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ORIGINAL RESEARCH

Performance of electronic medical record tool in predicting 6-month mortality in hospitalized patients with cancer

Nita S. Kulkarni MD[1] | Matthew P. Landler MD[1] | Elaine R. Cohen MEd[1] | Diane B. Wayne MD[2] | Eytan Szmuilowicz MD[1]

[1]Department of Medicine, Northwestern University Feinberg School of Medicine, Chicago, Illinois, USA

[2]Department of Medicine and Medical Education, Northwestern University Feinberg School of Medicine, Chicago, Illinois, USA

Correspondence
Nita S. Kulkarni, MD, Department of Medicine, Division of Hospital Medicine, Northwestern University Feinberg School of Medicine, 211 E. Ontario St, Suite 700, Chicago, IL 60611, USA.
Email: n-kulkarni@northwestern.edu;
X (formerly known as Twitter): @NitaKulk

Abstract

Background: A systematic tool to identify hospitalized patients with high mortality risk may be beneficial for targeting palliative care to those in greatest need.

Objective: Evaluate the performance of the End-of-life Index (EOLI; Epic Systems Corporation) in identifying patients at the highest 6-month mortality risk among hospitalized patients with cancer.

Methods: We conducted a retrospective study of adults with cancer admitted to oncology services in a 959-bed hospital between July 1 and December 31, 2023. We evaluated EOLI score performance in determining mortality risk using the area under the receiver operating characteristic curve (AUC). The primary outcome was 6-month mortality for patients with an EOLI score above and below the optimal threshold value. Secondary outcomes included in-hospital mortality, 30-day mortality, length of stay, intensive care unit (ICU) utilization, palliative care consultation, do-not-resuscitate status on discharge, and discharge disposition.

Results: The EOLI score had moderate accuracy in identifying patients at higher risk of 6-month mortality (AUC: 0.71) with an optimal threshold value of 40. For patients with EOLI > 40 and < 40, the 6-month mortality was 45.9% and 16.3%, respectively ($p < .001$). Patients with EOLI > 40 had higher ICU utilization (12.4% vs. 6.5%, $p = .002$) and were more likely to be discharged to a location other than home (13.5% vs. 5.3%; $p < .001$).

Conclusions: For hospitalized patients with cancer, the EOLI shows moderate accuracy in identifying patients with a high risk of 6-month mortality. As a screening tool, the EOLI can be used to identify patients who may benefit from timely palliative care.

INTRODUCTION

Hospitalizations are common in patients with advanced cancer. In a cohort of older adults with metastatic disease, 83%–92% were hospitalized at least once in the period between diagnosis of cancer and death.[1] Hospital-based palliative services can be beneficial to patients nearing the end of life, providing symptom control and an opportunity for patients to clarify their goals of care and treatment preferences.[2] However, access to inpatient palliative care is met with barriers including inaccurate prognostication by physicians, lack of standard referral procedures, and absence of trained staff.[3–5]

Models using electronic medical record (EMR) data have been proposed to predict mortality in patients with chronic illnesses in the inpatient and outpatient settings to guide advanced care planning.[6–8]

While some models are developed locally, others are proprietary models created by companies that own and provide the EMR.[9,10] One such model is the Epic End of Life index (EOLI; Epic Systems Corporation), a logistic regression model that utilizes clinical data from the Epic EMR including patient demographics, labs, and comorbidities to generate a score from 0 to 100 to assess a patient's risk of 1-year mortality.[11] Epic has previously suggested an EOLI cutoff score of 45 or greater as a threshold for a higher risk of 1-year mortality in a general ambulatory patient population.[11] However, to our knowledge, the ability of the EOLI score to predict clinical outcomes such as mortality in a population of high-risk individuals has not been published.

The use of an objective score such as the EOLI to identify hospitalized patients with cancer who are at high risk of mortality may help allocate resources including palliative care more appropriately, improving both the quality and efficiency of care. In evaluating the EOLI score, our current study had three aims. First, we assessed the performance of the EOLI score in predicting the risk of 6-month mortality in hospitalized patients with cancer at a large academic medical center. We chose a 6-month period because hospice enrollment by Medicare is based on a life expectancy of 6 months or less.[12] Second, we determined a threshold score that distinguishes between higher and lower risks of mortality in this patient population. Third, we examined resource utilization for patients at higher and lower risk of mortality as determined by the EOLI threshold score.

METHODS

Our study cohort included all patients aged 18 years or older with active cancer who were admitted to oncology inpatient services managed by hospitalists and oncologists at a 959-bed urban, academic tertiary care hospital between July 1, 2023, and December 31, 2023. Admission to these services requires an active cancer diagnosis. These patients were identified from the EMR using the Northwestern Enterprise Data Warehouse (EDW).[13] The EDW query reported patient age, gender, race, ethnicity, EOLI score at admission, presence of palliative care consult, intensive care unit (ICU) encounter, ICU length of stay (LOS), cancer site, discharge disposition, death date (if applicable), and code status on admission and discharge. Patients admitted from the emergency department, as well as patients admitted directly from the clinic and those transferred from outside hospitals, were included. For patients with multiple hospitalizations during the designated time period, only the first hospitalization was included in the data set. The study was approved with a waiver of consent by the Institutional Review Board of the Northwestern University Feinberg School of Medicine.

The EOLI score was generated from the Epic EOL index developed by Epic Systems Corporation and is composed of variables that are readily available in the EMR, including demographics, labs, comorbidities, and medications (Appendix SA). The score has a range of 0–100 with higher scores indicating an increased risk of mortality. Specific details of the development and validation of the model are available from Epic.[11] The EOLI score was not used in any formal clinical workflows within the hospital during the study period.

The primary outcome was all-cause mortality within 6 months of hospital discharge as identified in the health system's EMR. Secondary outcomes included in-hospital mortality, 30-day mortality, hospital LOS, ICU admission and LOS, presence of palliative care consultation, presence of a do-not-resuscitate (DNR) status on discharge, and discharge disposition. We chose these outcomes as indicators of the intensity of care and resource utilization at the end of life.

STATISTICAL ANALYSIS

We used descriptive statistics including median (interquartile range), mean (standard deviation), and frequency (percentage) to report overall patient demographics and outcomes. To measure hospitalized patients' first EOLI's ability to discriminate between 6-month mortality and survival, we used the receiver operating characteristic (ROC) curve analysis and calculated the area under the receiver operating characteristic curve (AUC) with 95% confidence intervals (CIs). We used the resulting sensitivity and specificity from the ROC curve and the results of Youden's index to determine the optimal cutoff value for the EOLI. We compared primary and secondary outcomes for patients above and below this cutoff value. We used independent samples *t* tests and Mann–Whitney *U* tests to compare continuous variables between groups and χ^2 tests to compare categorical variables. Additionally, we compared 6-month mortality across EOLI decile for all patients and in subgroups of vulnerable patient populations using the χ^2 statistic and Fisher's exact test. Statistical analyses were performed using IBM SPSS version 29.0.

RESULTS

We identified 871 hospitalizations for unique patients to oncology services from July 1, 2023, to December 31, 2023. The majority of patients were admitted through the emergency department (56%). No missing data were observed in the data set. In cases where patients declined to respond (e.g., race and ethnicity), these data were categorized as "No response." The mean (SD) age was 61.4 (15.0) years; 53.2% were female, 59.4% were White, 21.1% were Black, 9.1% were of Hispanic/Latino ethnicity, and 48.5% had Traditional Medicare or Medicare Advantage as their primary payor (Table 1). The mean age of Hispanic/Latino patients was significantly lower than non-Hispanic/Latino patients and patients who did not provide a response on ethnicity (53 years [SD = 18] for Hispanic/Latino, 62 years [SD = 14] for non-Hispanic/Latino, 63 years [SD = 14] for no response; $p < .001$). The median (interquartile range [IQR]) EOLI score for the entire cohort was 31.00 (11.00, 66.00). Overall, 41.6% of the cohort was identified as having an EOLI score ≥ 40.

The ROC curve analysis revealed that the EOLI had the ability to predict 6-month mortality with an AUC of 0.71

TABLE 1 Baseline patient characteristics overall and comparisons of characteristics by EOLI score < 40 and ≥ 40.

Variable	All patients (*n* = 871)	EOLI < 40 (*n* = 509)	EOLI ≥ 40 (*n* = 362)	*p* Value
EOLI, median (IQR)	31.00 (31.00, 66.00)	14.00 (6.00, 24.00)	70.00 (56.00, 86.25)	<.001
Age, mean (SD)	61.35 (15.02)	56.52 (15.08)	68.14 (11.97)	<.001
Sex, *n* (%)				
Female	463 (53.2)	271 (53.2)	192 (53.0)	.95
Male	408 (46.8)	238 (46.8)	170 (47.0)	
Race, *n* (%)				
White	517 (59.4)	312 (61.3)	205 (56.6)	.09
Black	184 (21.1)	91 (17.9)	93 (25.7)	
Asian	51 (5.9)	32 (6.3)	19 (5.2)	
Other	68 (7.8)	43 (8.4)	25 (6.9)	
No response	51 (5.9)	31 (6.1)	20 (5.5)	
Hispanic/Latino origin, *n* (%)				
Yes	79 (9.1)	50 (9.8)	29 (8.0)	.65
No	727 (83.5)	421 (82.7)	306 (84.5)	
No response	65 (7.5)	38 (7.5)	27 (7.5)	
Payor, *n* (%)				
Medicare	272 (31.2)	120 (23.6)	152 (42.0)	<.001
Medicare advantage	151 (17.3)	60 (11.8)	91 (25.1)	
Medicaid	103 (11.8)	67 (13.2)	36 (9.9)	
Commercial	338 (38.8)	255 (50.0)	83 (22.9)	
Uninsured	7 (0.8)	7 (1.4)	0 (0)	
Cancer diagnosis, *n* (%)				
Bone	18 (2.1)	13 (2.6)	5 (1.4)	<.001
Breast	49 (5.6)	36 (7.1)	13 (3.6)	
Endocrine	20 (2.3)	5 (1.0)	15 (4.1)	
Female reproductive	57 (6.5)	37 (7.3)	20 (5.5)	
Gastrointestinal	174 (20)	75 (14.7)	99 (27.3)	
Genitourinary	35 (4.0)	14 (2.8)	21 (5.8)	
Head and neck	15 (1.7)	6 (1.2)	9 (2.5)	
Hematologic	354 (40.6)	280 (55)	74 (20.4)	
Lung	124 (14.2)	31 (6.1)	93 (25.7)	
Neurologic	15 (1.7)	9 (1.8)	6 (1.7)	
Skin	10 (1.1)	3 (0.6)	7 (1.9)	

Abbreviations: EOLI, End-of-Life Index; IQR, interquartile range.

(95% CI: 0.67–0.75, $p < .001$; Figure 1). From that, we derived the optimal cutoff value for the EOLI score of 40.0 with a sensitivity of 0.67 (95% CI: 0.60–0.72), a specificity of 0.69 (95% CI: 0.65–0.72), a positive predictive value (PPV) of 0.46 (95% CI: 0.41–0.51), and a negative predictive value (NPV) of 0.84 (95% CI: 0.80–0.87). We used this value to divide the study sample into two groups (EOLI score < 40 and ≥ 40) for further analysis.

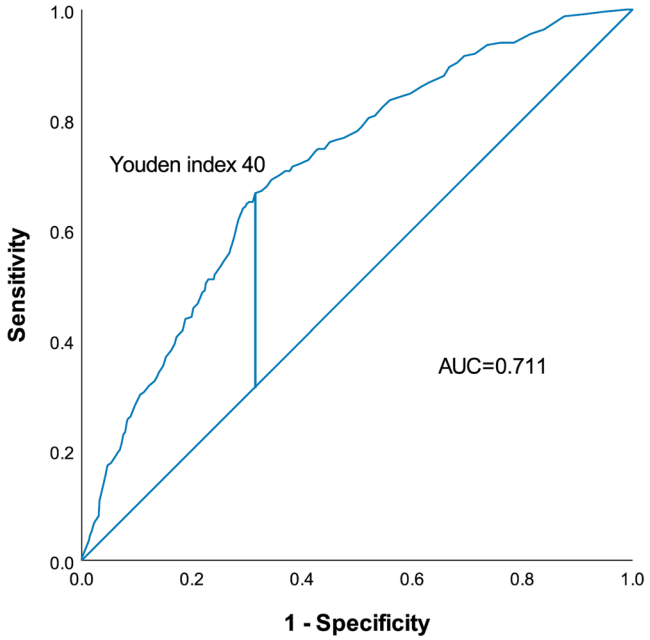

FIGURE 1 Receiver operating characteristic (ROC) curve for the diagnostic ability of the End-of-Life Index (EOLI) score to predict 6-month mortality in hospitalized patients with cancer with an area under the receiver operating characteristic curve (AUC) of 0.71 and an optimal cutoff value of 40.

Compared with those with a lower EOLI score, patients with an EOLI score ≥ 40 were older (68.1 vs. 57.0 years, $p < .001$) and were more likely to have Traditional Medicare or Medicare Advantage (67.1% vs. 35.4%). Overall, 53% of the high EOLI score patients had either gastrointestinal or lung cancer as a primary diagnosis, while 55% of patients in the low EOLI group had hematological cancer. Of the 184 Black patients, 50.5% fell into the high EOLI score category. This trended higher than the proportion of high EOLI patients seen in the White (39.7%) and Asian (37.3%) populations ($p = .09$). This was also higher than the proportion of high EOLI patients in the Hispanic/Latino population (36.7%).

Death within 6 months of hospital discharge occurred in 249 patients in the cohort (28.6%). Most deaths occurred between 31 and 180 days. When we stratified by EOLI score decile range, the 6-month mortality rates increased significantly by decile ($p < .001$; Figure 2). Table 2 shows comparisons of outcomes between EOLI score groups < 40 and ≥ 40. Overall, 45.9% of patients with an EOLI score of 40 or higher died within 6 months compared with 16.3% of patients with a score below 40 ($p < .001$). Findings were consistent across all time intervals. Subgroup analyses of Black patients and Hispanic/Latino patients showed similar findings of 6-month mortality at the threshold score of 40 (Black patients: 41.9% vs. 24.2%; Hispanic/Latino patients: 41.4% vs. 24.0%). While there was no statistically significant difference in hospital LOS between the high and low EOLI groups, high EOLI patients were more likely to have an intensive care unit stay during the hospitalization (12.4% vs. 6.5%, $p = .002$). The high EOLI group also received more palliative care consultations in the hospital and had more DNR orders on discharge compared with the low EOLI group; however, rates were low in both cohorts (18.8% vs. 13.2% for palliative care, $p = .002$; 26.8% vs. 11.6% for DNR status, $p < .001$). Patients with high EOLI scores were more likely to be discharged to a location other than home (13.5% vs. 5.3%, $p < .001$).

DISCUSSION

In this prognostic cohort study, we determined that the EOLI score, an EMR-based tool, can be used to predict mortality in a group of patients hospitalized with cancer. Specifically, an EOLI score ≥ 40 upon arrival to the hospital showed moderate accuracy for predicting 6-month mortality. Despite being developed in a general ambulatory population and concern that it may not be as useful in an oncology cohort due to lack of staging information,[11] we found that the EOLI can aid in determining mortality risk in this patient population. Further, the high NPV for the cutoff score is reassuring, suggesting that we are not missing patients who may be at greater risk of death by 6 months.

Almost half of the patients with a high EOLI score died within 6 months of the hospitalization, with most deaths occurring between 31 and 180 days following discharge. The high EOLI group also had higher in-patient mortality which may have contributed toward a shorter, albeit nonsignificant, hospital LOS. Regarding our third study aim, we found that resource utilization was higher in the high EOLI group. In patients with EOLI scores ≥ 40, 12% required ICU admission with a median ICU LOS of 3.1 days and 14% were discharged to a location other than home, mostly skilled nursing facilities. Despite a high 6-month mortality rate, only a small percentage of these patients received palliative care consultations, had DNR orders on discharge, or were discharged with hospice. Our findings highlight the opportunity to improve the quality of care received by hospitalized patients with cancer who are approaching end-of-life.

Earlier palliative care in end-of-life hospitalized patients is associated with decreased hospital LOS and ICU utilization, increased hospice care upon discharge, and reduced hospital costs.[14–17] Moreover, palliative care consultation is associated with improved pain and symptom management, a decrease in unnecessary diagnostic testing at the end-of-life, and discharge planning that better aligns with patient preferences.[18] Once a highly limited resource, palliative care availability has increased in hospitals in the United States in the last decade, with almost three-quarters of hospitals with 50 or more beds reporting access to a palliative care team.[19] While this is reassuring, referrals for palliative care remain inconsistent and delayed, especially in certain patient populations including women and racial minorities.[20,21] This could be due to many factors, but raises concerns for practice variation and/or the potential for unconscious bias among clinicians. The current study supports the use of the EOLI score in the inpatient setting, but it is important to go beyond validation to assess clinical outcomes.[22] Using prognostic information to guide palliative care involvement is just one way to

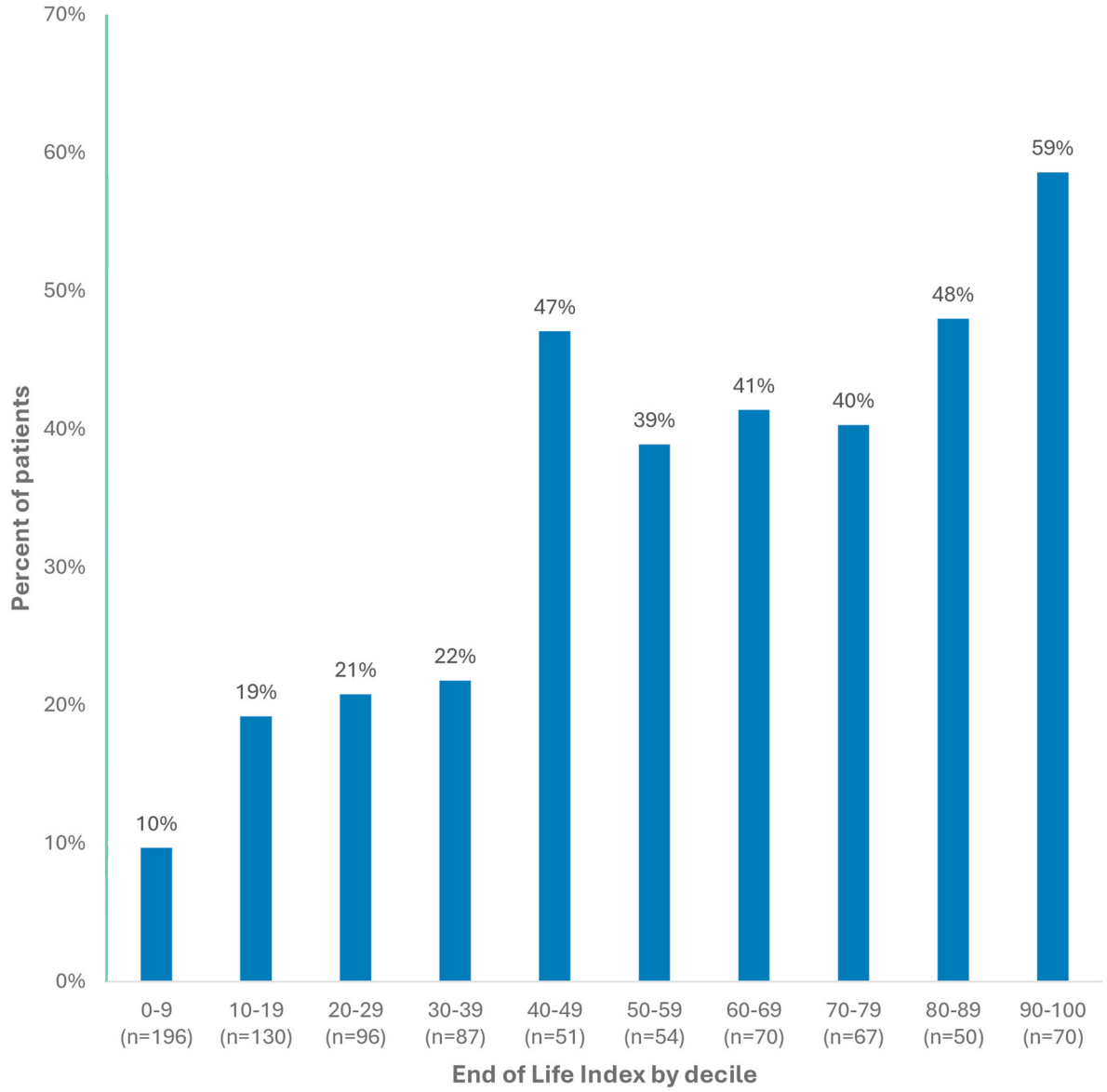

FIGURE 2 Six-month mortality rates by the End-of-Life Index (EOLI) score decile range.

deploy palliative care; other methods involve standardizing assessment of unmet patient and family care needs. Other institutions have described the use of locally grown mortality prediction models to enhance the implementation of advance care planning.[23,24] Future studies at our institution will focus on integrating the EOLI score into the patient care workflow, using it as a trigger for earlier palliative care consultation for hospitalized oncology patients without having to rely solely on clinician judgment.

Three other notable findings in this study require mention. First is the timing of deaths in the patients with high EOLI scores. Scores > 40 predicted a higher risk of dying during the admission, but the majority of deaths occurred after discharge. Overall, 60% of deaths occurred within 31–180 days of discharge. This suggests that the EOLI score does not necessarily signal the acuity of illness during the hospitalization, but rather reflects the chronic underlying conditions and overall deterioration over time of this patient population. Having this knowledge presents an opportunity for physicians and other providers to provide ongoing palliative care and develop care plans that align with patient preferences and may include a gradual transition to lower acuity care and/or hospice services.

The second finding is the larger proportion of patients with high EOLI scores in the Black population: 50% had an EOLI score of 40 or greater compared with approximately 40% of the White, Asian, and Hispanic/Latino populations. This may be a consequence of healthcare disparities resulting in a greater number of chronic illnesses and comorbidities that ultimately add to the EOLI score. One explanation for the lack of a similarly higher proportion of Hispanic/Latino patients with an EOLI > 40 may be due to the comparatively younger age of this cohort. Further study with a larger population is required to confirm and understand these findings in more detail.

TABLE 2 Primary and secondary outcomes overall and comparisons of outcomes by EOLI score < 40 and ≥ 40.

Outcome	All patients (*n* = 871)	EOLI < 40 (*n* = 509)	EOLI ≥ 40 (*n* = 362)	*p* Value
Deaths within 180 days of discharge, *n* (%)				
Total deaths	249 (28.6)	83 (16.3)	166 (45.9)	<.001
Within 31 to 180 days	152 (17.5)	52 (10.2)	100 (27.6)	<.001
Within 1–30 days	44 (5.1)	9 (1.8)	35 (9.7)	<.001
In-hospital	53 (6.1)	22 (4.3)	31 (8.6)	.01
Resource utilization				
Hospital LOS, median (IQR)	7.5 (3.34, 7.51)	7.98 (3.42, 16.40)	7.05 (3.26, 12.96)	.05
Intensive care unit admission, *n* (%)	78 (9.0)	33 (6.5)	45 (12.4)	.002
Intensive care unit LOS, median (IQR)	2.92 (1.41, 5.28)	2.32 (1.32, 7.88)	3.07 (1.49, 4.14)	.49
Palliative care consultation, *n* (%)	135 (15.5)	67 (13.2)	68 (18.8)	.02
Do-not-resuscitate order, *n* (%)	165 (17.9)	59 (11.6)	97 (26.8)	<.001
Discharge disposition, *n* (%)				
Acute inpatient rehab	14 (1.6)	5 (1.0)	9 (2.5)	<.001
Assisted living	2 (0.2)	1 (0.2)	1 (0.3)	
Expired	53 (6.1)	22 (4.3)	31 (8.6)	
Home with hospice	31 (3.6)	12 (2.4)	19 (5.2)	
Home without hospice	703 (80.7)	441 (86.6)	262 (72.4)	
Inpatient hospice	10 (1.1)	2 (0.4)	8 (2.2)	
Left against medical advice	6 (0.7)	5 (1.0)	1 (0.3)	
Long-term acute care hospital	1 (0.1)	1 (0.2)	0	
Skilled nursing facility/nursing home	51 (5.9)	19 (3.7)	32 (8.8)	

Abbreviations: EOLI, End-of-Life Index; IQR, interquartile range.

A third finding is the higher 6-month mortality rate in the EOLI < 40 category among Black and Hispanic/Latino patients compared with the overall cohort (24.2% Black patients and 24.0% Hispanic/Latino patients vs. 16.3% total population). While the model shows that the EOLI threshold score can provide reliable risk discrimination across diverse patient populations, more study with a larger population are required to examine race-specific calibration measures and understand reasons for differences in observed versus expected mortality within racial subgroups.

Our study has a few limitations. First, it was conducted in a single urban tertiary care center and only included patients admitted to oncology services, thus making the results less generalizable to other populations and communities. However, the demographics of the almost 900 patients in the overall cohort showed diversity of sex, race, ethnicity, payor, and primary cancer diagnosis. Additionally, the predictive ability of the EOLI score remained consistent across vulnerable populations. Second, the EOLI score showed only modest values of sensitivity and specificity, limiting its accuracy. A high NPV is reassuring, however, in the potential use of the threshold score as a screening tool for the delivery of early palliative care. Third, we did not compare the EOLI with other measures of disease severity. While multiple models for predicting mortality in patients with cancer have been proposed in different clinical settings with varying accuracies and gradations in ease of use,[6–9,25,26] the EOLI benefits in comparison due to its utility at the point of care. Fourth, an EOLI threshold score of 40 to predict 6-month mortality may not be applicable to other chronically ill patient populations as only hospitalized patients with cancer were included in this study. Fifth, patient deaths were determined solely by data obtained from the EMR and thus may not reflect all patient deaths. Sixth, the primary cancer diagnoses for study patients were obtained through diagnostic codes in the EMR, rather than chart review, and may have been miscategorized in some instances. Additionally, we did not have information on the cancer stage or the presence of metastatic disease. Seventh, subgroup populations by race/ethnicity had small sample sizes; these findings should be confirmed in larger cohorts. Finally, this model relies on the EPIC platform which is not universally available. However, as of 2023, the Epic EMR was installed in almost 40% of US acute care hospitals covering 51.5% of hospital beds, making it the leader in the EMR hospital market share.[27,28]

In summary, our results demonstrate that the EOLI score can be used to predict 6-month mortality for hospitalized patients with

cancer. As a tool for predicting mortality, the EOLI score is easy to use for bedside providers and readily available within the Epic EMR platform. Further study is needed to assess the usefulness of the EOLI score compared with other models/indices of disease severity for predicting mortality in hospitalized patients. By adopting a systematic approach to identify patients who will benefit from palliative care consultation, we hope to improve the quality of end-of-life care as well as to manage resource utilization within the hospital more appropriately.

CONCLUSION

Palliative care consultation leads to higher quality care that is aligned with patient preferences and associated with improved outcomes. Though palliative care is an option in many US hospitals, it remains a finite resource that is often deployed late in the course of illness. Our study validates the role of the EOLI score in identifying patients at higher risk of 6-month mortality in a cohort of hospitalized patients with cancer. Future studies should focus on the implementation of the EOLI score in the hospital as a screening tool for palliative care consultation with the goal of improving the delivery, quality, and patient-centeredness of care at the end of life.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

ORCID

Nita S. Kulkarni http://orcid.org/0000-0003-2449-1126

X (FORMERLY KNOWN AS TWITTER)

Nita S. Kulkarni 𝕏@NitaKulk

Diane B. Wayne 𝕏@dianebwayne

Eytan Szmuilowicz 𝕏@eszmuilo

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SUPPORTING INFORMATION

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

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