Sepsis Among Medicare Beneficiaries: 4. Precoronavirus Disease 2019 Update January 2012–February 2020

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OBJECTIVES: To provide updated information on the burdens of sepsis during acute inpatient admissions for Medicare beneficiaries.

DESIGN: Analysis of paid Medicare claims via the Centers for Medicare and Medicaid Services DataLink Project.

SETTING: All U.S. acute-care hospitals, excluding federally operated hospitals (Veterans Administration and Defense Health Agency).

PATIENTS: All Medicare beneficiaries, January 2012–February 2020, with an explicit sepsis diagnostic code assigned during an inpatient admission.

INTERVENTIONS: None.

MEASUREMENTS AND MAIN RESULTS: The count of Medicare Part A/B (fee-for-service) plus Medicare Advantage inpatient sepsis admissions rose from 981,027 (CY2012) to 1,700,433 (CY 2019). The proportion of total admissions with sepsis in the Medicare Advantage population rose from 21.43% to 35.39%, reflecting the increasing beneficiary proportion enrolled in Medicare Advantage. In CY2019, 6-month mortality rates in Medicare fee-for-service beneficiaries for sepsis continued to decline, but remained high: 59.9% for septic shock, 35.5% for severe sepsis, 30.8% for sepsis attributed to a specific organism, and 26.5% for unspecified sepsis. Total fee-for-service-only inpatient hospital costs rose from $17.79B (CY2012) to $22.98B (CY2019). We estimated that the aggregate cost of sepsis hospital care for the entire U.S. population was at least $57.47B in 2019. Inclusion of 14 months' (January 2019–February 2020) newer data exposed new trends: the cost per patient, number of admissions, and fraction of patients with sepsis labeled as present on admission inflected around November 2015, coincident with the change to *International Classification of Diseases,* 10th Edition, and introduction of the Severe Sepsis and Septic Shock Management Bundle (SEP-1) metric.

CONCLUSIONS: Sepsis among Medicare beneficiaries precoronavirus disease 2019 imposed immense burdens upon patients, their families, and the taxpayers.

KEY WORDS: cost; Medicare; Mortality; sepsis

Sepsis is an overwhelming response to infection that can progress to organ dysfunction, organ failure, and death. In 2016, the Centers for Disease Control and Prevention estimated that at least 1.7 million Americans experience sepsis each year, with more than 270,000 of those patients then dying in the hospital (1). In 2016, the entire inpatient (IP) cost of sepsis for CY2013 in the United States was estimated to be less than $24B (2).

We recently reported the burdens of sepsis among Medicare beneficiaries from 2012 to 2018 (3–5). We noted increasing numbers and rates of sepsis IP admissions in this population. Mortality declined among all severities of sepsis. The aggregated costs of sepsis care rose sharply: based on data from 2012 to 2018,

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the IP hospital cost of sepsis care (excluding physician claims) in CY2019 was projected to total $23.6B for the Medicare fee-for-service (FFS) population alone (5).

Herein, we ask whether the patterns of change previously reported were sustained and whether our projections of case counts, mortality, and costs were realized. Where appropriate, we refine the models and projections. We carry the data through February 2020 to establish a foundation for determining the subsequent impact of coronavirus disease 2019 (COVID-19) on sepsis among Medicare beneficiaries. Our study now includes 11.32 million IP sepsis admissions among Medicare beneficiaries, the largest study of sepsis in this population to date.

MATERIALS AND METHODS

We echoed data sources and analyses described in Sepsis Among Medicare Beneficiaries, 1–3, with enhancements listed below (3–5). We used data that included all sepsis claims among the Medicare FFS and Medicare Advantage (MA) beneficiary populations, as defined by *International Classification of Diseases,* 9th Edition (ICD-9) and *International Classification of Diseases,* 10th Edition (ICD-10) diagnostic codes. Our updated study timeframe applied to all encounters from January 1, 2012, to February 29, 2020.

Compared with the prior cost model that included a linear trend and a single phasic term, we added additional phasic terms to better fit the seasonal effect. We further adjusted costs using the Healthcare Consumer Price Index (CPI), normalizing to the index value in December 2019 (6).

We examined whether the timing of the introduction of the Severe Sepsis and Septic Shock Management Bundle (SEP-1) metric and the transition to the ICD-10 coding system resulted in changes in cost per case, fraction of sepsis coded as present on admission (POA), and the occurrence of all sepsis cases in the Medicare population. This was performed using interrupted time series analyses to determine the timing of inflection points.

To extrapolate from the Medicare count and cost data to estimate the aggregate national cost of sepsis, we used updated data from the Healthcare Cost and Utilization Project (HCUP). HCUP provides counts, but not costs, of sepsis admissions among various payer categories (including FFS Medicare beneficiaries, for whom cost data are available through DataLink) (7). We applied the known sepsis costs incurred by FFS beneficiaries to infer the costs nationally. (Although the Congressional Budget Office [CBO] has estimated that commercial insurers may pay as much as 89% more than Medicare FFS for IP hospital services, we do not assume that these higher payments are correlated with higher costs for their beneficiaries [8]. The inferred national costs will therefore represent a rough order of magnitude [ROM] lower bound of the actual costs.)

All analyses were performed using STATA (Stata Statistical Software: Release 16: StataCorp LLC, College Station, TX) and SAS (SAS Systems for Windows: Version 9.4: SAS Institute, Cary, NC). Logistic regression specified covariate distributions as observed (not as means). Two-tailed significance was prespecified as $p < 0.05$ with reports to include 95% CIs.

This ongoing study of sepsis among Medicare beneficiaries is exempt from institutional review board oversight as it was conducted as an analysis of healthcare quality improvement. Centers for Medicare and Medicaid Services (CMS) is a covered entity. Deidentification was performed on all data in accordance with CMS policy, Privacy Act of 1974 (5 U.S.C. § 552a) and HIPAA (45 Code of Federal Regulations Part 160 and Subparts A and E of Part 164) requirements.

RESULTS

The count of IP admissions that include a sepsis ICD-10 diagnostic code in the Medicare population continued to increase (**Supplemental Digital Content**, http://links.lww.com/CCM/G872). The increase occurred among Medicare FFS and MA beneficiaries (**Fig. 1**). In 2012, there were 981,027 sepsis cases; 21.43% of those were MA beneficiaries. In 2019, there were 1,700,433 sepsis cases in the Medicare beneficiary pool alone; 35.39% of those were MA beneficiaries. This change reflects the increasing preference of beneficiaries for the MA option (9, 10).

The rate of sepsis IP admissions continued to increase beyond a rate attributable to the growth of the Medicare population (**Fig. 2*A***). Examining the peak seasonal months in each year (January 2018 and December 2019), there was an increase in the rate of

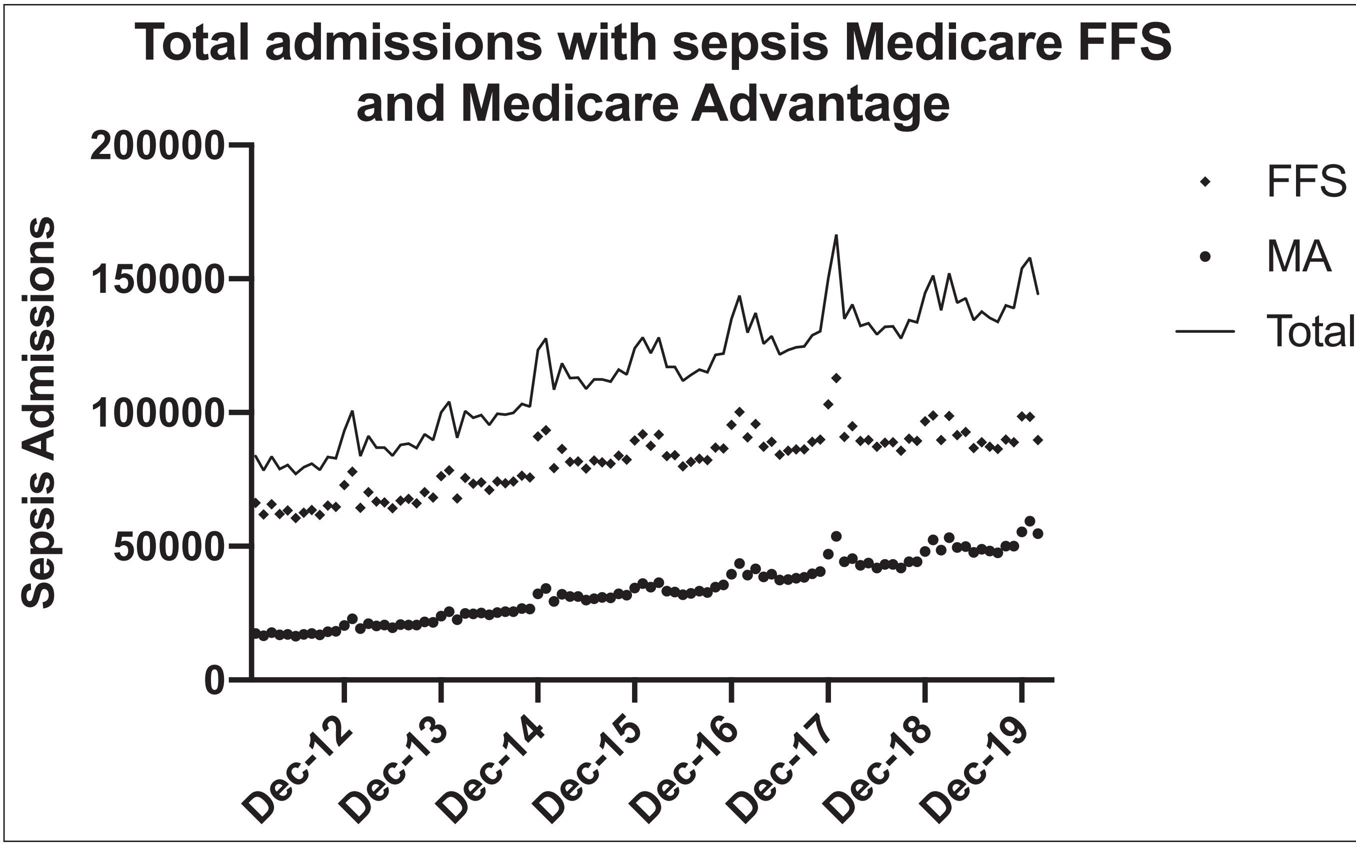

Figure 1. Total admissions with a sepsis diagnosis in Medicare beneficiaries, both fee-for-service (FFS) and Medicare Advantage (MA).

sepsis codes within all IP stays from 12.78% in January 2018 to 12.98% in December 2019 (**Fig. 2*B***). The rates of sepsis continued to increase across all severities, except for nonsevere sepsis without a specified organism, which had a declining trend from 2018 to 2019 (**Fig. 2*C***).

Aggregate sepsis mortality continued to decline (**Fig. 3**). Both 1-week and 6-month mortalities declined across all severities of sepsis (**Fig. 4**). The steepest decline in mortality was in severe sepsis (i.e., sepsis with organ dysfunction): in 2012, the early (1-week) mortality rate was 26.9%, and in 2019, that rate was 14.4% (thus, the 1-week mortality has been nearly halved). The intermediate (6-month) mortality rate declined from 49.3% in 2012 to 35.5% in 2019 (a 38.9% relative reduction). Septic shock mortality also declined, but that mortality remains at 39.9% (1 wk) and 59.9% (6 mo) in 2019.

The total cost of sepsis care continued to rise owing to increases in the rate of sepsis admissions and the now-rising costs per case (**Fig. 5**). The total cost of IP care for sepsis in the Medicare FFS population was $22.98B for 2019, a 2.17% increase from 2018. The average Healthcare CPI-adjusted cost of an IP admission with a sepsis diagnostic code reached a nadir of $17,876 in July 2015 (6). By 2019, this average Healthcare CPI-adjusted cost rebounded to $20,172, which is 4.9% higher than in 2018 ($19,232). Thus, both the case count and the cost per IP admission rose. Imputing and including the Medicare MA costs from the known cost per case of the FFS population, the total 2019 Medicare IP sepsis cost is estimated to be $35.45B.

We further investigated this rebounding cost per case by retrieving the use and associated costs of the most common diagnosis-related groups (DRGs) for beneficiaries with sepsis POA. From CY2012-2019, these seven most common DRG for patients with a sepsis diagnostic code POA represented an increasing fraction of all DRGs (**Fig. 6*A***). The average cost for these seven DRGs inflected from CY2015 to CY2016 and continued to rise thereafter (**Fig. 6*B***).

We observed two other changes that coincided with the redirection of cost per IP admission in November 2015. The fraction of sepsis cases labeled as POA continued to rise but inflected to a reduced rate (**Fig. 7**).

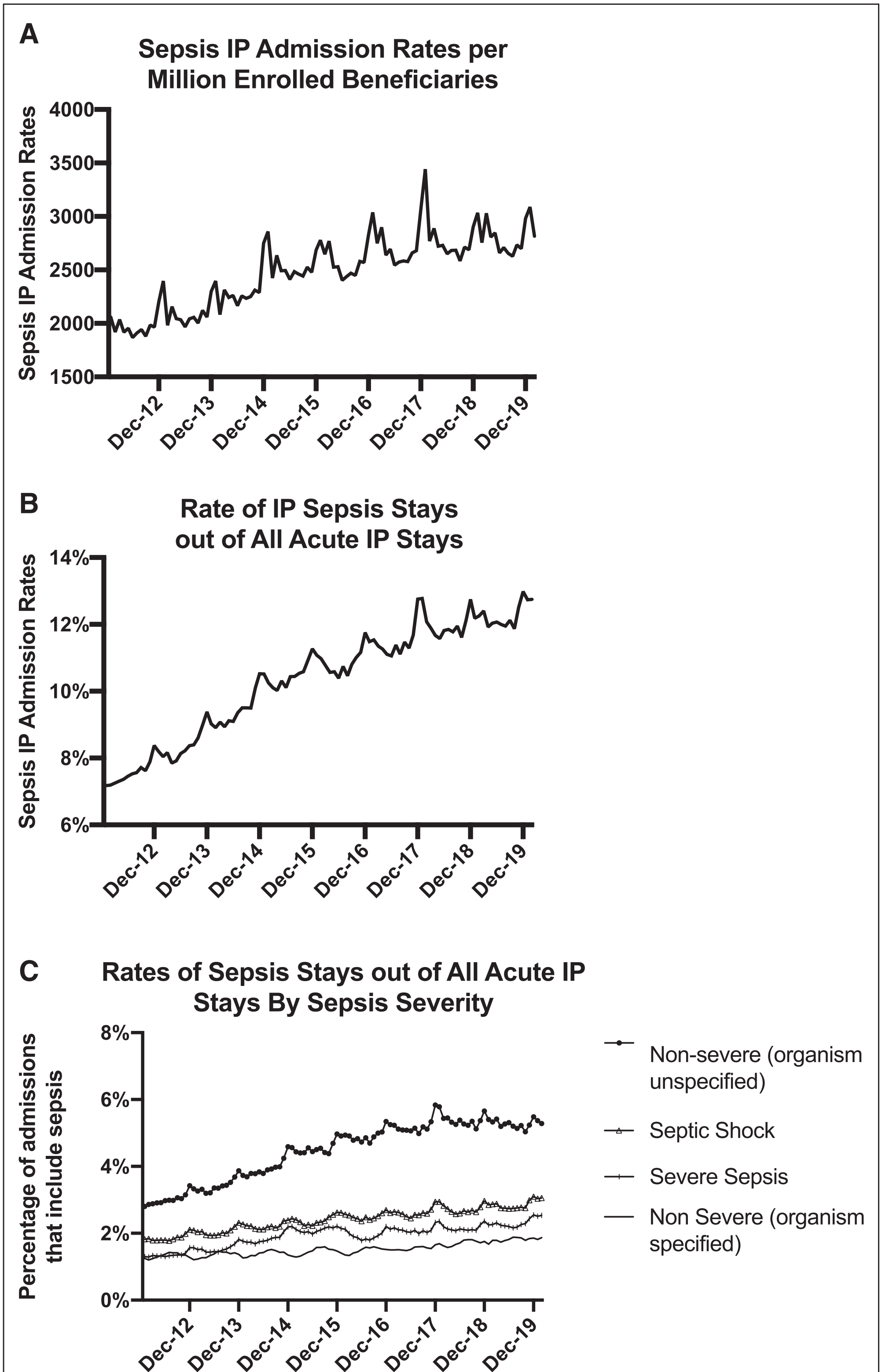

Figure 2. Trends in inpatient (IP) sepsis admissions to acute care hospitals of Medicare fee-for-service beneficiaries. **A**, Sepsis IP admissions per million enrolled beneficiaries per month. **B**, Rate of sepsis IP admissions out of all IP admissions in the Medicare fee-for-service beneficiary population. **C**, Rates of sepsis stay out of all Medicare fee-for-service IP admissions stratified by sepsis severity.

In CY2012, the sepsis POA rate was 88.06%. In the 12 months prior to the inflection (November 2014–October 2015), the POA rate had reached 91.22%, and in the 12 months after the inflection (November 2015–October 2016), the POA rate rose more slowly to 91.85%. The final POA rate for the 12 months prior to the onset of COVID-19 in the United States was 92.82%. The linear trend in combined (FFS and MA) Medicare beneficiary sepsis case counts also continued to rise, but this trend inflected to a shallower rise (**Fig. 8**). All three of these inflections—the increased cost per case, the reduced rate of rise in the POA fraction, and the linear trend in the incidence of all Medicare sepsis cases—occurred around November 2015, that is, around the time of the transition from ICD-9 to ICD-10 and the coincident introduction of the SEP-1 metric.

Our prior models had forecast the 2019 cost of hospital sepsis care for Medicare FFS-only IP admissions to be $23.55B (3, 5). The 2019 cost data revealed that this forecast overestimated the actual cost ($22.98B) by 2.5% as the FFS-only case count rose more slowly. A revised model that now includes

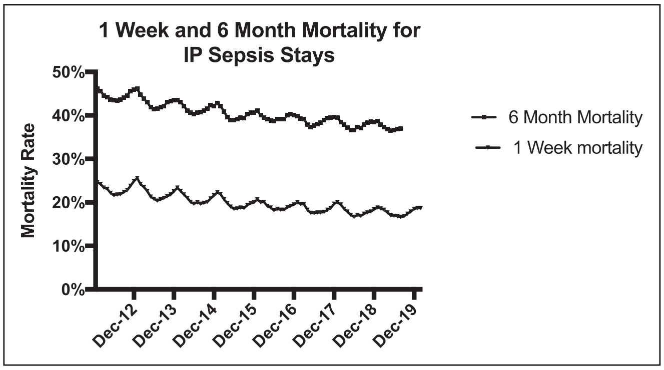

Figure 3. One-wk and 6-mo mortality in Medicare fee-for-service patients with sepsis. IP = inpatient.

additional phasic terms to refine the impact of seasonal sepsis variation using cost data from 2012 to 2018 improved the forecast for 2019 Medicare FFS-only cost for IP sepsis admissions to $22.81B (only $170M or 0.75% different from the actual) (**Table 1** and **Fig. 9**).

Using linear regression to project the fraction of non-Medicare patients with sepsis codes in the HCUP dataset, we predicted that 39.71% (95% CI, 37.56–41.86%) of patients who received IP care for sepsis in 2019 will be non-Medicare beneficiaries. From the known count of Medicare beneficiaries with sepsis, we extrapolated the aggregate sepsis counts for the United States in 2019. In order to calculate an ROM estimate of IP hospital costs, we assumed that the cost per stay for all sepsis IP admissions was the same as the cost for Medicare FFS IP admissions. The total predicted hospital costs for IP sepsis admissions including the Medicare, Medicaid, self-pay, and private insurance industry beneficiaries are forecasted to be $57.47B (95% CI, $55.49B–$59.60B) (**Table 2**). This new ROM lower bound estimate for 2019 IP hospital sepsis costs is 8.4% higher than our prior estimate of $53B. This estimate continues to omit professional fees ("doctor bills"), as well as all costs incurred in Veterans Administration hospitals and in military hospitals within the Defense Health Agency.

DISCUSSION

The burdens of sepsis upon Medicare, its beneficiaries, their families, and the taxpayer continue to climb. Furthermore, counts, costs, and cost per case appear to be rising. These rises through February 2020 occurred prior to knowledge of (much less to the effects of) COVID-19 in the United States.

The consistent decline in sepsis mortality is reassuring given the increasing incidence of sepsis. The most significant declines remain in severe sepsis (sepsis with organ failure, but without shock), although modest improvements occurred in all severity classes of sepsis. Septic shock remains highly lethal, with only small improvements in mortality occurring from January 2012 to February 2020. Notably, sepsis mortality trends follow a seasonal pattern with sepsis incidence, which is likely a representation of the generalized sepsis risk in the population and the pathogens circulating in the environment at any given time. For example, more crowded indoor settings and the incidence of respiratory viral infections in winter months may drive both sepsis cases and deaths.

A limitation to the financial analysis carries over from our prior report (3–5). We inferred costs of care for MA patients from diagnoses and could not compute them from claims data: the costs are known only to the payer, and CMS does not receive any financial information directly. As before, we impute those costs as equal to those incurred by FFS beneficiaries with similar diagnostic codes. This same imputation is applied to non-Medicare beneficiaries, although the CBO estimates

TABLE 1.
Revised Regression Parameters for Modeling Cost of Inpatient Care for Sepsis Among Medicare Fee-for-Service Beneficiaries When Using Additional Phasic Terms

2012–2018 Model			2019 Projection		
Adjusted R^2	Root Mean Square Error	2019 Actual	Projection	95% Lower Bound	95% Upper Bound
0.897	$63,282,906	$22,981,348,196	$22,805,635,977	$21,868,867,396	$23,742,404,559

Modeled on cost data from 2012 to 2018. All input values adjusted using the Healthcare Consumer Price Index, normalized to the index value in December 2019 (6).

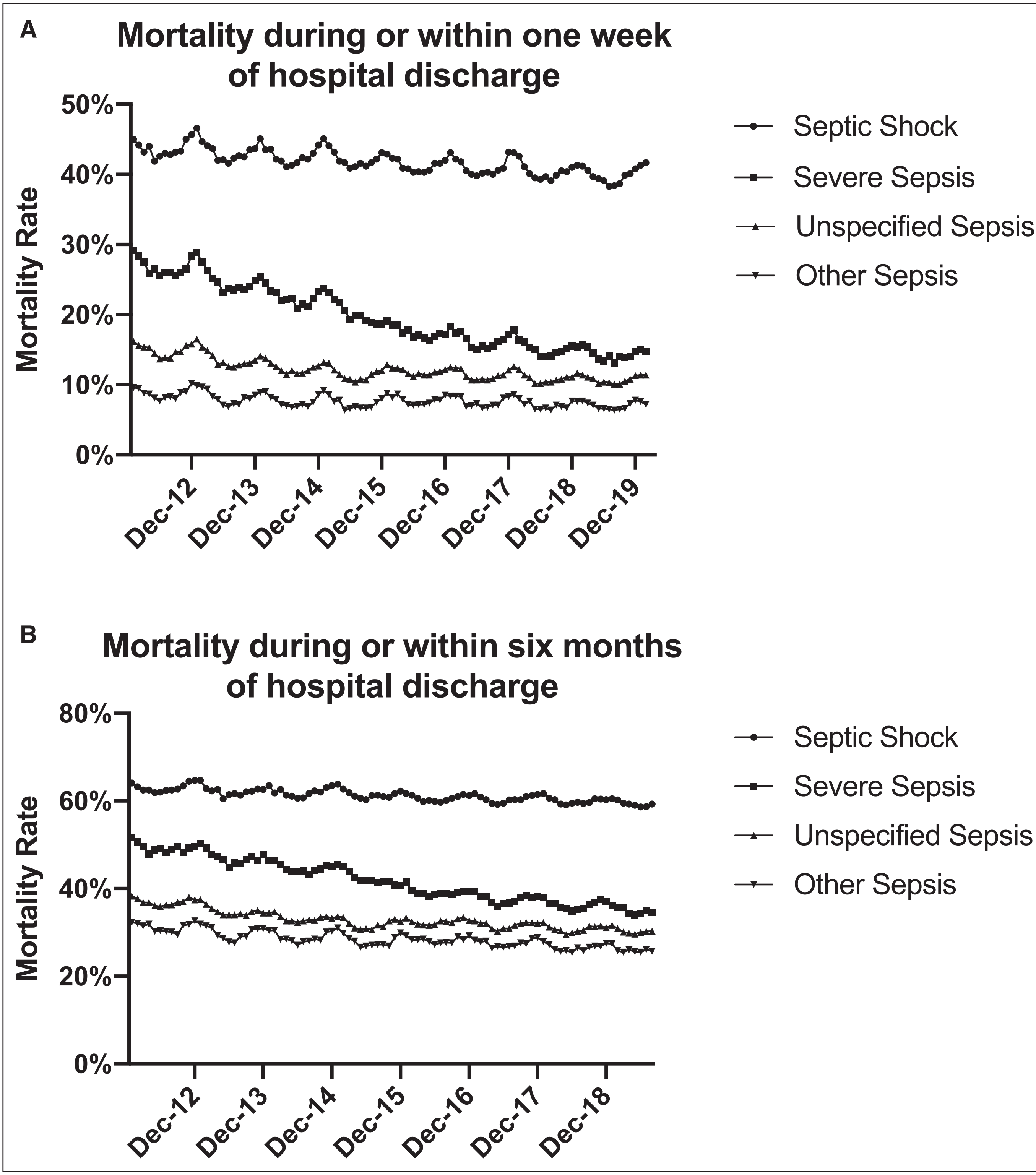

Figure 4. Mortality among the Medicare fee-for-service population stratified by sepsis severity within 1 wk (**A**) and 6 mo (**B**).

that commercial insurers pay much higher rates (8). Therefore, our cost estimates remain ROM lower bounds. Due to the increasing proportion of enrollees in MA, estimates of total Medicare costs attributable to sepsis IP admissions are subject to greater future error.

A further limitation of this study is the use of sepsis diagnostic codes and administrative data. As diagnostic codes and practices around their use change in time, the true incidence and impacts of sepsis may be hard to define. Sepsis coding data are biased by clinical

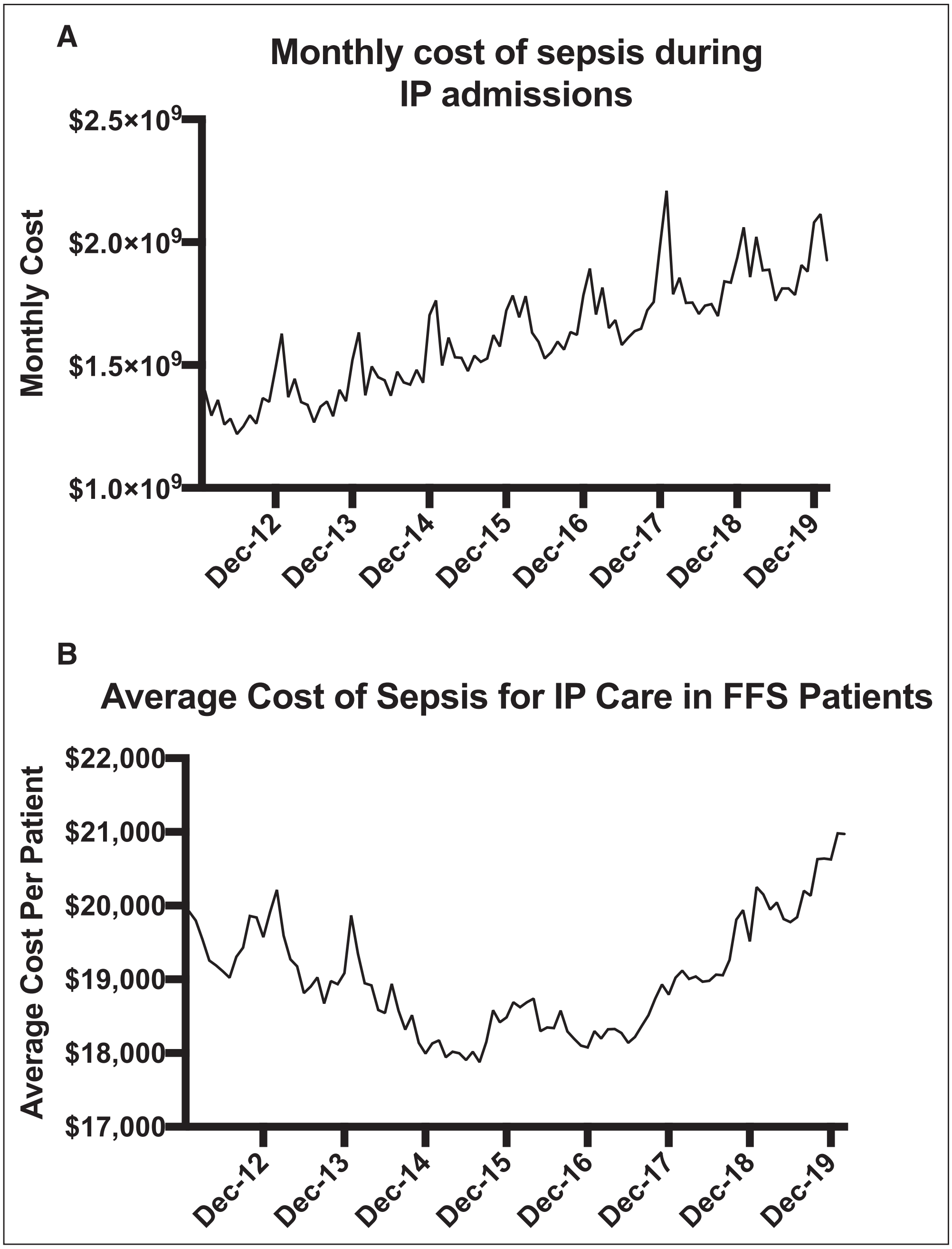

Figure 5. Monthly inpatient (IP) costs for sepsis among Medicare fee-for-service (FFS) beneficiaries Healthcare Consumer Price Index adjusted to December 2019 U.S. dollar values (6). **A**, Total costs. **B**, Average cost per patient.

practices that change over time in response to a myriad of clinical and administrative concerns. Electronic health record–based sepsis surveillance is beyond the scope of this study, but an important endeavor for the basis of future studies.

We observed three changes in the data trends since our previous reports (3–5). These changes became clear through the addition of 14 months of data (January 2019—February 2020).

The first change observed was a reversal in the cost per case. In 2012–2015, there was a decline in cost per case even while case counts were rising. In a sense, the effects of rising volumes were previously tempered by lower costs. However, costs are now growing both because of rising sepsis rates and rising per-patient costs, which was not clearly visible in prior analyses due to the initially slow rise in costs. The rise has now accelerated, surpassing the 2012 costs in November 2018. Healthcare CPI-adjusted average costs per patient were higher in 2019 than in 2012 ($20,172 vs $19,488), and they rose monthly. This is in contrast to the average Healthcare CPI-adjusted overall Medicare Part A/B per-enrollee spending, which has been declining ($11,151 in 2013 vs $10,536 in 2019). The healthcare CPI-adjusted compound annual growth rate of sepsis costs per patient was 0.43% from January 2012 to February 2020, compared with –0.81% for average Medicare expenditures per patient from 2013 to 2019 (the time period for which data are available) (6). The increasing representation of the most common DRGs (septicemia or severe sepsis without mechanical ventilation [MV] greater than 96 hr with major complication or comorbidity [MCC], septicemia or severe sepsis without MV > 96 hr without MCC, and infectious and parasitic diseases with operative procedure with MCC) and their rising costs may

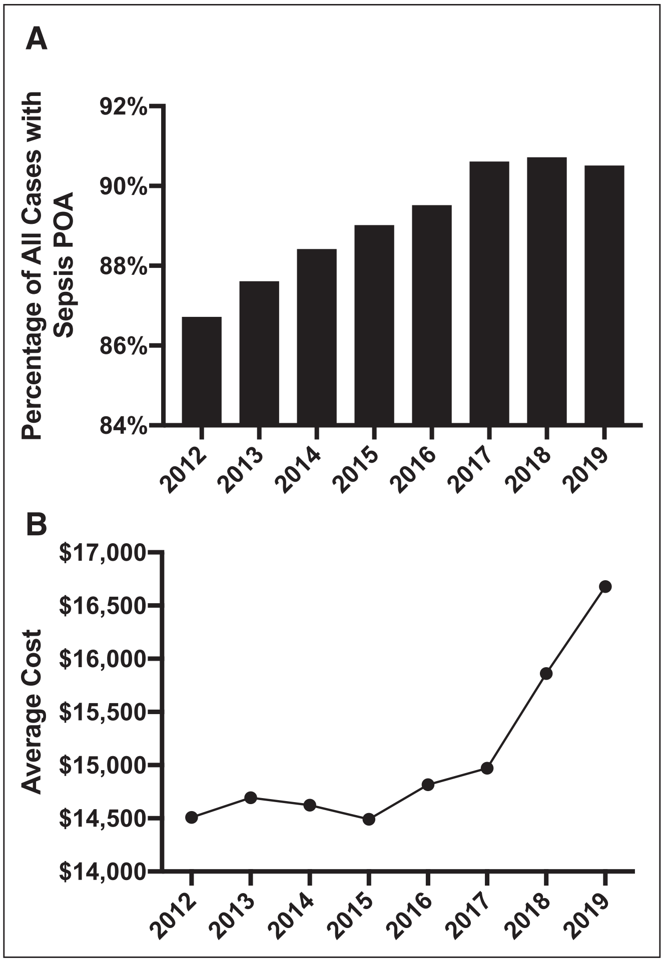

Figure 6. Analysis of the seven most common diagnosis-related groups (DRGs) for admissions with a sepsis diagnostic code labeled as present on admission (POA). **A**, Percentage of all admissions assigned to the seven most common DRGs. **B**, Average cost-per-case for the top seven most common DRGs (costs are adjusted using the Healthcare Consumer Price Index, normalized to the index year 2019) (6). Costs inflected in 2015. The DRGs represented (in order of frequency): septicemia or severe sepsis without mechanical ventilation (MV) > 96 hr with major complication or comorbidity (MCC), septicemia or severe sepsis without MV > 96 hr without MCC, infectious and parasitic diseases with operating room (OR) procedure with MCC, septicemia or severe sepsis with MV greater than 96 hr or peripheral extracorporeal membrane oxygenation, other kidney and urinary tract diagnoses with MCC, infectious and parasitic diseases with OR procedure with complication or comorbidity, other circulatory system diagnoses with MCC.

be driving overall cost increases; their now-rising cost-per-patient can no longer temper other higher cost admissions (Supplemental Digital Content, http://links.lww.com/CCM/G872) (6, 11). However, the rising cost is not solely attributable to the relative use of particular DRGs: CMS revises the weights assigned to common DRGs annually, and the increase in the weights of those DRGs combined with their more frequent use results in higher costs. (See data in the Supplemental Digital Content, http://links.lww.com/CCM/G872, tabs of DRG, and weights by year.) The average cost of sepsis in the Medicare FFS population is comparable with the $21,568 identified by Paoli et al (12) when examining a broader population that was not restricted to Medicare beneficiaries.

The second change observed was a slowing of the increase in case counts. The linear trend in IP admissions with a sepsis diagnostic code appeared to inflect in November 2015 (subject to seasonal variation depending on the intensity of the respiratory season). The resultant plateaus in sepsis rates emerged in both the FFS and MA beneficiaries. This change, therefore, cannot be explained by less healthy beneficiaries switching between FFS and MA plans. This change may be due to greater precision in coding following the transition from ICD-9 to ICD-10 owing to the availability of a greater number of more specific diagnostic codes for sepsis.

There is an alternative explanation for this trend, namely, that the inflections may reflect changes in coding behavior and care following the introduction of the SEP-1 metric in October 2015. This quality metric encourages compliance via pay-for-reporting programs that provide added revenues to healthcare systems that comply. Tracking the actions—testing and interventions, around SEP-1 performance specifically and sepsis patients generally—is also important to healthcare systems when petitioning for outlier payments that collectively add 7–10% to the DRG costs. Thus, metric compliance reinforces cost escalation: the costs for each case inform the DRG relative weight in future years. More services provided for a given DRG, relative to other DRGs, will yield a higher weight. This means that if costs for cases with a given DRG are consistently exceeding the reimbursement provided for that DRG, Medicare will increase the DRG reimbursement amount in future years. To this end, Medicare considers the "charges" reported on the claims and each individual facility's cost-to-charge ratio derived from cost reports. Thus, costs that qualified a given case for an outlier payment would also be included (13–16).

Of note, there was no apparent reciprocal improvement in short-term outcome; the patterns of 1-week

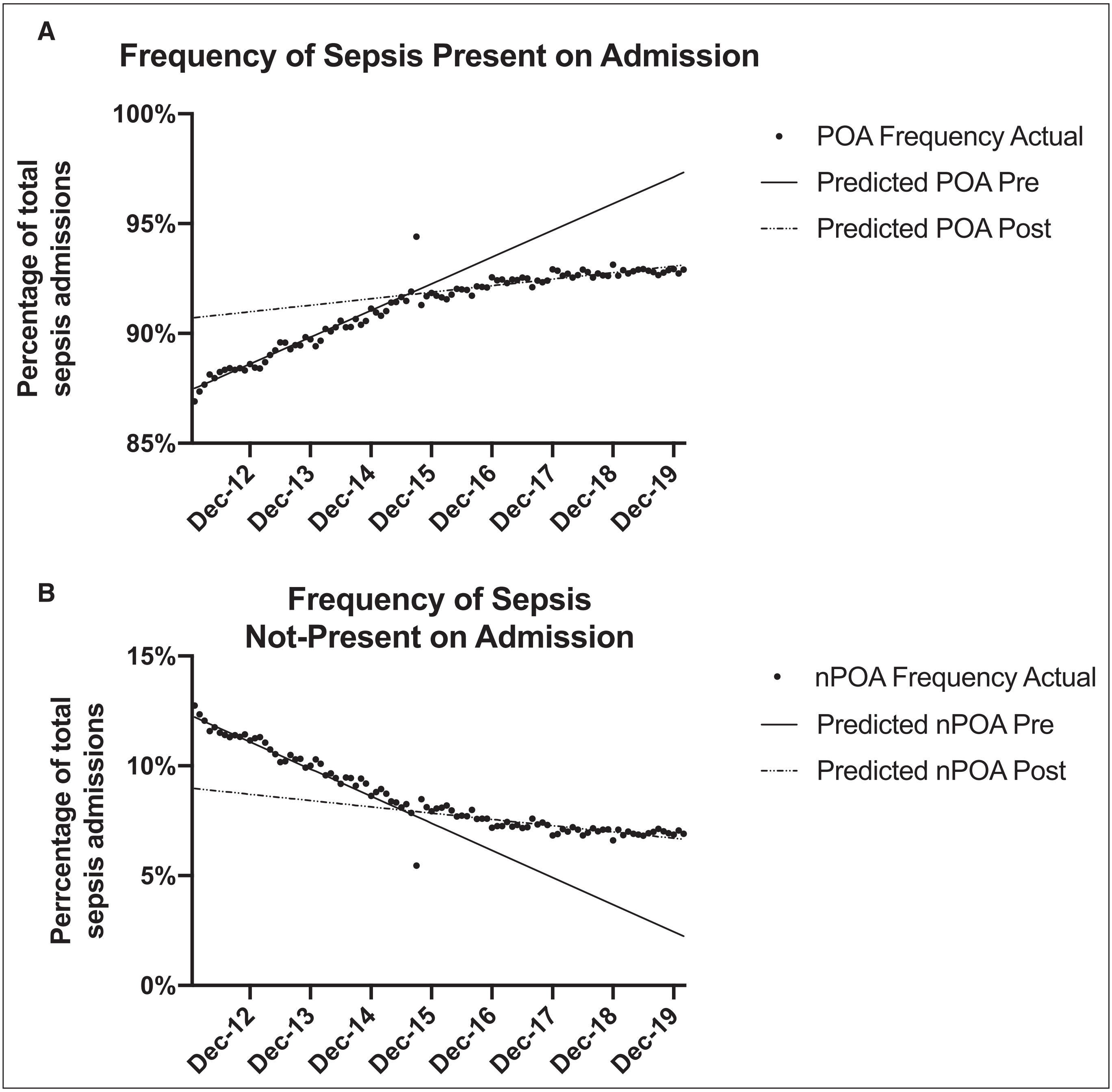

Figure 7. Interrupted time series regression analysis of change in frequency of diagnosis of sepsis as present on admission (POA) (**A**) and not POA (nPOA) (**B**). Interruption occurs in November 2015.

and 6-month mortalities show no comparable interruption. This apparent lack of impact of SEP-1 on outcomes has been previously reported (17, 18).

The third change observed was the slowing of the increase in sepsis cases labeled as POA. The linear trend in sepsis cases also appeared to inflect in November 2015. This may reflect variability in identifying "time zero" for a sepsis diagnosis (19). Given the penalties for hospital-acquired infections and the rewards for reporting sepsis under SEP-1, a shift in coding behavior may be occurring to favor labeling the "time zero" as POA to avoid penalties and also gain benefits under SEP-1. This coding behavior also reflects increased awareness of sepsis when the patient arrives at the hospital, allowing earlier intervention and also diagnosis and coding. We speculate that the slowing rate of increase of implies that the effect of these factors is reaching its ceiling.

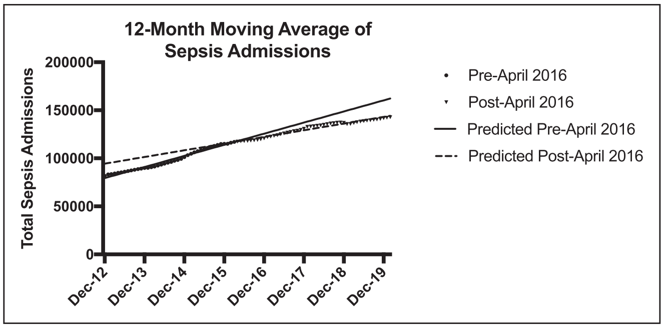

Figure 8. Interrupted time series analysis of the 12-month moving average sepsis admissions among Medicare fee-for-service and Medicare Advantage beneficiaries. The point of maximal difference occurs in April 2016, reflecting that the inflection occurred in October 2015, 6 mo prior.

Seasonal variation in sepsis rates plays a key role in predicting costs. Our prior cost model accounted for this with a single phasic term (5). Although this model offered a fair prediction of future costs, it overpredicted the 2019 sepsis costs by 2.5%. We refined the model to include additional phasic terms that better accounted for the seasonal variations in sepsis. This model provided a closer estimate of future sepsis costs, and it may serve as an additional surveillance tool to evaluate deviations due to surges in infectious disease by identifying actual costs deviating from projections. We do not propose using this model specifically for budget forecasting.

Our extrapolation of Medicare cost data to a broader range of payer categories provided an estimated IP sepsis cost of \$57.47B for 2019. This compares unfavorably with Torio and Moore's (2) 2016 estimate of \$24B based on 2013 data. The actual total exceeded our prior forecast of \$53B, which had been generated from rough estimates of the number of patients in different payer categories. Similar to the prior estimate, this revised estimate represents only the IP hospital costs, and not the professional, outpatient, skilled nursing facility, Department of Veterans Affairs, and Defense Health Agency costs. Thus, it represents a conservative, ROM lower bound for IP hospital sepsis costs only. Although it omits a large component of the cost of sepsis care, the trends may reflect the direction and magnitude of other cost changes.

This update extends our analysis through the prepandemic period—before the appearance of COVID-19 and its subsequent toll on Medicare beneficiaries and the Nation. We intend for the analysis and these forecasts to serve as a basis for understanding COVID-19's

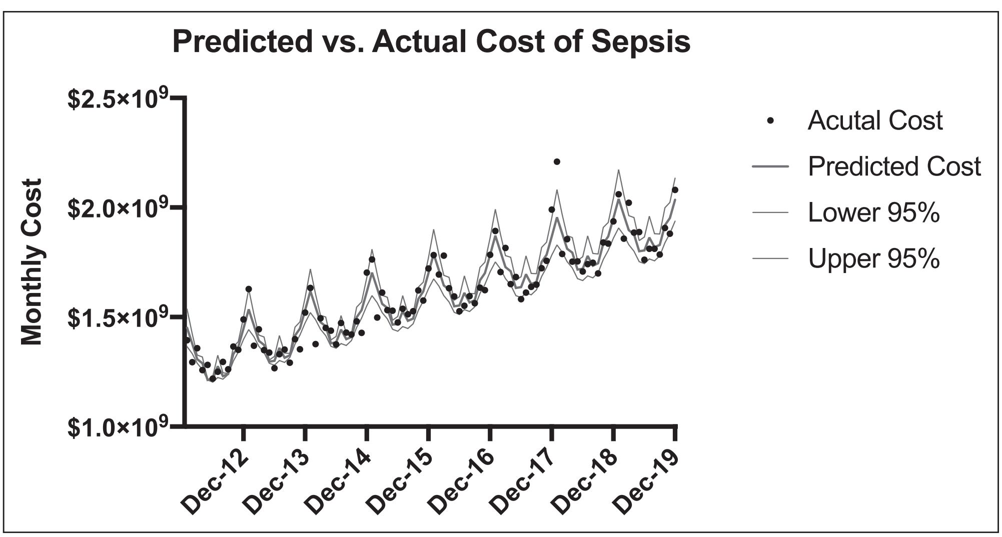

Figure 9. Predicted and actual sepsis costs among Medicare fee-for-service beneficiaries. All values adjusted using the Healthcare Consumer Price Index, normalized to the index value in December 2019 (6).

TABLE 2.
Regression Parameters and Projected Fraction of Non-Medicare Patients With Sepsis, Total Patients Admitted With Sepsis, and Total Sepsis Costs From Analysis of the Healthcare Cost and Utilization Project Primary Payer Trends for Sepsis

Model Parameters			2019 Projections		
Adjusted R^2	Root Mean Square Error		Projection	95% Lower Bound	95% Upper Bound
0.693	0.948%	Fraction non-Medicare	39.71%	37.56%	41.86%
		Total patients	2,820,419	2,723,472	2,924,529
		Total cost	\$57,474,499,109	\$55,498,903,631	\$59,596,053,494

subsequent impacts on Medicare beneficiaries, the Nation, and the world. Severe COVID-19—that is, COVID-19 that requires hospitalization and continuous support to offset organ dysfunction—is sepsis by definition (20).

CONCLUSIONS

Sepsis IP admission rates, namely, the count of sepsis IP admissions per (number of) beneficiaries, continue to rise even as the number of beneficiaries also continues to rise. Despite the rise in counts, mortality declined. The trend in cost per case reversed in 2015, and there is evidence that even with correction for the healthcare CPI, that cost-per-case was rising before the beginning of the pandemic.

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