide cost-center cluster charge detail—hence, the need for alternative cost estimation methods that rely on ED visit total charges only.

Table 1 illustrates our motivation for evaluating alternative ED visit costing methods. First, median CCRs vary widely across cost-center clusters. Second, the observed distribution of charges for ED visits from the SEDD differs markedly from both the HCRIS total charge and outpatient charge distributions. For example, 18.9% of SEDD ED visit charges were incurred in the computed tomography (CT) scan cost center, whereas corresponding percentages for HCRIS total and outpatient charges were 5.3% and 7.3%, respectively. The very small CCR for CT scans (0.04 national median) implies a large mark-up of charges over costs. This, in turn, leads to potential bias when estimating costs from a CCR method relying on total charges only, unless cost centers entering into the CCR calculation are chosen on the basis of ED service use.

Because ED treat-and-release visits are outpatient encounters, an initial approach is to restrict CCR computations to non-accommodation cost centers only, identified in Table 1. Using information about charge distributions in the SEDD, however, we can propose CCRs based on other cost-center combinations. The narrowest approach used four cost centers that accounted for approximately 80% of SEDD charges in 2017. A second broader approach used six cost centers that accounted for about 88% of SEDD charges that year. A description of the baseline and four alternative methods follows.

2.2.1 | Baseline method: Detailed cost-center cluster CCRs (DETAIL-CCR)

The baseline method calculates cost (VISIT_COST) as the sum of detailed charges (DETAILED_CHARGE) obtained from the SEDD multiplied by their respective corresponding CCRs (CCR) derived from the HCRIS cost report for that year:

$$\text{VISIT\_COST}_{ijy} = \sum\nolimits_k \left(\text{DETAILED\_CHARGE}_{ijky} \times \text{CCR}_{jky}\right),$$

with *i* indexing visits, *j* indexing hospitals, *k* indexing cost-center clusters associated with line-item charges, and *y* indexing year. Note that the cost-center cluster CCRs, CCR_{jky}, are hospital and cost-center cluster specific for each year.

2.2.2 | Alternative method 1: Ancillary CCR ratio estimate (ANC-CCR)

This method uses costs and charges for all nonaccommodation (ancillary) cost centers (see Table 1). An overall CCR for ancillary cost centers (ANC-CCR) is calculated by dividing the sum of all costs for the ancillary cost centers by the sum of all charges for those cost centers. If ANC-CCR_{jy} is the ancillary CCR calculated for hospital *j* in year *y*, and $\text{Total\_charge}_{ijy}$ is total charges for ED visit *i* to hospital *j* in year *y*, and then the estimated visit cost based on the ANC-CCR method is

$$\text{EST\_VISIT\_COST}_{iyj} = \text{ANC} - \text{CCR}_{jy} \ * \ \text{Total\_charge}_{ijy}.$$

2.2.3 | Alternative method 2: Ancillary CCR regression estimate (ANC-REG)

This method elaborates on the ANC-CCR method by using the ANC-CCR estimate as an independent variable in a regression model. We specified a log-log regression model predicting $\log(\text{VISIT\_COST}_{ijy})$ as a function of $\log(\text{ANC-CCR}_{iy} * \text{Total\_charge}_{ijy})$ and an intercept term:

$$\log\left(\text{EST\_VISIT\_COST}_{\text{ijy}}\right) = \alpha_y + \beta_y * \log\left(\text{ANC} - \text{CCR}_{\text{jy}} * \text{Total\_charge}_{\text{ijy}}\right) + \varepsilon_{ijy}.$$

The α_y and β_y parameters were estimated from the SEDD training sample, a 50% random sample, for each year analyzed. We used these to calculate an estimated value of $\log(\text{EST\_VISIT\_COST}_{ijy})$. That estimate was converted to the raw dollar scale using the "smearing" method described by Duan for analysis of the ANC-REG method's accuracy.[21]

2.2.4 | Alternative method 3: Ratio estimate with broader selection of cost centers (ED-CCR-B)

This method includes a broader set of cost-center clusters with the six most commonly observed ED charge clusters in our SEDD sample

(see Table 1). The ED-CCR-B method includes ED, CT scan, lab, radiology, observation beds, and pharmacy cost-center clusters, in order of proportion of ED visit charges, which account for 88% of SEDD ED visit charges in 2017.

To calculate ED-CCR-B, we start by calculating total costs, inpatient charges, and outpatient charges for these cost centers. Next, outpatient costs are estimated as the product of total costs and the proportion of outpatient charges in total charges. Finally, the CCR is calculated as the quotient of estimated outpatient costs to outpatient charges. The estimated ED visit cost is then calculated as

$$\text{EST\_VISIT\_COST}_{ijy} = \text{ED} - \text{CCR} - \text{B}_{jy} * \text{Total\_charge}_{ijy}.$$

2.2.5 | Alternative method 4: Ratio estimate with narrower selection of cost centers (ED-CCR-N)

This method includes a narrower set of cost-center clusters with the highest proportions of observed ED visit charges in our SEDD sample (see Table 1). The ED-CCR-N method includes ED, CT scan, lab, and radiology cost-center clusters, in order of proportion of ED visit charges, which account for 80% of SEDD ED visit charges in 2017. The ED-CCR-N value for each hospital is calculated similarly to the ED-CCR-B value but with the four selected cost-center clusters. The estimated ED visit cost is then calculated as

$$\text{EST\_VISIT\_COST}_{ijy} = \text{ED} - \text{CCR} - \text{N}_{jy} * \text{Total\_charge}_{ijy}.$$

For each method, we calculated ED visit cost estimates for all visits in our sample. (For the ANC-REG method only, we estimated regression coefficients using a 50% random training sample separately for each year in the study.) Next, estimation errors were calculated for each method (VISIT_COST − EST_VISIT_COST), treating VISIT_COST based on the original DETAIL-CCR estimate as the "true" cost. Finally, we calculated five performance metrics for each method at the visit and hospital levels using a 50% validation sample: mean and median estimation errors, empirical reduction in variance, distance between the 25th and 75th error percentiles, and distance between the fifth and 95th error percentiles.

We calculated performance summaries at two levels. At the first level, the ED visit was the unit of analysis. At the second level, ED visit costs were averaged by hospital, and hospital average costs were the unit of analysis.

3 | RESULTS

Table 2 contains descriptive statistics for the total sample and subsamples (training and validation) of visits. There were 180,930,297 total treat-and-release ED visits, with annual sample sizes ranging from 24.8 million (2013) to 43.8 million (2016). Hospital sample sizes varied from 1425 (2013) to 2153 (2016). The number of states represented by SEDD varied from 17 (2013) to 24 (2016).

Mean visit charges rose 54% over the study period, from $1805 (2013) to $2774 (2017). Mean estimated costs increased only 16%, however, from $363 (2013) to $420 (2017). At the hospital level, mean charges rose 52% over time, from $1576 to $2388, whereas mean estimated costs increased only 15%, from $426 to $491. There were no notable differences in mean charge or cost trends between the training and validation subsamples and the total sample.

Table 3 contains the estimation error summary for the visit- and hospital-level analyses for the validation sample. When comparing performance of the four alternative methods, we use the term *overestimate* to mean that the method produces a larger estimate than DETAIL-CCR, thus a negative difference. *Underestimation* occurs when the estimate is smaller than DETAIL-CCR, leading to a positive difference.

The ANC-CCR method overestimated by $63-$113 per visit across years. The ANC-REG method overestimated, with estimation errors ranging from $2 to $3, depending on the year. The ED-CCR-B and ED-CCR-N methods underestimated by $1–$38, with ED-CCR-B performing somewhat better. Median estimation errors followed a pattern like the means, except that ANC-REG overestimated by a larger amount, although still only by $10–$11 per visit.

Empirical reduction-in-variance metrics were similar (64%–73%) for all methods except ANC-CCR, which was substantially lower, ranging from 29% to 48% by year.

Table 3 also contains the distance between the fifth and 95th estimation error percentiles and between the 25th and 75th percentiles. ED-CCR-N tends to be lowest across years for both ranges, with ANC-REG and ED-CCR-B somewhat larger. The ANC-CCR method had notably larger percentile ranges and a more dispersed estimation error distribution.

The ANC-CCR method overestimated hospital mean costs by $31–$71 across years; the other methods underestimated costs by $40–$62. In terms of median error at the hospital level, the ANC-REG method was lowest, underestimating by $12–$15.

ED-CCR-N and ED-CCR-B produced higher empirical reduction-in-variance values compared with the other methods. For the estimation error percentile ranges, ANC-CCR was notably higher; ED-CCR-N and ED-CCR-B were somewhat lower across all years. The ANC-CCR method had the largest estimation error dispersion in all years.

The percentile range estimates in Table 3 convey information about the precision of cost estimates produced by the four methods. Table 4 shows a different view of precision, with estimates of two-sided 95% confidence intervals for predicted mean visit costs of the four methods studied, for different ED visit volumes that individual hospitals are likely to experience. At a volume of 25,000 ED visits, approximately the median volume of ED visits for US hospitals, the ANC-REG and ED-CCR-B methods have confidence intervals that overlap the DETAIL-CCR costs in most years, and the size of the two-sided confidence intervals ranges between $4 and $7. The size of these confidence intervals increases with decreasing visit volume. For many visit volumes, the estimates of prediction error in Table 3 can be interpreted as having a low level of statistical variance: the ANC-CCR

TABLE 2 Emergency department visits, mean charges, and costs, 2013–2017[a,b]

Sample/metric	2013	2014	2015	2016	2017
Total					
Visits (*N*)	24,797,992	32,829,816	40,983,300	43,815,287	38,503,902
Total charge visit mean ($)	1805	2123	2384	2551	2774
Detailed cost visit mean ($)	363	393	401	417	420
Hospitals (*N*)	1425	1614	2011	2153	1979
Total charge hospital mean ($)	1576	1817	2064	2203	2388
Detailed cost hospital mean ($)	426	446	459	475	491
Training					
Visits (*N*)	12,397,970	16,414,949	20,491,427	21,907,164	19,251,570
Total charge visit mean ($)	1805	2123	2384	2551	2774
Detailed cost visit mean ($)	363	393	401	417	420
Hospitals (*N*)	1421	1612	2005	2146	1971
Total charge hospital mean ($)	1580	1811	2056	2196	2380
Detailed cost hospital mean ($)	426	445	457	475	491
Validation					
Visits (*N*)	12,400,022	16,414,867	20,491,873	21,908,123	19,252,332
Total charge visit mean ($)	1805	2123	2384	2551	2774
Detailed cost visit mean ($)	363	393	401	417	420
Hospitals (*N*)	1425	1612	2007	2151	1976
Total charge hospital mean ($)	1572	1817	2066	2203	2381
Detailed cost hospital mean ($)	426	445	459	474	490
Number of states included	17	20	22	24	23

[a]Charges and costs are not adjusted for inflation.
[b]The source for data in this table is the Agency for Healthcare Research and Quality, Healthcare Cost and Utilization Project, and State Emergency Department Databases, 2013–2017.
Abbreviation: SEDD, State Emergency Department Databases.

method has much larger bias compared with the three other methods studied here.

4 | DISCUSSION

Hospital ED costs are an important component of overall national health expenditures. Because of the high growth rate of ED service delivery costs, methods for estimating them are needed to identify mechanisms for controlling cost increases and spending for ED services. In addition, individual hospitals require information on ED service delivery costs to ensure that their service delivery costs are appropriate, balancing cost and quality.

This study compared four methods for estimating ED service delivery cost: three based on CCR methods and a fourth using regression adjustments to a CCR method. Generally, CCR estimates constructed from all nonaccommodation charges and costs (ANC-CCR) performed the worst. The CCR method restricting services to lab, radiology, ED, and CT scan services with adjustment for outpatient costs and charges (ED-CCR-N) performed well at both the visit and hospital levels. However, the CCR method restricting services to lab, radiology, ED, CT scan, pharmacy, and observation services (ED-CCR-B), and the regression method (ANC-REG) performed as well or better for some metrics, levels of analysis (visit vs. hospital), and years.

In concept, we recommend use of detailed CCR estimates (DETAIL-CCR) incorporating all cost centers, but cost-center-level charge detail is not available for many hospital ED data sources. Consequently, a cost estimation method that relies only on total ED charges is desirable. In that context, we would avoid using the ANC-CCR method and recommend applying one of the other methods tested in this study. The ED-CCR-N and ED-CCR-B methods may be preferred because these approaches perform well compared with ANC-REG and are easier to implement.

Our study has limitations. First, the "true" cost of ED visit treatment is unknown. Sophisticated cost-accounting methods can derive service delivery costs for specific hospitals, but these are not generally available in regional and nationwide databases. Second, we focused exclusively on treat-and-release ED visits. These visits constitute more than 85% of all ED encounters.[22] Thus, we do not think that excluding ED visits resulting in an inpatient admission led to significant bias in estimating ED service-related costs. It is possible that the

TABLE 3 Comparison of cost estimation methods, 2013–2017, validation sample[a]

	Visit analysis					Hospital analysis				
Metric/model	**2013**	**2014**	**2015**	**2016**	**2017**	**2013**	**2014**	**2015**	**2016**	**2017**
Detailed cost mean ($)										
DETAIL-CCR	363	393	401	417	420	426	445	459	474	490
Predicted cost mean ($)										
ANC-CCR	426	482	501	525	533	457	500	518	544	562
ANC-REG	365	395	403	420	422	383	405	413	430	439
ED-CCR-N	328	358	364	381	385	366	389	398	414	428
ED-CCR-B	341	380	391	411	419	371	401	412	431	446
Estimation error mean ($)										
ANC-CCR	−63	−89	−100	−108	−113	−31	−55	−60	−69	−71
ANC-REG	−2	−2	−2	−3	−2	43	40	46	44	52
ED-CCR-N	35	35	38	36	35	60	56	61	61	62
ED-CCR-B	23	13	10	6	1	55	44	47	43	44
Estimation error median ($)										
ANC-CCR	−13	−24	−28	−31	−32	−33	−56	−64	−74	−77
ANC-REG	−10	−10	−11	−10	−10	15	15	12	13	15
ED-CCR-N	36	37	39	39	39	44	42	41	41	40
ED-CCR-B	31	26	26	26	24	39	31	27	25	25
Reduction in variance (%)[b]										
ANC-CCR	48	40	35	32	29	69	50	44	40	38
ANC-REG	72	73	72	73	71	65	60	53	52	49
ED-CCR-N	70	71	71	71	70	74	71	71	68	62
ED-CCR-B	69	68	67	67	64	73	68	67	67	61
95th–5th error percentiles ($)										
ANC-CCR	631	726	773	797	836	339	361	416	426	441
ANC-REG	445	494	513	532	555	362	361	396	405	442
ED-CCR-N	450	490	505	526	548	244	250	260	266	281
ED-CCR-B	475	531	554	580	609	285	287	304	312	350
75th–25th error percentiles ($)										
ANC-CCR	101	121	130	140	144	115	121	140	141	152
ANC-REG	83	91	92	98	101	114	116	115	114	124
ED-CCR-N	76	78	80	84	86	83	77	76	78	85
ED-CCR-B	78	83	82	86	90	90	85	85	86	93

[a]The source for data in this table is the Agency for Healthcare Research and Quality, Healthcare Cost and Utilization Project, and State Emergency Department Databases, 2013–2017.

[b]Empirical reduction in variance is defined as follows: 1 − (sum of squared estimation errors/total detailed cost corrected sum of squares).

Abbreviations: ANC-CCR, ancillary CCR ratio estimate; ANC-REG, ancillary CCR regression estimate; CCR, cost-to-charge ratio; ED, emergency department; ED-CCR-B, ratio estimate with six cost centers; ED-CCR-N, ratio estimate with four cost centers.

ED and related service costs prior to admission of a patient entering through the ED are higher than our estimates for treat-and-release visits. However, estimating these service costs would require precise date/time stamps of procedures and services delivered prior to admission—data not available in the vast majority of aggregate hospital databases. Third, our study sample did not include encounters in freestanding EDs. The number of freestanding EDs has grown rapidly since 2010 and totaled more than 500 nationally by 2016, including 363 hospital-affiliated off-campus EDs (OCEDs) and 203 non-hospital-affiliated independent freestanding emergency centers (IFECs).[23] It is unclear how inclusion of encounter and financial data from OCEDs and IFECs would affect the analyses reported here.

The methods outlined in this study provide analysts with transparent methods for estimating ED service costs for patient and hospital segments. In the subsequent work, we will illustrate how the cost estimation methods evaluated here can be used to study ED cost trends.

TABLE 4 Confidence intervals for predicted visit cost mean and selected emergency department visit volumes[a]

Metric	Model	2013	2014	2015	2016	2017
Detailed cost mean ($)	NA	363	393	401	417	420
Predicted cost mean ($)	ANC-CCR	426	482	501	525	533
	ANC-REG	365	395	403	420	422
	ED-CCR-N	328	358	364	381	385
	ED-CCR-B	341	380	391	411	419
25,000 visits: Width of 95% confidence interval for predicted cost mean ($)	ANC-CCR	5	6	7	7	7
	ANC-REG	4	4	4	4	5
	ED-CCR-N	4	4	4	5	5
	ED-CCR-B	4	5	5	5	5
10,000 visits: Width of 95% confidence interval for predicted cost mean ($)	ANC-CCR	10	11	12	12	13
	ANC-REG	7	8	8	8	8
	ED-CCR-N	7	8	8	8	8
	ED-CCR-B	7	8	8	9	9
5000 visits: Width of 95% confidence interval for predicted cost mean ($)	ANC-CCR	14	16	17	17	18
	ANC-REG	10	11	11	11	11
	ED-CCR-N	10	11	11	11	12
	ED-CCR-B	10	12	12	12	13
1000 visits: Width of 95% confidence interval for predicted cost mean ($)	ANC-CCR	30	35	37	39	41
	ANC-REG	22	24	24	25	26
	ED-CCR-N	23	24	25	25	26
	ED-CCR-B	23	26	26	27	29

[a]The source for data in this table is the Agency for Healthcare Research and Quality, Healthcare Cost and Utilization Project, and State Emergency Department Databases, 2013–2017.

Abbreviations: ANC-CCR, ancillary CCR ratio estimate; ANC-REG, ancillary CCR regression estimate; CCR, cost-to-charge ratio; ED, emergency department; ED-CCR-B, ratio estimate with six cost centers; ED-CCR-N, ratio estimate with four cost centers.

DISCLAIMER

The views expressed in this article are those of the authors and do not necessarily reflect those of the Agency for Healthcare Research and Quality or the US Department of Health and Human Services.

ACKNOWLEDGMENTS

The authors gratefully acknowledge two anonymous reviewers whose comments improved the quality of our manuscript. We also wish to acknowledge Mary Beth Schaefer (IBM Watson Health) for providing editorial review of the manuscript. Finally, we acknowledge the HCUP partner organizations that contributed to the data used in this study: Arkansas Department of Health, Georgia Hospital Association, Illinois Department of Public Health, Iowa Hospital Association, Kentucky Cabinet for Health and Family Services, Maine Health Data Organization, Maryland Health Services Cost Review Commission, Minnesota Hospital Association, Mississippi State Department of Health, Montana Hospital Association, Nebraska Hospital Association, Nevada Department of Health and Human Services, New Jersey Department of Health, New York State Department of Health, North Carolina Department of Health and Human Services, North Dakota (data provided by the Minnesota Hospital Association), Oregon Office of Health Analytics, South Carolina Revenue and Fiscal Affairs Office, South Dakota Association of Healthcare Organizations, Tennessee Hospital Association, Texas Department of State Health Services, Utah Department of Health, Vermont Association of Hospitals and Health Systems, and Wisconsin Department of Health Services. This research was supported by the Agency for Healthcare Research and Quality (AHRQ), Center for Financing, Access and Cost Trends (CFACT), and Healthcare Cost and Utilization Project (HCUP).

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

ORCID

Gary T. Pickens https://orcid.org/0000-0003-4689-185X
Zeynal Karaca https://orcid.org/0000-0001-7744-4476

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

How to cite this article: Pickens GT, Moore B, Smith MW, McDermott KW, Mummert A, Karaca Z. Methods for estimating the cost of treat-and-release emergency department visits. *Health Serv Res*. 2021;56(5):953-961. https://doi.org/10.1111/1475-6773.13709