

Influence of Age, Health, and Function on Cancer Screening in Older Adults with Limited Life Expectancy

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BACKGROUND/OBJECTIVES: We examined the relationship between cancer screening and life expectancy predictors, focusing on the influence of age versus health and function, in older adults with limited life expectancy.

DESIGN: Longitudinal cohort study

SETTING: National Health and Aging Trends Study (NHATS) with linked Medicare claims.

PARTICIPANTS: Three cohorts of adults 65+ enrolled in fee-for-service Medicare were constructed: women eligible for breast cancer screening ($n=2043$); men eligible for prostate cancer screening ($n=1287$); men and women eligible for colorectal cancer screening ($n=3759$).

MEASUREMENTS: We assessed 10-year mortality risk using 2011 NHATS data, then used claims data to assess 2-year prostate and breast cancer screening rates and 3-year colorectal cancer screening rates. Among those with limited life expectancy (10-year mortality risk > 50%), we stratified participants at each level of predicted mortality risk and split participants in each risk stratum by the median age. We assembled two sub-groups from these strata that were matched on predicted life expectancy: a “younger sub-group” with relatively poorer health/functional status and an “older sub-group” with relatively better health/functional status. We compared screening rates between sub-groups.

RESULTS: For all three cancer screenings, the younger sub-groups (average ages 73.4–76.1) had higher screening rates than the older sub-groups (average ages 83.6–86.9); screening rates were 42.9% versus 34.2% for prostate cancer screening ($p=0.02$), 33.6% versus 20.6% for breast cancer screening ($p<0.001$), 13.1% versus 6.7% for colorectal cancer screening in women ($p=0.006$), and 20.5% versus 12.1% for colorectal cancer screening in men ($p=0.002$).

CONCLUSION: Among older adults with limited life expectancy, those who are relatively younger with poorer health and functional status are over-screened for cancer at higher rates than those who are older with the same predicted life expectancy.

KEY WORDS: geriatrics; cancer screening; health status; functional status.

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INTRODUCTION

The benefit of cancer screening takes many years to accrue while the harms are more immediate.^{1–13} There is a lag time of at least 10 years before patients screened for breast, colorectal, or prostate cancers derive benefit.^{2, 8, 11, 12} On the other hand, multiple harms from screening can occur in the short term, such as complications from screening and follow-up tests, over-treatment of clinically unimportant cancers, psychological stress from false positive results, diverted attention from other health conditions or more impactful health interventions, and increased burden for patients.^{1, 3–13} Therefore, cancer screening in older adults with limited life expectancy may inappropriately subject them to harm with little chance of benefit.

Traditionally, age has been used as a proxy for life expectancy, but a growing body of literature demonstrates that older adults of the same age can have very heterogeneous health status and health trajectories.^{1, 14} For this reason, clinical practice guidelines increasingly use limited life expectancy, often defined as < 10 years, to guide when routine cancer screening should stop, as opposed to using only age thresholds.^{13, 15–18} However, the screening rate among older adults with limited life expectancy remains high despite little chance for benefit and greater probability of harm.^{19–23}

In addition to age, health status and functional status factors are also important predictors of life expectancy.^{24, 25} In our prior work, we found that clinicians were reluctant to stop screening when the older adult with limited life expectancy was relatively younger (e.g., 60-year-olds compared to 80-year-olds),²⁶ suggesting that younger age may be more influential in the screening decisions than other life expectancy predictors. A few studies have explored the relationship between age, life expectancy, and cancer screening in national samples but yielded contradicting findings regarding whether age is associated with

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screening independent of mortality risk.^{19, 20, 27–29} We aimed to extend this body of literature by examining the relationship between different predictors of mortality risk in older adults, in particular focused on the influence of age versus health and functional status, and receipt of cancer screening in a nationally representative cohort of older adults.

METHODS

Data Source and Study Sample

We draw on data from the National Health and Aging Trends Study (NHATS) linked to Medicare claims. NHATS is a population-based survey of health and disability trends among Medicare beneficiaries aged 65 years and older with focus on late-life functioning. Annual, in-person interviews collect detailed information from participants regarding their physical and cognitive health, social environment, and participation in daily activities. The NHATS design and procedures have been described previously.³⁰ For this study, we included community-dwelling older adults who responded to the first wave of NHATS in 2011 (response rate 71%). We constructed three separate cohorts in which we identified subsets of older adults eligible for each type of cancer screening (breast, colorectal, and prostate) who were continuously enrolled in fee-for-service Medicare for the relevant time period (Fig. 1). Participants for whom we did not have access to complete information necessary for predicting life expectancy (see subsequent section “Life Expectancy Estimates”) were excluded ($n = 355$). We used published algorithms to exclude those ineligible for screening using claims data in the previous 1 year (2010–2011).^{31–33} We then followed study participants forward in time using claims data to assess screening rates over the relevant observation period. For breast and prostate cancer

screenings, we assessed rates of screening mammograms and prostate-specific antigen (PSA) tests, respectively, over a 2-year period (2011–2013) because recommended intervals for these two screening tests range from annually to biennially.^{10, 13, 15, 16, 34} For colorectal cancer screening, we included any screening colonoscopy, sigmoidoscopy, or fecal occult blood test during the study period. The recommended interval for colorectal cancer screening is 10 years using colonoscopy, 5 years using sigmoidoscopy, and yearly using fecal occult blood test.^{9, 35} Our observation period was limited through 2014 and we therefore measured screening rate over the time period 2011–2014. Details of screening test identification in the claims data are described in the Appendix. Study participants who died before the end of the observation periods were included in the analyses. This project was approved by a Johns Hopkins School of Medicine institutional review board.

Life Expectancy Estimates

We used an index developed by Lee et al. to estimate the 10-year mortality risk of the study participants.²⁴ This index incorporates information on both health and function, is applicable to community-dwelling older adults, has excellent discrimination with a *c*-statistic of 0.834, and is quantified using questions available from the NHATS interviews, and its 10-year time frame is the estimated time horizon for benefit from breast, prostate, and colorectal cancer screenings.^{2, 8, 11, 12} Several cancer screening guidelines define limited life expectancy as less than 10 years.^{13, 17, 36} Accordingly, we defined limited life expectancy in this study as those with > 50% 10-year mortality risk, which corresponds to a median life expectancy of less than 10 years.

The Lee index (Table 1) employs 12 items including age, sex, health status/comorbidities (body mass index, diabetes, cancer, lung disease, heart disease, smoking), and functional

NHATS 2011 Community-dwelling Participants

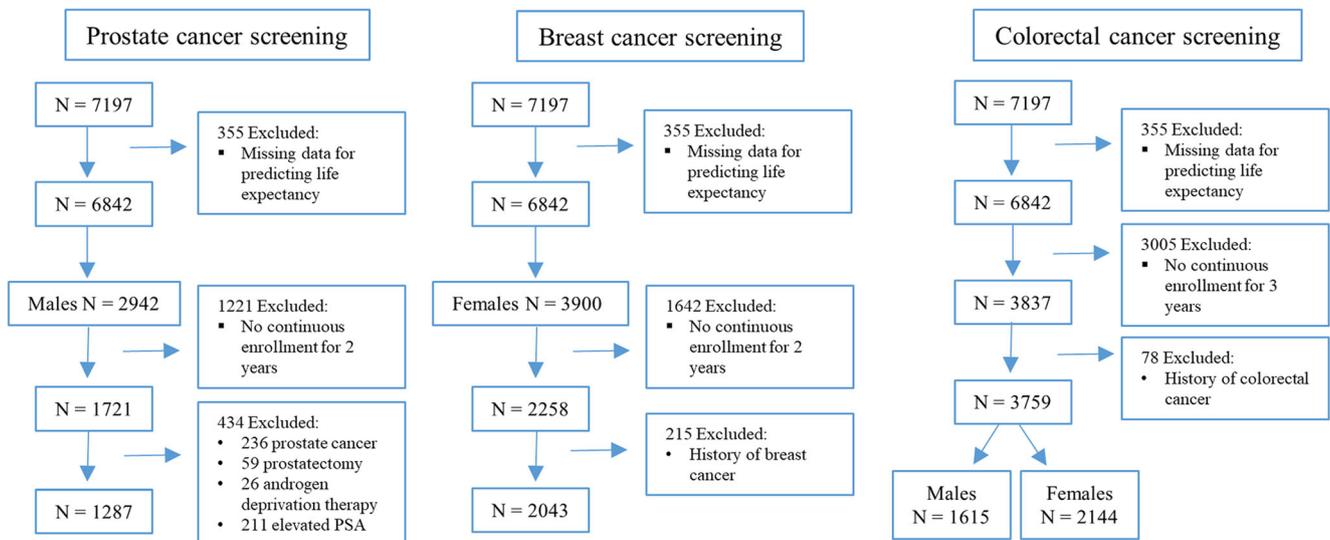


Figure 1 Construction of the three study analytic samples for prostate, breast, and colorectal cancer screening respectively.

Table 1 The Mortality Risk Index by Lee et al.^{24, 37}

| Index items | | | Mortality risk prediction | |
|--|-------|----------|---------------------------|-----------------------------------|
| | | | Total points (0–26) | 10-year mortality risk % (95% CI) |
| Age | 60–64 | 1 point | 0 | 2.8 (1.3–4.2) |
| | 65–69 | 2 points | 1 | 4.0 (2.6–5.4) |
| | 70–74 | 3 points | 2 | 6.0 (4.8–7.3) |
| | 75–79 | 4 points | 3 | 9.1 (7.6–11) |
| | 80–84 | 5 points | 4 | 14 (12–16) |
| | ≥85 | 7 points | 5 | 21 (19–23) |
| Male sex | | 2 points | 6 | 30 (27–33) |
| Body mass index <25 | | 1 point | 7 | 40 (36–43) |
| Diabetes | | 1 point | 8 | 52 (48–55) |
| Cancer | | 2 points | 9 | 62 (58–66) |
| Chronic lung disease | | 2 points | 10 | 71 (67–76) |
| Heart failure | | 2 points | 11 | 81 (76–85) |
| Smoking | | 2 points | 12 | 85 (81–90) |
| Difficulty with bathing or showering | | 2 points | 13 | 89 (85–94) |
| Difficulty managing money | | 2 points | ≥14 | 95 (93–98) |
| Difficulty walking several blocks | | 2 points | | |
| Difficulty with pulling or pushing large objects | | 1 point | | |

status (difficulty bathing or showering, difficulty managing money, difficulty walking several blocks, and difficulty pushing/pulling large objects).²⁴ The sum of the points from all items (maximum possible 26 points) is then used to calculate 10-year mortality risk ranging from 2.8% in the lowest risk group with 0 points to 95% in the highest risk group with ≥14 points.²⁴ Body mass index was calculated from self-reported height and weight. For the Lee index question that asked about difficulty with pulling or pushing large objects such as a living room chair, we relied on the NHATS question which asks about difficulty carrying 20 pounds.

Analytic Approach

We first compared the screening rate by predicted median life expectancy (<10 years versus >10 years) using chi-square test. For colorectal cancer, we stratified the analysis by sex since male sex is associated with increased mortality risk and is one of the items in the Lee index.

Next, we examined whether the screening rates differed by age among those with limited life expectancy, while holding predicted life expectancy constant. To accomplish this, we stratified participants at each level of predicted mortality risk (e.g., with the same Lee index score) and split participants within each mortality risk stratum by median age. We then assembled a younger sub-group and an older sub-group from these strata. Since the two sub-groups were matched on the same predicted mortality risk, those who were in the younger sub-group by definition had more

comorbidities and/or functional deficits than their older counterparts in order to accrue the same amount of total mortality risk points. This allowed us to compare the screening rates between participants who were relatively younger with poorer health and/or functional status versus those who were older with relatively better health and/or functional status but with the same predicted life expectancy. The comparison of screening rates was accomplished by chi-square test. We hypothesize that among older adults with limited life expectancy (defined as >50% 10-year mortality risk), those who are relatively younger (for example, those in their 60–70s) but have poor health status and/or poor functional status are more likely to receive cancer screening than those who are older (for example, those in their 80s), despite the same predicted life expectancies. All analyses were performed using SAS 9.4 software and incorporated the survey design variables and sampling weights.³⁰

RESULTS

The final analytic sample included 1287 men in the prostate cancer screening cohort, 2043 women in the breast cancer screening cohort, and 3759 older adults (2144 women, 1615 men) in the colorectal cancer screening cohort (Fig. 1). Characteristics of the three analytic samples are shown in Table 2. Among the three cohorts, 36.7–45.6% had limited life expectancy of <10 years according to the Lee index. Those with more limited life expectancy were older in age, had lower self-rated health, had more cognitive impairment, and had lower educational level (all $p < 0.001$). Compared to participants with 10+ years of life expectancy, those with limited life expectancy were screened at lower but still substantial rates for all three types of cancers (Table 2). Below, we present the screening rates by age sub-groups among those with limited life expectancy for each type of cancer screening. As expected, the younger sub-groups had more comorbidities and more functional deficits than the older sub-groups but had similar predicted mortality rate over 10 years and had similar observed mortality rate during the observation periods (Table 3).

Prostate Cancer Screening. Among the participants in the analytic sample who had <10-year life expectancy, overall screening rate was 38.4%. The average ages in the two sub-groups were 73.4 and 83.6 years respectively. The younger sub-group had a screening rate of 42.9% and the older sub-group had a screening rate of 34.2% ($p = 0.02$).

Breast Cancer Screening. Among the participants in the analytic sample who had <10-year life expectancy, overall screening rate was 27.0%. The average ages in the two sub-groups were 75.8 and 86.9 years respectively. The younger sub-group had a screening rate of 33.6% and the older sub-group had a screening rate of 20.6% ($p < 0.001$).

Table 2 Study Participant Characteristics

| | Prostate cancer screening N= 1287 | | | Breast cancer screening N= 2043 | | | Colorectal cancer screening N= 3759 | | |
|---|--------------------------------------|-------------------|---------|------------------------------------|-------------------|---------|--|-------------------|---------|
| | < 10 y LE* | > 10 y LE | p | < 10 y LE | > 10 y LE | p | < 10 y LE | > 10 y LE | p |
| Sample size (%) | 733 (45.6%) | 554 (54.4%) | | 973 (36.7%) | 1070 (63.3%) | | 1997 (42.0%) | 1762 (58.0%) | |
| Age, mean (SD) | 78.6 (0.3) | 71.3 (0.2) | < 0.001 | 81.5 (0.3) | 72.7 (0.2) | < 0.001 | 80.1 (0.2) | 72.2 (0.1) | < 0.001 |
| Age, median (range) | 78.1 (65.0, 100.0) | 69.7 (65.0, 84.0) | | 81.5 (65.0, 105.0) | 71.1 (65.0, 91.0) | | 79.9 (65.0, 105.0) | 70.6 (65.0, 91.0) | |
| % female | | | | | | | 49.1% | 60.6% | < 0.001 |
| Mortality risk points, [†] mean (SD) | 10.7 (0.12) | 5.6 (0.05) | < 0.001 | 10.8 (0.09) | 4.6 (0.05) | < 0.001 | 10.8 (0.07) | 5.0 (0.04) | < 0.001 |
| Self-rated health | | | | | | | | | |
| Excellent | 8.2% | 24.4% | < 0.001 | 4.4% | 18.7% | < 0.001 | 6.3% | 19.7% | < 0.001 |
| Very good | 19.2% | 37.4% | | 16.8% | 36.3% | | 18.8% | 38.0% | |
| Good | 30.3% | 25.0% | | 31.9% | 31.6% | | 32.4% | 29.3% | |
| Fair | 28.5% | 11.4% | | 31.8% | 11.9% | | 28.6% | 11.5% | |
| Poor | 13.8% | 1.8% | | 15.1% | 1.4% | | 13.9% | 1.5% | |
| Educational level [‡] | | | | | | | | | |
| < HS | 28.4% | 16.6% | < 0.001 | 27.9% | 15.2% | < 0.001 | 27.0% | 14.2% | < 0.001 |
| HS/GED | 31.7% | 27.0% | | 41.5% | 39.7% | | 35.8% | 35.2% | |
| > HS | 39.9% | 56.5% | | 30.5% | 45.1% | | 37.2% | 50.7% | |
| Cognitive impairment [§] | | | | | | | | | |
| No dementia | 69.1% | 89.7% | < 0.001 | 63.3% | 90.7% | < 0.001 | 68.3% | 91.0% | < 0.001 |
| Possible dementia | 14.2% | 7.6% | | 13.6% | 6.1% | | 13.8% | 6.3% | |
| Probable dementia | 16.7% | 2.7% | | 23.2% | 3.2% | | 17.9% | 2.7% | |
| % received screening | 38.4% | 55.6% | < 0.001 | 27.0% | 60.7% | < 0.001 | 13.1% | 25.4% | < 0.001 |

*We defined limited life expectancy (LE) in this study as those with > 50% mortality risk, which corresponds to a median life expectancy less than 10 years

[†]Based on the index by Lee et al.²⁴ Total number of possible points ranges from 0 to 26

[‡]HS, high school; GED, general equivalency diploma; y, year

[§]NHATS participants are classified into three groups according to an established scheme³⁸

^{||}Weighted percentages

Colorectal Cancer Screening. Among the participants in the analytic sample who had < 10-year life expectancy, screening rate was 16.3% among males and 9.9% among females (13.1% combined). Among the females, the average ages in the two sub-groups were 76.1 and 86.8 years respectively. The screening rate in the younger sub-group was significantly higher (13.1%) than that of the older sub-group (6.7%) with $p = 0.006$. Among the males, the average ages in the two sub-groups were 73.8 and 83.8 years respectively. The screening rate in the younger sub-group was significantly higher (20.5%) compared to the older sub-group (12.1%) with $p = 0.002$.

DISCUSSION

The findings of our analyses indicate that older adults with estimated life expectancy of less than 10 years still receive screening tests at substantial rates. These screening tests subject older adults to risks of screening when they have little chance of benefit, may lead to over-diagnosis and over-treatment of cancers, and detract from other more impactful health interventions.¹⁻¹³ On the other hand, healthy older adults may be under-screened, for example, breast cancer screening rate is only 60.7% among older adults with 10+

years of predicted life expectancy. This suggests missed opportunities for a significant number of healthy older women who may live long enough to benefit from screening.

The cancer screening rates found in NHATS, however, were lower than rates found in other national studies, both for those with normal and limited life expectancies.^{19, 20, 22, 28} For example, one study using National Health Interview Study data found screening rates among those with limited life expectancy and those with normal life expectancy ranged from 55–70% for prostate cancer, 38–74% for breast cancer, and 41–51% for colorectal cancer.¹⁹ The difference is potentially because these other studies relied on self-reported cancer screening rates whereas we used claims-based data to determine screening rates. Self-reported cancer screening rates have been shown to be prone to recall bias and over-estimate screening rates by up to 14% compared to claims or medical record review.³⁹ Another potential reason for the lower screening rates in our study may be due to the inclusion of those participants who died before the end of observation periods. However, since the study focus is on older adults with limited life expectancy, we chose to include these participants in the analyses. A third potential explanation is that the screening rate overall has declined over time, since our project examined a more recent time period than previous studies. Declining screening rate over time has been suggested for breast and

Table 3 Comparisons Between Younger and Older Sub-groups Among Those with <10-Year Predicted Life Expectancy

| Prostate cancer screening* | | | |
|--|-------------------|--------------------|----------|
| | Younger sub-group | Older sub-group | <i>p</i> |
| Age (mean) | 73.4 | 83.6 | < 0.001 |
| Age, median (range) | 72.4 (65.0, 87.0) | 82.5 (75.0, 100.0) | |
| Mortality risk score from health conditions [†] | 3.2 | 1.8 | < 0.001 |
| Mortality risk score from functional deficits [‡] | 2.1 | 1.3 | < 0.001 |
| Total mortality risk score [§] | 10.6 | 10.7 | 0.80 |
| Predicted 10-year mortality risk | 71.4% | 71.6% | 0.85 |
| Percent died during observation period (2011–2013) | 18.3% | 14.4% | 0.20 |
| Screening rate | 42.9% | 34.2% | 0.02 |
| Breast cancer screening | | | |
| Age (mean) | 75.8 | 86.9 | < 0.001 |
| Age, median (range) | 75.6 (65.0, 88.0) | 85.9 (80.0, 105.0) | |
| Mortality risk score from health conditions [†] | 3.0 | 1.7 | < 0.001 |
| Mortality risk score from functional deficits [‡] | 3.9 | 2.8 | < 0.001 |
| Total mortality risk score [§] | 10.8 | 10.9 | 0.57 |
| Predicted 10-year mortality risk | 72.9% | 73.4% | 0.69 |
| Percent died during observation period (2011–2013) | 16.6% | 17.1% | 0.85 |
| Screening rate | 33.6% | 20.6% | < 0.001 |
| Colorectal cancer screening in women | | | |
| Age (mean) | 76.1 | 86.8 | < 0.001 |
| Age, median (range) | 75.8 (65.0, 88.0) | 85.8 (80.0, 105.0) | |
| Mortality risk score from health conditions [†] | 3.2 | 1.8 | < 0.001 |
| Mortality risk score from functional deficits [‡] | 3.8 | 2.8 | < 0.001 |
| Total mortality risk score [§] | 10.8 | 10.9 | 0.76 |
| Predicted 10-year mortality risk | 73.1% | 73.4% | 0.83 |
| Percent died during observation period (2011–2014) | 21.6% | 27.0% | 0.06 |
| Screening rate | 13.1% | 6.7% | 0.006 |
| Colorectal cancer screening in men | | | |
| Age (mean) | 73.8 | 83.8 | < 0.001 |
| Age, median (range) | 73.2 (65.0, 87.0) | 82.8 (75.0, 100.0) | |
| Mortality risk score from health conditions [†] | 3.3 | 1.9 | < 0.001 |
| Mortality risk score from functional deficits [‡] | 2.0 | 1.2 | < 0.001 |
| Total mortality risk score [§] | 10.7 | 10.7 | 0.77 |
| Predicted 10-year mortality risk | 71.6% | 71.7% | 0.86 |
| Percent died during observation period (2011–2014) | 19.9% | 21.6% | 0.59 |
| Screening rate | 20.5% | 12.1% | 0.002 |

*All values except screening rates are averages unless otherwise noted

[†]Weighted score assigned in the Lee mortality index related to health, including 1 point for low body mass index, 1 point for diabetes, 2 points for cancer, 2 points for lung disease, 2 points for congestive heart failure, 2 points for smoking. Total possible 10

[‡]Weighted score assigned in the Lee mortality index related to function, including 2 points for difficulty with bathing, 2 points for difficulty managing finances, 2 points for difficulty walking, and 1 point for difficulty pushing/pulling large objects. Total possible 7

[§]Total mortality risk scores range from 0 to 26. In addition to the above health and function-related scores, 2 points for male sex and up to 7 points for various ages from 60 to 85+

^{||}Weighted percentages

prostate cancer screenings.^{40, 41} For colorectal cancer screening, studies suggest increased screening over time,^{20, 42} and the low colorectal screening rate in our study likely reflects under-estimation due to the observation period being constrained to 3 years.

Our study extends the previous work by relying on claims-based assessments of cancer screening utilization and leveraging the rich health and functional status from the NHATS survey data to estimate life expectancy. Our study is also novel in that we assessed screening rates in a time period subsequent to, rather than preceding, the time point where life expectancy is estimated. Previous studies using only survey data often gathered information that were used to estimate life expectancy while asking about screenings in the past.^{19, 20, 27–29} Our approach is arguably more accurate in assessing the extent of over-screening in those with limited life expectancy since life expectancy tends to decrease over time. If screening rates are measured several years before life expectancy assessment, it is conceivable that life expectancy at the time of screening was

long enough to justify screening. By measuring screening rate after life expectancy assessment, this type of misclassification is much less likely.

To our knowledge, this is the first study to examine the influence of age versus health and functional status among individuals with closely matched predicted mortality risk. Compared to previous studies where mortality risk was categorized by quartiles of risk (i.e., all those with 9-year mortality risk from 50 to 74% were analyzed together in a single group),^{19, 20, 27–29} we stratified the participants in our study into finer mortality risk strata (intra-stratum mortality risk ranged from < 5 to 9%) so as to minimize residual confounding and better isolate the effect of age on cancer screening independent of mortality risk. Previous studies had found contradicting results. Regarding breast cancer screening, one study found that within each mortality risk category, there was no difference in the screening rate by age.²⁷ On the other hand, two other studies found that younger age was associated with receipt of screening mammograms even after controlling for

mortality risk categories.^{28, 29} Regarding colorectal cancer screening, one study found that younger age and lower mortality risk were both associated with higher screening but another study found that only age, but not mortality risk, was associated with screening.^{19, 20} We examined three types of cancer screening, including prostate cancer screening which has only been examined in one previous study in terms of the relationship between age, life expectancy, and receipt of cancer screening.¹⁹ We found that among those with the same extent of limited life expectancy, younger participants with poorer health and/or functional status received significantly higher screening rates compared with those who were older with relatively better health or functional status. The trend was consistent across all three types of cancer screening. This result extends the previous literature and supports our hypothesis that those who have limited life expectancy primarily due to poor health and/or functional status but are relatively younger are particularly prone to being over-screened.

Several reasons may explain this finding. First, cancer screening guidelines have traditionally used age as metrics to guide screening decisions.^{9–11} More recently, research has advocated using life expectancy, which incorporates not only age but also an individual's health and functional status, to inform screening decisions.⁴³ The adoption of this framework in cancer screening guidelines is variable—some guidelines recommend stopping screening based on either a specific age (most often > 75 years old for breast, colorectal, and prostate cancers) or limited life expectancy (< 10 years);^{15, 18, 44} some guidelines use limited life expectancy alone;^{13, 17, 36} still others use age cutoffs alone while acknowledging the importance of considering life expectancy and other competing causes of mortality.^{9, 10, 16} How to approach the cancer screening decision in a patient who is younger than 75 with limited life expectancy is not clear. Further, clinicians have reported pressure to adhere to age-based screening guidelines, in part due to health system performance metrics that are based on these guidelines, and fear of litigation if they chose to deviate from these guidelines.²⁶ The health system is increasingly shifting to value-based care focused on quality but quality metrics are still often defined by age-based screening guidelines; this leads to high risk of misaligned incentives that reward over-screening in patients who are relatively younger but have limited life expectancy.⁴⁵ More consensus in the guidelines and practical ways to implement quality metrics that incorporate patients' life expectancies are needed.

Second, it is possible that clinicians do not always recognize poor health or functional deficits as predictors of limited life expectancy or that screening is not indicated in these scenarios. Third, younger patients may be more likely to want or request continued screening, since older adults report older age as a common reason for them to decide to stop screening.⁴⁶ Future studies are needed to better understand the causes of the high rates of screening in this population, for whom the harms of screening may outweigh the benefits, in order to craft appropriate interventions. More education is likely needed among

both clinicians and patients to recognize that poor health and functional status may be indicators that screening is no longer recommended. The results also highlight the importance to reconcile guidelines that use age and those that use life expectancy to guide when routine screening should stop.

Our study has a number of limitations. We adapted the Lee index to be used in the NHATS; although much of the same information is collected, the wording of some questions is not identical and may lead to different results of predicted life expectancy. However, we do not expect the general trend of our findings to be significantly altered. We used published algorithm to identify screening tests in the claims, but claims data can be susceptible for coding error and these algorithms may not be completely accurate.^{31–33} We were only able to assess colorectal cancer screening during a 3-year interval when screening colonoscopy is usually recommended every 10 years and screening sigmoidoscopy every 5 years. Therefore, we were not able to assess colonoscopies within 10 years or sigmoidoscopies within 5 years but outside our observation period to identify participants who were not yet due for screening during the study period; this likely resulted in under-estimation of the colorectal screening rate in our study. We were not able to further delineate if health status versus functional status had differential impact on the receipt of screening. Our study only included those participants with continuous Medicare fee-for-service coverage and more work is needed to confirm if the results also apply to older adults covered by Medicare Advantage plans. Lastly, this study does not allow for examination of the role of patient preference in screening decisions.

In summary, we found that a substantial proportion of older adults with limited life expectancy still receive breast, prostate, and colorectal cancer screenings while healthy older adults with 10+ years of life expectancy may be under-screened. Furthermore, those who are relatively younger with poorer health or functional status are over-screened at even higher rates compared to those who are older, despite having the same predicted life expectancy. Understanding the causes for this discrepancy is critical for identifying targets for intervention to reduce over-screening in this vulnerable population.

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Author Contributions Dr. Schoenborn had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Schoenborn, Huang, Sheehan, Wolff, Roth, Boyd. Data analysis and interpretation: Schoenborn, Huang, Sheehan, Wolff, Roth, Boyd. Preparation and review of the manuscript: Schoenborn, Huang, Sheehan, Wolff, Roth, Boyd.

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Compliance with Ethical Standards

This project was approved by a Johns Hopkins School of Medicine institutional review board.

Conflict of Interest. The authors declare no conflicts of interest. Dr. Cynthia Boyd received a small payment from UptoDate for having co-authored a chapter on Multimorbidity; however, we do not believe this has resulted in any conflict with the design, methodology, or results presented in this manuscript.

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APPENDIX. ALGORITHMS USED TO IDENTIFY BREAST, PROSTATE, AND COLORECTAL CANCER SCREENING IN MEDICARE CLAIMS DATA

Screening mammograms

We used a three-step algorithm to distinguish screening from diagnostic mammograms validated by Fenton et al.³²

- (1) Include if mammography was for screening (76092, 77057, G0202, any GG modifier, G0203/05); exclude if mammography was for diagnosis (76090, 76091, 77055, 77056, G0204, G0206);
- (2) Exclude mammography if the woman has already received mammography in the prior 9 months;
- (3) Exclude if any ICD-9 code for breast cancer in the prior year (174x, 233.0, V103, 611.72);

Screening prostate-specific antigen (PSA) test

We used the algorithm used by Walter et al.³¹

PSA test: CPT code G0103 and 84153.

We excluded men who were ineligible for screening either due to prior history or symptoms (in the 3 months prior to PSA testing) that suggested the test was more likely to be diagnostic rather than screening:

Prior history:

- Prostate cancer (ICD-9 185, V1046)
- Prostatectomy (ICD-9 60.21, 60.29, 60.3-60.6, 60.61, 60.62, 60.69, CPT 55810, 55812, 55815, 55801, 55821, 55831, 55842, 55845)
- Androgen deprivation therapy (CPT J1950, J9202, J9217, J9218, J9219)
- History of elevated PSA (ICD-9 790.93)

Symptoms:

- Urinary obstruction (ICD-9 599.6)

- Hematuria (ICD-9 599.7)
- Prostatitis (ICD-9 601-601.9)
- Other disorders of the prostate (ICD-9 602-602.9)
- Unexplained weight loss (ICD-9 783.21)
- Back pain (ICD-9 724.5)

Colorectal cancer screening

Colonoscopy: we used the algorithm used by Mittal et al.³³ which included CPT codes 45378 45380, 45382, 45383, 45384, 45385, HCPCS codes G0105, G0121, and ICD-9 codes 45.23, 45.25, 45.27, 45.41, 45.42, 45.43.

Sigmoidoscopy: we used CPT codes 45300, 45303, 45305, 45308, 45309, 45315, 45320, 45330, 45331, 45332, 45333, 45334, 45337, 45338, 45339, and HCPCS code G0104 (Maroongroge et al. *JCO* 2018;41(4):339-347)

Fecal occult blood test: we used CPT codes 82270, 82272, 82273, 82274, and HCPCS code G0107, G0328. (Maroongroge et al. *JCO* 2018;41(4):339-347)

For all three types of screening modalities, we excluded patients if they had symptoms or diagnoses that suggested the test was more likely to be diagnostic rather than screening³³:

- High risk diagnoses: history of colon cancer (153.0, 153.1, 153.2, 153.3, 153.4, 153.6, 153.7, 153.8, 153.9, 154.0, 154.1, 230.3, 230.4, V10.05, V10.06), inflammatory bowel diseases (555.0, 555.1, 555.2, 555.9., 556.0, 556.1, 556.4, 556.9, 556.2, 556.6, 556.8, 556.5), and other conditions where a colonoscopy might plausibly be indicated (260- 263, 558.1, 560.2, 560.30, 560.39, 793.4, 783.21, 569.82, 558.1, 569.2, 569.41, 569.61, 569.62, 569.69, 569.81, 569.82, 596.1, 710.3, 863.44, 863.45, 936, 997.4, V44.3, V45.3, V55.3, V58.42, V58.49, V58.75, V67.0, V67.1, V67.9).
- Anemia (280.0, 280.1, 280.8, 280.9, 281.0, 281.8, 281.9, 285.1, 285.2, 285.9)
- Gastrointestinal bleeding (286.5, 459.0, 562.02, 562.03, 562.12, 562.13, 569.3, 569.84, 569.85, 569.86, 578.1, 578.9, 792.1, 998.11).
- Other related symptoms: constipation (564.0, 564.00, 564.09, 564.01, 564.02), diarrhea (008.42, 008.43, 008.45, 008.5, 008.8, 009.0-009.3, 558.2, 558.3, 558.9, 564.4, 564.5, 564.8, 564.9, 787.91), abdominal pain (789.0, 787.3, 789.4, 789.6), ischemic bowel disease (557.0, 557.1, 557.9), irritated bowel syndrome (564.1), bowel habits change (787.99), hemorrhoid (455), and weight loss (783.2, 783.7).
- Diverticulitis (562.11).ACCEPTED MANUSCRIPT
- Barium enema: CPT codes 74270, 74280, HCPCS codes G0106, G0120, G0122 and ICD-9-CM procedure code 87.64.
- Abdominal computerized tomographic scan: CPT codes 72191, 72192, 72193, 72194, 74150, 74160, 74170, 74175, 75635, 74261, 74262, 74263 and ICD-9-CM procedure codes 88.01, 88.02.