

# Integrating Age and Comorbidity to Assess Screening Mammography Utilization

Alai Tan, MD, PhD, Yong-Fang Kuo, PhD, James S. Goodwin, MD

**Background:** Most studies use age as a cutoff to evaluate screening mammography utilization, generally examining screening up to age 75 years (the age-cutoff method). However, many experts and guidelines encourage clinicians to consider patient health and/or life expectancy.

**Purpose:** To compare the accuracy of estimating screening mammography utilization in older women using the age-cutoff method versus using a method based on the projected life expectancy.

**Methods:** Two cohorts were selected from female Medicare beneficiaries aged 67–90 years living in Texas in 2001 and 2006. The 2001 cohort ( $n=716,279$ ) was used to generate life-expectancy estimates by age and comorbidity, which were then applied to the 2006 cohort ( $n=697,825$ ). Screening mammography utilization during 2006–2007 was measured for the 2006 cohort. Data were collected in 2000–2007 and analyzed in 2011.

**Results:** The screening rate was 52.7% in women aged 67–74 years based on age alone, compared to 53.5% in women in the same age group with a life expectancy of  $\geq 7$  years. A large proportion (63.4%) of women aged 75–90 years ( $n=370,583$ ) had a life expectancy of  $\geq 7$  years. Those women had a screening rate of 42.7%. The screening rate was 35.7% in women aged 75–90 years based on age alone, compared to 16.3% in women in the same age group with a life expectancy of  $< 5$  years.

**Conclusions:** Estimating screening mammography utilization among older women can be improved by using projected life expectancy rather than the age-cutoff method.

(*Am J Prev Med* 2012;42(3):229–234) Published by Elsevier Inc. on behalf of American Journal of Preventive Medicine

## Introduction

Current cancer screening guidelines base their recommendations primarily on age.<sup>1–3</sup> For example, the U.S. Preventive Services Task Force (USPSTF) Guideline<sup>3</sup> recommends biennial screening mammograms in women aged 50–74 years. Screening mammography is not routinely recommended in women aged  $\geq 75$  years.<sup>3</sup> Although older women have a higher risk of breast cancer and lower risk of false-positive screening than younger women, their limited life expectancy reduces the potential benefit from breast cancer screening.<sup>3–6</sup> Older women are also more likely to be diagnosed and treated for screen-detected cancer that would never have become symptomatic in their lifetime.<sup>7,8</sup>

Using age cutoffs to define appropriate target populations for screening mammography has recognized limitations. For example, screening mammography may not be appropriate in women aged 50–74 years with poor health and short life expectancy. Recent studies<sup>9,10</sup> report that one quarter of women aged 70–74 years with severe cognitive impairment and 12% of those aged 65–74 years with advanced cancer at another site still receive screening mammography. On the other hand, some women aged  $> 75$  years with good health and excellent functional status may live long enough to benefit from screening mammography.<sup>11</sup>

A number of authors<sup>12–14</sup> have argued that life expectancy should be taken into account when making screening decisions. Nevertheless, studies continue to use age cutoffs to evaluate screening mammography utilization in the community. For example, a recent study<sup>15</sup> found that poor self-reported health predicted nonadherence to mammography screening and concluded that women with poor health may need more support from their providers to receive regular mammography screening. Such a conclusion failed to recognize that screening mammography may not be appropriate in women with

From the Department of Preventive Medicine and Community Health (Tan, Kuo, Goodwin), Department of Internal Medicine (Kuo, Goodwin), and Sealy Center on Aging, University of Texas Medical Branch (Tan, Kuo, Goodwin), Galveston, Texas

Address correspondence to: Alai Tan, MD, PhD, Department of Preventive Medicine and Community Health, University of Texas Medical Branch, 301 University Boulevard, Galveston TX 77555-1148. E-mail: altan@utmb.edu.

0749-3797/\$36.00

doi: 10.1016/j.amepre.2011.11.008

poor health and limited life expectancy. Another study<sup>16</sup> found a low screening rate among women aged 40–64 years with severe mental illness and recommended intervention targeting women with severe mental illness to ensure regular mammography screening. The study neglected the fact that patients with severe mental illness die on average 13–32 years earlier than the general population.<sup>17</sup>

The present study used Texas Medicare claims data from 2000–2007 to develop a methodologic framework using life expectancy to define appropriate use and overuse of screening mammography in older women and compare the estimates of screening rates to those using an age-cutoff method.

## Methods

### Data Sources

The 100% Texas Medicare claims data from 2000–2007 were used in the current study, including Medicare enrollment files, Carrier files, Outpatient Statistical Analysis Files (OUTSAF), and Medicare Provider Analysis and Review (MEDPAR) files. Data were collected in 2000–2007 and were analyzed in 2011.

### Study Subjects

Appendix A (available online at [www.ajpmonline.org](http://www.ajpmonline.org)) demonstrates the sample selection. The main study cohort ( $n=697,825$ ) was selected from female beneficiaries aged 67–90 years and residing in Texas in 2006. The cohort included only those with full Medicare Parts A and B coverage and without HMO coverage in the 2 years after the year studied. Women with HMO coverage were excluded because their claims are not routinely included in Medicare claims. Subjects were aged  $\geq 67$  years to allow for a 2-year look-back period in the Medicare claims to ascertain any past diagnosis of breast cancer or breast mass (any claims with ICD-9-CM codes 174xx, 2330, and 61172). Those with any previous claim for breast cancer and/or breast mass were excluded.

A second cohort ( $n=716,279$ ) also was created from female Medicare beneficiaries aged 67–90 years in 2001. The inclusion and exclusion criteria were the same as those for the 2006 cohort, except that the data allowed only a 1-year look-back period for the 2001 cohort. The 2001 cohort was used to generate life-expectancy estimates by age and comorbidity, which were then applied to the 2006 cohort.

### Measures

**Screening mammography.** Two years of claims data (January 1, 2006–December 31, 2007) were reviewed to establish whether a woman in the 2006 cohort had a screening mammogram. Because the claims data are limited in their ability to distinguish screening from diagnostic mammography,<sup>18–20</sup> the present study used the algorithm developed and validated by Freeman and associates<sup>21,22</sup> to identify a screening mammogram. Specifically, the algorithm defines a screening mammogram as a bilateral mammogram (Carrier files with a Current Procedure Terminology [CPT] code of 76091 or 76092) with (1) no mammogram (CPT codes 76090, 76091, and 76092) in the previous 11 months

and (2) no diagnosis of breast cancer or breast mass (any claim with ICD-9-CM codes 174xx, 2330, and 61172) in the previous 2 years.

The second criterion was not necessary for the current study because women with any diagnosis of breast cancer or breast mass in the previous 2 years were excluded from the study cohort. In addition, for mammography claims with a screening CPT code (76092), the algorithm also requires a screening diagnosis code (ICD-9-CM code) of V16.3, V10.3, V72.5, or V1589.<sup>22</sup> Freeman et al.<sup>21</sup> validated the algorithm and estimated that about 92% of the algorithm-identified screening mammograms were confirmed screenings.

**Age, comorbidity, and life expectancy.** Each subject's age was calculated from that at the beginning of the study year (e.g., January 1, 2006, for the 2006 cohort). The subjects were stratified by 2-year age intervals.

Comorbidity was assessed by using Klabunde's adaption of the Charlson comorbidity index based on outpatient, inpatient, and carrier claims in the previous 12 months.<sup>23,24</sup> Comorbidity was categorized as none, 1, 2, and 3 or more.

A grid of median survival time was generated for each age-comorbidity group based on the cohort of female Medicare beneficiaries in Texas in 2001 ( $n=716,279$ ) followed up until December 31, 2007, or until date of death. The Texas Medicare claims in the year 2000 were used to ensure a 12-month look-back period to assess comorbidity. For each age and comorbidity group, the Kaplan–Meier survival analysis<sup>25</sup> was used to estimate median survival time. The median survival time was then applied to the corresponding age-comorbidity group of women in the 2006 cohort to project their life expectancy. Statistically, median survival time and life expectancy are different terms. Conceptually, however, both indicate the prognosis of a cohort, and median survival time is often used as a proxy measure of life expectancy.<sup>26</sup>

**Definitions of appropriate target population for screening mammography.** Using the life-expectancy method, the appropriate target population for screening mammography was defined as women with  $\geq 7$  years of life expectancy. Women with a life expectancy of  $< 5$  years were defined as an inappropriate population for screening mammography. Women with life expectancies between 5 and 7 years were defined as a “gray zone” for screening mammography. The 5- and 7-year cut-off points were chosen because (1) studies suggest that screening mammography is not beneficial to women with  $< 5$ –10 years of life expectancy<sup>12,14</sup> and (2) the longest follow-up time for life-expectancy estimates in the present data is 7 years.

Using the age-cutoff method, the appropriate target population for screening mammography was defined as women aged 67–74 years. Women aged 75–90 years were defined as an inappropriate target population for screening mammography. There was no “gray zone” based on the age-cutoff method.

### Statistical Analysis

Descriptive analysis was used to summarize the sample characteristics of age (2-year interval from 67 to 90 years); race (white, black, Other/Unknown); and comorbidity (0, 1, 2, and 3+) for the study cohorts. The estimates of screening mammography rates using the age-cutoff method and life-expectancy method were compared.

SAS, version 9.2, was used for all statistical analyses. The study is overpowered because of large sample size. Therefore, the actual

estimates are reported here with an emphasis on the public health importance rather than the statistical significance of results.

## Results

### Cohort Characteristics

Among the women in the 2006 cohort, approximately 53.1% were aged  $\geq 75$  years, 85.2% were white, and 5.1% had a Charlson comorbidity score of 3 or more. Characteristics were similar in the 2001 cohort (Appendix B, available online at [www.ajpmonline.org](http://www.ajpmonline.org)).

### Survival by Age and Comorbidity

Table 1 presents the survival experience of the 716,279 women in the 2001 cohort, stratified by age and comorbidities. Increasing age and comorbidities were both associated with shorter survival. The unshaded areas indicate age–comorbidity groups with median survival of  $\geq 7$  years. The light-gray shaded areas indicate age–comorbidity groups with median survival of 5–7 years and the dark-gray shaded areas indicate age–comorbidity groups with median survival  $< 5$  years. The median survival time ranged from 5.6 to  $\geq 7$  years among women aged 67–74

years. The heterogeneity of median survival time increases among women aged 75–90 years, with a range of 3.6 to  $\geq 7$  years.

Among those in the age–comorbidity groups with median survival of  $< 5$  years ( $n=25,954$ ), about 70.9% died in 5 years. Among those in the age–comorbidity group with median survival of  $\geq 7$  years ( $n=581,643$ ), about 75.9% survived for  $\geq 7$  years.

### Life Expectancy and Rate of Screening Mammography

Table 2 presents screening mammography rates by age and comorbidity for the 2006 cohort ( $n=697,825$ ). It is set up like Table 1, using unshaded, light-gray and dark-gray shaded areas to indicate the predicted average life expectancy of  $\geq 7$ , 5–7, and  $< 5$  years, respectively. About 78.7% of the women had a life expectancy of  $\geq 7$  years, 16.7% had a life expectancy of 5–7 years, and 4.6% had a life expectancy of  $< 5$  years.

A large proportion (63.4%) of women aged 75–90 years ( $n=370,583$ ) had a life expectancy of  $\geq 7$  years. For women aged 67–90 years with a life expectancy of  $\geq 7$  years, the range of screening rates in the different age and comorbidity groups was 31.2% to 55.9% with an overall rate of 48.9%. In contrast, the screening rate was 16.3% (range 6.8%–22.9%) for those in age–comorbidity groups with an estimated life expectancy of  $< 5$  years (Table 2).

### Comparison of the Age-Cutoff Versus Life-Expectancy Methods

Table 3 compares the estimates of screening mammography rates using the age-cutoff versus life-expectancy methods to determine the appropriate target population for mammography screening. In women aged 67–74 years, the screening rate was 52.7%, compared to 48.9% in women of all ages with a life expectancy of  $\geq 7$  years. The screening rates were 53.5% in women aged 67–74 years with a life expectancy of  $\geq 7$  years and 42.7% in women aged

**Table 1.** Median survival in years (95% CI), by age and comorbidity,<sup>a</sup> for the 2001 cohort<sup>b,c,d,e</sup>

Age (years)	Comorbidity			
	0	1	2	$\geq 3$
67–68	>7.0	>7.0	>7.0	6.4 (6.1, 6.7)
69–70	>7.0	>7.0	>7.0	6.1 (6.0, 6.3)
71–72	>7.0	>7.0	>7.0	5.9 (5.6, 6.0)
73–74	>7.0	>7.0	>7.0	5.6 (5.4, 5.9)
75–76	>7.0	>7.0	>7.0	5.2 (5.1, 5.5)
77–78	>7.0	>7.0	6.3 (6.2, 6.5)	5.1 (5.0, 5.1)
79–80	>7.0	>7.0	5.9 (5.8, 6.0)	4.7 (4.5, 4.9)
81–82	>7.0	6.3 (6.2, 6.4)	5.3 (5.2, 5.5)	4.4 (4.3, 4.6)
83–84	>7.0	5.8 (5.7, 5.9)	5.0 (4.8, 5.1)	4.2 (4.1, 4.4)
85–86	6.4 (6.4, 6.5)	5.1 (5.1, 5.2)	4.4 (4.2, 4.5)	3.9 (3.8, 4.1)
87–88	5.8 (5.7, 5.9)	4.9 (4.8, 5.0)	4.1 (4.0, 4.1)	3.7 (3.5, 3.9)
89–90	5.1 (5.1, 5.2)	4.2 (4.2, 4.3)	3.9 (3.8, 4.0)	3.6 (3.5, 3.8)

Note: 95% CI was not assessed for comorbidities  $> 7.0$ .

<sup>a</sup>Comorbidity was assessed by using Klabunde's adaption of the Charlson comorbidity index based on outpatient, inpatient, and carrier claims in the previous 12 months.<sup>23,24</sup> It represents a weighted comorbidity score and was categorized as 0, 1, 2, and  $\geq 3$  in the study.

<sup>b</sup>The unshaded areas (except for row delineation) are the age–comorbidity groups with median survival of  $\geq 7$  years.

<sup>c</sup>The light-gray shaded areas are the age–comorbidity groups with median survival of 5–7 years.

<sup>d</sup>The dark-gray shaded areas are the age–comorbidity groups with median survival of  $< 5$  years.

<sup>e</sup>The Kaplan-Meier survival analysis was used to estimate median survival time for each age–comorbidity group in the 2001 cohort ( $n=716,279$ ). Women in the 2001 cohort were followed up until December 31, 2007, or until date of death.

75–90 years with a life expectancy of  $\geq 7$  years.

Also shown in Table 3 are estimates of mammography overscreening. In the age-cutoff method, overscreening was defined as screening mammography in women aged  $\geq 75$  years. In the life-expectancy method, it was defined as screening mammography in those with a life expectancy of  $< 5$  years. The rates of potential overscreening were 35.7% in women aged 75–90 years, compared to 16.3% in women with a life expectancy of  $< 5$  years.

For women in “Gray Zone” (with a life expectancy of 5–7 years), 26.8% received screening mammography. The screening rates were 35.9% in women aged 67–74 years with a life expectancy of 5–7 years and 25.7% in women aged 75–90 years with a life expectancy of 5–7 years.

## Discussion

The present study concurs with Lee and Walter’s commentary that calls for life expectancy–based assessment of cancer screening in older adults to avoid inappropriate judgment and unintended harms caused by age-based assessment.<sup>27</sup> In the current analyses, the difference between the age-cutoff and life-expectancy methods in defining appropriate target populations for screening mammography exists mainly in women aged 75–90 years. A large proportion (63.4%) of women aged 75–90 years had a life expectancy of  $\geq 7$  years. These older healthy women were less likely to be screened than women aged 67–74 years.

The findings are consistent with studies reporting that about 40% of healthy women aged 80–84 years with an estimated life expectancy of  $\geq 10$  years did not have a recent screening mammography.<sup>28,29</sup> The age-cutoff method fails to consider the heterogeneity of life expectancy among older women.<sup>14</sup> As a result, estimates of potential overscreening based on the age-cutoff method are considerably higher than estimates based on the life-expectancy method that integrated age with comorbidity (35.7% vs 16.3%).

**Table 2.** Rate of screening mammography, by age and comorbidity,<sup>a</sup> for the 2006 cohort, *n* (%)<sup>b,c,d,e</sup>

Age (years)	Comorbidity			
	0	1	2	$\geq 3$
67–68	65,711 (55.3)	16,995 (55.9)	4774 (49.9)	3111 (37.9)
69–70	59,593 (54.7)	16,835 (53.7)	5136 (48.4)	3237 (34.6)
71–72	53,536 (53.7)	16,264 (52.7)	5181 (45.6)	3339 (35.6)
73–74	49,109 (52.4)	15,782 (50.5)	5153 (42.5)	3486 (33.0)
75–76	46,117 (49.9)	15,478 (47.4)	5357 (41.0)	3715 (31.0)
77–78	41,543 (46.7)	14,278 (43.3)	5184 (36.5)	3551 (29.8)
79–80	37,820 (42.3)	13,344 (38.5)	4957 (32.7)	3504 (22.9)
81–82	33,081 (37.4)	11,941 (34.1)	4575 (27.9)	3336 (22.2)
83–84	28,085 (31.2)	10,166 (28.6)	4045 (22.9)	2888 (17.9)
85–86	21,123 (25.5)	7,841 (22.7)	3264 (18.4)	2384 (14.6)
87–88	15,344 (19.8)	5,758 (17.2)	2412 (14.3)	1680 (10.4)
89–90	10,695 (13.3)	4,068 (12.6)	1827 (8.3)	1222 (6.8)

<sup>a</sup>Comorbidity was assessed by using Klabunde’s adaptation of the Charlson comorbidity index based on outpatient, inpatient, and carrier claims in the previous 12 months.<sup>23,24</sup> It represents a weighted comorbidity score and was categorized as 0, 1, 2, and  $\geq 3$  in the study.

<sup>b</sup>The unshaded areas (except for row delineation) are the age–comorbidity groups with median survival of  $\geq 7$  years.

<sup>c</sup>The light-gray shaded areas are the age–comorbidity groups with median survival of 5–7 years.

<sup>d</sup>The dark-gray shaded areas are the age–comorbidity groups with median survival of  $< 5$  years.

<sup>e</sup>The estimated median survival time from the 2001 cohort was applied to the corresponding age–comorbidity group of women in the 2006 cohort ( $n=697,825$ ) to project their life expectancy.

Many experts and guidelines encourage clinicians to consider patient health and/or life expectancy in making screening recommendations. A recent study found that screening mammography use was associated with a lower risk of 4-year all-cause mortality among older Medicare beneficiaries, suggesting that patients and providers consider prognosis in mammography screening decisions.<sup>30</sup> Estimates from the life-expectancy approach should give policymakers a more realistic view of the problems in implementing appropriate cancer screening in the community.

A variety of research questions can be re-evaluated using a life-expectancy method, including racial disparities and geographic variation in screening mammography utilization. See Appendix C (available online at [www.ajpmonline.org](http://www.ajpmonline.org)) for an example of evaluating disparities between white and black women in screening mammography utilization using the life-expectancy method. Health service quality measures are valuable in modifying insurance reimbursement, changing clinician behavior, and improving quality of care. Quality measures of screening mammography utilization should consider life expectancy also.<sup>27,31</sup> Balanced quality measures,



**Table 3.** Screening mammography rates for the 2006 cohort, using an age-cutoff method versus a life-expectancy method

Target population, by method <sup>a</sup>	<i>n</i>	Screening rate, % (95% CI)
<b>APPROPRIATE TARGET POPULATION<sup>b</sup></b>		
Aged 67–74 years	327,242	52.7 (52.5, 52.9)
Life expectancy $\geq 7$ years	549,172	48.9 (48.7, 49.1)
Aged 67–74 years	314,069	53.5 (53.2, 53.8)
Aged 75–90 years	235,103	42.7 (42.4, 43.0)
<b>INAPPROPRIATE TARGET POPULATION<sup>c</sup></b>		
Aged 75–90 years	370,583	35.7 (35.5, 35.9)
Life expectancy $< 5$ years	32,343	16.3 (15.9, 16.7)
Aged 67–74 years	0	n/a
Aged 75–90 years	32,343	16.3 (15.9, 16.7)
<b>POPULATION IN “GRAY ZONE”<sup>d</sup></b>		
Life expectancy 5–7 years	116,310	26.8 (26.5, 27.1)
Aged 67–74 years	13,173	35.9 (34.9, 36.9)
Aged 75–90 years	103,137	25.7 (25.4, 26.0)

<sup>a</sup>The age-cutoff and life-expectancy methods were used to determine whether the target population was appropriate for screening mammography.

<sup>b</sup>Using the life-expectancy method, an appropriate target population for screening mammography was defined as women with  $\geq 7$  years of life expectancy. Using the age-cutoff method, an appropriate target population for screening mammography was defined as women aged 67–74 years.

<sup>c</sup>Using the life-expectancy method, the inappropriate target population for screening mammography was defined as women with a life expectancy of  $< 5$  years. Using the age-cutoff method, the inappropriate target population for screening mammography was defined as women aged 75–90 years.

<sup>d</sup>The “gray zone” for screening mammography was defined as women with a life expectancy of 5–7 years. There was no “gray zone” based on the age-cutoff method.

n/a, not applicable

including both appropriate and over-utilization, can be evaluated based on patients’ life expectancy.

The present study has several limitations. First, age and comorbidity were used to estimate patients’ life expectancy. The claims data do not contain other clinically relevant information associated with life expectancy and risk of breast cancer, such as self-rated health and functional status.<sup>32,33</sup> Other data sources such as the National Health Interview Survey would allow incorporation of these predictors to improve estimates of life expectancy.<sup>34</sup>

Integrating age and comorbidity is just an initial step in estimating life expectancy. The results show that 70.9% of the women with median survival time  $< 5$  years died in

5 years and 75.9% of the women with median survival time of  $\geq 7$  years survived for  $\geq 7$  years. The projected life expectancy may be further improved by including additional variables in the survival model, such as number of hospital admissions, number of provider visits, and use of selected medications in the past 12 months. The study also did not include the severity of the comorbid illnesses in estimating life expectancy.<sup>35</sup> The recently available Medicare Part D data may allow researchers to incorporate the Chronic Disease Score, a pharmacy-based measure of illness burden, to assess illness severity.<sup>36,37</sup>

In addition, life expectancy in older adults is increasing. The CDC reported that the life expectancy for women aged 65 years increased from 19.1 to 19.7 years during 2001 to 2006.<sup>11</sup> Thus, using the life expectancy of the 2001 cohort slightly underestimated the actual life expectancy of the 2006 cohort. Because only 2000–2007 Texas Medicare claims data were available for the study, the maximum life expectancy that could be estimated was 7 years. Using a 10-year life expectancy would be more desirable.<sup>12</sup> Moreover, the study could not evaluate the impact of patient preference on the appropriateness of screening mammography decisions.

Finally, the study used Texas Medicare claims data. Compared to the U.S. Medicare population, the Texas Medicare population is slightly younger and poorer, and contains a much larger proportion of Hispanics.<sup>38</sup> Researchers evaluating screening utilization using a life-expectancy method should generate life-expectancy estimates based on their specific populations, rather than using life expectancies estimated in the current sample.

## Conclusion

The method to evaluate appropriate use and over-use of screening mammography based on patients’ life expectancy allows for a more valid description of the quality of care in screening mammography utilization than does one based solely on age cutoffs. Although the methodologic details need further refinement, future studies to evaluate population-based estimates of appropriateness of screening should follow the proposed framework and directions.

The study was supported by the Cancer Prevention Research Institute of Texas (RP101201) and NIH (K05CA134923). The funding agency had no role in the study’s design, conduct, analysis, or interpretation of data. Sarah Toombs Smith, PhD, science editor and assistant professor in the Sealy Center on Aging, University of Texas Medical Branch at Galveston, provided editorial assistance in manuscript preparation.

No financial disclosures were reported by the authors of this paper.

## References

- Nelson HD, Tyne K, Naik A, Bougatsos C, Chan BK, Humphrey L. Screening for breast cancer: an update for the U.S. Preventive Services Task Force. *Ann Intern Med* 2009;151(10):727–37, W237–42.
- Smith RA, Cokkinides V, Brooks D, Saslow D, Brawley OW. Cancer screening in the U.S., 2010: a review of current American Cancer Society guidelines and issues in cancer screening. *CA Cancer J Clin* 2010;60(2):99–119.
- USPSTF. Screening for breast cancer: U.S. Preventive Services Task Force recommendation statement. *Ann Intern Med* 2009;151(10):716–26, W-236.
- Randolph WM, Goodwin JS, Mahnken JD, Freeman JL. Regular mammography use is associated with elimination of age-related disparities in size and stage of breast cancer at diagnosis. *Ann Intern Med* 2002;137(10):783–90.
- Kerlikowske K. Evidence-based breast cancer prevention: the importance of individual risk. *Ann Intern Med* 2009;151(10):750–2.
- Satariano WA, Ragland DR. The effect of comorbidity on 3-year survival of women with primary breast cancer. *Ann Intern Med* 1994;120(2):104–10.
- Fonseca R, Hartmann LC, Petersen IA, Donohue JH, Crotty TB, Gissvold JJ. Ductal carcinoma in situ of the breast. *Ann Intern Med* 1997;127(11):1013–22.
- Ernster VL, Ballard-Barbash R, Barlow WE, et al. Detection of ductal carcinoma in situ in women undergoing screening mammography. *J Natl Cancer Inst* 2002;94(20):1546–54.
- Mehta KM, Fung KZ, Kistler CE, Chang A, Walter LC. Impact of cognitive impairment on screening mammography use in older U.S. women. *Am J Public Health* 2010;100(10):1917–23.
- Sima CS, Panageas KS, Schrag D. Cancer screening among patients with advanced cancer. *JAMA* 2010;304(14):1584–91.
- Arias E. U.S. Life Tables, 2006. National vital statistics reports; vol 58 no 21. Hyattsville MD: National Center for Health Statistics, 2010.
- Fletcher SW, Elmore JG. Clinical practice. Mammographic screening for breast cancer. *N Engl J Med* 2003;348(17):1672–80.
- Gross CP, McAvay GJ, Krumholz HM, Paltiel AD, Bhasin D, Tinetti ME. The effect of age and chronic illness on life expectancy after a diagnosis of colorectal cancer: implications for screening. *Ann Intern Med* 2006;145(9):646–53.
- Walter LC, Covinsky KE. Cancer screening in elderly patients: a framework for individualized decision making. *JAMA* 2001;285(21):2750–6.
- Gierisch JM, Earp JA, Brewer NT, Rimer BK. Longitudinal predictors of nonadherence to maintenance of mammography. *Cancer Epidemiol Biomarkers Prev* 2010;19(4):1103–11.
- Carney CP, Jones LE. The influence of type and severity of mental illness on receipt of screening mammography. *J Gen Intern Med* 2006;21(10):1097–104.
- Piatt EE, Munetz MR, Ritter C. An examination of premature mortality among decedents with serious mental illness and those in the general population. *Psychiatr Serv* 2010;61(7):663–8.
- Blustein J. Medicare coverage, supplemental insurance, and the use of mammography by older women. *N Engl J Med* 1995;332(17):1138–43.
- Freeman JL, Klabunde CN, Schussler N, Warren JL, Virnig BA, Cooper GS. Measuring breast, colorectal, and prostate cancer screening with Medicare claims data. *Med Care* 2002;40(8S):IV-36–42.
- Welch HG, Fisher ES. Diagnostic testing following screening mammography in the elderly. *J Natl Cancer Inst* 1998;90(18):1389–92.
- Freeman JL, Goodwin JS, Zhang D, Nattinger AB, Freeman DH Jr. Measuring the performance of screening mammography in community practice with Medicare claims data. *Womens Health* 2003;37(2):1–15.
- Randolph WM, Mahnken JD, Goodwin JS, Freeman JL. Using Medicare data to estimate the prevalence of breast cancer screening in older women: comparison of different methods to identify screening mammograms. *Health Serv Res* 2002;37(6):1643–57.
- Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987;40(5):373–83.
- Klabunde CN, Potosky AL, Legler JM, Warren JL. Development of a comorbidity index using physician claims data. *J Clin Epidemiol* 2000;53(12):1258–67.
- Lee EA. *Statistical methods for survival data analysis*. New York: Wiley, 1992.
- Walter LC, Bertenthal D, Lindquist K, Konety BR. PSA screening among elderly men with limited life expectancies. *JAMA* 2006;296(19):2336–42.
- Lee SJ, Walter LC. Quality indicators for older adults: preventing unintended harms. *JAMA* 2011;306(13):1481–2.
- Schonberg MA, McCarthy EP, Davis RB, Phillips RS, Hamel MB. Breast cancer screening in women aged 80 and older: results from a national survey. *J Am Geriatr Soc* 2004;52(10):1688–95.
- Walter LC, Lindquist K, Covinsky KE. Relationship between health status and use of screening mammography and Papanicolaou smears among women older than 70 years of age. *Ann Intern Med* 2004;140(9):681–8.
- Koya DL, Chen JG, Smith TG, Moran WP. Screening mammography use in Medicare beneficiaries reflects 4-year mortality risk. *Am J Med* 2011;124(4):369.e18.
- Walter LC, Davidowitz NP, Heineken PA, Covinsky KE. Pitfalls of converting practice guidelines into quality measures: lessons learned from a VA performance measure. *JAMA* 2004;291(20):2466–70.
- Lee SJ, Lindquist K, Segal MR, Covinsky KE. Development and validation of a prognostic index for 4-year mortality in older adults. *JAMA* 2006;295(7):801–8.
- Lesser GT. Social and productive activities in elderly people. Self rated health is important predictor of mortality. *BMJ* 2000;320(7228):185.
- Schonberg MA, Davis RB, McCarthy EP, Marcantonio ER. Index to predict 5-year mortality of community-dwelling adults aged 65 and older using data from the National Health Interview Survey. *J Gen Intern Med* 2009;24(10):1115–22.
- Hughes J. 3M health information systems (HIS) APR™-DRG classification software—overview. In: *Mortality measurement*. Rockville MD: Agency for Healthcare Research and Quality, 2009.
- Klabunde CN, Warren JL, Legler JM. Assessing comorbidity using claims data: an overview. *Med Care* 2002;40(8S):IV-26–35.
- Von Korff M, Wagner EH, Saunders K. A chronic disease score from automated pharmacy data. *J Clin Epidemiol* 1992;45(2):197–203.
- The Kaiser Family Foundation. Texas: Medicare population demographics. [www.statehealthfacts.org/profileind.jsp?cat=6&sub=75&rgn=45](http://www.statehealthfacts.org/profileind.jsp?cat=6&sub=75&rgn=45).

## Appendix

### Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.amepre.2011.11.008.