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ORIGINAL RESEARCH

Gaps in Dyslipidemia Care Among Working-Aged Individuals With Employer-Sponsored Health Care

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BACKGROUND: The American Heart Association and American College of Cardiology guidelines defined patient-management groups that would benefit from lowering of low-density lipoprotein cholesterol (LDL-C). We assessed gaps in dyslipidemia care among employees and spouses with health benefits.

METHODS AND RESULTS: We studied 17 889 employees and spouses who were covered by an employer-sponsored health plan and participated in an annual health assessment. Using medical claims, laboratory tests, and risk assessment questionnaires, we found that 43% of participants were in one of 4 patient-management groups: secondary prevention, severe hypercholesterolemia (LDL-C ≥190 mg/dL at least once in the preceding 5 years), diabetes mellitus, or elevated 10-year risk of cardiovascular disease. To assess gaps in dyslipidemia care, we used LDL-C ≤70 mg/dL as the goal for both the secondary prevention group and those in the elevated 10-year risk group with >20% risk; LDL-C ≤100 mg/dL was used for the other groups. Among those in patient-management groups, 27.3% were in the secondary prevention group, 7.4% were in the severe hypercholesterolemia group, 29.9% were in the diabetes mellitus group, and 35.4% were in the elevated 10-year risk group. About 74% of those in patient-management groups had above-goal LDL-C levels, whereas only 31% had evidence of a lipid-lowering therapy in the past 6 months: 45% in the secondary prevention group, 31% in the severe hypercholesterolemia group, 36% in the diabetes mellitus group, and 17% in the elevated 10-year risk group.

CONCLUSIONS: The substantial gaps in LDL-C treatment and goal attainment among members of an employer-sponsored medical plan who were mostly aware of their LDL-C levels indicate the need for gap-closure initiatives.

Key Words: cholesterol reduction ■ epidemiology ■ guideline adherence

Multiple clinical trials have found that reducing low-density lipoprotein cholesterol (LDL-C) levels effectively prevents both primary and secondary cardiovascular disease (CVD) events. Relative risk reduction in these trials was ≈20% for each 40-mg/dL reduction of LDL-C.[1,2] Therefore, achieving and maintaining LDL-C at or below goal has been a major emphasis of CVD prevention guidelines.[3,4]

Despite the well-recognized benefit of maintaining LDL-C levels at or below goal, elevated LDL-C levels remain a population health problem for a variety of reasons. Many adults who do not regularly visit a primary-care provider[5] or may not be aware of their high LDL-C levels or elevated CVD risk.[6] Even if LDL-C–lowering therapy is initiated, it may not be adjusted to achieve LDL-C at or below goal levels.[7] Lack of periodic feedback from primary-care providers may also result in poor adherence to lipid-lowering therapy, and poor adherence has been shown to be associated with greater risk of dying.[8]

Gaps in dyslipidemia care have been reported among patients with established CVD,[9–13] stroke,[14] and peripheral artery disease[15]; in those with greater

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CLINICAL PERSPECTIVE

What Is New?

- Gaps in dyslipidemia care were assessed in 17 889 employees and spouses of a US employer with employees in all 50 states.
- Study participants were covered by an employer-sponsored health plan and participated in an annual health assessment offered by the employer.
- Substantial gaps in dyslipidemia care were observed in all 4 American Heart Association and American College of Cardiology–defined patient-management groups. Many patients were not treated with lipid-lowering therapies and did not achieve low-density lipoprotein cholesterol goals.

What Are the Clinical Implications?

- Dyslipidemia care is not appropriately managed even among individuals with access to medical care and who are aware of their cardiovascular health.
- Programs designed to improve dyslipidemia care targeting both patients and care providers seem warranted.

Nonstandard Abbreviations and Acronyms

AHA	American Heart Association
ACC	American College of Cardiology
CVD	cardiovascular disease
NHANES	National Health and Nutrition Examination Survey

numbers of CVD risk factors[11,16]; and in those eligible for treatment according to guidelines.[17,18] These studies were based on analyses of information limited to patients already under a physician's care, such as patient discharge records,[12] patient registries,[13,16]medical insurance claims[10,11] or physician surveys.[17] In addition, analyses based on national survey data[18] do not consider the effect of the participants' medical insurance availability on lipid-lowering therapy utilization. We set out to assess gaps in dyslipidemia care in those who are members of a group health plan (who may or may not have a relationship with a healthcare provider) and who are likely to be aware of their cardiovascular health.

Many employers in the US offer annual employer-sponsored population health assessment programs that include CVD risk assessment and lipid-level laboratory tests.[19] Information collected in health assessment programs can be used to measure gaps in care for working-aged populations with employer-provided health benefits.

We investigated the prevalence of above-goal LDL-C levels and the prevalence of lipid-lowering therapy among employees and spouses who were covered by an employer-sponsored health plan and participated in an annual health assessment offered by a US nationwide employer.

METHODS

The population of the study was drawn from 35 276 individuals who participated in an annual health assessment program between September 2017 and June 2018. The health assessment program was offered by a major US clinical diagnostics provider with employees in all 50 states to all its employees and their spouses. A majority of the workforce held jobs related to laboratory testing, phlebotomy, or sample-handling logistics. We excluded those who did not participate in the employer-sponsored group health plan for at least 12 consecutive months immediately before participating in the health screening program (n=10 709), those who were aged >75 or <40 years (n=6433), and those with missing data (n=245). The remaining 17 889 participants were included in the analysis (Figure 1). An institutional review board waived the requirement for informed consent by determining that this research was conducted according to the Health Insurance Portability and Accountability Act (HIPAA) Privacy Rule, 45 CFR 164.514(e), which allows the use of retrospective limited data sets from which direct patient identifiers have been removed. The code developed for the statistical analysis in this article will be provided on request sent to the corresponding author. The data will not be available because distribution of limited data sets is limited by the HIPAA Privacy Rule.

The health assessment program included (1) measurement of blood pressure, height, and weight; (2) a health assessment questionnaire, including questions about smoking, diabetes mellitus status, and family history of myocardial infarction; and (3) a panel of laboratory tests performed on freshly drawn fasting blood samples including high-density lipoprotein cholesterol (HDL-C), LDL-C, total cholesterol, triglycerides, high-sensitivity C-reactive protein, glucose, hemoglobin A_{1C}, and cotinine. Secondary prevention patients were identified based on the *International Classification of Diseases, Ninth Revision* (*ICD-9*) and *ICD-10* codes in medical claims filed in the 12 months before health assessment program enrollment and up to 5 years before, if available. The *ICD* codes used to identify secondary prevention patients are listed in Table S1. The use of antihypertensive therapy and lipid-lowering therapy was defined as a pharmacy claim for a relevant therapy category (Tables S2 and S3) within the past 6 months or a self-reported use of therapy. Lipid-lowering

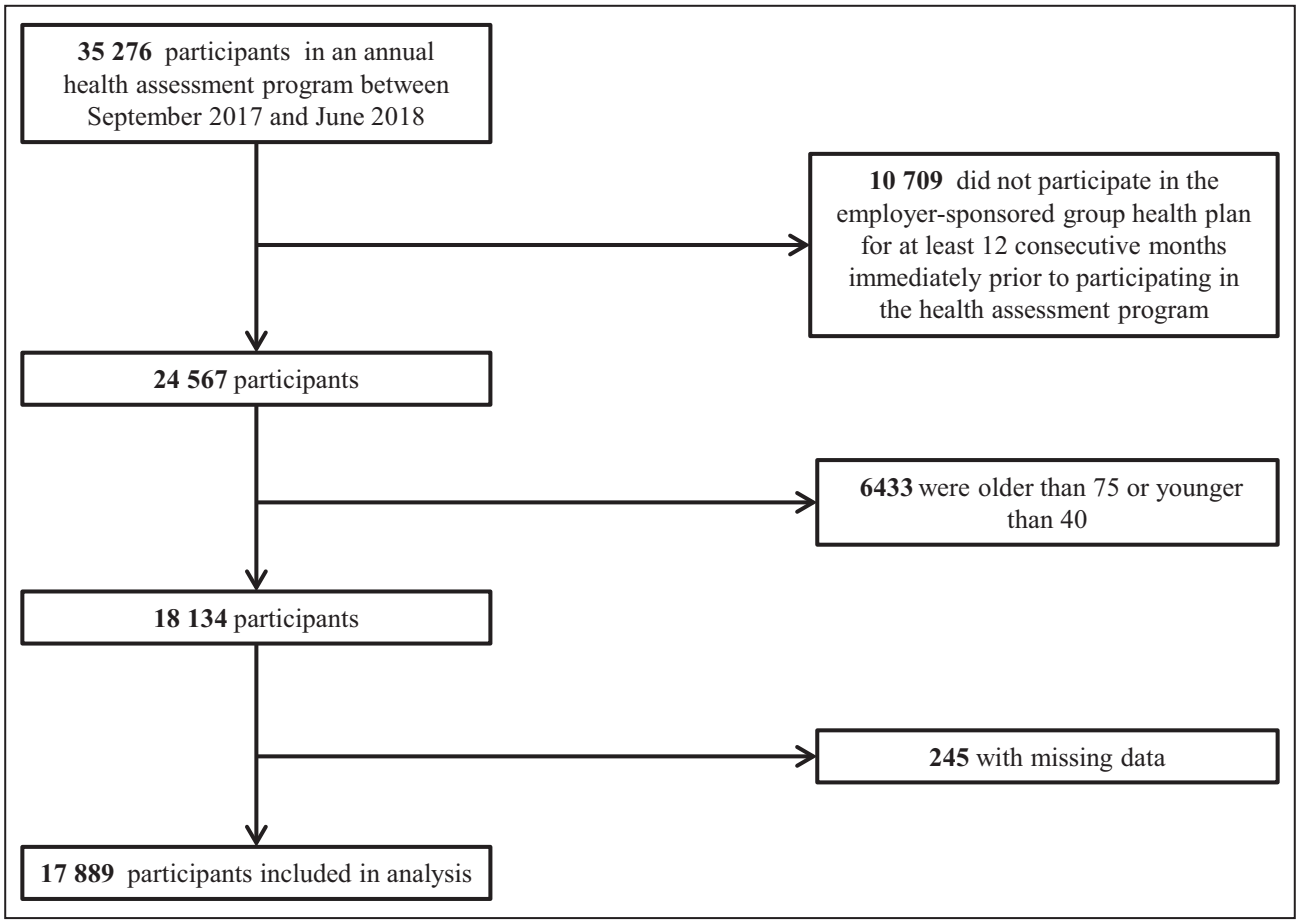

Figure 1. Study participants flow diagram. Horizontal arrows indicate exclusion from the study.
Vertical arrows indicate flow of participants leading to final study population.

discontinuation was defined as a pharmacy claim for lipid-lowering therapy filed 7 to 12 months before health assessment program enrollment and up to 5 years before, if available, among those not using lipid-lowering therapy. Statin intensity was defined according to the 2018 American Heart Association and American College of Cardiology (AHA/ACC) guideline on the management of blood cholesterol.[3,4] Diabetes mellitus was defined as having a fasting blood glucose level >125 mg/dL, hemoglobin A_{1c} >6.4%, a prescription for a diabetic medication in the past 6 months, or a self-reported physician diagnosis of diabetes mellitus. Hypertension was defined as having systolic blood pressure ≥140 mm Hg, diastolic blood pressure ≥90 mm Hg, antihypertensive medication prescription in the past 6 months, or a self-reported physician diagnosis of hypertension. Smoking status was defined as a positive cotinine test (>2 ng/mL) or self-reported smoking. Metabolic syndrome was defined using criteria reported in the 2018 AHA/ACC guideline on the management of blood cholesterol.[3] The 10-year risk of CVD for participants without prevalent CVD was calculated using the pooled cohort equations.[20]

Patient-management groups were defined according to the criteria in the 2013 and 2018 AHA/ACC guideline on the management of blood cholesterol.[3,4] For this analysis, we placed patients in only 1 patient-management group. Patients who met the criteria for >1 group were placed in the first group for which they qualified in the following order: (1) the secondary prevention group (those with prevalent CVD), (2) the severe hypercholesterolemia group (those with LDL-C ≥190 mg/dL at least once in the preceding 5 years), (3) the diabetes mellitus group, and (4) the elevated 10-year risk of CVD group (>7.5% 10-year risk or >5% for those with at least 1 risk enhancer). In this study, risk enhancers were defined as LDL-C ≥160 mg/dL, estimated glomerular filtration rate <60 mL/min per 1.73 m^2, triglycerides ≥175 mg/dL, high-sensitivity C-reactive protein ≥2 ng/L, or having a metabolic syndrome. LDL-C goals were defined as ≤70 mg/dL for the secondary prevention group and for those in the elevated 10-year risk group with >20% 10-year risk; LDL-C ≤100 mg/dL was used for the other groups, consistent with the AHA/ACC guideline on the management of blood

Table. Characteristics of Study Population According to Patient-Management Group

	Not in Patient-Management Group	Primary Prevention Groups						Secondary Prevention Group	*P* value*
		Severe Hypercholesterolemia†	*P* Value*	Diabetes Mellitus	*P* Value*	Elevated 10-y Risk of CVD	*P* Value*		
n	10 261	567	NA	2277	NA	2702	NA	2082	NA
Achieve LDL-C goal (n)	NA	41	NA	1075	NA	563	NA	337	NA
Age, y, mean (SD)	50 (7)	54 (7)	9×10^{-26}	54 (7)	$<1\times10^{-100}$	59 (7)	$<1\times10^{-100}$	57 (8)	$<1\times10^{-100}$
Women, n (%)	7553 (74)	369 (65)	1×10^{-5}	1319 (58)	6×10^{-50}	882 (33)	$<1\times10^{-100}$	1140 (55)	5×10^{-66}
HDL-C, mg/dL, mean (SD)	60 (18)	54 (14)	9×10^{-17}	49 (14)	$<1\times10^{-100}$	50 (15)	$<1\times10^{-100}$	53 (17)	4×10^{-65}
LDL-C, mg/dL, mean (SD)	110 (28)	171 (43)	$<1\times10^{-100}$	101 (30)	3×10^{-37}	123 (26)	$<1\times10^{-100}$	103 (34)	3×10^{-18}
TC, mg/dL, mean (SD)	191 (33)	253 (48)	3×10^{-124}	175 (36)	1×10^{-77}	198 (32)	2×10^{-27}	179 (40)	3×10^{-35}
Triglycerides, mg/dL, median (IQR)	93 (69–129)	134 (99–184)	3×10^{-63}	126 (92–176)	$<1\times10^{-100}$	126 (91–178)	$<1\times10^{-100}$	111 (79–161)	7×10^{-45}
CRP, mg/L, mean (SD)	3.2 (5.3)	3.5 (4.7)	0.1	5.1 (8.2)	3×10^{-25}	3.5 (4.9)	2×10^{-2}	4.0 (7.7)	6×10^{-6}
Fasting glucose, mg/dL, mean (SD)	92 (9)	104 (36)	5×10^{-14}	137 (51)	$<1\times10^{-100}$	97 (10)	$<1\times10^{-100}$	108 (36)	7×10^{-78}
HbA_1c, %, mean (SD)	5.3 (0.3)	5.7 (1.2)	5×10^{-16}	7.0 (1.5)	$<1\times10^{-100}$	5.4 (0.3)	8×10^{-87}	5.9 (1.2)	2×10^{-99}
SBP, mm Hg, mean (SD)	120 (14)	126 (16)	6×10^{-16}	128 (16)	8×10^{-96}	134 (15)	$<1\times10^{-100}$	127 (16)	3×10^{-69}
DBP, mm Hg, mean (SD)	76 (10)	77 (11)	3×10^{-4}	78 (10)	2×10^{-29}	81 (10)	$<1\times10^{-100}$	76 (10)	2×10^{-4}
BMI, kg/m^2, mean (SD)	28 (6)	29 (6)	0.04	33 (8)	$<1\times10^{-100}$	30 (6)	7×10^{-21}	30 (7)	1×10^{-28}
Hypertension, n (%)	3241 (32)	250 (44)	8×10^{-10}	1688 (74)	$<1\times10^{-100}$	1822 (67)	$<1\times10^{-100}$	1475 (71)	$<1\times10^{-100}$
Smoking, n (%)	816 (8)	78 (14)	2×10^{-6}	250 (11)	3×10^{-6}	603 (22)	4×10^{-100}	278 (13)	4×10^{-15}
Diabetes mellitus, n (%)	0 (0)	79 (14)	NA	2277 (100)	NA	0 (0)	NA	593 (28)	NA
FH of MI, n (%)	1007 (10)	65 (11)	0.2	324 (14)	8×10^{-10}	342 (13)	2×10^{-5}	369 (18)	2×10^{-25}

Between-group differences in continuous variables were assessed by Student *t* test, except for triglycerides for which Wilcoxon rank sum test was used. Differences in categorical variables were assessed by the χ^2 test. Continuous variables are presented as mean (SD), except for triglycerides, which are presented as median (IQR). Categorical variables are summarized by counts (percentage). BMI indicates body mass index; CRP, C-reactive protein; CVD, cardiovascular disease; DBP, diastolic blood pressure; FH, family history; $HbA_{1C,}$ hemoglobin A_{1C}; HDL-C, high-density lipoprotein cholesterol; IQR, interquartile range; LDL-C, low-density lipoprotein cholesterol; MI, myocardial infarction; NA, not assessed; SBP, systolic blood pressure; and TC, total cholesterol.

**P* values are for comparison to the first column (not in patient-management group).

†LDL-C ≥190 mg/dL at least once in the preceding 5 y.

cholesterol[3] and the 2015 National Lipid Association Recommendations.[21]

Statistical Analysis

Continuous baseline variables were summarized as mean±SD for normally distributed variables and as median and interquartile range otherwise. Categorical variables were summarized as count and percentage. Comparisons of continuous variables between groups were assessed by *t* test for normally distributed variables and by Wilcoxon rank sum test otherwise. Categorical variables were compared by χ^2 test.

The 10-year risk of CVD at baseline was estimated using the pooled cohort equations.[20] The 10-year survival, S(t), where t=10, is 1–(10-year risk of CVD). Assuming a constant hazard, the baseline hazard (h_b) was estimated as $h_b=[-\log_e S(10)]/10$. The 10-year risk of CVD after LDL-C lowering was estimated by considering the reported hazard ratio for LDL-C lowering as 0.79 for each 39 mg/dL (1.0 mmol/L) lowered.[1,2] Therefore, the hazards after LDL-C lowering (h_a) were estimated as $h_a = h_b \times e^{x \times \log_e(0.79)}$, where *x* is the difference in LDL-C at baseline and LDL-C level after lowering. The 10-year risk of CVD after LDL-C lowering was estimated from the hazard as $1-e^{-h_a \times t}$. The projected CVD events after 10 years of follow-up at baseline and after LDL-C lowering were calculated from the means of the estimated 10-year risks at baseline and after LDL-C lowering, assuming exponential distribution of time to event with a constant hazard, $S(t)=e^{(-h \times t)}$, where t=10. Comparison of 10-year risk of CVD before and after LDL-C lowering was assessed by *t* test of the natural log–transformed difference in 10-year risk.

The difference between LDL-C levels in those with and without lipid-lowering therapy was evaluated by the Wilcoxon rank sum test. Comparisons among LDL-C goal achievement, lipid-lowering therapy, and lipid-lowering therapy discontinuation between women and men were assessed in logistic regression models adjusted for age. All analyses were performed in R software.[22]

RESULTS

This cross-sectional study included 17 889 participants, of whom 7628 (43%) were in 1 of 4 patient-management groups: the secondary prevention group (27.3%, n=2082), the severe hypercholesterolemia group (LDL-C ≥190 mg/dL at least once in the preceding 5 years; 7.4%, n=567), the diabetes mellitus group (29.9%, n=2277), and the elevated 10-year risk of CVD group (35.4%, n=2702). The remaining 10 261 participants were not in any patient-management group and, as expected, had lower levels of CVD risk factors than those in patient management groups (Table).

Only 26% of the participants in patient-management groups had LDL-C levels at or below goal. Of particular note, only 16% of those in the secondary prevention group were at or below LDL-C goal. A smaller fraction of women (11%) than men (22%) achieved LDL-C goals in this secondary prevention group ($P=5\times10^{-9}$; Figure 2A). The highest level of goal achievement (47% in women, 48% in men) was observed for those in the diabetes mellitus group. In both the primary and the secondary prevention groups, many participants with LDL-C levels above goal were young to middle-aged (Figure 3). In those above goal, 36% of men were younger than 55 years, and 60% of women were younger than 60.

Among women, the highest lipid-lowering therapy use was 46% in the diabetes mellitus group (Figure 2B). Among men, the highest lipid-lowering therapy use was observed in the secondary prevention group (64%). Men received lipid-lowering therapy more commonly than did women in the diabetes mellitus group and in the secondary prevention group ($P\leq3\times10^{-4}$). The lipid-lowering therapy discontinuation rate ranged from a high of 26% among men in the secondary prevention group to 10% in men with elevated 10-year risk of CVD (Figure 2C). Those with self-reported family history of myocardial infarction were more likely to have evidence of lipid-lowering therapy (50.5%; 95% CI, 47.5–53.4%) than did those without family history (37.7%; 95% CI, 36.5–38.8%). In all patient-management groups, lipid-lowering therapy was more common in those with LDL-C level at or below goal than in those above goal (Figure 4). High-intensity statin therapy, which is recommended for all secondary-prevention patients, was evident in only 16% of those in the secondary-prevention patient-management group, and its use was even lower (ranging from 1% to 11%) in other patient-management groups.

In both the primary and secondary prevention groups, those using lipid-lowering therapy had lower LDL-C levels than did those who did not use therapy ($P<0.0001$; Figure 5). For the primary prevention groups, the median LDL-C level was 97 mg/dL (interquartile range: 79–120 mg/dL) among those who used lipid-lowering therapy (84% with a statin prescription) and 125 mg/dL among those who did not. Similarly, in the secondary prevention group, median LDL-C was 87 mg/dL (interquartile range: 69–109 mg/dL) among those who used lipid-lowering-therapy and 114 mg/dL among those who did not.

Lowering LDL-C levels to goal in the 3867 participants in the primary prevention groups with LDL-C levels above goal could almost double the fraction

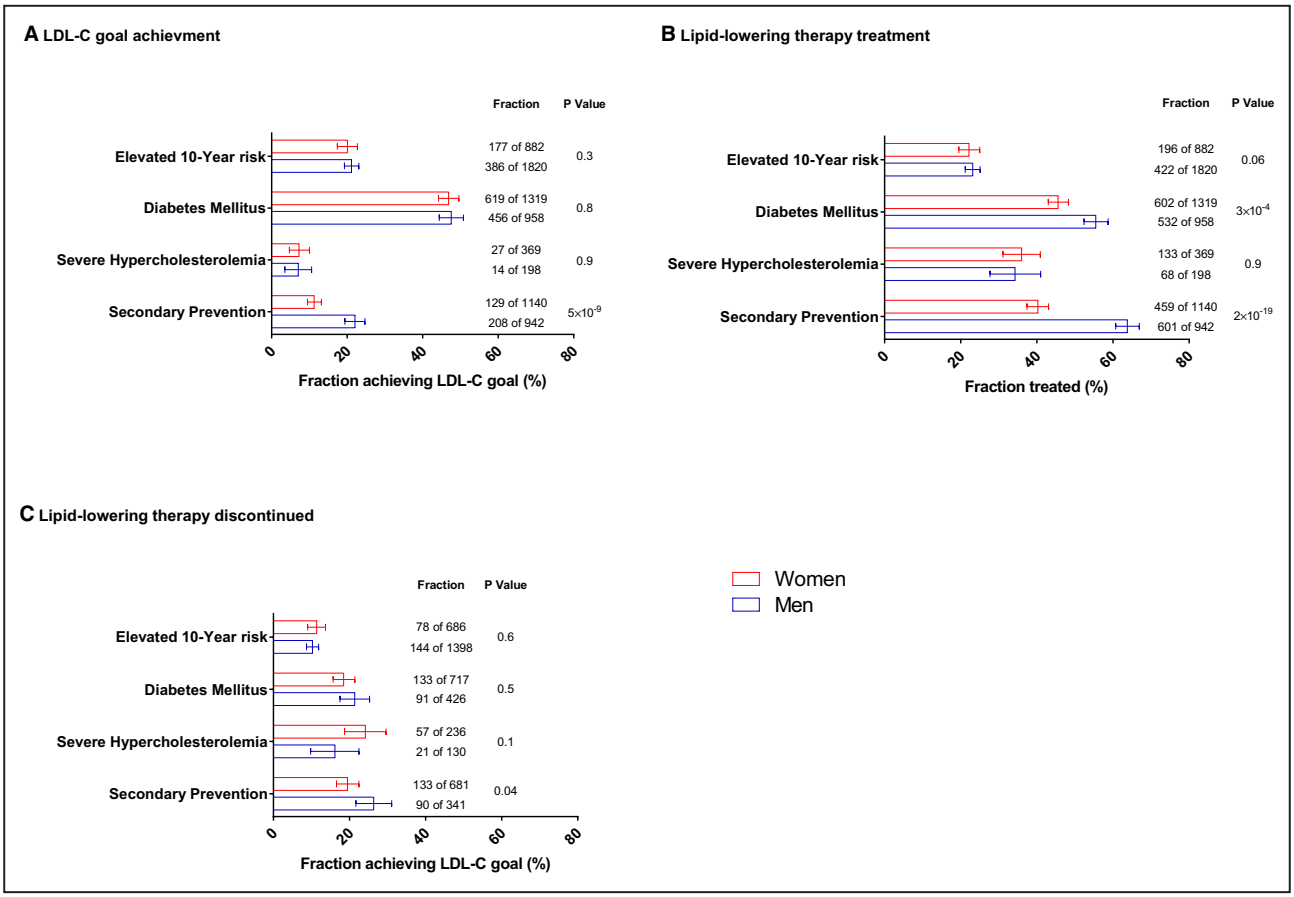

Figure 2. Fraction of patients achieving low-density lipoprotein cholesterol (LDL-C) goal, treated with lipid lowering therapy, and discontinuing lipid-lowering therapy.
The percentages of patients in each patient-management group who have achieved LDL-C goal (**A**), who are receiving lipid-lowering therapy (**B**), and who have discontinued lipid-lowering therapy (of those not receiving therapy) (**C**) are presented for women (red) and men (blue). Error bars are 95% CIs. The number of patients in each fraction as well as the total number of patients is indicated. *P* values are age-adjusted for the difference between fractions in women and men.

of those with 10-year risk of CVD <5% from 16.2% to 30.2% (Figure 6) and could increase, by 36%, the fraction of those with 10-year risk <7.5% (from 39.5% to 53.7%). Overall, lowering LDL-C to goal would reduce the mean 10-year CVD risk to 8.6% from 10.6% ($P<0.0001$). We estimate that reducing LDL-C to goal levels in the primary prevention groups would prevent about 20% of the CVD events projected to occur over the following 10 years (77 of the 408 projected CVD events).

DISCUSSION

In a working-aged population that was covered by a group health plan and participated in an annual health screen program, we found that LDL-C levels were above goal in about 74% of those in patient-management groups that could benefit from lipid-lowering therapy. Failure to reach goal was particularly common in the secondary prevention group (84%) and in the severe hypercholesterolemia group (93%; those with LDL-C ≥190 mg/dL at least once in any of the preceding 5 years). These gaps in care are surprising when we consider that 93% of the study population also participated in a health screening program in the prior year and thus were aware of their LDL-C levels and overall cardiovascular health status for at least 2 consecutive years and should have had an opportunity to address their elevated LDL-C levels.

More than 40% of participants were in patient-management groups—groups that would benefit from LDL-C lowering. The fraction of those in patient-management groups was similar to the 39% found in the offspring and third-generation cohorts of the Framingham Heart Study[23] but somewhat lower than the 49% found among US adults between the ages of 40 and 75 years in the 2005–2010 National Health and Nutrition Examination Survey (NHANES).[24] The higher fraction found in NHANES may reflect

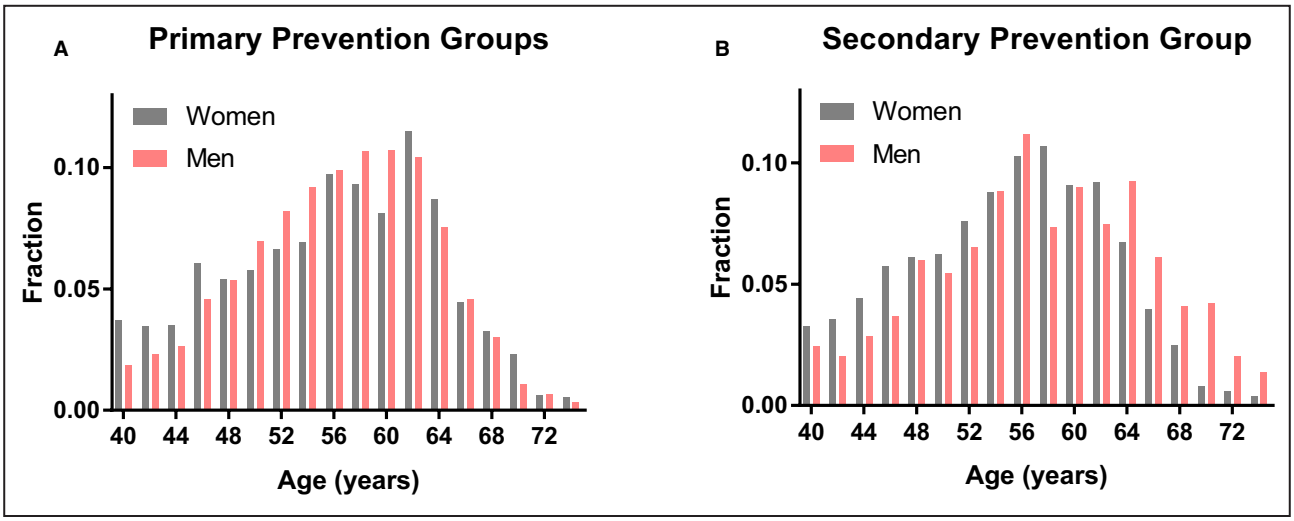

Figure 3. Age distribution in primary and secondary prevention groups.
Histograms of age for patients with low-density lipoprotein cholesterol (LDL-C) above goal in the primary prevention groups (**A**) and the secondary prevention group (**B**). Histograms are plotted for women (gray) and men (pink).

the roughly 10-year difference in the timing of the NHANES analysis and the current study, or it may be that the population of actively working employees with full medical benefits in the current study are simply healthier than the general population represented in NHANES.

About half of those in the secondary prevention and diabetes mellitus groups did not receive guideline-recommended lipid-lowering therapy. The fraction using lipid-lowering therapy was even lower in the severe hypercholesterolemia group and the elevated 10-year risk of CVD group—only 35% and 23%, respectively, of these groups were on lipid-lowering therapy (Figure 3). Our findings differ from an analysis of a cardiology practices registry (PINNACLE; National Cardiovascular Data Registry Practice Innovation and Clinical Excellence)[25] that found most (about 68%) eligible patients receive lipid-lowering therapy; perhaps this difference is because all patients in the PINNACLE study were drawn from cardiology clinics and might have been more likely to receive cardiovascular care.

In the secondary prevention group, we found that the fraction receiving lipid-lowering therapy was substantially smaller for women than for men; perhaps consequently, a smaller fraction of women achieved the LDL-C goal for secondary prevention patients. However, lipid-lowering therapy discontinuation was less common among women than among men in the secondary prevention group; therefore, this

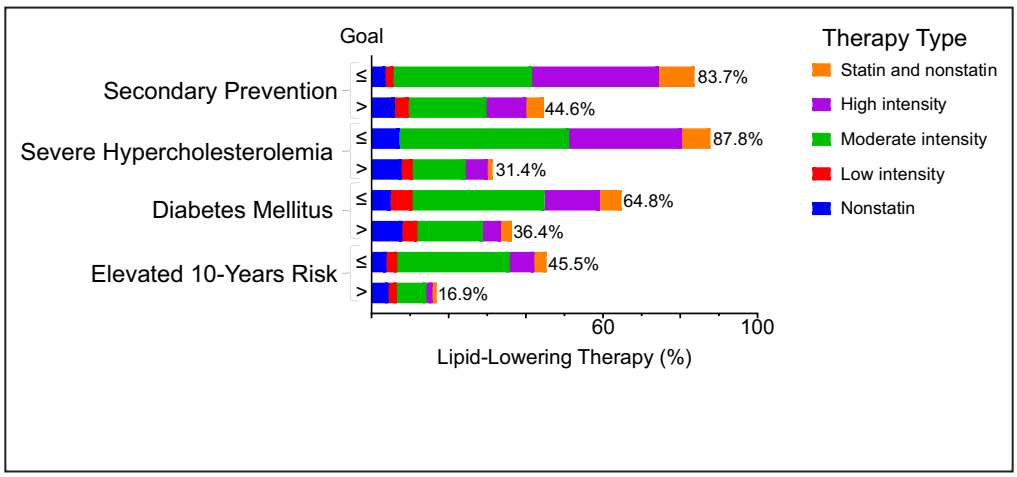

Figure 4. Lipid-lowering therapy type by patient-management group.
Fraction of patients in each patient-management group receiving high-, moderate-, or low-intensity statin therapy; other lipid-lowering therapy; or both statin and nonstatin therapy, according to low-density lipoprotein cholesterol (LDL-C) goal achievement.

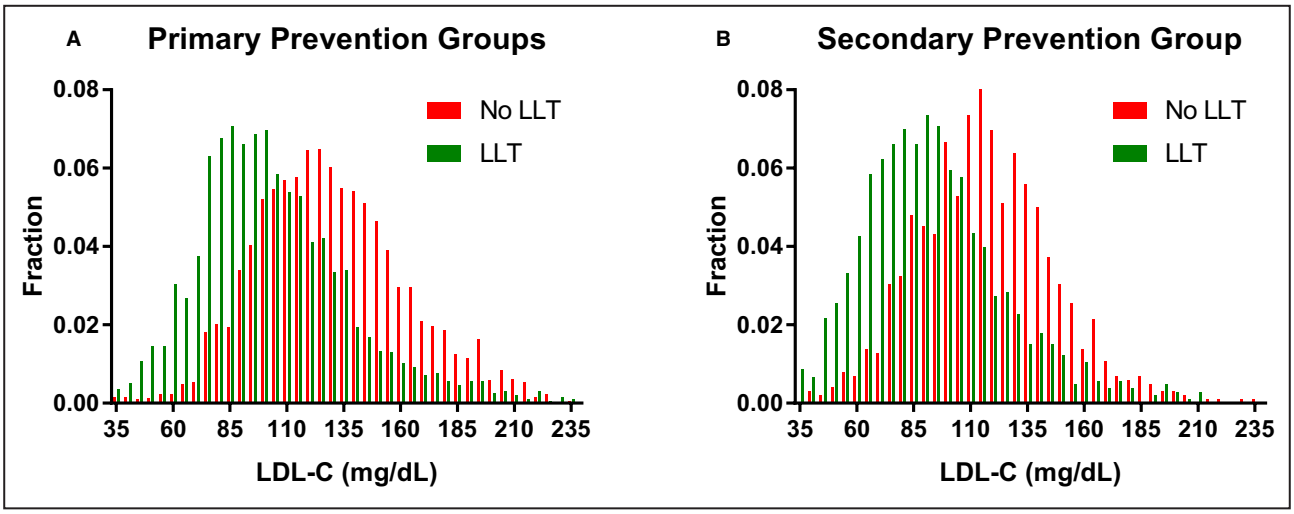

Figure 5. Low-density lipoprotein cholesterol (LDL-C) distribution.
Histograms of LDL-C levels among patients in the primary prevention groups (**A**) and among patients in the secondary prevention group (**B**). Histograms are plotted for patients not receiving lipid-lowering therapy (LLT; red) and patients receiving LLT (green).

discontinuation is unlikely to explain the lower therapy and goal achievement in women. This observation is consistent with an analysis of the 2011–2012 NHANES data that found a smaller fraction of women than men achieved LDL-C goals.[18] The discontinuation rates we observed (10–26%) are consistent with the published discontinuation rate among 75-year-old primary prevention patients in France (14%)[26] but lower than that reported in Japan.[27,28] Statin discontinuation might be detrimental beyond its effect of LDL-C,[29] and discontinuation has been reported to be associated with 33% increased risk of cardiovascular events in 75-year old primary prevention patients.[26] Similarly, in patients of the Veterans Administration System with CVD, low adherence to statin therapy was associated with mortality.[8] Therefore, reduction or elimination of lipid-lowering therapy discontinuation in this population could improve health outcomes.

Our analyses also highlighted a potential underuse of nonstatin lipid-lowering therapy in those above goal, particularly in those in the secondary prevention group and in the severe hypercholesterolemia group (LDL-C ≥190 mg/dL at least once in the preceding 5 years). In these groups, >60% of the participants receiving high-intensity statin had LDL-C levels above goal. Although guidelines[3] suggest considering the addition of ezetimibe to statin in these patients, only 3.8% had prescription for both statin and nonstatin therapy in those above goal in these 2 groups.

We estimated that reducing LDL-C to goal levels in the primary prevention groups would prevent about 20% of CVD events over the next 10 years in these groups. And given that many in these groups were young to middle-aged, lowering risk in this group should add a substantial number of quality-adjusted life-years to this population.

Although the study population was covered by an employer-sponsored group health plan and thus was less likely to have financial reasons for not receiving therapy than would the general population, we found gaps in LDL-C goal attainment and low rates of appropriate lipid-lowering therapy. This might be explained by the multiple steps that are required to effectively treat dyslipidemia: (1) the patient has to visit a healthcare provider, (2) the healthcare provider has to recognize the need for lipid-lowering therapy and provide a prescription, (3) the patient has to fill the prescription and begin to use the medication as prescribed, (4) the healthcare provider has to reevaluate the patient after initial prescription and adjust the prescription if needed, and (5) the patient

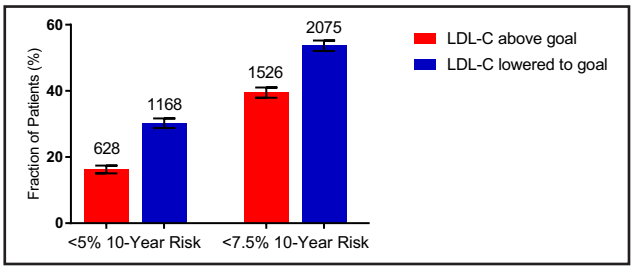

Figure 6. Ten-year risk of cardiovascular disease (CVD) in primary prevention groups.
Fraction of patients with low (<5%) or moderately low (<7.5%) 10-year risk of CVD among those in the primary prevention groups who were above low-density lipoprotein cholesterol (LDL-C) goal (red) and aspirational fraction of patients in these groups (blue). The aspirational fractions were calculated by assuming LDL-C was lowered to goal. Error bars are 95% CIs. Number of patients in each fraction is indicated above bars.

has to continue to use the prescribed medication. Failure to continue to use statin therapy has been ascribed to side effects,[30,31] costs,[32,33] perceived lack effectiveness, and negative news stories about effectiveness.[33,34]

Nevertheless, statin discontinuation is only one of the potential causes of gaps in care—a breakdown at any of the multiple steps could create a gap in dyslipidemia care. More research that might identify groups of patients who are less likely to achieve LDL-C goals might be considered. Wong et al,[18] for example, reported low LDL-C goal achievement in Hispanics and in those with history of stroke. Addressing gaps in dyslipidemia care will require programs that appropriately target steps that have the greatest impact on generating these gaps. To design effective programs, further investigation is needed to understand the causes and relative impact of failure at each step.

This study has several limitations related to potential incompleteness of medical claims data. For example, we likely underestimated the number of secondary prevention patients and the fraction who have discontinued their lipid-lowering therapy because, although we had access to medical claims from at least the 12 months before study initiation (and from up to the preceding 5 years for some), a longer record of claims for all participants would have likely identified more secondary prevention patients and more evidence of lipid-lowering therapy discontinuation. Similarly, the record of medication prescriptions in the 6 months before annual health screening participation could be incomplete if, for example, a patient obtained prescription medication outside the employer-sponsored program (eg, using a spouse insurance plan). We also did not have LDL-C test results if tests were not performed as part of the annual health screening program. Therefore, we might have underestimated the number of participants who had had severe hypercholesterolemia. Another limitation relates to the use of LDL-C goals in this study. Although the 2018 AHA/ACC guideline on the management of blood cholesterol set LDL-C goals for the secondary prevention and severe hypercholesterolemia groups, LDL-C reduction goals were set for other patient-management groups. Because this study is based on a single LDL-C assessment, we were unable to assess percentage of LDL-C reduction, and instead used clinically reasonable goals to assess goal attainment for all patient-management groups.

CONCLUSIONS

We have found substantial gaps in LDL-C treatment and goal attainment in working-aged employees and spouses with employer-sponsored medical plan and who were mostly aware of their LDL-C levels. Investigation into the causes of these gaps would help inform the design of gap-closure programs.

ARTICLE INFORMATION

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Disclosures

Shiffman, Louie, Devlin, and McPhaul are employees of Quest Diagnostics. Knowles has no disclosures to report.

Supplementary Materials

Tables S1–S3

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Supplemental Material

Table S1. ICD9 and ICD10 codes defining atherosclerotic cardiovascular disease.

ICD Type	ICD Code	Description
ICD-10-CM	G450	Vertebro-basilar artery syndrome
ICD-10-CM	G451	Carotid artery syndrome (hemispheric)
ICD-10-CM	G452	Multiple and bilateral precerebral artery syndromes
ICD-10-CM	G453	Amaurosis fugax
ICD-10-CM	G454	Transient global amnesia
ICD-10-CM	G458	Oth transient cerebral ischemic attacks and related synd
ICD-10-CM	G459	Transient cerebral ischemic attack, unspecified
ICD-10-CM	I200	Unstable angina
ICD-10-CM	I201	Angina pectoris with documented spasm
ICD-10-CM	I208	Other forms of angina pectoris
ICD-10-CM	I209	Angina pectoris, unspecified
ICD-10-CM	I2102	STEMI involving left anterior descending coronary artery
ICD-10-CM	I2109	STEMI involving oth coronary artery of anterior wall
ICD-10-CM	I2111	STEMI involving right coronary artery
ICD-10-CM	I2119	STEMI involving oth coronary artery of inferior wall
ICD-10-CM	I2121	STEMI involving left circumflex coronary artery
ICD-10-CM	I2129	STEMI involving oth sites
ICD-10-CM	I213	ST elevation (STEMI) myocardial infarction of unsp site
ICD-10-CM	I214	Non-ST elevation (NSTEMI) myocardial infarction
ICD-10-CM	I219	Acute myocardial infarction, unspecified
ICD-10-CM	I222	Subsequent non-ST elevation (NSTEMI) myocardial infarction
ICD-10-CM	I240	Acute coronary thrombosis not resulting in myocardial infrc
ICD-10-CM	I241	Dressler's syndrome
ICD-10-CM	I248	Other forms of acute ischemic heart disease
ICD-10-CM	I249	Acute ischemic heart disease, unspecified
ICD-10-CM	I2510	Athscl heart disease of native coronary artery w/o ang pctrs
ICD-10-CM	I25110	Athscl heart disease of native cor art w unstable ang pctrs
ICD-10-CM	I25111	Athscl heart disease of native cor art w ang pctrs w spasm
ICD-10-CM	I25118	Athscl heart disease of native cor art w oth ang pctrs
ICD-10-CM	I25119	Athscl heart disease of native cor art w unsp ang pctrs
ICD-10-CM	I252	Old myocardial infarction
ICD-10-CM	I253	Aneurysm of heart
ICD-10-CM	I2542	Coronary artery dissection
ICD-10-CM	I255	Ischemic cardiomyopathy
ICD-10-CM	I256	silent myocardial ischemia
ICD-10-CM	I25700	Atherosclerosis of coronary artery bypass graft(s), unspecified, with unstable angina pectoris
ICD-10-CM	I25708	Atherosclerosis of CABG, unsp, w oth angina pectoris
ICD-10-CM	I25709	Atherosclerosis of CABG, unsp, w unsp angina pectoris

ICD Type	ICD Code	Description
ICD-10-CM	I25710	Athscl autologous vein CABG w unstable angina pectoris
ICD-10-CM	I25719	Athscl autologous vein CABG w unsp angina pectoris
ICD-10-CM	I25790	Atherosclerosis of CABG w unstable angina pectoris
ICD-10-CM	I25810	Atherosclerosis of CABG w/o angina pectoris
ICD-10-CM	I25811	Athscl native cor art of transplanted heart w/o ang pctrs
ICD-10-CM	I2582	Chronic total occlusion of coronary artery
ICD-10-CM	I2583	Coronary atherosclerosis due to lipid rich plaque
ICD-10-CM	I2584	Coronary atherosclerosis due to calcified coronary lesion
ICD-10-CM	I2589	Other forms of chronic ischemic heart disease
ICD-10-CM	I259	Chronic ischemic heart disease, unspecified
ICD-10-CM	I609	Nontraumatic subarachnoid hemorrhage, unspecified
ICD-10-CM	I610	Nontraumatic intcrbl hemorrhage in hemisphere, subcortical
ICD-10-CM	I611	Nontraumatic intcrbl hemorrhage in hemisphere, cortical
ICD-10-CM	I612	Nontraumatic intracerebral hemorrhage in hemisphere, unsp
ICD-10-CM	I615	Nontraumatic intracerebral hemorrhage, intraventricular
ICD-10-CM	I619	Nontraumatic intracerebral hemorrhage, unspecified
ICD-10-CM	I6200	Nontraumatic subdural hemorrhage, unspecified
ICD-10-CM	I6201	Nontraumatic acute subdural hemorrhage
ICD-10-CM	I6202	Nontraumatic subacute subdural hemorrhage
ICD-10-CM	I6203	Nontraumatic chronic subdural hemorrhage
ICD-10-CM	I629	Nontraumatic intracranial hemorrhage, unspecified
ICD-10-CM	I63011	Cerebral infarction due to thrombosis of r verteb art
ICD-10-CM	I6309	Cerebral infarction due to thrombosis of precerebral artery
ICD-10-CM	I6310	Cerebral infarction due to embolism of unsp precerb artery
ICD-10-CM	I63112	Cerebral infarction due to embolism of left vertebral artery
ICD-10-CM	I63132	Cerebral infarction due to embolism of left carotid artery
ICD-10-CM	I63139	Cerebral infarction due to embolism of unsp carotid artery
ICD-10-CM	I6320	Cereb infrc due to unsp occls or stenos of unsp precerb art
ICD-10-CM	I63211	Cerebral infrc due to unsp occls or stenosis of r verteb art
ICD-10-CM	I63212	Cerebral infrc due to unsp occls or stenosis of l verteb art
ICD-10-CM	I63231	Cereb infrc due to unsp occls or stenos of right carotid art
ICD-10-CM	I63232	Cereb infrc due to unsp occls or stenos of left carotid art
ICD-10-CM	I63239	Cereb infrc due to unsp occls or stenos of unsp carotid art
ICD-10-CM	I6330	Cerebral infarction due to thombos unsp cerebral artery
ICD-10-CM	I63311	Cereb infrc due to thombos of right middle cerebral artery
ICD-10-CM	I63312	Cerebral infrc due to thombos of left middle cerebral artery
ICD-10-CM	I63319	Cerebral infrc due to thombos unsp middle cerebral artery
ICD-10-CM	I63332	Cerebral infrc due to thombos of left post cerebral artery
ICD-10-CM	I6340	Cerebral infarction due to embolism of unsp cerebral artery
ICD-10-CM	I63411	Cereb infrc due to embolism of right middle cerebral artery
ICD-10-CM	I63412	Cereb infrc due to embolism of left middle cerebral artery
ICD-10-CM	I63421	Cerebral infrc due to embolism of right ant cerebral artery
ICD-10-CM	I63432	Cerebral infrc due to embolism of left post cerebral artery

ICD Type	ICD Code	Description
ICD-10-CM	I6349	Cerebral infarction due to embolism of other cerebral artery
ICD-10-CM	I6350	Cereb infrc due to unsp occls or stenos of unsp cereb artery
ICD-10-CM	I63511	Cereb infrc d/t unsp occls or stenos of right mid cereb art
ICD-10-CM	I63512	Cereb infrc d/t unsp occls or stenos of left mid cereb art
ICD-10-CM	I63531	Cereb infrc d/t unsp occls or stenos of right post cereb art
ICD-10-CM	I63532	Cereb infrc d/t unsp occls or stenos of left post cereb art
ICD-10-CM	I63541	Cereb infrc due to unsp occls or stenos of right cereblr art
ICD-10-CM	I63542	Cereb infrc due to unsp occls or stenos of left cereblr art
ICD-10-CM	I6359	Cereb infrc due to unsp occls or stenosis of cerebral artery
ICD-10-CM	I638	Other cerebral infarction
ICD-10-CM	I639	Cerebral infarction, unspecified
ICD-10-CM	I6501	Occlusion and stenosis of right vertebral artery
ICD-10-CM	I6502	Occlusion and stenosis of left vertebral artery
ICD-10-CM	I6503	Occlusion and stenosis of bilateral vertebral arteries
ICD-10-CM	I6509	Occlusion and stenosis of unspecified vertebral artery
ICD-10-CM	I6521	Occlusion and stenosis of right carotid artery
ICD-10-CM	I6522	Occlusion and stenosis of left carotid artery
ICD-10-CM	I6523	Occlusion and stenosis of bilateral carotid arteries
ICD-10-CM	I6529	Occlusion and stenosis of unspecified carotid artery
ICD-10-CM	I658	Occlusion and stenosis of other precerebral arteries
ICD-10-CM	I6601	Occlusion and stenosis of right middle cerebral artery
ICD-10-CM	I6602	Occlusion and stenosis of left middle cerebral artery
ICD-10-CM	I6613	Occlusion and stenosis of bi anterior cerebral arteries
ICD-10-CM	I668	Occlusion and stenosis of other cerebral arteries
ICD-10-CM	I669	Occlusion and stenosis of unspecified cerebral artery
ICD-10-CM	I670	Dissection of cerebral arteries, nonruptured
ICD-10-CM	I671	Cerebral aneurysm, nonruptured
ICD-10-CM	I672	Cerebral atherosclerosis
ICD-10-CM	I674	Hypertensive encephalopathy
ICD-10-CM	I675	Moyamoya disease
ICD-10-CM	I676	Nonpyogenic thrombosis of intracranial venous system
ICD-10-CM	I6781	Acute cerebrovascular insufficiency
ICD-10-CM	I6782	Cerebral ischemia
ICD-10-CM	I67848	Other cerebrovascular vasospasm and vasoconstriction
ICD-10-CM	I6789	Other cerebrovascular disease
ICD-10-CM	I679	Cerebrovascular disease, unspecified
ICD-10-CM	I69053	Hemiplga following ntrm subarach hemor aff right nondom side
ICD-10-CM	I69054	Hemiplga following ntrm subarach hemor aff left nondom side
ICD-10-CM	I6910	Unsp sequelae of nontraumatic intracerebral hemorrhage
ICD-10-CM	I6911	Cognitive deficits following nontrau (Invalid, Non-Billable)
ICD-10-CM	I69154	Hemiplga following ntrm intcrbl hemor aff left nondom side
ICD-10-CM	I6921	Cognitive deficits following oth ntr (Invalid, Non-Billable)
ICD-10-CM	I69291	Dysphagia following oth nontraumatic intracranial hemorrhage

ICD Type	ICD Code	Description
ICD-10-CM	I6930	Unspecified sequelae of cerebral infarction
ICD-10-CM	I6931	Cognitive deficits following cerebra (Invalid, Non-Billable)
ICD-10-CM	I69310	Attention and concentration deficit following cerebral infrc
ICD-10-CM	I69311	Memory deficit following cerebral infarction
ICD-10-CM	I69320	Aphasia following cerebral infarction
ICD-10-CM	I69321	Dysphasia following cerebral infarction
ICD-10-CM	I69322	Dysarthria following cerebral infarction
ICD-10-CM	I69328	Oth speech/lang deficits following cerebral infarction
ICD-10-CM	I69331	Monoplg upr lmb fol cerebral infrc aff right dominant side
ICD-10-CM	I69341	Monoplg low lmb fol cerebral infrc aff right dominant side
ICD-10-CM	I69351	Hemiplga following cerebral infrc aff right dominant side
ICD-10-CM	I69352	Hemiplga following cerebral infrc aff left dominant side
ICD-10-CM	I69354	Hemiplga following cerebral infrc affecting left nondom side
ICD-10-CM	I69359	Hemiplga following cerebral infarction affecting unsp side
ICD-10-CM	I69391	Dysphagia following cerebral infarction
ICD-10-CM	I69392	Facial weakness following cerebral infarction
ICD-10-CM	I69393	Ataxia following cerebral infarction
ICD-10-CM	I69398	Other sequelae of cerebral infarction
ICD-10-CM	I6981	Cognitive deficits following other c (Invalid, Non-Billable)
ICD-10-CM	I69820	Aphasia following other cerebrovascular disease
ICD-10-CM	I69854	Hemiplga fol oth cerebvasc disease aff left nondom side
ICD-10-CM	I69859	Hemiplga following oth cerebvasc disease affecting unsp side
ICD-10-CM	I69898	Other sequelae of other cerebrovascular disease
ICD-10-CM	I6990	Unspecified sequelae of unspecified cerebrovascular disease
ICD-10-CM	I69920	Aphasia following unspecified cerebrovascular disease
ICD-10-CM	I69928	Oth speech/lang deficits following unsp cerebvasc disease
ICD-10-CM	I69953	Hemiplga fol unsp cerebvasc disease aff right nondom side
ICD-10-CM	I69959	Hemiplga following unsp cerebvasc disease aff unsp side
ICD-10-CM	I69991	Dysphagia following unspecified cerebrovascular disease
ICD-10-CM	I69993	Ataxia following unspecified cerebrovascular disease
ICD-10-CM	I69998	Other sequelae following unspecified cerebrovascular disease
ICD-10-CM	I720	Aneurysm of carotid artery
ICD-10-CM	I722	Aneurysm of renal artery
ICD-10-CM	I723	Aneurysm of iliac artery
ICD-10-CM	I724	Aneurysm of artery of lower extremity
ICD-10-CM	I728	Aneurysm of other specified arteries
ICD-10-CM	I729	Aneurysm of unspecified site
ICD-10-CM	I7300	Raynaud's syndrome without gangrene
ICD-10-CM	I7301	Raynaud's syndrome with gangrene
ICD-10-CM	I731	Thromboangiitis obliterans [Buerger's disease]
ICD-10-CM	I7389	Other specified peripheral vascular diseases
ICD-10-CM	I739	Peripheral vascular disease, unspecified
ICD-10-CM	Z950	Presence of cardiac pacemaker

ICD Type	ICD Code	Description
ICD-10-CM	Z951	Presence of aortocoronary bypass graft
ICD-10-CM	Z952	Presence of prosthetic heart valve
ICD-10-CM	Z953	Presence of xenogenic heart valve
ICD-10-CM	Z954	Presence of other heart-valve replacement
ICD-10-CM	Z955	Presence of coronary angioplasty implant and graft
ICD-10-CM	Z95810	Presence of automatic (implantable) cardiac defibrillator
ICD-10-CM	Z95818	Presence of other cardiac implants and grafts
ICD-10-CM	Z95820	Peripheral vascular angioplasty status w implants and grafts
ICD-10-CM	Z95828	Presence of other vascular implants and grafts
ICD-10-CM	Z959	Presence of cardiac and vascular implant and graft, unsp
ICD-10-PCS	_0210099	Bypass 1 Cor Art from L Int Mammary w Autol Vn, Open
ICD-10-PCS	_021009W	Bypass 1 Cor Art from Aorta with Autol Vn, Open Approach
ICD-10-PCS	_02100A8	Bypass 1 Cor Art from R Int Mammary w Autol Art, Open
ICD-10-PCS	_02100A9	Bypass 1 Cor Art from L Int Mammary w Autol Art, Open
ICD-10-PCS	_02100AW	Bypass 1 Cor Art from Aorta with Autol Art, Open Approach
ICD-10-PCS	_02100Z8	Bypass 1 Cor Art from R Int Mammary, Open Approach
ICD-10-PCS	_02100Z9	Bypass 1 Cor Art from L Int Mammary, Open Approach
ICD-10-PCS	_021109W	Bypass 2 Cor Art from Aorta with Autol Vn, Open Approach
ICD-10-PCS	_02110A3	Bypass 2 Cor Art from Cor Art with Autol Art, Open Approach
ICD-10-PCS	_021209W	Bypass 3 Cor Art from Aorta with Autol Vn, Open Approach
ICD-10-PCS	_0213093	Bypass 4+ Cor Art from Cor Art with Autol Vn, Open Approach
ICD-10-PCS	_0270346	Dilate 1 Cor Art, Bifurc, w Drug-elut Intra, Perc
ICD-10-PCS	_027034Z	Dilation of 1 Cor Art with Drug-elut Intra, Perc Approach
ICD-10-PCS	_027036Z	Dilation of 1 Cor Art with 3 Drug-elut, Perc Approach
ICD-10-PCS	_02703DZ	Dilation of 1 Cor Art with Intralum Dev, Perc Approach
ICD-10-PCS	_02703Z6	Dilation of 1 Cor Art, Bifurc, Perc Approach
ICD-10-PCS	_02703ZZ	Dilation of Coronary Artery, One Artery, Perc Approach
ICD-10-PCS	_027134Z	Dilation of 2 Cor Art with Drug-elut Intra, Perc Approach
ICD-10-PCS	_0271356	Dilate of 2 Cor Art, Bifurc, with 2 Drug-elut, Perc Approach
ICD-10-PCS	_027135Z	Dilation of 2 Cor Art with 2 Drug-elut, Perc Approach
ICD-10-PCS	_0272346	Dilate 3 Cor Art, Bifurc, w Drug-elut Intra, Perc
ICD-10-PCS	_027234Z	Dilation of 3 Cor Art with Drug-elut Intra, Perc Approach
ICD-9-CM	412	OLD MYOCARDIAL INFARCT
ICD-9-CM	430	SUBARACHNOID HEMORRHAGE
ICD-9-CM	431	INTRACEREBRAL HEMORRHAG
ICD-9-CM	436	Acute, but ill-defined, cerebrovascular disease
ICD-9-CM	3950	RHEUMAT AORTIC STENOSIS
ICD-9-CM	4100	Acute myocardial infarction of anterolateral wall
ICD-9-CM	4104	Acute myocardial infarction of other inferior wall
ICD-9-CM	4107	Subendocardial infarction
ICD-9-CM	4110	POST MI SYNDROME
ICD-9-CM	4111	INTERMED CORONARY SYND
ICD-9-CM	4130	ANGINA DECUBITUS

ICD Type	ICD Code	Description
ICD-9-CM	4131	PRINZMETAL ANGINA
ICD-9-CM	4139	ANGINA PECTORIS NEC/NOS
ICD-9-CM	4140	Coronary atherosclerosis
ICD-9-CM	4141	Aneurysm and dissection of heart
ICD-9-CM	4142	CHR TOT OCCLUS COR ARTR
ICD-9-CM	4143	COR ATH D/T LPD RCH PLA
ICD-9-CM	4144	COR ATH D/T CALC COR LS
ICD-9-CM	4148	CHR ISCHEMIC HRT DIS NE
ICD-9-CM	4149	CHR ISCHEMIC HRT DIS NO
ICD-9-CM	4321	SUBDURAL HEMORRHAGE
ICD-9-CM	4329	INTRACRANIAL HEMORR NOS
ICD-9-CM	4331	Occlusion and stenosis of carotid artery
ICD-9-CM	4333	Occlusion and stenosis of multiple and bilateral precerebral arteries
ICD-9-CM	4350	BASILAR ARTERY SYNDROME
ICD-9-CM	4351	VERTEBRAL ARTERY SYNDRO
ICD-9-CM	4352	SUBCLAVIAN STEAL SYNDRO
ICD-9-CM	4353	VERTBROBASLR ARTERY SYN
ICD-9-CM	4358	TRANS CEREB ISCHEMIA NE
ICD-9-CM	4359	TRANS CEREB ISCHEMIA NO
ICD-9-CM	4370	CEREBRAL ATHEROSCLEROSI
ICD-9-CM	4371	AC CEREBROVASC INSUF NO
ICD-9-CM	4372	HYPERTENS ENCEPHALOPATH
ICD-9-CM	4373	NONRUPT CEREBRAL ANEURY
ICD-9-CM	4375	MOYAMOYA DISEASE
ICD-9-CM	4376	NONPYOGEN THROMBOS SINU
ICD-9-CM	4377	TRANSIENT GLOBAL AMNESI
ICD-9-CM	4378	CEREBROVASC DISEASE NEC
ICD-9-CM	4379	CEREBROVASC DISEASE NOS
ICD-9-CM	4380	LATE EF CV DIS-COGNF DE
ICD-9-CM	4384	Monoplegia of lower limb
ICD-9-CM	4386	ALTERATION OF SENSATION
ICD-9-CM	4387	DISTURBANCES OF VISION
ICD-9-CM	4389	LATE EFFECT CV DIS NOS
ICD-9-CM	4419	AORTIC ANEURYSM NOS
ICD-9-CM	4439	PERIPH VASCULAR DIS NOS
ICD-9-CM	25070	DMII CIRC NT ST UNCNTRL
ICD-9-CM	25071	DMI CIRC NT ST UNCNTRLD
ICD-9-CM	25072	DMII CIRC UNCNTRLD
ICD-9-CM	25073	DMI CIRC UNCNTRLD
ICD-9-CM	41000	AMI ANTEROLATERAL,UNSPE
ICD-9-CM	41001	AMI ANTEROLATERAL, INIT
ICD-9-CM	41010	AMI ANTERIOR WALL,UNSPE
ICD-9-CM	41011	AMI ANTERIOR WALL, INIT

ICD Type	ICD Code	Description
ICD-9-CM	41012	AMI ANTERIOR WALL,SUBSE
ICD-9-CM	41020	AMI INFEROLATERAL,UNSPE
ICD-9-CM	41021	AMI INFEROLATERAL, INIT
ICD-9-CM	41030	AMI INFEROPOST, UNSPEC
ICD-9-CM	41031	AMI INFEROPOST, INITIAL
ICD-9-CM	41040	AMI INFERIOR WALL,UNSPE
ICD-9-CM	41041	AMI INFERIOR WALL, INIT
ICD-9-CM	41042	AMI INFERIOR WALL,SUBSE
ICD-9-CM	41051	AMI LATERAL NEC, INITIA
ICD-9-CM	41060	TRUE POST INFARCT,UNSPE
ICD-9-CM	41061	TRUE POST INFARCT, INIT
ICD-9-CM	41070	SUBENDO INFARCT, UNSPEC
ICD-9-CM	41071	SUBENDO INFARCT, INITIA
ICD-9-CM	41072	SUBENDO INFARCT, SUBSEQ
ICD-9-CM	41080	AMI NEC, UNSPECIFIED
ICD-9-CM	41081	AMI NEC, INITIAL
ICD-9-CM	41082	AMI NEC, SUBSEQUENT
ICD-9-CM	41090	AMI NOS, UNSPECIFIED
ICD-9-CM	41091	AMI NOS, INITIAL
ICD-9-CM	41092	AMI NOS, SUBSEQUENT
ICD-9-CM	41181	ACUTE COR OCCLSN W/O MI
ICD-9-CM	41189	AC ISCHEMIC HRT DIS NEC
ICD-9-CM	41400	COR ATH UNSP VSL NTV/GF
ICD-9-CM	41401	CRNRY ATHRSCL NATVE VSS
ICD-9-CM	41402	CRN ATH ATLG VN BPS GRF
ICD-9-CM	41404	COR ATH ARTRY BYPAS GRF
ICD-9-CM	41405	COR ATH BYPASS GRAFT NO
ICD-9-CM	41406	COR ATH NATV ART TP HRT
ICD-9-CM	41407	COR ATH BPS GRAFT TP HR
ICD-9-CM	41410	ANEURYSM OF HEART
ICD-9-CM	41411	ANEURYSM CORONARY VESSE
ICD-9-CM	41412	DISSECTION COR ARTERY
ICD-9-CM	43300	OCL BSLR ART WO INFRCT
ICD-9-CM	43310	OCL CRTD ART WO INFRCT
ICD-9-CM	43311	OCL CRTD ART W INFRCT
ICD-9-CM	43320	OCL VRTB ART WO INFRCT
ICD-9-CM	43321	OCL VRTB ART W INFRCT
ICD-9-CM	43330	OCL MLT BI ART WO INFRC
ICD-9-CM	43331	OCL MLT BI ART W INFRCT
ICD-9-CM	43380	OCL SPCF ART WO INFRCT
ICD-9-CM	43381	OCL SPCF ART W INFRCT
ICD-9-CM	43390	OCL ART NOS WO INFRCT
ICD-9-CM	43391	OCL ART NOS W INFRCT

ICD Type	ICD Code	Description
ICD-9-CM	43400	CRBL THRMBS WO INFRCT
ICD-9-CM	43401	CRBL THRMBS W INFRCT
ICD-9-CM	43410	CRBL EMBLSM WO INFRCT
ICD-9-CM	43411	CRBL EMBLSM W INFRCT
ICD-9-CM	43490	CRBL ART OC NOS WO INFR
ICD-9-CM	43491	CRBL ART OCL NOS W INFR
ICD-9-CM	43810	LATE EF-SPCH/LNG DEF NO
ICD-9-CM	43811	LATE EFF CV DIS-APHASIA
ICD-9-CM	43812	LATE EFF CV DIS-DYSPHSI
ICD-9-CM	43813	LATE EFF CV-DYSARTHRIA
ICD-9-CM	43819	LATE EF-SPCH/LANG DF NE
ICD-9-CM	43820	LATE EF-HEMPLGA SIDE NO
ICD-9-CM	43821	LATE EF-HEMPLGA DOM SID
ICD-9-CM	43822	LATE EF-HEMIPLGA NON-DO
ICD-9-CM	43831	LATE EF-MPLGA UP LMB DO
ICD-9-CM	43841	LTE EF-MPLGA LOW LMB DO
ICD-9-CM	43882	LATE EF CV DIS DYSPHAGI
ICD-9-CM	43883	FACIAL WEAKNESS
ICD-9-CM	43884	ATAXIA
ICD-9-CM	43885	VERTIGO
ICD-9-CM	43889	LATE EFFECT CV DIS NEC
ICD-9-CM	44020	ATHSCL EXTRM NTV ART NO
ICD-9-CM	44021	ATH EXT NTV AT W CLAUDC
ICD-9-CM	44022	ATH EXT NTV AT W RST PN
ICD-9-CM	44023	ATH EXT NTV ART ULCRTIO
ICD-9-CM	44024	ATH EXT NTV ART GNGRENE
ICD-9-CM	44029	ATHRSC EXTRM NTV ART OT
ICD-9-CM	44381	ANGIOPATHY IN OTHER DIS
ICD-9-CM	44389	PERIPH VASCULAR DIS NEC
ICD-9-PCS	3606	INS NONDRUG ELUT COR ST
ICD-9-PCS	3607	INS DRUG-ELUT CORONRY ST
ICD-9-PCS	3611	AORTOCOR BYPAS-1 COR ART
ICD-9-PCS	3612	AORTOCOR BYPAS-2 COR ART
ICD-9-PCS	3613	AORTOCOR BYPAS-3 COR ART
ICD-9-PCS	3615	1 INT MAM-COR ART BYPASS
ICD-9-PCS	3616	2 INT MAM-COR ART BYPASS
ICD-9-PCS	3619	HRT REVAS BYPS ANAS NEC
ICD-9-PCS	_0066	PTCA OR CORONARY ATHER

Table S2. Prescription lipid lowering therapy drugs.

Brand Name	Generic Name
PRALUENT PEN	alirocumab
EZETIMIBE-SIMVASTATIN	ezetimibe/simvastatin
VYTORIN	ezetimibe/simvastatin
CHOLESTYRAMINE	cholestyramine (with sugar)
CHOLESTYRAMINE LIGHT	cholestyramine/aspartame
COLESTIPOL HCL	colestipol HCl
PREVALITE	cholestyramine/aspartame
WELCHOL	colesevelam HCl
ANTARA	fenofibrate,micronized
FENOFIBRATE	fenofibrate
FENOFIBRATE	fenofibrate nanocrystallized
FENOFIBRATE	fenofibrate,micronized
FENOFIBRIC ACID	fenofibric acid (choline)
GEMFIBROZIL	gemfibrozil
TRICOR	fenofibrate nanocrystallized
ATORVASTATIN CALCIUM	atorvastatin calcium
CRESTOR	rosuvastatin calcium
FLUVASTATIN SODIUM	fluvastatin sodium
LIPITOR	atorvastatin calcium
LIVALO	pitavastatin calcium
LOVASTATIN	lovastatin
PRAVASTATIN SODIUM	pravastatin sodium
ROSUVASTATIN CALCIUM	rosuvastatin calcium
SIMVASTATIN	simvastatin
NIACIN ER	niacin
EZETIMIBE	ezetimibe
ZETIA	ezetimibe
LOVAZA	omega-3 acid ethyl esters
OMEGA-3 ACID ETHYL ESTERS	omega-3 acid ethyl esters
VASCEPA	icosapent ethyl

Table S3. Prescription antihypertensive drugs.

Brand Name	Generic Name
ACCURETIC	quinapril/hydrochlorothiazide
ACEBUTOLOL HCL	acebutolol HCl
ACETAZOLAMIDE	acetazolamide
ADEMPAS	riociguat
AMILORIDE HCL	amiloride HCl
AMILORIDE-HYDROCHLOROTHIAZIDE	amiloride/hydrochlorothiazide
AMLODIPINE BESYLATE	amlodipine besylate
AMLODIPINE BESYLATE-BENAZEPRIL	amlodipine besylate/benazepril
AMLODIPINE-OLMESARTAN	amlodipine bes/olmesartan med
AMLODIPINE-VALSARTAN	amlodipine besylate/valsartan
AMLODIPINE-VALSARTAN-HCTZ	amlodipine/valsartan/hcthiazid
ATENOLOL	atenolol
ATENOLOL-CHLORTHALIDONE	atenolol/chlorthalidone
AZOR	amlodipine bes/olmesartan med
BENAZEPRIL HCL	benazepril HCl
BENAZEPRIL-HYDROCHLOROTHIAZIDE	benazepril/hydrochlorothiazide
BENICAR	olmesartan medoxomil
BENICAR HCT	olmesartan/hydrochlorothiazide
BISOPROLOL FUMARATE	bisoprolol fumarate
BISOPROLOL-HYDROCHLOROTHIAZIDE	bisoprolol/hydrochlorothiazide
BUMETANIDE	bumetanide
BYSTOLIC	nebivolol HCl
CANDESARTAN CILEXETIL	candesartan cilexetil
CANDESARTAN-HYDROCHLOROTHIAZID	candesartan/hydrochlorothiazid
CAPTOPRIL	captopril
CAPTOPRIL-HYDROCHLOROTHIAZIDE	captopril/hydrochlorothiazide
CARDIZEM LA	diltiazem HCl
CARTIA XT	diltiazem HCl
CARVEDILOL	carvedilol
CHLORTHALIDONE	chlorthalidone
CLONIDINE	clonidine
CLONIDINE HCL	clonidine HCl
COREG CR	carvedilol phosphate
COZAAR	losartan potassium
DILTIAZEM 12HR ER	diltiazem HCl
DILTIAZEM 24HR CD	diltiazem HCl
DILTIAZEM 24HR ER	diltiazem HCl
DILTIAZEM ER	diltiazem HCl
DILTIAZEM HCL	diltiazem HCl
DILT-XR	diltiazem HCl
DOXAZOSIN MESYLATE	doxazosin mesylate
DYAZIDE	triamterene/hydrochlorothiazid
EDARBI	azilsartan medoxomil

Brand Name	Generic Name
EDARBYCLOR	azilsartan med/chlorthalidone
ENALAPRIL MALEATE	enalapril maleate
ENALAPRIL-HYDROCHLOROTHIAZIDE	enalapril/hydrochlorothiazide
ENTRESTO	sacubitril/valsartan
EPLERENONE	eplerenone
EXFORGE	amlodipine besylate/valsartan
FELODIPINE ER	felodipine
FOSINOPRIL SODIUM	fosinopril sodium
FOSINOPRIL-HYDROCHLOROTHIAZIDE	fosinopril/hydrochlorothiazide
FUROSEMIDE	furosemide
HYDRALAZINE HCL	hydralazine HCl
HYDROCHLOROTHIAZIDE	hydrochlorothiazide
INDAPAMIDE	indapamide
IRBESARTAN	irbesartan
IRBESARTAN-HYDROCHLOROTHIAZIDE	irbesartan/hydrochlorothiazide
ISRADIPINE	isradipine
LABETALOL HCL	labetalol HCl
LASIX	furosemide
LETAIRIS	ambrisentan
LISINOPRIL	lisinopril
LISINOPRIL-HYDROCHLOROTHIAZIDE	lisinopril/hydrochlorothiazide
LOSARTAN POTASSIUM	losartan potassium
LOSARTAN-HYDROCHLOROTHIAZIDE	losartan/hydrochlorothiazide
MATZIM LA	diltiazem HCl
METHAZOLAMIDE	methazolamide
METHYLDOPA	methyldopa
METHYLDOPA-HYDROCHLOROTHIAZIDE	methyldopa/hydrochlorothiazide
METOLAZONE	metolazone
METOPROLOL SUCCINATE	metoprolol succinate
METOPROLOL TARTRATE	metoprolol tartrate
METOPROLOL-HYDROCHLOROTHIAZIDE	metoprolol/hydrochlorothiazide
MINOXIDIL	minoxidil
MOEXIPRIL HCL	moexipril HCl
NADOLOL	nadolol
NIFEDIPINE	nifedipine
NIFEDIPINE ER	nifedipine
NISOLDIPINE	nisoldipine
OLMESARTAN MEDOXOMIL	olmesartan medoxomil
OLMESARTAN-AMLODIPINE-HCTZ	olmesartan/amlodipin/hcthiazid
OLMESARTAN-HYDROCHLOROTHIAZIDE	olmesartan/hydrochlorothiazide
PERINDOPRIL ERBUMINE	perindopril erbumine
PRAZOSIN HCL	prazosin HCl

Brand Name	Generic Name
PROPRANOLOL HCL	propranolol HCl
PROPRANOLOL HCL ER	propranolol HCl
QUINAPRIL HCL	quinapril HCl
QUINAPRIL-HYDROCHLOROTHIAZIDE	quinapril/hydrochlorothiazide
RAMIPRIL	ramipril
REVATIO	sildenafil citrate
SILDENAFIL	sildenafil citrate
SPIRONOLACTONE	spironolactone
SPIRONOLACTONE-HCTZ	spironolact/hydrochlorothiazid
TARKA	trandolapril/verapamil HCl
TAZTIA XT	diltiazem HCl
TEKTURNA	aliskiren hemifumarate
TELMISARTAN	telmisartan
TELMISARTAN-HYDROCHLOROTHIAZID	telmisartan/hydrochlorothiazid
TENORMIN	atenolol
TERAZOSIN HCL	terazosin HCl
TIMOLOL MALEATE	timolol maleate
TOPROL XL	metoprolol succinate
TORSEMIDE	torsemide
TRACLEER	bosentan
TRANDOLAPRIL	trandolapril
TRANDOLAPRIL-VERAPAMIL ER	trandolapril/verapamil HCl
TRIAMTERENE-HYDROCHLOROTHIAZID	triamterene/hydrochlorothiazid
TRIBENZOR	olmesartan/amlodipin/hcthiazid
VALSARTAN	valsartan
VALSARTAN-HYDROCHLOROTHIAZIDE	valsartan/hydrochlorothiazide
VERAPAMIL ER	verapamil HCl
VERAPAMIL ER PM	verapamil HCl
VERAPAMIL HCL	verapamil HCl
VERAPAMIL SR	verapamil HCl