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ORIGINAL REPORT

Breast Cancer Diagnosis and Treatment After High-Deductible Insurance Enrollment

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ABSTRACT

Purpose
High-deductible health plans (HDHPs) require substantial out-of-pocket spending and might delay crucial health services. Breast cancer treatment delays of as little as 2 months are associated with adverse outcomes.

Methods
We used a controlled prepost design with survival analysis to assess timing of breast cancer care events among 273,499 women age 25 to 64 years without evidence of breast cancer before inclusion. Women were included if continuously enrolled for 1 year in a low-deductible ($0 to $500) plan followed by up to 4 years in a HDHP (at least $1,000 deductible) after an employer-mandated switch. Study inclusion was on a rolling basis, and members were followed between 2003 and 2012. The comparison group comprised 2.4 million contemporaneously matched women whose employers offered only low-deductible plans. Measures were times to first diagnostic breast imaging (diagnostic mammogram, breast ultrasound, or breast magnetic resonance imaging), breast biopsy, incident early-stage breast cancer diagnosis, and breast cancer chemotherapy. Outcomes were analyzed by using Cox models and adjusted for age-group, morbidity score, poverty level, US region, index date, and employer size.

Results
After the index date, HDHP members experienced delays in receipt of diagnostic imaging (adjusted hazard ratio [aHR], 0.95; 95% CI, 0.94 to 0.96), biopsy (aHR, 0.92; 95% CI, 0.89 to 0.95), early-stage breast cancer diagnosis (aHR, 0.83; 0.78 to 0.90), and chemotherapy initiation (aHR, 0.79; 95% CI, 0.72 to 0.86) compared with the control group.

Conclusion
Women switched to HDHPs experienced delays in diagnostic breast imaging, breast biopsy, early-stage breast cancer diagnosis, and chemotherapy initiation. Additional research should determine whether such delays cause adverse health outcomes, and policymakers should consider selectively reducing out-of-pocket costs for key breast cancer services.

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INTRODUCTION

Breast cancer is the most common nonskin malignancy among US women and the second-leading cause of cancer death.[1] The diagnosis and treatment of breast cancer require a series of expensive services, such as diagnostic breast imaging, specialist visits, breast biopsy, mastectomy, lumpectomy, and chemotherapy.[2,3] Women who face high out-of-pocket costs might delay receipt of these services.

High-deductible health plans (HDHPs) have become the predominant commercial health insurance arrangement in the United States.[4] This insurance type requires potential annual out-of-pocket spending of between $1,000 and $6,000 per person for most nonpreventive care, including services for cancer diagnosis and treatment. In 2016, 51% of covered workers had deductibles of ≥ $1,000.[4]

Experts have voiced concerns that the increasing out-of-pocket burden of cancer[5,6] is causing financial toxicity that could harm the health of patients with cancer,[7,8] but research that has quantified such harm is limited. Neugut et al[9] studied the association of copayments and aromatase inhibitor nonpersistence among patients

ASSOCIATED CONTENT

Appendix
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with breast cancer and found that copayments > $90 were associated with lower persistence. Dusetzina et al[10] found that patients with chronic myeloid leukemia with higher out-of-pocket payments had a greater likelihood of imatinib discontinuation or nonadherence than matched patients with lower out-of-pocket payments.

The effects of cost sharing on other key services along the spectrum from cancer diagnostic testing to treatment are unknown. Whether women in HDHPs will generally accept high out-of-pocket payments to receive potentially life-saving breast cancer care or will delay services and risk adverse health consequences is unclear. Breast cancer treatment delays of as few as 2 months are associated with adverse outcomes.[11-13] We hypothesized that breast cancer diagnostic testing, diagnosis, and treatment would be delayed among women after they transition to HDHPs.

METHODS

Population

We drew our study population from commercially insured members in the deidentified Optum database (Eden Prairie, MN) enrolled between January 2003 and December 2012. Data comprised all medical, pharmacy, and hospitalization claims from members of a large national health plan. We included members on the basis of their employers' health insurance offerings. We defined employers with low- and high-deductible coverage as those that offer exclusively annual deductibles of $0 to $500 and ≥ $1,000, respectively (Appendix, online only). To determine employer annual deductibles, we used a benefits variable available for most smaller employers (approximately ≤ 100 employees). For larger employers, we imputed deductible levels by using out-of-pocket spending among employees who used health services, an algorithm that had 96.2% sensitivity and 97.0% specificity (Appendix Table A1, online only).

Both high- and low-deductible plans generally cover breast cancer screening and preventive primary care visits at low or no out-of-pocket cost. However, HDHP members on average must pay substantially higher amounts than low-deductible members for specialist care, diagnostic tests, and surgical procedures.[4]

Our population of interest was composed of generally healthy women without breast cancer at the beginning of the study period so that we could observe their progression along the pathway from breast cancer work-up (ie, screening mammography, diagnostic imaging, biopsy) to diagnosis and treatment. Study members were drawn from employers who were present for at least 1 year before and after either a mandated HDHP switch or a mandated continuation in low-deductible plans (n = 18,258,838 members), which minimized self-selection. We excluded 26,066 women who had at least one breast cancer diagnosis (International Classification of Diseases, 9th Revision, codes 174.xx, 233.0) before the baseline year. From a subset of women age 25 to 64 years at baseline (n = 5,853,802), we selected 3,594,311 with 12 potential baseline months of enrollment in a low-deductible plan followed by ≥ 1 month in a high-deductible or low-deductible plan. We included women age 25 to 39 years because initial work-ups for breast lumps are common in this population,[14] and delayed evaluation could cause substantial anxiety irrespective of cancer risk. Furthermore, although rare, women in this group do develop breast cancer.[15]

Because a subset of women could have multiple eligible 12-month low-deductible baseline periods, we randomly selected one per woman, leaving 273,663 high-deductible and 2,432,894 control pool members (Table 1). We defined the beginning of the month of the low- to high-deductible transition as the index date.

To further minimize potential selection effects, especially at the employer level, we used a coarsened exact match[17-19] on employer- and member-level propensity[20,21] to join HDHPs (Appendix); baseline annual out-of-pocket spending category (< $100, $100 to 999, $1,000 to $9,999, ≥ $10,000); whether members had a baseline breast diagnostic image, breast biopsy, early-stage breast cancer diagnosis, or breast cancer chemotherapy treatment (Appendix Table A2, online only); and follow-up duration divided into 6-month categories (to minimize differential dropout). We included baseline indicators of outcome measures (eg, breast imaging, biopsy) to balance the future population-level need for breast cancer services during the follow-up period.

Compared with the unmatched sample, the coarsened exact match (after applying match-generated weights) increased the similarity of the HDHP and control groups across all baseline characteristics (Table 1). The final groups included 273,356 women in HDHPs and 2,420,790 women in the matched control group.

Design

We first displayed weighted and marginally adjusted Kaplan-Meier plots of outcomes in the high-deductible and control groups and then compared times to events in the groups before and after the index date. Controlled survival designs test the null hypothesis that the hazard ratios of the intervention and control groups are the same.

Measures

We defined time $zero_b$ as the beginning of the 12-month baseline period and time $zero_f$ as the beginning of the follow-up period. In the baseline and follow-up periods, we measured months from time $zero_b$ and $zero_f$, respectively, until the first observed breast cancer diagnostic imaging (diagnostic mammogram, breast ultrasound, or breast MRI [Appendix]),[22] first breast biopsy (Appendix),[23-25] first incident early-stage cancer diagnosis (by using an algorithm validated by Nattinger et al[23]), and first breast cancer chemotherapy treatment (defined herein). At the patient level, the breast cancer diagnostic imaging and biopsy measures could occur in both the baseline and the follow-up periods (once per woman per period) given that repeat diagnostic testing occurs. For the incident early-stage breast cancer diagnosis and chemotherapy initiation measures, we allowed a given woman to have only a single first event over the entire study period. The Nattinger incident early-stage breast cancer diagnosis algorithm is based on evidence of both breast cancer diagnosis and early-stage breast cancer treatment (mastectomy or combined lumpectomy and radiotherapy), so this measure describes timing of both early-stage diagnosis and treatment.[23] We measured first chemotherapy initiation to assess the timing of treatment of more-advanced breast cancers (ie, those that spread at least to local lymph nodes).[26] This outcome required evidence of first chemotherapy administration preceded (at most 3 months before) by a breast cancer diagnosis. We derived chemotherapy codes on the basis of the SEER-Medicare claims-based algorithm[27] and then restricted to agents used for breast cancer[3,28] or codes specific to chemotherapy administration (Appendix).

Because screening mammography (Appendix) has low out-of-pocket costs in HDHPs, we measured this as a control outcome that we hypothesized would be less affected by the HDHP switch in contrast to the previously described expensive breast cancer services. To generate more clinically intuitive measures of potential delays among HDHP members, we measured intervals (in months) between time $zero_f$ and any subsequent first diagnostic breast imaging, breast biopsy, incident early-stage breast cancer diagnosis, or breast cancer chemotherapy. We conducted sensitivity analyses to determine whether estimates differed if we restricted to women age 40 to 64 years or restricted to women with at least 6 months follow-up after the index date.

Covariates

Using 2000 US Census block group data and validated methods,[29,30] we defined four neighborhood income and education levels (Table 1).[29-31] We applied the ACG comorbidity algorithm, a validated measure that predicts mortality,[32,33] to members' baseline year to estimate comorbidity. We classified members as white, black, Hispanic, Asian, or mixed race/ethnicity neighborhood on the basis of a combination of geocoding and surname analysis (Appendix).[34,35] Other covariates included age category (25 to 39 and 40 to 64 years), employer size (10 to 99, 100 to 999, and ≥ 1,000 enrollees), and US region (West, Midwest, South, Northeast).

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Table 1. Baseline Characteristics of the High-Deductible Health Plan Group and the Control Group, Before and After Coarsened Exact Matching

Characteristic	Before Match: HDHP Group (n = 273,663)		Before Match: Control Group (n = 2,432,894)		Standardized Difference†	After Match and Weighting*: HDHP Group (n = 273,356)		After Match and Weighting*: Control Group (n = 2,420,790)		Standardized Difference
Age > 40 on index date	170,836	(62.4)	1,432,476	(58.9)	0.0726	170,597	(62.4)	1,508,212	(62.3)	0.0022
Age on index date, mean (SD)	43.5	(10.4)	42.8	(10.6)	0.0682	43.5	(10.4)	43.5	(10.6)	−0.0063
Live in neighborhoods with below-poverty levels, %										0.0193
< 5‡	120,931	(44.2)	1,103,334	(45.4)		120,828	(44.3)	1,086,904	(45.0)	
5-9.9‡	72,749	(26.6)	633,468	(26.1)		72,672	(26.6)	645,270	(26.7)	
10-19.9[4]	54,612	(20.0)	466,676	(19.2)		54,553	(20.0)	474,349	(19.6)	
≥ 20[4]	25,026	(9.2)	224,250	(9.2)		25,004	(9.2)	211,358	(8.7)	
Missing poverty data	345	(0.0)	5,166	(0.0)		299	(0.0)	2,910	(0.0)	
Live in neighborhoods with below high-school education levels, %					0.0418					0.0319
< 15‖	159,402	(58.3)	1,456,963	(60.0)		159,260	(58.3)	1,448,179	(59.9)	
15-24.9‖	63,462	(23.2)	534,629	(22.0)		63,398	(23.2)	540,899	(22.4)	
25-39.9¶	38,210	(14.0)	320,424	(13.2)		38,163	(14.0)	324,878	(13.4)	
≥ 40¶	12,244	(4.5)	115,712	(4.8)		12,236	(4.5)	103,924	(4.3)	
Missing education data	345	(0.0)	5,166	(0.0)		299	(0.0)	2,910	(0.0)	
Race/ethnicity#					0.1296					0.0317
Hispanic	24,097	(8.8)	249,408	(10.3)		24,081	(8.8)	213,561	(8.8)	
Asian	7,117	(2.6)	96,175	(4.0)		7,112	(2.6)	72,554	(3.0)	
Black neighborhood	5,384	(2.0)	66,846	(2.8)		5,380	(2.0)	49,879	(2.1)	
Mixed neighborhood	36,425	(13.3)	366,371	(15.1)		36,389	(13.3)	336,082	(13.9)	
White neighborhood	200,111	(73.3)	1,647,269	(67.9)		199,911	(73.3)	1,744,227	(72.2)	
Missing race/ethnicity data	529	(0.0)	6,825	(0.0)		483	(0.0)	4,487	(0.0)	
ACG score, mean (SD)	1.2	(1.8)	1.1	(1.7)	0.023	1.2	(1.8)	1.2	(1.8)	−0.0271
United States region					0.2748					0.0758
West	34,411	(12.6)	316,399	(13.0)		34,388	(12.6)	314,957	(13.0)	
Midwest	94,518	(34.6)	737,906	(30.4)		94,456	(34.6)	790,299	(32.6)	
South	127,802	(46.7)	1,030,373	(42.4)		127,697	(46.7)	1,197,448	(49.5)	
Northwest	16,826	(6.2)	346,420	(14.2)		16,815	(6.2)	118,085	(4.9)	
Missing region data	106	(0.0)	1,796	(0.0)		0	(0.0)	0	(0.0)	
Employer size					1.1903					0.1364
0-99	111,329	(40.7)	335,658	(13.8)		111,176	(40.7)	1,078,282	(44.5)	
100-999	137,097	(50.1)	725,579	(29.8)		136,962	(50.1)	1,057,443	(43.7)	
≥ 1000	25,237	(9.2)	1,371,657	(56.4)		25,218	(9.2)	285,065	(11.8)	

NOTE. Data presented as No. (%) unless otherwise indicated.
Abbreviations: HDHP, high-deductible health plan; SD, standard deviation.
*Coarsened exact match creates weights for control group members to account for differing ratios of intervention: control group members within and across matching strata.
†For the approach to calculating standardized differences for means, binary categorical variables, and categorical variables with multiple categories, see Yang et al[16] A standardized difference below 0.2 indicates minimal differences between the groups.
‡Defined as high income.
§Defined as low income.
‖Defined as high education.
¶Defined as low education.
#See the "Covariates" section of the manuscript for definition of race/ethnicity categories.

Analysis

We compared baseline characteristics of our study groups by using a standardized differences approach.[16] We analyzed time to the four primary outcomes independently by using Cox proportional hazards regression models adjusted for baseline age-group, ACG score, employer size, poverty level, US region, and index date. We analyzed time to event in the baseline and time to event in the follow-up periods in separate models. Women were censored if they dropped from the sample (eg, as a result of disenrollment), reached age 65 years (when Medicare coverage begins), or reached the end of follow-up (1 year for the baseline model and 4 years for the follow-up model). The key term of interest from the baseline and follow-up period regression models was a binary indicator of membership in the high-deductible group. This term generated an adjusted hazard ratio (aHR) of the high-deductible group compared with the control group. For example, a follow-up period aHR with CI bounds < 1.0 is interpreted as indicating that the high-deductible group experienced a delay in the outcome of interest during follow-up relative to the control group.

To develop insights about the clinical significance of any statistically significant aHRs at follow-up, we predicted the interval in months between time $zero_f$ and the month that the control group reached half of its final follow-up period rate (derived from the Cox models) and the corresponding time for the high-deductible group to reach this same percentage (half of the control group's final follow-up rate), which assumed that event time followed a Weibull distribution and used an accelerated failure time model.[36]

RESULTS

After matching and applying match-generated weights, all standardized differences between HDHP and control group characteristics were well below 0.2 (Table 1), which indicates minimal differences.[16] The mean age of HDHP and control members was

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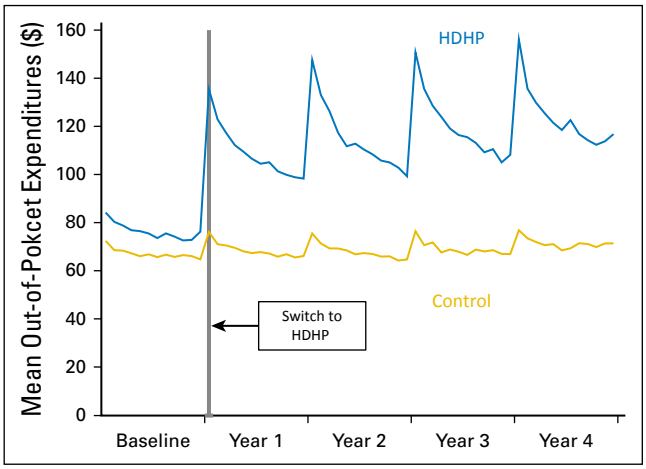

Fig 1. Mean total out-of-pocket medical spending (ie, nonpharmacy deductible, copayment, coinsurance amounts) per month in the high-deductible health plan (HDHP) and control groups before and after the HDHP switch, which indicates the extent of the cost-sharing exposure in the HDHP group.

43.5 years (standard deviation, 10.4 to 10.6; Table 1). Twenty-eight percent to 29% lived in low-income neighborhoods, 18% to 19% lived in low-education neighborhoods, and 9% were of Hispanic ethnicity. The HDHP and control groups were well balanced with respect to morbidity at baseline, with ACG scores (standard deviation) of 1.2 (1.8) and a standardized difference of −0.027.

From baseline to follow-up, HDHP members experienced increases in total out-of-pocket medical spending (ie, nonpharmacy deductible, copayment, coinsurance amounts) relative to control group members of between 39.0% (37.5% to 40.4%) to 50.2% (47.4% to 52.9%) across the follow-up years (Fig 1).

At baseline (before the index date), no evidence of delay in times to first breast diagnostic imaging, breast biopsy, incident early-stage breast cancer, and breast cancer chemotherapy initiation were found in the matched high-deductible group relative to the control group (Table 2; Fig 2). Over the follow-up period, women in HDHPs experienced delays in receipt of first observed breast diagnostic imaging (aHR, 0.95; 95% CI, 0.94 to 0.96), breast biopsy (aHR, 0.92; 95% CI, 0.89 to 0.95), incident early-stage breast cancer diagnosis (aHR, 0.83; 95% CI, 0.78 to 0.90), and breast cancer chemotherapy initiation (aHR, 0.79; 95% CI, 0.72 to 0.86) compared with control group members. The baseline aHR for time to first breast cancer screening was 1.00 (95% CI, 1.00 to 1.01; data not shown), and the follow-up period aHR was 0.97 (95% CI, 0.96 to 0.98).

The estimated interval between time $zero_f$ and reaching half of the final follow-up breast diagnostic imaging rate of the control group was 22.8 months (95% CI, 22.5 to 23.1 months) among HDHP members and 21.6 months (95% CI, 21.4 to 21.8 months) among control group members for a relative high-deductible group delay of 1.2 months (95% CI, 0.9 to 1.5 months; Table 3). Corresponding delays in time to first breast biopsy, early-stage breast cancer diagnosis, and chemotherapy initiation were 2.1 months (95% CI, 1.3 to 2.9 months), 5.8 months (95% CI, 3.4 to 8.3 months), and 7.4 months (95% CI, 4.5 to 10.4 months), respectively, among HDHP members relative to control group members. Sensitivity analyses that restricted the population to women age 40 to 64 years or to women with at least 6 months follow-up after the index date (Appendix Tables A3 and A4, online only) demonstrated nearly identical effect estimates compared with the overall analyses.

DISCUSSION

Women experienced delays in breast cancer diagnostic testing, early-stage diagnosis, and chemotherapy initiation after an employer-mandated switch to HDHPs. The findings imply that the high out-of-pocket obligations under HDHPs might be a barrier to timely receipt of essential breast cancer services. Women in HDHPs might either delay presenting for concerning symptoms or, if proceeding along the pathway from breast cancer screening to diagnostic testing to treatment, be hesitant to undergo subsequent (and generally more-expensive) care. In the current sample, it seems that small to moderate delays between earlier stages of care (ie, diagnostic imaging, biopsy, breast cancer diagnosis), including those we did not capture (eg, oncology visits), accumulated to a substantial delay from the point of HDHP enrollment to chemotherapy initiation.

The study cohorts began as generally healthy women without breast cancer, and we observed for progression along the path from breast cancer work-up to diagnosis and treatment. Thus, the majority of HDHP members would have faced sizeable financial barriers to obtaining the services we examined. The small subset of HDHP members who were ultimately diagnosed with breast cancer likely exceeded their deductible and, therefore, subsequently faced lower out-of-pocket burden until their deductibles reset in the next benefit year. Such lower cost sharing, in combination with fear of a life-threatening diagnosis, might lead to lessened delays among HDHPs from the point of breast cancer diagnosis to initiation of treatment (eg, surgery, radiotherapy, chemotherapy).

Table 2. HDHP Versus Control Group HRs at Baseline and Follow-Up for Time-to-Event Analyses

Time to First	Baseline HDHP *v* Control, HR (95% CI)	Follow-Up HDHP *v* Control, HR (95% CI)
Diagnostic breast imaging	1.01 (1.00 to 1.02)	0.95 (0.94 to 0.96)
Breast biopsy	1.02 (0.98 to 1.06)	0.92 (0.89 to 0.95)
Early-stage breast cancer	1.02 (0.93 to 1.13)	0.83 (0.78 to 0.90)
Breast cancer chemotherapy	1.01 (0.90 to 1.13)	0.79 (0.72 to 0.86)

NOTE. HRs derived from Cox proportional hazards regression models adjusted for age-group, race/ethnicity, poverty level, US region, index date, and duration of enrollment before baseline. Determined from the Wald test for the joint hypothesis.
Abbreviations: HDHP, high-deductible health plan; HR, hazard ratio.

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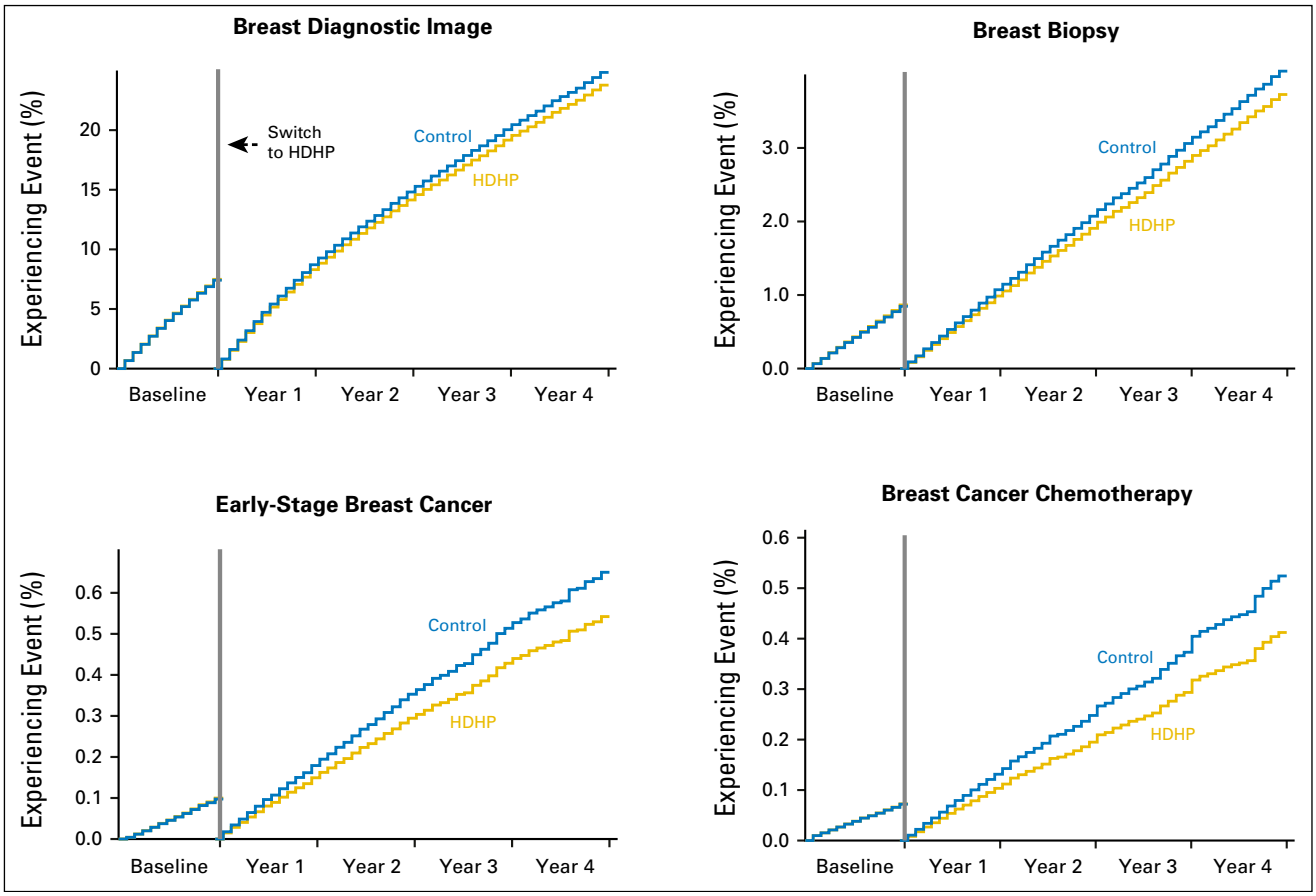

Fig 2. Adjusted plots show the time to first breast cancer–related services in a population of women age 25 to 64 years at 12 months before and up to 48 months after a mandated high-deductible health plan (HDHP) switch compared with a contemporaneous control group that remained in low-deductible plans.

During follow-up, the high-deductible group compared with the control group experienced relative delays of 1.2, 2.1, 5.8, and 7.4 months in reaching comparable rates of diagnostic mammography, breast biopsy, early-stage breast cancer diagnosis, and chemotherapy initiation, respectively. Although these population-level delays cannot be directly translated to the person level, results suggest that HDHP members might experience adverse breast cancer outcomes. Small delays of 2 to 3 months between breast cancer diagnosis and surgery,[11] surgery and adjuvant chemotherapy initiation,[12] or lumpectomy and radiotherapy[13] are associated with adverse outcomes. Women in HDHPs who undergo breast cancer work-ups might also experience anxiety related to their cost-sharing burden and delayed care,[37-39] although the current study was not designed to assess such outcomes. Such delays could have other adverse effects on quality of life that should be addressed by subsequent studies of women in HDHPs.

Previous research has not addressed the effects of HDHPs on cancer diagnosis and treatment. Two studies investigated effects of high out-of-pocket costs on adherence to oral anticancer therapies and found an association between higher cost sharing and suboptimal medication use.[9,10] The current study adds a comprehensive assessment of the effect of high cost sharing on key events

Table 3. Estimated Intervals Between Time Zero$_f$ and Reaching Half of the Final Follow-Up Rate (per Measure) of Control Group Members Among HDHP and Control Group Members in the Follow-Up Period

	Mean Interval During Follow-Up,* Months (95% CI)		
Interval Between Time Zero$_f$ and First	HDHP Group	Control Group	HDHP *v* Control Group
Diagnostic breast imaging	22.8 (22.5 to 23.1)	21.6 (21.4 to 21.8)	1.2 (0.9 to 1.5)
Breast biopsy	27.9 (26.8 to 28.9)	25.8 (25.1 to 26.5)	2.1 (1.3 to 2.9)
Early-stage breast cancer	35.7 (32.2 to 39.1)	29.8 (27.7 to 31.9)	5.8 (3.4 to 8.3)
Breast cancer chemotherapy	36.9 (33.0 to 40.7)	29.4 (27.2 to 31.7)	7.4 (4.5 to 10.4)

NOTE. Outcomes were modeled by using weighted negative binomial regression and adjusting for timing of index screening mammogram relative to the index month, morbidity, age, index month, poverty level, US region, and employer size.
Abbreviation: HDHP, high-deductible health plan.
*Separate analyses run per measure after restricting to women who had both screening mammography and the subsequent measure in question.

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along the pathway from breast cancer diagnostic testing to treatment, which demonstrates delays at all stages of care that might have adverse long-term effects. In addition, previous HDHP research generally has not examined expensive services, and no studies have addressed rare, life-threatening conditions, such as cancers that include major out-of-pocket expenses.

HDHP enrollment is expected to increase dramatically over the decade, and our findings raise concerns about the effects on patients who face expensive, potentially life-threatening diseases. In the short-term, providers and payers should identify, monitor, and educate HDHP members at risk for expensive cancer work-ups who might forgo needed care. In the longer term, policymakers, health insurers, and employers should consider designing or incentivizing health insurance benefits that facilitate transitions through key steps along the cancer care pathway. This could take the form of population-targeted exclusions of essential care (ie, low or no out-of-pocket obligations for certain services, such as diagnostic breast cancer testing).[40,41] For example, value-based design features for cancer screening generally have been successful in maintaining rates among HDHP populations[21,42-46] and are now mandated by the Affordable Care Act. Such cost-sharing exemptions could be applied across entire populations or more selectively[41] if future research identifies key subgroups at risk for delayed cancer care under HDHPs.

Future studies should assess HDHP effects on cancer stage at diagnosis, adherence to oral cancer medications, survival, and breast cancer expenditures. Larger studies also should assess potentially at-risk HDHP subgroups, such as low-income and vulnerable minority patients, and effects of generously funded health savings accounts on outcomes.

This study has several limitations. Women were not randomly assigned to study groups, but we included only members who did not have a choice of a low- or high-deductible plan, which reduced selection bias. HDHP and control members possibly differed on unmeasured characteristics that influence the likelihood of breast cancer occurrence or aggressiveness, but this seems unlikely given the substantial balance between groups across multiple important baseline characteristics (Table 1). Similar to many long-term studies, attrition occurred over the study period, but our approach of matching on follow-up duration and adjusting time-to-event estimates should minimize the effects of differential attrition. We were unable to determine whether HDHP enrollment delayed care long enough to shift the stage of presentation from earlier to later stages because of the lack of validated algorithms to measure incident later-stage breast cancer. Because the events we studied are rare, the study was not powered to determine effects among key HDHP subgroups, such as low-income or vulnerable minority populations. We also were unable to analyze HDHP members with especially high deductibles (eg, ≥ $2,000) because of very low prevalence during our 2003 to 2012 study period.[4] The results, therefore, do not necessarily generalize to women with such benefit arrangements. Given constraints of the data environment, we were unable to determine precise reasons for why women experienced delays in care. For example, delays could be related to general apprehension about facing high out-of-pocket costs and to women who put off care until they have exceeded their annual deductible level. Finally, the study does not represent state health insurance exchange members or people whose first exposure to insurance is under HDHPs.

In conclusion, women who were switched to HDHPs experienced delays in breast cancer diagnostic testing, early-stage diagnosis, and chemotherapy initiation. Such delays might lead to adverse long-term breast cancer outcomes. Policymakers, health insurers, and employers should consider designing or incentivizing health insurance benefits that facilitate transitions through key steps along the cancer care pathway. This could take the form of population-targeted exclusions of essential care[41] so that women would pay minimal amounts for services such as breast diagnostic imaging and biopsy.

AUTHORS' DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST

Disclosures provided by the authors are available with this article at jco.org.

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Conception and design: J. Frank Wharam, Christine Y. Lu, Larissa Nekhlyudov, Stephen B. Soumerai, Dennis Ross-Degnan
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Breast Cancer Diagnosis and Treatment After High-Deductible Insurance Enrollment

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Appendix

Study Group Construction and Deductible Imputation Algorithm

To determine employer deductible levels, we used a benefits type variable that we had for most smaller employers (with approximately ≤ 100 employees). For larger employers, we took advantage of the fact that health insurance claims data are the most accurate source for assessing out-of-pocket obligations among patients who use health services. The claims data contained an in-network/out-of-network deductible payment field. For patients who use expensive or frequent services, the sum of their yearly deductible payments add up to clearly identifiable exact amounts, such as $500.00, $1,000.00, and $2,000.00. When even several members have these same amounts, it provides strong evidence that the employer offered such an annual deductible level. It is also possible to detect that employers offer choices of deductible levels when multiple employees have deductibles at two or more levels, such as 20 employees with an exact annual amount of $1,000.00 and 12 employees with $500.00. For employers with at least 10 workers, we therefore summed each member's in-network deductible payments and number of claims over the enrollment year and assessed other key characteristics, such as percentage with health savings accounts. We randomly selected half of the employer data set that contained both our calculated employer characteristics (independent variables) and actual annual deductible levels from the benefits table (dependent variable, after categorization). We then used a logistic model that predicted the three-level outcome of deductible (≤ $500, $500 to $999, and > $1,000 [again, dependent variable]) on the basis of multiple aggregate employer characteristics (independent variables), such as the first and second most common whole-number deductible value; percentage with health savings accounts or health reimbursement arrangements; median deductible payment; percentage of employees who use services; employer size; and percentage of employees with summed annual deductible amounts (from claims data) between $100 and ≤ $500, > $500 and < $1,000, ≥ $1,000 and ≤ $2,500, and > $2,500. This predictive model output the probability that employers had deductibles in the three categories (which summed to 1), and we assigned the employer to the level that had the highest probability. If we detected employers that had ≥ 10 employees with whole-number deductible levels both > and < $500 (eg, $250.00 and $1,500.00), we assigned the employers' category as choice. If 100% of employees had health savings accounts, we also overwrote any previous assignment to classify the employer as a high-deductible employer. We tested the predictive model on the other half of the sample for which we had actual deductible levels from the benefits table (Table A1). For employers with 75 to 100 enrollees, we found sensitivity and a specificity of > 96%. The sensitivity and specificity would be expected to be even higher for employers with > 100 enrollees (because more claims data would be available to provide evidence of deductible levels), but we were unable to test this because the data set for which we had actual deductibles included employers with generally ≤ 100 enrollees.

Rationale for Low- and High-Deductible Cutoff Values. When health savings account–eligible high-deductible health plans (HDHPs) came to market in 2006, the Internal Revenue Service set the minimum deductible level for qualifying HDHPs at $1,050 (which could be adjusted upward for inflation annually). The range of this minimum deductible during our study period was $1,050 to $1,200. For these reasons, we defined HDHPs as annual individual deductibles of at least $1,000 (otherwise, health savings account plans would be excluded). In addition, this cutoff (eg, as opposed to $2,000) also improves the sensitivity and specificity of the imputation because this deductible level is common, and more enrollees per employer meet this threshold. This cutoff is also a real-world deductible minimum that allows the most generalizable results. We did not create a separate imputation algorithm for deductible levels of, for example, ≥ $2,000 because of concerns that a less-sensitive and -specific algorithm would lead to biased effect estimates and a smaller HDHP sample size. Note that $1,000 was the minimum annual deductible level, not the mean deductible level. We cannot calculate the mean deductible level of the HDHP group directly, but we would expect it to be in the range of approximately $1,500 to $2,000. We defined traditional plans as having deductible levels of ≤ $500 after determining that a threshold of ≤ $250 would lead to an inadequate sample size for the control group. Again, the mean deductible level of the control group members would be < $500.

After assigning deductible levels at the employer plan-year level, we began with 1,830,665 employer plan-years. We excluded 201,230 plan-years (11%) that included deductible levels other than only low or only high. Among the remaining 1,629,435 plan-years, we excluded 191,519 plan-years (12%) that did not have 2 years of continuous enrollment. Finally, from the remaining 1,437,916 employer plan-years, we excluded 549,638 plan-years (38%) that were not transitions of low deductible to low deductible

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or low deductible to high deductible. Most of these exclusions were a result of employers having high deductibles at their initial appearance in our data set and remaining with HDHPs.

Our HDHP group, therefore, comprised the enrollment years of employers that had a year-on-year transition from low- to high-deductible coverage (from ≤ $500 to ≥ $1,000). Some employers had multiple eligible index dates (eg, multiple low- to low-deductible years or both low- to low- and low- to high-deductible years). In these cases, we randomly assigned employers to the HDHP or control pool and then randomly selected one of their index dates (and their corresponding before-after enrollment years). We then identified women age 25 to 64 years and made further exclusions as described in the article.

Coarsened Exact Matching Approach

Coarsened exact matching helps to control for the confounding influence of baseline study group differences by reducing the imbalance on matching variables between the intervention (eg, HDHP) and control groups.[1,2] We used a coarsened exact match[11,12] on employer- and member-level propensity[13,14] to join HDHPs; baseline annual out-of-pocket spending category (< $100, $100 to $999, $1,000 to $9,999, and ≥ $10,000); and whether at baseline members had a first observed breast diagnostic image, breast biopsy, early-stage breast cancer diagnosis, or breast cancer chemotherapy treatment. The logistic model for calculating employer propensity[6-9] to join an HDHP predicted this likelihood on the basis of calendar index month (ie, anniversary month when employers and/or enrollees can change benefits each year); employer size (< 50, 50 to 99, 100 to 249, 250 to 499, ≥ 500 employees); percentage of women, members in income strata, education strata, age strata, race strata, and region strata; employer baseline cost level and trend; average employer ACG score; and outpatient copay. We constructed the corresponding member-level propensity model to ensure contemporaneous study groups as well as to balance key characteristics that had substantial prematch imbalance (high prematch standardized differences); thus, this model included age category, employer size category, US region, and calendar year of the index date. Evidence suggests that matching on baseline levels or trends of outcome measures in quasi-experimental studies closely approximates the effect estimates of randomized controlled trials.[10] We therefore included the key outcomes of whether at baseline, members had a first-observed breast diagnostic image, breast biopsy, early-stage breast cancer diagnosis, or breast cancer chemotherapy treatment as binary measures per 4-month period. Our final group included 273,499 women in HDHPs and 2,424,868 matched control members.

Covariates

To derive proxy demographic measures, the data vendor linked members' most recent residential street addresses to their 2000 US Census block group.[19] Census-based measures of socioeconomic status have been validated[17,18] and used in multiple studies to examine the effect of policy changes on disadvantaged populations.[20-22]

We classified members as from predominantly white, black, or Hispanic neighborhoods if they lived in a census block group (geocoding) with at least 75% of members of the respective race/ethnicity. We then applied a superseding ethnicity assignment if members had an Asian or Hispanic surname[23] and classified remaining members as from mixed race/ethnicity neighborhoods. This validated approach of combining surname analysis and census data has positive and negative predictive values of approximately 80% and 90%, respectively.[24]

Table A1. Validation of Deductible Imputation Algorithm

Imputation	Gold Standard* = High Deductible	Gold Standard = Low Deductible
High deductible, No.	611,541	14,335
Low deductible, No.	24,017	465,120
Sensitivity, %	96.2	97.0
Specificity, %	97.0	96.2
Positive predictive value, %	97.7	95.1

*Gold standard was a benefits variable specific to each employer derived from a benefits table and obtained from the health insurer through the data vendor.

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Table A2. Codes Used to Create Breast Cancer Chemotherapy Measures

Category	Codes
Screening mammography	
CPT	76083, 76092, 77055, 77056, 77057
HCPCS	G0202, G0203, G0205
ICD-9	V7611, V7612, V761, V7610, V7619
Breast diagnostic imaging	
Diagnostic mammogram	
CPT	76082, 76091, 77055, 77056, 76090
HCPCS	G0204-G0207
Breast ultrasound	
CPT	76645
ICD-9 procedure	88.73
Breast MRI	
CPT	76093, 76094, 77058, 77059, as well as 77058 and 77059 after 2006 and 76093 and 76094 before 2007
HCPCS	C8903-C8908
Breast biopsy	
CPT	19000, 19001, 19100-19103, 19110, 19112
ICD-9 procedure	85.11-85.14, 85.16-85.19
Chemotherapy prescription NDC	00093747306, 00093747306, 00093747489, 00093747489, 54569571700, 54868414300, 54868414301, 54868414302, 54868526000, 54868526001, 54868526002, 54868526003, 54868526004, 54868526005, 54868526006, 54868526007, 54868526008, 54868526009, 68258903601, 00004110020, 00004110051, 00004110051, 00004110116, 00004110175, 00004110150, 00004110116, 00409112910, 00409112911, 00409112912, 00591333626, 00591333712, 00591333889, 00591345460, 00703326401, 00703327401, 00703327601, 00703424401, 10019091701, 10139006005, 10139006015, 10139006045, 15210006112, 15210006312, 15210006612, 15210006712, 50111096676, 55390015301, 55390015401, 55390015501, 55390015501, 55390015601, 55390022001, 55390022101, 55390022201, 61703033918, 61703033922, 61703036018, 61703036022, 61703036050, 63323016610, 63323016721, 63323017245, 66860010001, 66860010101, 66860010201, 00703324611, 00703424601, 00703324611, 55390015101, 00703424801, 61703033950, 00703324811, 00703324811, 00703327801, 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(continued on following page)

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Table A2. Codes Used to Create Breast Cancer Chemotherapy Measures (continued)

Category	Codes
	38779002509, 51552073301, 51552073302, 51552073304, 51552073305, 51927108500, 68682008531, 00004197701, 00469171060, 00004197701, 00469171060, 68682000431, 10139006320, 00069017301, 00069017302, 16729027667, 00069017401, 16729027611, 00069017601, 16729027638, 10139006310, 00069016901, 16729027668, 00187395364, 63323011751, 63323011761, 00187395364, 63323011710, 63323011720, 51672406201, 51672406301, 38779002503, 38779002506, 62991148604, 00013103691, 00013103695, 00013104694, 00081039001, 00081039003, 00182306863, 00418017110, 00469171030, 00469171040, 00469171100, 00702171030, 10019095002, 38779002510, 38779002525, 39769001210, 39769001240, 39769001290, 51309021710, 51309021720, 51309021750, 51309021798, 51432040910, 51432047010, 53258171003, 53258171100, 53905011110, 61703040932, 61703040953, 61703040967, 62991148601, 62991148603, 66758004401, 66758004403, 00187360060, 16729011711, 63323012553, 00069385910, 16729011838, 16729009203, 63323010213, 23155021431, 23155021331, 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Table A2. Codes Used to Create Breast Cancer Chemotherapy Measures (continued)

Category	Codes
Chemotherapy procedure	
CPT	0519F, 36640, 4180F, 61517, 96400, 96401, 96402, 96405, 96406, 96408, 96409, 96410, 96411, 96412, 96413, 96414, 96415, 96416, 96417, 96420, 96422, 96423, 96425, 96440, 96445, 96446, 96450, 96542, 96545, 96549
HCPCS	J9179, C9214, C9257, J9035, Q2024, S0116, J8520, J8521, J9045, C8953, C8954, C8955, G0355, G0357, G0358, G0359, G0360, G0361, G0362, G8372, G9021, G9022, G9023, G9024, G9025, G9026, G9027, G9028, G9029, G9030, G9031, G9032, J7150, J8999, J9999, Q0083, Q0084, Q0085, S5019, S5020, S9329, S9330, S9331, C9418, J9060, J9062, C9420, C9421, J8530, J9070, J9080, J9090, J9091, J9092, J9093, J9094, J9095, J9096, J9097, J9170, J9171, C9415, J9000, J9001, J9002, Q2049, C1167, J9178, J9180, C9414, C9425, J8560, J9181, J9182, J9190, J9201, J9207, J8610, J9250, J9260, C9432, J9280, J9290, J9291, J9293, C9431, J9264, J9265, J9355, J9360, J9370, J9375, J9380, C9440, J9390
Chemotherapy ICD-9 diagnosis	V58.1, V58.11, E930.7, E933.1, V07.3, V07.39, 00.10, 99.25
Chemotherapy hospitalization DRG	410, 023, 837, 838
Chemotherapy revenue	331, 332, 335

Abbreviations: CPT, Current Procedural Terminology; DRG, Diagnosis-Related Group; HCPCS, Healthcare Common Procedure Coding System; ICD-9, International Classification of Diseases, Ninth Revision; MRI, magnetic resonance imaging; NDC, National Drug Code.

Table A3. Sensitivity Analysis of HDHP Versus Control Group HRs at Baseline and Follow-Up for Time-to-Event Analyses Restricted to Women Ages 40 to 64 Years

	HDHP *v* Control Group, HR (95% CI)	
Time to First	Baseline	Follow-up
Diagnostic breast imaging	1.01 (0.99 to 1.03)	0.95 (0.94 to 0.96)
Breast biopsy	1.02 (0.98 to 1.07)	0.92 (0.89 to 0.95)
Early-stage breast cancer	1.02 (0.92 to 1.14)	0.85 (0.78 to 0.91)
Breast cancer chemotherapy	1.00 (0.89 to 1.13)	0.80 (0.73 to 0.88)

NOTE. HRs derived from Cox proportional hazards regression models adjusted for age-group, race/ethnicity, education level, poverty level, US region, index date, and duration of enrollment before baseline. Determined from the Wald test for the joint hypothesis.
Abbreviations: HDHP, high-deductible health plan; HR, hazard ratio.

Table A4. Sensitivity Analysis of HDHP Versus Control Group HRs at Baseline and Follow-Up for Time-to-Event Analyses Restricted to Women With at Least 6 Months of Follow-Up Time

	HDHP *v* Control Group, HR (95% CI)	
Time to First	Baseline	Follow-up
Diagnostic breast imaging	1.01 (1.00 to 1.03)	0.95 (0.94 to 0.96)
Breast biopsy	1.02 (0.98 to 1.07)	0.92 (0.89 to 0.95)
Early-stage breast cancer	1.03 (0.93 to 1.14)	0.83 (0.77 to 0.89)
Breast cancer chemotherapy	1.02 (0.90 to 1.14)	0.78 (0.72 to 0.85)

NOTE. HRs derived from Cox proportional hazard regression models adjusted for age-group, race/ethnicity, education level, poverty level, US region, index date, and duration of enrollment before baseline. Determined from the Wald test for the joint hypothesis.
Abbreviations: HDHP, high-deductible health plan; HR, hazard ratio.

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