ORIGINAL ARTICLE

A Simple and Interpretable Mortality-Based Value Metric for Condition- or Procedure-Specific Hospital Performance Reporting

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Abstract

Objective: To develop a simple, interpretable value metric (VM) to assess the value of care of hospitals for specific procedures or conditions by operationalizing the value equation: Value = Quality/Cost.

Patients and Methods: The present study was conducted on a retrospective cohort from 2015 to 2018 drawn from the 100% US sample of Medicare inpatient claims. The final cohort comprised 637,341 consecutive inpatient encounters with a cancer-related Medicare Severity-Diagnosis Related Grouping and 13,307 consecutive inpatient encounters with the *International Classification of Diseases, Ninth Revision* or *International Classification of Diseases, Tenth Revision* procedure code for partial or total gastrectomy. Claims-based demographic and clinical variables were used for risk adjustment, including age, sex, year, dual eligibility, reason for Medicare entitlement, and binary indicators for each of the Elixhauser comorbidities used in the Elixhauser mortality index. Risk-adjusted 30-day mortality and risk-adjusted encounter-specific costs were combined to form the VM, which was calculated as follows: number needed to treat = 1/(Mortality$_{\text{national}}$ − Mortality$_{\text{hospital}}$), and VM = number needed to treat × risk-adjusted cost per encounter.

Results: Among hospitals with better-than-average 30-day cancer mortality rates, the cost to prevent 1 excess 30-day mortality for an inpatient cancer encounter ranged from $71,000 (best value) to $1.4 billion (worst value), with a median value of $543,000. Among hospitals with better-than-average 30-day gastrectomy mortality rates, the cost to prevent 1 excess 30-day mortality for an inpatient gastrectomy encounter ranged from $710,000 (best value) to $95 million (worst value), with a median value of $1.8 million.

Conclusion: This simple VM may have utility for interpretable reporting of hospitals' value of care for specific conditions or procedures. We found substantial inter- and intrahospital variation in value when defined as the costs of preventing 1 excess cancer or gastrectomy mortality compared with the national average, implying that hospitals with similar quality of care may differ widely in the value of that care.

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Health care spending in the United States continues to grow at unsustainable levels, with the Medicare Trustees Report estimating that the Trust Fund will reach insolvency by 2026.[1] Simultaneously, the value of the care delivered with these dollars remains in question, with outcomes in the United States lagging behind those of peer Organization for Economic Co-operation and Development countries.[2] The value movement aims to transform the United States health care system to deliver greater value for the dollars spent, resulting in a shift from payment on the basis of fee-for-service to value-based payment. Implicit in this shift is a need to accurately measure value; however, the methods used to assess value remain nascent relative to the pressure placed on these measures to drive us toward the health care system of tomorrow. Our measurement capabilities will determine how safe, equitable, efficient, innovative, and patient-centered our

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care delivery models will be in the future; thus, the field must invest in the development of new methodologies and challenge existing measurements.

Considering this context, we developed a measure assessing the value of care delivered at US hospitals. Our objective was to create a simple, interpretable mortality-based value metric (VM) while encouraging renewed discourse on the science of value measurement, which has for decades been recognized as important, but with little progress made toward concrete attempts at the creation of useful value measures.[3-6]

Here, we present an intuitive VM, which operationalizes the value equation: Value = Quality/Cost.[7] The VM quantifies a hospital's cost of avoiding 1 excess 30-day mortality by incorporating the cost of treatment at a given hospital. For potential value measures, the concept of "time" is important to define. The time component enters into the VM in 2 ways: the outcome of mortality is measured over a 30-day time horizon, whereas the cost component includes the encounter-specific costs of hospitalization, during which length of stay is the time component and functions as a construct of both the effectiveness and efficiency of a hospital's care processes. We applied the VM to assess the value of care provided across US hospitals for 1 condition and 1 procedure and concluded with a discussion of the broader policy and practice implications of this measure.

PATIENTS AND METHODS

Construction of VM

The VM is a composite metric that quantifies a hospital's cost to prevent 1 excess condition-specific or procedure-specific 30-day mortality. The metric can be used to report and compare performance across hospitals. The metric operationalized in this paper is a derivation of the foundational value equation: Value = Quality/Cost. Value can be increased by providing higher-quality and/or lower-cost health care services. For a unique hospital, the cost of preventing an excess mortality is calculated as the number needed to treat (NNT) multiplied by the risk-adjusted cost per encounter. In this calculation, NNT is computed by subtracting the condition-specific (or procedure-specific) risk-standardized 30-day mortality rate at the unique hospital from the national average condition-specific (or procedure-specific) 30-day mortality rate and finding the inverse of that value as follows:

$$\text{NNT} = 1 \,/\, (\text{Mortality}_{\text{national}} - \text{Mortality}_{\text{hospital}})$$

$$\text{VM} = \text{NNT} \times \text{risk-adjusted cost per encounter}$$

Figure 1 outlines a hypothetical VM calculation for "hospital A," which has a condition-specific risk-standardized 30-day mortality rate of 6.5%. The national average condition-specific mortality rate in this example is 8.5%. Hospital A has a condition-specific average encounter cost of $10,900, bringing the cost of preventing 1 excess condition-specific 30-day mortality to $545,000.

Data and Study Population

To illustrate the VM, we calculated the measure across US hospitals for 1 general high-volume condition (cancer) and 1 specific low-volume procedure (gastrectomy). We used the 2015-2018 Centers for Medicare and Medicaid Services (CMS) Inpatient Standard Analytical File Limited Data Sets, which included 100% of Medicare Fee-for-Service inpatient encounters across 4484 US hospitals, the Master Beneficiary Summary Files from 2016 to 2018, and the Denominator file from 2015. Within these files, we utilized cohort-specific data from July 1, 2015, to June 30, 2018, among patients aged 65 years and older.

The condition-specific cancer cohort included 637,341 consecutive encounters with a cancer-related Medicare Severity-Diagnosis Related Grouping (MS-DRG) at 2535 US hospitals, with the cancer cohort definition mirroring the MS-DRGs for cancer in the US News and World Report's Best Hospitals cancer specialty ranking.[8] For this analysis, we only included cancer encounters from hospitals with at least 25 cancer encounters during the study period. The eligible cancer encounters at each hospital ranged from 25 to 9646, with a median of 129 encounters and mean of 251 encounters. These 637,341 encounters were mapped to 503,886 patients, with the patient-level encounter count ranging from 1 to 36, with a median of 1 encounter and mean of 1 encounter per patient.

The procedure-specific gastrectomy cohort included 13,307 consecutive encounters with the *International Classification of Diseases, Ninth Revision* or *International Classification of Diseases, Tenth Revision* procedure code for partial or total gastrectomy among the 242 US hospitals that had at least 25 gastrectomy encounters during the study period. An encounter with any of the following *International Classification of Diseases, Ninth Revision* or *International Classification of Diseases, Tenth Revision* procedure codes was included in the gastrectomy cohort: 0DT60ZZ, 0DT70ZZ, 0DT64ZZ, 0DT74ZZ, 0DB60ZZ, 0DB70ZZ, 0DB64ZZ, 0DB74ZZ, 435, 436, 437, 4381, 4382, 4389, 4391, and 4399. The eligible gastrectomy encounters at each hospital ranged from 25 to 480, with a median of 41 encounters and a mean of 55 encounters. These 13,307 encounters were mapped to 13,216 patients, with the patient-level encounter count ranging from 1 to 3, with a median of 1 encounter and mean of 1 encounter.

Statistical Analyses

Claims-based demographic and clinical variables were used for risk-standardization of inpatient encounter-level charges and 30-day mortality in hierarchical logistic regression models. The variables included were age, sex, year, dual eligibility, reason for Medicare entitlement, and binary indicators for each of the Elixhauser comorbidities used in the Elixhauser mortality index.[9] Additionally, the gastrectomy models included a variable for whether the procedure was a total gastrectomy (yes/no) and the cancer models included a variable for the MS-DRG category. In the total charge models, we excluded potential outliers (very high or very low charges), defined as charges above the 99th percentile or below the first percentile. We multiplied risk-adjusted total charges by hospital-specific cost-to-charge ratios from the 2014 CMS Final Cost Report to convert charges to costs.[10] Separate VMs were calculated for cancer and gastrectomy by multiplying hospital-level NNT to prevent 1 mortality by the mean risk-standardized costs of cancer or gastrectomy encounters. Thus, the VM is interpreted as the cost to prevent 1 excess 30-day mortality compared with the national condition- or procedure-specific mortality rate. For our NNT calculation, we observed a national average condition-specific 30-day mortality rate of 22.88% for the cancer cohort and national average procedure-specific 30-day mortality rate of 7.40% for the gastrectomy cohort.

Hypothetical example, hospital A:

National average condition-specific 30-day mortality rate=8.5%
Condition-specific risk-standardized 30-day mortality rate at hospital A=6.5%
Hospital A condition-specific average cost of encounter=$10,900

NNT=1/(0.085 - 0.065); NNT=50

Value metric=50×$10,900=$545,000

Interpretation: The cost of preventing one excess condition-specific 30-day mortality at hospital A is $545,000

-OR-

For every $545,000 spent during an inpatient encounter for this condition at hospital A, one excess mortality is prevented

FIGURE 1. Hypothetical example of value metric. NNT, number needed to treat.

Uncertainty in the VM calculation was represented by multiplying hospital-specific mean lower and upper 95% Wald CIs of risk-adjusted costs by the NNT. The intrahospital correlation between VM percentiles for cancer and gastrectomy were tested using the Pearson correlation to demonstrate whether hospitals provided similar relative value for both cancer and gastrectomy. The Table presents descriptive information on the distribution of the hospital-level characteristics and outcomes, including risk-standardized mortality for both the cancer and gastrectomy VM calculations, as well as the hospital-level mean risk-standardized costs of cancer or gastrectomy encounters.

RESULTS

After risk adjustment and exclusion of potential outlier charges, the cancer cohort consisted of 624,595 encounters across 2504 hospitals and the gastrectomy cohort consisted of 13,039 encounters across 241 hospitals. Figure 2 depicts the cancer-specific VM for US hospitals. Among

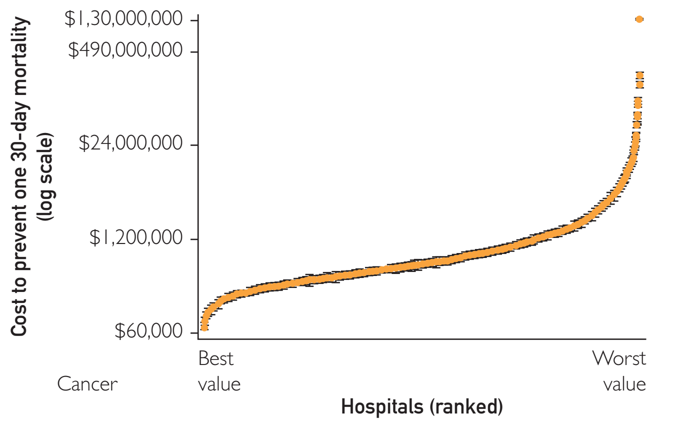

FIGURE 2. Interhospital variation in cancer value metric (cost to prevent 1 excess 30-day mortality) from July 1, 2015, to June 30, 2018. Patients aged 65 years and older extracted from Medicare Inpatient Standard Analytic File, the Master Beneficiary Summary Files, and the 2015 Denominator File. Yellow dots indicate point estimate, and black bars indicate 95% confidence limits.

hospitals with better-than-average 30-day mortality rates, the VM ranged from $71,000 (best value) to $1.4 billion (worst value), with a median (interquartile range) of $543,000 ($329,000 to $1.2 million) (Table). A total of 1262 hospitals (50.4% of 2504 hospitals assigned a VM) had 30-day mortality rates better than the national average. Figure 3 depicts the gastrectomy-specific VM for US hospitals. Among hospitals with better-than-average 30-day mortality rates, the VM ranged from $710,000 (best value) to $95 million (worst value), with a median (interquartile range) of $1.8 million ($1.1-$3.0 million). A total of 158 hospitals (65.6% of 241 hospitals assigned a VM) had 30-day mortality rates better than the national average.

When presenting the VM as a percentile (99 = best value; 1 = worst value), we found that VMs for gastrectomy and cancer were weakly correlated ($r = 0.28$), with only 32 of 241 (13.3%) hospitals achieving the top VM quartile for both cancer and gastrectomy.

DISCUSSION

The VM is a novel yet simple metric that can be used to compare value across US hospitals. It focuses on one key outcome measure—mortality—while also considering the cost associated with delivering care. We found substantial national variation in the value of care when defined as a hospital's cost to prevent 1 condition- or procedure-specific excess 30-day mortality. At the highest-value hospital, 1 excess postgastrectomy 30-day mortality was prevented for less than $1 million, whereas the equivalent mortality reduction cost $95 million at the lowest-value hospital. At the highest-value hospital, 1 excess cancer 30-day mortality was prevented for $71,000, whereas the equivalent mortality reduction cost $1.4 billion at the lowest-value hospital. Interestingly, hospitals that provided high-value care for a specific procedure or condition did not necessarily provide high-value care for other procedures or conditions. This implies that composite measures of value that aggregate multiple areas of clinical focus may mask important underlying variation within a single institution.

The large interinstitutional variation in the VM is notable and important for the development of policy. The implications are twofold: the disparity between high and low performers is alarming and merits deeper consideration of available interventions and resources to move these hospitals to higher performing status. At the same time, the high-quality and cost-saving performance of the best value hospitals may not be adequately recognized in our current reporting paradigm, leading to missed opportunities to learn from their successes. Ranking and rating methodologies that produce rank-ordered assessments or categorized group ratings are not designed to reflect information on the relative or absolute differences in performance. Therefore, they cannot ascribe an assessment of the magnitude of the positive or negative performance. For purposes of fostering innovation and recognizing our health system's greatest limitations, it is important that methodologies capture and quantify very high or low performers.

The Merit-based Incentive Payment System (MIPS) and development of MIPS Value Pathways under this program are recent examples of a broad scale value measurement initiative that creates comparisons across system stakeholders. Under MIPS, the concept of value is operationalized by assessing performance on separate measurement domains (quality, cost, improvement activities, and promoting interoperability), followed by a process of weighting and combining domain scores to arrive at a

TABLE. Distribution of Hospital-Level Characteristics Among Gastrectomy and Cancer Encounters From July 1, 2015, to June 30, 2018; Patients Aged 65 Years and Older Extracted From Medicare Inpatient Standard Analytic File, the Master Beneficiary Summary Files, and the 2015 Denominator File

Characteristic Cohort (No. of hospitals)	First percentile	25th percentile	50th percentile	75th percentile	99th percentile
Age, y					
Gastrectomy (n=241)	69.2	72.1	72.8	73.7	77.1
Cancer (n=2504)	71.6	75.3	76.6	77.8	82.1
Female, %					
Gastrectomy (n=241)	28.9	41.5	47.1	53.5	75.8
Cancer (n=2504)	34.8	48.6	53.2	57.7	75.0
Elixhauser index score					
Gastrectomy (n=241)	2.85	7.78	9.86	11.75	17.09
Cancer (n=2504)	2.93	7.30	8.50	9.76	13.62
Outcome Cohort (No. of hospitals)	**First percentile**	**25th percentile**	**50th percentile**	**75th percentile**	**99th percentile**
Risk-adjusted 30-day mortality[a]					
Gastrectomy (n=241)	13.22%	8.03%	6.24%	4.91%	2.84%
Cancer (n=2504)	30.56%	24.74%	22.84%	20.90%	15.29%
Risk-adjusted cost per encounter[a]					
Gastrectomy (n=241)	$64,917	$41,397	$33,146	$26,453	$16,979
Cancer (n=2504)	$31,711	$12,631	$9648	$7637	$4484
Number needed to treat to prevent 1 excess mortality[b]					
Gastrectomy (n=158)	1016	85	50	35	22
Cancer (n=1262)	2378	107	51	30	12
Value metric: cost to prevent 1 excess mortality[b]					
Gastrectomy (n=158)	$25,531,068	$3,012,262	$1,817,525	$1,123,390	$712,502
Cancer (n=1262)	$27,972,318	$1,176,072	$542,932	$328,633	$118,516

[a]Adjusted for age, sex, year, dual eligibility, reason for Medicare entitlement, and binary indicators for each of the Elixhauser comorbidities used in the Elixhauser mortality index. Additionally, the gastrectomy models included a variable for whether the procedure was a total gastrectomy (yes/no) and the cancer models included a variable for the MS-DRG category.
[b]Among hospitals with better than national average mortality.

single standardized score that can be ranked and compared across participants and used to adjust Medicare part B payments for value.[11,12] In 2022, the cost domain under MIPS incorporates a collection of measures that include a Medicare Spending per Beneficiary (MSPB) clinician measure, which includes hospital episodic costs combined with pre- and posthospitalization costs within a limited time window and a Total Per Capita Cost measure.[9] Although there are elements of similarity between some of the MIPS cost metrics and our VM in terms of quantifying episodic costs as a component within the measurement framework, MIPS is focused on measuring clinician performance. In our VM, the assessment is at the level of the hospital. Similarly, the current use of the MSPB measure under the Hospital Value-Based Purchasing program, as well as similar cost measures used under value-based payment initiatives, provide examples of how the Medicare program assesses provider or hospital efficiency in providing a unit of care. The MSPB measure provides an opportunity to compare the average beneficiary risk-adjusted and price-standardized payment per episode of care.[10] Our measure captures a different perspective on the efficiency and value of care delivery that remains directly linked to a patient-focused and meaningful outcome of

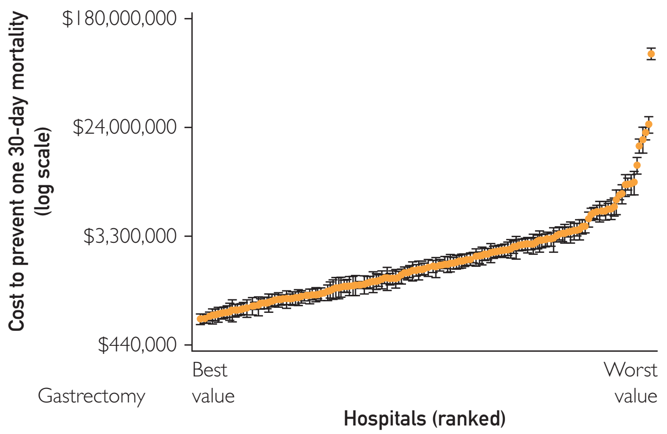

FIGURE 3. Interhospital variation in gastrectomy value metric (cost to prevent 1 excess 30-day mortality) from July 1, 2015, to June 30, 2018. Patients aged 65 years and older extracted from Medicare Inpatient Standard Analytic File, the Master Beneficiary Summary Files, and the 2015 Denominator File. Yellow dots indicate point estimate, and black bars indicate 95% confidence limits.

clinical significance. Relative to the measures outlined above, it may prove to be easier to interpret for system stakeholders.

Recently, the Lown Institute has designed a methodology to create risk-adjusted cost-efficiency measures, which similar to our VM involves a blending of episodic costs of care with outcomes such as mortality.[13] Although there are similarities between our proposed measure and those from the Lown Institute, our VM offers a greater degree of simplicity in interpretation while retaining the ability to identify top performers and magnitudes of difference in performance. Additionally, Herrin et al[14] have proposed a hospital value benchmark that combines the CMS Overall Hospital Star rating as an overall hospital "quality" proxy with MSPB as the cost component. Although Herrin et al[14] have taken this reasonable approach to create such a benchmark, our VM allows a more direct and interpretable reporting of hospital value for conditions or procedures. For example, when seeking complex care for cancer, would a patient or payer prefer a hospital with an overall unit-less value score of 0.6 vs 0.5 based on the hospital's CMS Star rating or should they select a hospital that has been reported to prevent 1 excess cancer-specific mortality below the national average for $150,000 vs $2,000,000?

Some limitations are worth noting. First, the VM is directly interpretable only if the performance is better than the national average. If a hospital performs below the national average mortality rate, the interpretation is not appropriate as it implies that a negative cost will save lives. For this reason, the VM may lend itself to direct reporting for specific conditions or procedures rather than as a standalone overall hospital value benchmark, although below-average hospitals can still be percentile-ranked by the VM, which is important given that mixed-effect models used to generate this metric are inherently normally distributed and will generally result in approximately half of the hospitals performing below-average by definition. An alternative interpretation might posit that once a hospital performs below the national average in mortality, cost is no longer relevant as the hospital is performing in an unacceptable range of quality. This interpretation places significant weight on meeting a meaningful quality threshold before the cost of providing care is considered when measuring a hospital's performance. From the perspective of some system stakeholders, this focus on quality before considering cost may be desirable. A limitation of this interpretation, however, is that the difference between a hospital slightly above the average vs slightly below the average may be minimal; however, it may result in a significantly different assessment of performance. Although this is notable, we believe that it does not significantly limit the utility of the proposed VM. The aim of computing our VM should be to highlight current performance and continuously drive improvement.

A second limitation is that the sample size for rare procedures or conditions might make the application of this metric infeasible for such unique populations or make it necessary to consider grouping hospitals by volume or other characteristics such as rural or urban status before reporting. However, we note that its application would nonetheless be widespread and appropriate across a large set of common inpatient procedures and conditions, with potential expansion to high-volume procedures and conditions in the ambulatory setting. Finally, we note that more rigorous bootstrapping/95% CI would be ideal for this type of metric before placement in pay-for-performance programs, including additional analyses to confirm important statistical qualities such as reliability and validity among different cohorts. Of note, our risk-adjustment models were similar in both conceptual framework and discrimination (c-statistic) to the 30-day mortality risk models used by US News and World Report and CMS.[8,15] However, the simple calculation of the metric in its current form may be extremely useful for conceptualizing public reporting of condition- or procedure-specific value where no similar VMs exist. Also, of note, patient experience and equity are key factors that should be incorporated into the overall hospital value equation, and both are not captured in our measure, although our measure could very easily be stratified and tested by race/ethnicity. Future work should examine how these key domains can be incorporated into further development of this metric and its application in performance rankings and assessments.

A third limitation is that the component of cost is limited to the encounter and does not include hospital-related costs after discharge. The exclusion of the pre- and posthospital periods in the cost definition adopted here aligns with the focus on hospital assessment. There is a stronger argument to include hospital costs during the 30-day post discharge window, and we suggest that this is an alternative variation of the measure that merits exploration. However, this alternative specification would introduce additional complexity in determining which costs during the postdischarge window relate to the initial episode. Lastly, 30-day mortality is only one of many relevant quality measures, and others such as readmission, patient safety, or patient experience could be considered along with a longer time window such as 90-day or 1-year mortality.

Although we recognize that there are limitations of the proposed VM and that even our examples of gastrectomy or cancer cohorts could be defined differently, we believe that the measure is surprisingly simple with results that are clearly informative. This definition of value presents a new view of performance in the health care system, and we hope that it generates additional evaluation of the way we measure and reward value in the value-based care transformation. Medicare and other payers must develop novel value measures to allow for evidence-based decisions regarding where to seek high-value care for their members. The value-based care transformation must be complemented with the continued development of the science of value measurement to ensure that we are adequately driving the delivery system toward outcomes that matter most for patients.

CONCLUSION

The VM can be applied to assess and compare value of care for specific conditions or procedures at hospitals with better-than-average 30-day mortality. We found substantial inter- and intrahospital variation in value when defined as the hospital costs of preventing 1 excess cancer or gastrectomy mortality among older adults compared with the national average. The VM could be extended to include costs of preventing readmissions, patient safety events, and other traditional hospital quality outcomes. It may be computed across a variety of conditions and procedures with potentially wide-ranging applications for driving the health care delivery system toward greater value. Future work should explore the validation and application of this VM and similar VMs across a range of conditions and procedures, and examine the potential to design a higher-level value composite metric that amalgamates the VM for multiple procedures and conditions.

POTENTIAL COMPETING INTERESTS

Dr Pollock reports consulting fees from Delta Airlines. Dr Meier holds leadership or fiduciary roles in Advanced Care at Home Coalition and Alliance for Technology Driven Health. Dr Shah is employed with Delta Airlines. Dr Ting holds leadership or fiduciary roles in Agency for Healthcare Research and Quality National Advisory Committee and Delta Airlines. The other authors report no competing interests.

Abbreviations and Acronyms: **CMS,** Centers for Medicare and Medicaid Services; **MIPS,** Merit-based Incentive Payment System; **MS-DRG,** Medicare Severity-Diagnosis Related Grouping; **MSPB,** Medicare Spending per Beneficiary; **NNT,** number needed to treat; **VM,** value metric

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