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Comparing Prognostic Tools for Cancer Screening: Considerations for Clinical Practice and Performance Assessment

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Abstract

Background—Clinical guidelines increasingly call for providers to incorporate life expectancy into their clinical decision-making.

Objectives—To compare the agreement and rates of cancer screening using four prognostic tools that require different types of clinical information.

Design, Setting, and Participants—Observational retrospective cohort study using the 2009 and 2010 waves of the Medicare Current Beneficiary Survey. We included adults ages 66 to 90 with both survey and claims data.

Exposures—Four indices predicting short-term (4–5 year) and long-term (9–10 year) survival.

Main Outcomes and Measures—Agreement between measures in classifying individuals as having limited short and long-term survival; self-reported breast and prostate cancer screening.

Results—Among the 9,469 respondents, agreement between the four prognostic tools were high. Pearson correlation coefficients ranged from 0.63 to 0.90 for short-term survival and from 0.68 to 0.94 for long-term survival. When defining limited short-term life expectancy as <25% chance of surviving 4 or 5 years, all four tools agreed in 96.4% of the sample. All four tools agreed in their

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placement of patients into limited or not limited long-term life expectancy in 77.1% of participants (<25% chance of surviving 9 or 10 years). Rates of cancer screening were similarly high among individuals with limited long-term life expectancy regardless of the tool used: above 31% for mammographic screening among women and above 69% for prostate cancer screening.

Conclusion—There is substantial agreement among different prognostic tools for short and long-term survival among Medicare beneficiaries. The high rates of cancer screening among patients with limited life expectancy suggest the importance of incorporating tools into clinical decision-making.

Keywords

Life expectancy; prognosis; cancer screening

INTRODUCTION

Guidelines increasingly recognize the potential harms of cancer screening among patients with limited life expectancies.^{1–7} Psychological distress from cancer screening and diagnosis, complications from biopsies and treatment, and the individual and societal costs occur shortly after screening whereas the potential gains in life expectancy take many years to accrue.^{8–10} Thus, patients with limited life expectancies may be more likely to experience the harms of cancer screening without experiencing the potential benefits.¹¹

To help address this concern, researchers have developed tools that can help clinicians predict life expectancy among community-dwelling older adults.¹² Though multiple prognostic tools have been validated for their accuracy in predicting mortality, the extent to which these tools identify the same individuals as having limited life expectancy remains unknown. Comparing different prognostic tools provides an important foundation for clinicians trying to understand the potential trade-offs involved in choosing one tool over another. It is possible that different approaches to estimating prognosis may lead clinicians and their patients to different conclusions about the appropriateness of screening. In addition, with quality indicators that have been proposed around inappropriate cancer screening based on advanced patient age, comparing prognostic tools offers critical information on the potential appropriateness of quality metrics and provider profiling.¹³

In this context, this project first aims to describe differences and similarities between prognostic tools published in the peer-reviewed literature and second examine rates of cancer screening among participants identified as having limited life expectancy according to each tool. We focus on four tools have been validated for long term life expectancy and may be useful when deciding about cancer screening. Two of the tools use diagnostic codes from insurance claims data to calculate life expectancy.^{14,15} These are appealing because they can be easily extracted from existing insurance claims data. The other two tools incorporate patient self-report of their functional status,^{16,17} information which may have greater face validity with clinicians but cannot be easily automated from existing claims or electronic medical record data. Each of the methods have been validated in predicting survival, thus our goal was to understand how frequently these different tools may lead

clinicians to different conclusions about a patient's prognosis and the utility of cancer screening.

METHODS

We performed a retrospective analysis of participants in the 2009 and 2010 Medicare Current Beneficiary Survey (MCBS). MCBS includes a patient survey linked to Medicare claims data. The study was approved by the Johns Hopkins School of Medicine Institutional Review Board.

Individuals were required to have a full calendar year of fee for service Part A and B Medicare claims. For individuals enrolled for both study years, we included only data from the most recent year (2010). To conform to the exclusions of the selected life expectancy tools, we excluded patients younger than 66 (N=3,292) and over 90 (N=745), patients with leukemia (N=136), and patients residing outside the United States (N=283) for a total of 5,559 (35.7%) patients excluded. Among the remaining 10,014 patients, we also excluded those with missing data needed to calculate life expectancy (N=545). The majority (N=480/545, 88.1%) of these patients did not report weight or height on the survey, resulting in a missing value for BMI, a component of the Lee and Schonberg indices. The final analytic cohort included 9,469 individuals.

Prognosis: Survival and Limited Life expectancy

Prognostic tools quantify health using different statistical approaches (e.g., life tables, regression analyses) and different outcomes (e.g., median survival time, probability of mortality). To facilitate comparison between measures, we focus on two measures of health: probability of survival and limited life expectancy. Survival represents the chance that the individual will be alive at the end of the time period and is calculated as 1 minus cumulative mortality. Limited life expectancy is defined as <25% probability of surviving. We compare four different indices to assess prognosis which were selected based on their ability to calculate long term life expectancy among community-dwelling older adults.

The Tan method was developed using a 5% sample of Medicare beneficiaries ages 66 to 90 in the year 2000 with follow-up through 2009; the C-statistic for death at 10 years was 0.80 and 0.77 among women and men respectively.¹⁴ The method is based on the Elixhauser comorbidity index, in which ICD-9 diagnosis codes are used to define 31 different comorbidities derived exclusively from insurance claims data. To increase the specificity, comorbidities are required to appear (a) on 2 or more physician and/or outpatient claims at least 30 days apart or (b) on at least 1 inpatient claim. Hazard ratio estimates associated with each comorbidity are combined with patient age and sex to predict 5- and 10-year mortality.

Similarly, the Cho method uses insurance claims data to group diagnostic codes into comorbidities.¹⁵ It was also developed using a 5% sample of Medicare beneficiaries from 1992 to 2005. Beneficiaries ages 66 and older were included and life expectancy was calculated based on comparisons to age-specific US life tables. Patient comorbidities were defined using the Charlson comorbidity index. In this method, patients were then categorized as having none, low/medium, or high levels of comorbidities based on a

comorbidity score. Patients were placed in the high comorbidity category if they had specific conditions (COPD, CHF, moderate/severe liver disease, chronic renal failure, dementia, cirrhosis and chronic hepatitis and AIDS) or if their comorbidity score was above a certain threshold. Cho and colleagues provide life expectancy estimates for sex and race-specific groups in 5-year age increments; we used linear interpolation to estimate 5- and 10-year cumulative survival probabilities in 1-year age increments.

The Schonberg index was developed and validated among community-dwelling adults ages 65 and older using 1997–2004 data from the National Health Interview Survey with follow-up until 2006 and has a C-index of 0.75.¹⁷ It is based on 11-items: sex, age, smoking status, body mass index (<25 or 25+), dependency in instrumental activity of daily living (IADLs), difficulty walking ¼ mile, hospitalizations in the past year, and having a diagnosis of COPD, diabetes, and/or cancer (excluding non-melanomatous skin cancer). MCBS survey data was used for all measures. BMI was based on self-reported height and weight. MCBS questions for IADLs and walking did not exactly match those used in the National Health Interview Survey on which the Schonberg index is based. Individuals were classified as having dependency on IADLs if they reported difficulty managing money, performing housework, making meals, or using the telephone due to a health or physical problem. Individuals who reported “some” or “a lot” of difficulty walking “several blocks” were classified as having difficulty with walking. Points are assigned to each item and the sum of the points was used to estimate 5- and 9-year mortality.

The Lee index was developed using community-dwelling adults ages 50 years and older from the 1998 wave of the Health and Retirement Survey; the C statistic in the validation cohort was 0.834.^{16,18} It employs 12 items including: age, BMI, chronic conditions (diabetes, non-skin cancer, chronic lung disease, and heart failure), difficulty bathing, difficulty managing finances, difficulty walking several blocks, and difficulty pushing/pulling large objects. The sum of the points was used to construct 4- and 10-year mortality.

Cancer screening

We examined receipt of self-reported screening for breast cancer (among women) and prostate cancer (among men) in the survey year according to the different estimates of life expectancy. Participants were excluded from these analyses if they reported a history of breast or prostate cancer prior to the study year (N=434 and 417 respectively) or if they did not report on cancer screening (N=34 for women and 226 for men). We opted not to examine colorectal cancer screening due to the potentially long intervals between screening tests.

Statistical analysis

After describing the demographic characteristics of the sample, we examined the correlations between pairs of life expectancy estimates using Pearson correlation coefficients. Correlations were performed separately for short (4 or 5-year) and long (9- or 10-year) survival. Because the utility of the tools may stem from classifying individuals into those with limited life expectancies (e.g., those who may not benefit from screening), we then divided patients into four groups based on their estimated short- and long-term survival probability: <25% chance of surviving to the end of the 4/5 year or 9/10 year period, 25 to

<50% chance of surviving, 50 to <75% chance of surviving, and >75% chance of surviving. Participants with <25% chance of surviving to the end of each time period were defined as having limited life expectancy. We assessed the agreement between the categorized measures calculated according to each method using the Kappa statistic, and we calculated proportion of agreement among all four measures with respect to limited short and long-term life expectancy. We also estimated the proportion of patients with limited short and long-term life expectancy who reported breast and prostate cancer screening in the preceding year.

In sensitivity analyses, we examined the frequency distribution for each measure for patients with different characteristics (male/female, age 66–74, age 75+, white, non-white), studied the agreement among indices predicting <33% and <50% chance of surviving, and examined rates of screening among patients with <50% chance of surviving.

Analyses were completed using SAS version 9.4 (SAS Institute, Inc., Cary, NC). All proportions, means, and ranges were estimated using SAS survey procedures to account for the complex multistage survey design of the MCBS and cross-sectional survey weights. The Kappa and Pearson correlation statistics were estimated using the cross-sectional survey weights within the SAS frequency and correlation procedures.¹⁹

RESULTS

Our sample consists of 9,469 Medicare beneficiaries (Table 1). The mean age was 75.2, over half (56.7%) were female, and the majority were white (87.6%). Appendix Figure 1 shows the correlations between pairs of life expectancy measures. For the continuously measured short-term survival probabilities, correlations were high between pairs of measures. Pearson correlation coefficients ranged from 0.63 (between the Cho and Lee indices) to 0.90 (between the Cho and Tan) measures for the whole cohort (Appendix Table 1 presents the overall correlations and by demographic characteristics). Correlations between pairs of measures were somewhat higher for long-term life expectancy probabilities with Pearson correlation coefficients ranging from 0.68 (between the Cho and Schonberg indices) to 0.94 (between the Cho and Tan indices). Kappa statistics for the categorized measures of short and long-term life expectancy followed the same pattern.

Table 2 shows the distribution of short- and long-term life expectancy probabilities when categorized into four groups and Table 3 shows the agreement among these measures. Overall, relatively few patients had limited life expectancy (<25% chance of surviving 4 or 5 years) according to each of the measures. The four measures agreed in their categorization of nearly all patients (96.4%) as having limited or not limited short-term life expectancy. The Tan method was most likely to disagree with the other three measures due to categorizing more patients as having limited short-term life expectancy.

Between 14.1% (Cho) and 18.6% (Tan) of patients had a limited long-term life expectancy (<25% chance of surviving 9/10 years). All four measures agreed in their placement of patients into limited or not limited long-term life expectancy in 77.1% of the subjects. In 12.9% of the cases, 3 out of the 4 measures agreed; the Tan index was most likely to

disagree. Appendix Tables 2 and 3 shows the categorization and the agreement between the measures according to different demographic characteristics. Agreement tended to be higher among patients in the younger age category (ages 66–74) compared to the older age category (ages 75–90), though in the younger age category there were very few patients who were classified as having a limited life expectancy. Agreement also tended to be higher among females compared to males. Agreement between the measures was lower when different thresholds for limited life expectancy were used (Appendix Table 4; all four measures agreed 73.1% of the time when we defined limited life expectancy as < 33% chance of surviving 9 or 10 years and 66.0% of the time when we defined limited long-term life expectancy as < 50% chance of survival).

We then examined cancer screening among patients with limited life expectancy. For mammographic screening, there were no eligible patients with limited short-term life expectancy for the Cho, Lee or Schonberg indices. About half (53.0%) of patients classified with limited short-term life expectancy according to the Tan index were screened. The mammographic screening rate was similar among the four different methods for measuring limited long-term life expectancy: 31.9 and 37.3% of patients with limited long-term life expectancies reported screening in the preceding year. For prostate cancer screening, screening was performed among 50.6% of men with limited short-term life expectancy according to the Cho method and 71.1% of men for the Tan method. Among men with limited long-term life expectancy, between 69.5% and 71.5% of men reported screening according to the different methods. Appendix Table 5 shows rates of screening among individuals with <50% chance of surviving 9 or 10 years, similarly demonstrating little variation in the rates of screening among patients classified as having limited life expectancies according to the different methods.

DISCUSSION

Overall, in a sample of Medicare beneficiaries, we find substantial agreement among different tools used to measure life expectancy with respect to both short-term and long-term life expectancy. All four measures agreed nearly 95% of the time with respect to limited short-term life expectancy. Agreement between all four tools measuring limited long-term life expectancy was somewhat lower: measures disagreed for approximately one in four patients. Further, we found high rates of cancer screening across patients with limited long-term life expectancy, regardless of the tool that was employed to categorize life expectancy. The results underscore both the potential importance of incorporating life expectancy into clinical practice as well as the pitfalls of relying on different tools.

The variability between life expectancy metrics highlights the challenges that patients, clinicians, and quality measure developers face. When choosing a threshold of 25% chance of living 9 or 10 years, the measures disagreed for approximately one in four patients. Disagreement became more frequent as the threshold increased from 25% to 33% and to 50% and among older patients. The correlations between the two measures that relied solely on comorbidity defined by administrative claims data were higher than their correlations with the Schonberg and Lee measures that incorporated patient reported functional status. The claims-based measures were also more likely to classify individuals as having limited

short-term life expectancy. Thus, providers who incorporate different prognostic tools may reach different conclusions as to whether or not to screen a given patient.

These tools—and the potential differences between them—may help shared decision-making between clinicians and patients with regard to cancer screening and other clinical scenarios. There is some evidence when clinicians are uncertain about a patient's health trajectory, they are more likely to seek patient input prior to making a screening recommendation.²⁰ Correspondingly, educational initiatives that emphasize the importance of an individual's trajectory and provide guidance on how to consider uncertainties in life expectancy estimate maybe an important component of increasing the acceptance and adoption of these tools.

The differences observed between the tools highlight the challenges in creating quality metrics around inappropriate cancer screening among patients with limited life expectancies. If the standard used in the quality metrics and the tools used by providers are not in alignment, there is the potential for misclassifying providers. Furthermore, these tools are intended to be used to promote patient-centered screening practices that incorporate patient expectations and preferences not necessarily steer patients away from cancer screenings.^{21,22} Quality measures that compare providers to a fixed benchmark may discourage patient-centered shared decision-making.

Irrespective of the prognostic measure, our findings support previous research on the high rates of cancer screening among patients with limited life expectancies. Over one-third of women with limited life long term expectancy underwent a mammogram. The age and life expectancy at which to stop breast cancer screening is controversial: the Society of Breast Imaging and American College of Radiology recommend discontinuing screening when women have less than a 5–7 year life expectancy²³ whereas the US Preventive Services Task Force notes insufficient evidence for patients 75 years and older.³ In this setting, it is possible that some of the high rates of breast cancer screening in this group may stem from clinical uncertainty.

At the same time, approximately two-thirds of men with limited life expectancies underwent prostate cancer screening. Of note, these results are higher than rates of screening among patients with limited life expectancy than those found with National Health Interview Survey; the reasons for this discrepancy are uncertain.^{24–26} Guidelines are more consistent in their recommendation against routine PSA screening among men with limited life expectancies.^{1,27} Though more recent guidelines have recommended against routine PSA-based prostate cancer screening in general,² these appear to have had a limited impact on population rates of screening.²⁸

Our results further support the importance of initiatives, such as the Choosing Wisely campaign, that seek to incorporate life expectancy into clinical decision-making around cancer screenings.^{6,29} Though the focus of this analysis has been on the important problem of overscreening, it is also possible that incorporating prognosis into cancer screening may help reduce under-screening by identifying patients with longer life expectancies despite advanced age who may continue to benefit from some types of cancer screening.

It is important to note several limitations in our study. By design, we assess agreement between the tools rather than determining which measure is most accurate in estimating life expectancy. Future research should address which tool achieves the greatest sensitivity and specificity in predicting life expectancy. We classify life expectancy as short-term and long-term which can be 4 or 5-year survival and 9 or 10-year survival depending on the measure. This did not appear to lead to widespread differences in estimates, however, assessing the same time frames would have been preferable. Self-reported cancer screening may be subject respondent bias. We excluded patients who did not have a full year of insurance claims which may have led us to underestimate the proportion of patients with limited life expectancies. Lastly, MCBS measures for functional status were similar albeit slightly different than the ones used in the Schonberg and Lee indices.

In summary, we find that there is substantial agreement among different measures predicting short and long-term limited life expectancy in Medicare beneficiaries. The high rates of cancer screening among patients with limited life expectancy suggest the importance of incorporating tools into clinical decision-making while also recognizing caution due to some variability between the different tools. In this way, the tools may be an important starting point for shared decision-making that engages clinicians and patients in discussions about how best to incorporate life expectancy into cancer screening and other medical decisions.^{30–32}

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Characteristics of patients from the 2009–2010 Medicare Current Beneficiary Survey

Characteristics	All Patients N = 9469 [^]
Age – mean (range)	75.2 (66, 90)
Gender – no. (%)	
Male	4137 (43.3)
Female	5332 (56.7)
Race – no. (%)	
African American	783 (7.9)
Caucasian	8284 (87.6)
Asian	104 (1.3)
Other	289 (3.1)
Number of comorbidities[*]	
0	6613 (71.1)
1	1579 (16.2)
2+	1277 (12.6)
Income	
< \$10,000	871 (8.6)
\$10,000 – 20,000	2323 (22.8)
\$20,000 – 30,000	2164 (22.5)
\$30,000 – 40,000	1274 (13.5)
\$40,000 – 50,000	1087 (12.1)
> \$50,000	1750 (20.5)
Marital status – no. (%)	
Married	5084 (56.1)
Widowed	3072 (29.2)
Divorced	964 (10.8)
Separated	86 (1.0)
Never married	261 (2.9)
Census region – no. (%)	
New England	299 (3.8)
Middle Atlantic	1310 (15.2)
East North Central	1583 (16.2)
West North Central	703 (7.0)
South Atlantic	2020 (20.2)
East South Central	789 (7.6)
West South Central	989 (9.8)
Mountain	774 (8.4)

Characteristics	All Patients N = 9469 [^]
Pacific	1002 (11.8)
Medicaid – no. (%)	
No	8383 (89.4)
Yes	1086 (10.6)
Cancer History – no. (%)	
Breast	504 (26.8)
Colon	252 (12.6)
Prostate	482 (23.7)
Cancer screening – no. (%)	
Mammogram	887 (48.0)
Prostate	1121 (60.1)

* Derived from the Charlson Comorbidity Index

[^] Estimates incorporate cross-sectional survey weights

Table 2Frequency distribution of categorized life expectancy probabilities for each tool, N= 9469[^]

	Cho	Lee	Schonberg	Tan
Short-term Life Expectancy – no. (%) [*]				
Low (< 25% chance of surviving)	45 (0.4)	0 (0)	0 (0)	428 (3.6)
Intermediate (25–50%)	727 (5.8)	1015 (8.7)	2057 (18.1)	927 (7.9)
Intermediate High (51–75%)	2491 (22.4)	1779 (16.1)	3211 (31.5)	2985 (26.4)
Very High (> 75%)	6206 (71.4)	6675 (75.2)	4201 (50.5)	5129 (62.2)
Long-term Life Expectancy – no. (%) [†]				
Low (< 25% chance of surviving)	1746 (14.1)	2044 (17.9)	2057 (18.1)	2209 (18.6)
Intermediate (25–50%)	2500 (22.9)	2617 (25.3)	3211 (31.5)	2517 (23.0)
Intermediate High (51–75%)	2550 (28.4)	2272 (24.7)	2389 (26.8)	3404 (40.0)
Very High (> 75%)	2673 (34.5)	2536 (32.1)	1812 (23.6)	1339 (18.3)

[^] Estimates incorporate cross-sectional survey weights^{*} Short term is after 4 years (Lee index) or 5 years (Cho, Tan, and Schonberg indices)[†] Long-term is after 9 years (Schonberg index) or 10 years (Cho, Tan, and Lee indices)

Table 3

Frequency distribution showing agreement in limited life expectancy between tools. Limited life expectancy is defined as having <25% chance of survival

	All Patients N=9469 [^]
Limited short term life expectancy [*]	
All 4 agree – no. (%)	9034 (96.4)
3/4 agree – no. (%)	397 (3.3)
1 that disagrees – no. (%)	
<i>Cho</i>	7 (0.05)
<i>Lee</i>	0 (0)
<i>Schonberg</i>	0 (0)
<i>Tan</i>	390 (3.3)
2/4 agree	38 (0.3)
Limited long term life expectancy [†]	
All 4 agree – no. (%)	6951 (77.1)
3/4 agree – no. (%)	1392 (12.9)
1 remaining that disagrees – no. (%)	
<i>Cho</i>	227 (2.1)
<i>Lee</i>	422 (3.9)
<i>Schonberg</i>	433 (3.9)
<i>Tan</i>	310 (9.6)
2/4 agree	1126 (10.0)

[^] Estimates incorporate cross-sectional survey weights

^{*} <25% chance of surviving 4 years (Lee index) or 5 years (Cho, Tan, and Schonberg indices)

[†] <25% chance of surviving 9 years (Schonberg index) or 10 years (Cho, Tan, and Lee indices)

Table 4

Frequency distribution of cancer screening. The sample is limited to individuals with limited life expectancy, defined as having <25% probability of survival [^]

	Limited short term life expectancy [*]				Limited long term life expectancy [†]			
	Cho	Lee	Schonberg	Tan	Cho	Lee	Schonberg	Tan
Mammography								
Patients with limited life expectancy eligible for screening, N	0	-	-	158	707	807	837	987
Received screening, N (%)	0	-	-	49 (32.1)	228 (31.9)	253 (32.7)	283 (34.5)	363 (37.3)
PSA screening								
Patients with limited life expectancy eligible for screening, N	36	-	-	193	752	801	827	863
Received screening, N (%)	18 (50.6)	-	-	137 (71.1)	526 (69.5)	575 (71.5)	586 (70.7)	608 (70.2)

[^] Estimates incorporate cross-sectional survey weights

^{*} <25% chance of surviving 4 years (Lee index) or 5 years (Cho, Tan, and Schonberg indices)

[†] <25% chance of surviving 9 years (Schonberg index) or 10 years (Cho, Tan, and Lee indices)