

Clinical and Economic Outcomes of a Collaborative Cardiology Care Program

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Germany's health care system does not have formal gatekeeping procedures or a system of medical homes. The resulting fragmentation between primary and specialist care has been criticized.¹ Fragmentation of health care provision is characterized by poor continuity and coordination of care, leading to unnecessary procedures and high costs (the highest as a percentage of gross domestic product in Europe).² Chronic cardiac conditions are the leading cause of death in Germany.³ Patients with such conditions can benefit from structured and coordinated care.⁴⁻⁶ In Germany, 2 major approaches currently exist to optimizing health care for patients with chronic conditions: disease management programs (DMPs) and selective care contracts.^{7,8} DMPs are structured care programs for patients with specific conditions. Based on disease-specific and evidence-based guidelines, they aim to improve continuous and coordinated care. Evaluations of German DMPs show that they have been successful in improving care.⁹⁻¹² Currently, the only cardiac condition for which a DMP exists is coronary heart disease (CHD). Since 2000, selective care contracts have allowed direct contracting between providers and statutory health insurers.⁷ Programs have also been launched to strengthen primary care and introduce gatekeeping. The largest such general practitioner–centered care (GPCC) program was established by the AOK health insurance fund in Baden-Wuerttemberg in 2008, based on § 73b of the German Social Code Book V. Participation in GPCC is voluntary for both GPs and patients. Patients who enroll agree to accept the gatekeeping system and, when they require medical assistance, primarily to consult GPs. Specialist care requires referral by the GP (except for emergencies, gynecologists, eye specialists, and pediatricians). The GPCC program aims to improve quality, coordinate care, and employ evidence-based practices. Evaluation of the GPCC program in Baden-Wuerttemberg has shown improvements in coordination and guideline adherence and reduced hospital admissions.^{13,14} Adverse clinical outcomes for patients with both diabetes and cardiac conditions have also improved compared with usual care.^{15,16}

Since 2010, the cardiology contract (according to § 73c of the German Social Code Book V) has extended GPCC to include a collaborative care program that involves GPs and cardiologists.

ABSTRACT

OBJECTIVES: We evaluated a collaborative care program aimed at improving cooperation among general practitioners (GPs) and cardiologists in Baden-Wuerttemberg, Germany. The program focused on improving care for patients with chronic cardiac conditions.

STUDY DESIGN: We conducted a retrospective cohort study. The observation period was 2 years.

METHODS: The study was based on claims data and compared groups of patients who participated in the collaborative care program (GP-centered care and the cardiology contract) with patients receiving usual care. The evaluation focused on care coordination, quality, health service utilization, and costs in patients with heart failure, coronary heart disease, heart rhythm disorders, and/or valvular heart disease (disease cohorts). Multivariable regression models were used to adjust for differences in patient characteristics between the groups.

RESULTS: Across all disease cohorts, participation in the collaborative care program was associated with better care coordination and improved quality in a broad range of indicators (pharmacotherapy and vaccination). Results showed lower emergency service utilization and hospitalizations, lower consultation frequencies with GPs and specialists, and a shift from inpatient to outpatient procedures. Program participation resulted in higher costs for outpatient cardiologist treatment, but disease-specific costs were lower overall.

CONCLUSIONS: The results underline evidence that health care service programs that strengthen collaboration between GPs and cardiologists can substantially improve the care of patients with chronic cardiac conditions while simultaneously reducing costs.

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Within GPCC, participating GPs are automatically part of the cardiology contract, whereas patients are free to enroll additionally in the cardiology contract by signing a written form of consent. The contract aims to improve primary care–specialist collaboration and evidence-based care of cardiac conditions. The main characteristics of the program are shown in the [Figure](#).

Based on claims data, we assessed clinical and economic outcomes for the collaborative care program for chronic cardiac conditions, and we compared them with usual care.

METHODS

Study Design

This retrospective longitudinal evaluation study (observation period of 2 years) compares patients enrolled in the collaborative care program (GPCC and cardiology contract; intervention group [IG]) with patients receiving usual care (control group [CG]) who had enrolled in neither GPCC nor the cardiology contract. Based on disease status in 2014, patients were assigned to the following disease cohorts: heart failure (HF; *International Classification of Diseases, Tenth Revision* code I50), CHD (I20–I25), heart rhythm disorders (HRDs; I42.80, I44–I49, Q24.6), and valvular heart disease (VHD; I05–I08, I34–I39, Q20–Q26). Specific indicators were analyzed in the subcohort of patients with atrial fibrillation (AF; I48).

Assignment to multiple cohorts was possible (patients with more than 1 of the conditions).

The evaluation was approved by the local ethics committees of the Department of Medicine of Goethe University in Frankfurt (No. 291/17) and Jena University Hospital (No. 5186-06/17). The evaluation is registered in the German Clinical Trials Register (No. DRKS00014859).

Data Source and Setting

Our analyses were based on claims data provided by AOK Baden-Wuerttemberg. Baden-Wuerttemberg is a state in the southwest of Germany (about 10.7 million inhabitants). Participation in the collaborative care program was offered to AOK Baden-Wuerttemberg insurees. AOK Baden-Wuerttemberg is the largest health insurance fund in the state (4.4 million insurees).

Study Population

Eligible patients had to be at least 18 years old in 2014 and live in Baden-Wuerttemberg. They had to have at least 1 of the cardiac

TAKEAWAY POINTS

Participation in a collaborative care program involving general practitioners and cardiology specialists led to substantially improved care for patients with chronic cardiac conditions.

- ▶ The program is associated with better pharmacotherapy guideline adherence, reduced emergency service utilization, and fewer hospitalizations.
- ▶ The program resulted in significantly lower disease-specific costs.
- ▶ The evaluation was based on a large data set, and it was possible to adjust for a broad set of potential confounders.

FIGURE. Characteristics of the Cardiology Contract to Improve Coordinated Care for Patients With Cardiac Conditions

- Cardiologists meet specific diagnostic requirements (eg, provision of echocardiography).
- Participation in disease management programs encouraged
- Appointments for regular referrals within 2 weeks and for urgent referrals on the same day
- Structured communication between GPs and cardiologists (templates for referrals, feedback to the GP within 3 days)
- GPs and cardiologists both participate in peer-review groups on pharmacotherapy.
- Electronic quality control system for interventional cardiology is required.
- Preventive interventions offered to patients (eg, nutrition counseling classes, fitness groups)
- The contract strengthens the role of evidence-based guidelines.
- Higher remuneration of cardiologists' outpatient care services compared with usual care
- Financial incentives for patient-physician communication, cost-effective pharmacotherapy, and fewer hospitalizations
- Team-based care: training and payment of physician assistants who help communicate with patients, coordinate care with GPs and other specialists, and assist in medication management

GP, general practitioner.

conditions mentioned above. Patients who were not continuously insured by AOK Baden-Wuerttemberg from 2014 through 2016 (excluding deaths in 2015 and 2016), who switched groups during the observation period, or who were enrolled in another selective care program were excluded from evaluation ([eAppendix A](#) [eAppendices available at ajmc.com]). Patients who were enrolled in the cardiology contract (for which enrollment in GPCC is required) and received care from a cardiologist as part of the collaborative care program at least once in 2014 were assigned to the IG. Patients who were not enrolled in the program and received usual care from a cardiologist who did not participate in the program at least once in 2014 were assigned to the CG. Both the IG and the CG were thus composed of patients who visited a cardiologist in order to ensure a representative sample of patients with actual cardiac care needs. Outcomes were assessed for the years 2015 and 2016.

Intervention

The intervention consisted of health care for cardiac conditions under the collaborative care program, as defined in the GPCC and

cardiology contracts. It is a complex multicomponent intervention. The components of GPCC are explained in more detail elsewhere.¹³ The characteristics of the cardiology contract that go beyond those of the GPCC are described in the Figure.

Outcome Measures

Contacts with outpatient cardiologists were analyzed to assess care coordination. Additionally, we assessed whether contacts were coordinated (referral by the GP). Disease-specific indicators based on previously published indicators were used for quality assessment.^{17,18} Most of those indicators were based on guideline-based pharmacotherapy or other evidence-based measures such as influenza immunization. Other relevant outcomes such as hospitalizations were also measured. Results for care coordination and quality assessment were reported for the years 2015 and 2016 combined. The assessment of health service utilization focused on relevant health economic indicators, and specifically the number of consultations, proportion of patients with at least 1 outpatient emergency cardiovascular consultation, number of cardiovascular hospitalizations, number of outpatient coronary interventions, and number of inpatient coronary interventions. For the health economic assessment, we also measured overall and specific (explicitly cardiology-related) costs from a health insurance perspective. Specific costs were calculated as the sum of the following: cost of cardiologist consultations (including outpatient coronary interventions by cardiologists), cost of pharmacotherapy prescribed by cardiologists, cost of outpatient emergency cardiovascular care, cost of cardiovascular hospitalization, cost of remedies prescribed by cardiologists, cost of therapeutic aids prescribed by cardiologists, and cost of home care prescriptions issued by cardiologists. For the overall cost assessment, all available cost categories were taken into account: outpatient consultations (GPs, cardiologists, other specialists), hospitalizations, ambulatory surgery in hospital, emergency service utilization, consultations in university and psychiatric outpatient clinics, drug prescriptions, remedy prescriptions, therapeutic aid prescriptions, home care prescriptions, and nursery care. Our health economic analyses separately assessed outcome measures for 2015 and 2016 to ensure that our data can be directly compared with utilization and cost data from other health services research, which is generally reported on an annual basis. Each outcome measure was prespecified in the study protocol.

Covariates

The observational study design meant that participant characteristics in the IG and CG could differ. To account for any such differences, a set of potential confounding factors was prespecified, based on their availability in the administrative data. The resulting covariates were assessed for each participant. Besides age and sex, the set of covariates accounted for socioeconomic characteristics, health service use, and health status. Health status was measured using the Charlson Comorbidity Index (CCI) score¹⁹ and selected cardiac

and noncardiac comorbidities.²⁰ In health economic analyses, an adjustment was made according to the Morbidity Index, as used in the German risk adjustment scheme ("Risikostrukturausgleich," used to calculate morbidity-adjusted funding needs of German statutory health insurers).²¹ Health service utilization outcomes and cost outcomes for the years 2015 and 2016 were also adjusted for survival status in 2015 and 2016 (death in 2015/2016: yes or no). Specifications of the covariates are shown in [eAppendix B](#). Because claims data were used, some potentially relevant covariates were unavailable (eg, household income, smoking status, laboratory data).

Data Preparation and Statistical Procedures

AOK Baden-Wuerttemberg provided pseudonymized data sets for the years 2014 to 2016. Descriptive statistics were calculated for all baseline characteristics, and unadjusted outcome measures were determined to compare intervention and control groups. Multivariable regression models used predefined covariates to adjust for patient characteristics and deal with imbalances between the groups. We used multivariable logistic regression for binary outcomes, multivariable negative binomial regression for count data, and multivariable linear regression for continuous outcomes. We calculated odds ratios and, where reasonable, rate ratios (RRs), taking into account person-time under risk, as well as mean differences. The application of covariates in the regression models was tested for collinearity, whereby the analyses revealed that exclusion of any covariates was not necessary. Adjustment using available covariates was not meaningful for some outcome indicators (mainly indicators for pharmacotherapy) and was not performed in these cases; we then compared intervention and control groups using χ^2 tests for categorical indicators and Mann-Whitney tests for continuous indicators. SAS version 9.4 (SAS Institute) and IBM SPSS Statistics version 22 (IBM) were used for statistical analyses.

RESULTS

Study Population

A total of 58,369 patients met the inclusion criteria and were assigned to at least 1 of the disease cohorts. Of these, 51.2% received care according to the cardiology contract (IG) and 48.8% received usual care (CG). Baseline characteristics by disease cohort are shown in [eAppendix C](#). There was substantial overlap across the cohorts in the study arms, with 5909 patients experiencing HF, CHD, HRDs, VHD, and AF. On average, participants in the IG had more comorbidities with a higher CCI score.

Care Coordination

In the IG, almost all specialist contacts followed a referral, indicating that the program has been successfully implemented, whereas the proportion of contacts that followed a referral was only about 65% in the CG. The mean number of per-patient contacts with different cardiologists was almost the same in both groups, with a tendency toward more contacts in the CG ([Table 1](#)).

TABLE 1. Care Coordination

	HF		CHD		HRDs		VHD	
	IG n = 13,404	CG n = 8776	IG n = 19,537	CG n = 16,696	IG n = 17,266	CG n = 15,770	IG n = 12,313	CG n = 9770
Proportion of cardiologist consultations following referral from GP in 2015 and 2016	99.1%	66.6%	98.5%	64.8%	98.8%	66.7%	98.0%	63.5%
Contacts with different cardiologists (mean in each group) in 2015 and 2016	1.85	1.89	1.82	1.91	1.81	1.86	1.83	1.91
	P = .007 ^a		P = .02 ^a		P = .046 ^a		P < .001 ^a	

CG, control group; CHD, coronary heart disease; HF, heart failure; HRD, heart rhythm disorder; IG, intervention group; VHD, valvular heart disease.

^aMann-Whitney test.

Quality Indicators

The set of quality indicators checks that treatments are recommended in current national guidelines. For patients with HF, we found that treatment with inhibitors of the renin-angiotensin-aldosterone system was of high quality in both groups but slightly better in the IG. Prescription of β -blockers was similarly high in both groups. Fewer than half the patients with a New York Heart Association class of at least III were taking a mineralocorticoid receptor agonist; the number in the CG was marginally higher. Patients with CHD received high-quality treatment, with a 5% higher proportion of statin prescriptions in the IG. More than 80% of patients with AF and an indication for anticoagulation received a statin. The proportion of patients vaccinated was much higher in the IG, but the proportion of vaccinated individuals was relatively low overall (Table 2).

Health Service Utilization

IG participants consulted cardiologists more frequently (Table 3) and at slightly higher cost (Table 4). The number of consultations with GPs and specialists (other than cardiologists) was substantially lower in the IG, before and after adjustment, and costs were correspondingly lower.

The proportion of patients with at least 1 outpatient coronary angiography, coronary intervention, or implantation of a cardiac pacemaker was higher (1.1- to 7.7-fold over all procedures and cohorts) in the IG. This was reflected in the lower proportion of patients who had at least 1 inpatient coronary angiography, coronary intervention, or implantation of a cardiac pacemaker (−7% to −20% over all procedures and cohorts) (Table 3).

In the IG, we also observed that a lower proportion of patients had at least 1 outpatient emergency cardiovascular consultation (CHD and HRDs). Additionally, patients had fewer days involving emergency physicians and rescue services that were followed by emergency cardiovascular hospitalization (HF and CHD). Furthermore, a lower proportion of patients underwent at least 1 emergency cardiovascular hospitalization (HF and VHD) (Table 3).

The number of cardiovascular hospitalizations in the IG was significantly lower in all disease cohorts. It was 7% lower in patients with HRDs (RR, 0.93; 95% CI, 0.88-0.99) and up to 12% lower in patients with HF (RR, 0.88; 95% CI, 0.82-0.94).

TABLE 2. Quality Indicators for Pharmacotherapy and Immunization

Indicator	Disease cohort	IG	CG	P ^a
ACE inhibitor or ARB in patients with HF	HF	81.8%	78.5%	<.001
β -Blocker in patients with HF and NYHA class \geq II	HF	78.6%	79.8%	.105
MCRA in patients with HF and NYHA class \geq III	HF	37.9%	40.8%	.011
Statin in patients with CHD	CHD	75.6%	70.1%	<.001
Antihypertensive drug in patients with CHD and hypertension	CHD	97.8%	97.4%	.014
β -Blocker in patients with CHD after MI	CHD	87.3%	84.4%	<.001
VKA in patients with AF ^b	HRD (AF)	49.6%	47.2%	.002
NOAC in patients with AF ^b	HRD (AF)	40.1%	40.8%	.348
VKA or NOAC in patients with AF ^b	HRD (AF)	83.7%	81.8%	.003
Influenza vaccination in patients with HF	HF	46.4%	37.6%	<.001
Influenza vaccination in patients with CHD	CHD	45.0%	37.1%	<.001

ACE, angiotensin-converting enzyme; AF, atrial fibrillation; ARB, angiotensin II receptor blocker; CHD, coronary heart disease; HF, heart failure; HRD, heart rhythm disorder; MCRA, mineralocorticoid receptor antagonist; MI, myocardial infarction; NOAC, non-vitamin K oral anticoagulant; NYHA, New York Heart Association; VKA, vitamin K antagonist.

^aChi-square test.

^bPatients with atrial fibrillation and a CHA₂DS₂-VASc (congestive heart failure, hypertension, age, diabetes mellitus, stroke, vascular disease, age, sex category) score \geq 3 points.

The results for health service utilization and costs reported here are for the year 2015 but are similar to those for 2016 (eAppendices D and E).

Specific and Overall Costs

Patients in the IG showed significantly lower specific costs per patient in all cohorts (Table 4). Per-patient costs were up to €271 lower in the HF cohort (95% CI, −€516 to −€25). This trend is also reflected in overall costs per patient, but statistical significance was reached only in patients with VHD (€478 lower; 95% CI, −€828 to −€128).

Major savings in specific costs were largely due to the lower cost of cardiovascular hospitalizations (up to €135 lower in the VHD

TABLE 3. Health Service Utilization by Disease Cohort, 2015

Resource utilization (per patient)	HF			CHD		
	IG n = 13,404 (mean [SD] or n [%]) ^a	CG n = 8776 (mean [SD] or n [%]) ^a	Adjusted difference (95% CI); P	IG n = 19,537 (mean [SD] or n [%]) ^a	CG n = 16,696 (mean [SD] or n [%]) ^a	Adjusted difference (95% CI); P
Outpatient care						
GP consultations (billed cases), ^b mean (SD)	4.59 (1.40)	5.34 (2.22)	0.85 (0.84-0.86) ($<.001$)	4.59 (1.34)	5.29 (2.10)	0.85 (0.84-0.86) ($<.001$)
Cardiologist consultations (billed cases), ^b mean (SD)	1.98 (1.53)	1.84 (1.60)	0.99 (0.97-1.01) (.309)	1.71 (1.39)	1.77 (1.50)	0.90 (0.88-0.91) ($<.001$)
Specialist (other than cardiologist) consultations (billed cases), ^b mean (SD)	7.83 (6.74)	9.69 (8.01)	0.80 (0.78-0.82) ($<.001$)	7.79 (6.65)	9.63 (7.59)	0.79 (0.78-0.81) ($<.001$)
Patients with at least 1 outpatient coronary angiography, ^c n (%)	233 (1.74)	101 (1.15)	1.28 (0.99-1.65) (.061)	447 (2.29)	213 (1.28)	1.78 (1.49-2.12) ($<.001$)
Patients with at least 1 outpatient coronary intervention, ^c n (%)	32 (0.24)	13 (0.15)	1.10 (0.55-2.20) (.784)	100 (0.51)	50 (0.30)	1.60 (1.12-2.29) (.011)
Patients with at least 1 outpatient implantation of cardiac pacemaker, ^c n (%)	N/A	N/A	N/A	N/A	N/A	N/A
Medication						
Number of drug prescriptions by GP, ^b mean (SD)	30.26 (20.25)	32.26 (23.23)	1.02 (1.00-1.04) (.024)	29.29 (19.15)	28.44 (21.08)	1.04 (1.03-1.05) ($<.001$)
Number of drug prescriptions by cardiologist, ^b mean (SD)	0.68 (2.67)	2.46 (8.72)	0.31 (0.28-0.35) ($<.001$)	0.52 (2.22)	2.22 (7.87)	0.25 (0.23-0.28) ($<.001$)
Emergency care						
Patients with at least 1 outpatient emergency cardiovascular consultation (billed cases), ^c n (%)	678 (5.06)	600 (6.84)	0.96 (0.85-1.09) (.545)	887 (4.54)	976 (5.85)	0.85 (0.77-0.94) (.002)
Days involving consultation with emergency physician and rescue service, followed by cardiovascular hospitalization, ^b mean (SD)	0.02 (0.18)	0.04 (0.24)	0.81 (0.67-0.99) (.035)	0.02 (0.14)	0.02 (0.18)	0.77 (0.64-0.94) (.008)
Hospital care						
Cardiovascular hospitalizations (billed cases), ^b mean (SD)	0.25 (0.67)	0.34 (0.78)	0.88 (0.82-0.94) ($<.001$)	0.23 (0.63)	0.26 (0.68)	0.91 (0.86-0.96) (.001)
Patients with at least 1 inpatient coronary angiography, ^c n (%)	816 (6.09)	601 (6.85)	0.85 (0.75-0.96) (.009)	1315 (6.73)	1267 (7.59)	0.85 (0.78-0.93) ($<.001$)
Patients with at least 1 inpatient coronary intervention, ^c n (%)	346 (2.58)	269 (3.07)	0.80 (0.67-0.95) (.013)	672 (3.44)	660 (3.95)	0.86 (0.76-0.96) (.010)
Patients with at least 1 inpatient implantation of cardiac stimulator, ^c n (%)	N/A	N/A	N/A	N/A	N/A	N/A
Patients with at least 1 emergency cardiovascular hospitalization, ^c n (%)	2417 (18.03)	1985 (22.62)	0.92 (0.85-1.00) (.043)	3251 (16.64)	3040 (18.21)	0.94 (0.89-1.00) (.058)

(continued »)

cohort; 95% CI, -€344 to -€74), and lower costs of pharmacotherapy prescribed by cardiologists (up to €160 lower in the HF cohort; 95% CI, -€256 to -€64). Major savings in overall costs can be observed in the cost of GP consultations, which were up to €182 lower per patient with HF (95% CI, -€202 to -€162), and specialist consultations (other than cardiologists), which were up to €126 lower per patient with HF (95% CI, -€218 to -€35).

DISCUSSION

For the years 2015 and 2016, we assessed outcomes of the cardiology contract in Baden-Wuerttemberg in terms of quality of care, health service utilization, and cost. The results show that health care for patients with cardiac conditions enrolled in the cardiology contract was associated with higher levels of care coordination, more guideline-adherent pharmacotherapy, less use of emergency

TABLE 3. (Continued) Health Service Utilization by Disease Cohort, 2015

Resource utilization (per patient)	HRDs			VHD		
	IG n = 17,266 (mean [SD] or n [%]) ^a	CG n = 15,770 (mean [SD] or n [%]) ^a	Adjusted difference (95% CI); P	IG n = 12,313 (mean [SD] or n [%]) ^a	CG n = 9770 (mean [SD] or n [%]) ^a	Adjusted difference (95% CI); P
Outpatient care						
GP consultations (billed cases), ^b mean (SD)	4.57 (1.33)	5.21 (2.16)	0.86 (0.85-0.87) ($<.001$)	4.52 (1.33)	5.10 (2.21)	0.87 (0.86-0.88) ($<.001$)
Cardiologist consultations (billed cases), ^b mean (SD)	1.83 (1.46)	1.77 (1.55)	0.94 (0.92-0.95) ($<.001$)	1.82 (1.45)	1.81 (1.52)	0.91 (0.89-0.93) ($<.001$)
Specialist (other than cardiologist) consultations (billed cases), ^b mean (SD)	7.97 (6.65)	9.86 (7.78)	0.79 (0.77-0.80) ($<.001$)	8.04 (6.81)	10.01 (7.84)	0.78 (0.76-0.80) ($<.001$)
Patients with at least 1 outpatient coronary angiography, ^c n (%)	260 (1.51)	124 (0.79)	1.62 (1.29-2.04) ($<.001$)	233 (1.89)	87 (0.89)	1.99 (1.53-2.58) ($<.001$)
Patients with at least 1 outpatient coronary intervention, ^c n (%)	N/A	N/A	N/A	N/A	N/A	N/A
Patients with at least 1 outpatient implantation of cardiac pacemaker, ^c n (%)	32 (0.19)	4 (0.03)	7.74 (2.65-22.60) ($<.001$)	N/A	N/A	N/A
Medication						
Number of drug prescriptions by GP, ^b mean (SD)	27.36 (19.17)	26.47 (20.87)	1.04 (1.02-1.05) ($<.001$)	26.27 (18.74)	24.94 (20.77)	1.04 (1.03-1.06) ($<.001$)
Number of drug prescriptions by cardiologist, ^b mean (SD)	0.54 (2.21)	2.13 (7.55)	0.26 (0.24-0.28) ($<.001$)	0.57 (2.21)	2.18 (7.43)	0.26 (0.24-0.29) ($<.001$)
Emergency care						
Patients with at least 1 outpatient emergency cardiovascular consultation (billed cases), ^c n (%)	826 (4.78)	1006 (6.38)	0.83 (0.75-0.91) ($<.001$)	567 (4.60)	519 (5.31)	0.98 (0.86-1.12) (.742)
Days involving consultation with emergency physician and rescue service, followed by cardiovascular hospitalization, ^b mean (SD)	0.02 (0.15)	0.02 (0.18)	0.91 (0.78-1.08) (.284)	0.02 (0.15)	0.02 (0.20)	0.83 (0.66-1.05) (.120)
Hospital care						
Cardiovascular hospitalizations (billed cases), ^b mean (SD)	0.23 (0.64)	0.26 (0.68)	0.93 (0.88-0.99) (.022)	0.23 (0.64)	0.27 (0.72)	0.89 (0.83-0.96) (.002)
Patients with at least 1 inpatient coronary angiography, ^c n (%)	919 (5.32)	817 (5.18)	0.93 (0.84-1.04) (.189)	706 (5.73)	590 (6.04)	0.88 (0.78-0.99) (.037)
Patients with at least 1 inpatient coronary intervention, ^c n (%)	N/A	N/A	N/A	N/A	N/A	N/A
Patients with at least 1 inpatient implantation of cardiac stimulator, ^c n (%)	138 (0.80)	156 (0.99)	0.85 (0.66-1.08) (.186)	N/A	N/A	N/A
Patients with at least 1 emergency cardiovascular hospitalization, ^c n (%)	2833 (16.41)	2818 (17.87)	0.96 (0.90-1.03) (.269)	1982 (16.10)	1750 (17.91)	0.92 (0.85-1.00) (.044)

CG, control group; CHD, coronary heart disease; HF, heart failure; HRD, heart rhythm disorder; IG, intervention group; GP, general practitioner; N/A, not applicable; VHD, valvular heart disease.

^aDepending on the applied statistical model, results are presented as mean (SD) (negative-binomial regression) or n (%) (logistic regression).

^bNegative-binomial regression: adjusted differences are rate ratios.

^cLogistic regression: adjusted differences are odds ratios.

care, fewer hospital admissions, and lower costs. As cost savings were combined with advantageous results on quality indicators, treatment under the collaborative care program is clearly preferable to usual care (“dominant” in health economic terms).

It appears plausible that the cardiology contract contributed to the improvements in clinical outcomes. Results are consistent with those of previous studies showing that multidisciplinary

interventions can improve care for patients with cardiac conditions.²² Our results do not permit us to identify precisely which aspects of the program are effective. However, we believe that the most relevant mechanisms are a strengthening of the GP’s role as continuous care provider,²³ improved coordination and communication between GPs and cardiologists,^{4,24} guideline adherence, and multidisciplinary (team-based) case management.²² An alternative explanation for

TABLE 4. Costs for Health Service Utilization by Disease Cohort, 2015

Cost position (per patient) in € ^a	HF			CHD		
	IG n = 13,404 (mean [SD])	CG n = 8776 (mean [SD])	Adjusted difference (95% CI); P	IG n = 19,537 (mean [SD])	CG n = 16,696 (mean [SD])	Adjusted difference (95% CI); P
Cardiovascular hospitalizations ^b	1560 (6740)	2021 (8553)	-104 [-322 to 114] (.349)	1293 (6020)	1395 (5953)	-53 [-182 to 77] (.424)
Cardiologist consultations ^b	258 (609)	215 (1272)	32 [3-60] (.026)	229 (558)	187 (1012)	28 [10-46] (.002)
GP consultations	497 (280)	666 (998)	-182 [-202 to -162] ($<.001$)	507 (261)	616 (814)	-147 [-160 to -134] ($<.001$)
Specialist (other than cardiologist) consultations	656 (2591)	970 (3848)	-126 [-218 to -35] (.006)	625 (2321)	830 (3234)	-91 [-151 to -32] (.003)
Drugs prescribed by cardiologists ^b	86 (1549)	365 (4745)	-160 [-257 to -64] (.001)	44 (630)	162 (1905)	-95 [-126 to -64] ($<.001$)
Therapeutic aids prescribed by cardiologists ^b	4 (86)	19 (194)	-9 [-14 to -5] ($<.001$)	3 (68)	10 (140)	-5 [-8 to -2] ($<.001$)
Home care prescribed by cardiologists ^b	3 (158)	30 (414)	-22 [-31 to -13] ($<.001$)	2 (132)	16 (314)	-11 [-17 to -5] ($<.001$)
Remedies prescribed by cardiologists ^b	1 (54)	11 (135)	-6 [-10 to -3] ($<.001$)	1 (47)	8 (117)	-5 [-8 to -3] ($<.001$)
Summarized costs						
Specific costs ^c	1937 (6989)	2694 (10,270)	-271 [-516 to -25] (.030)	1591 (6131)	1802 (6441)	-143 [-278 to -7] (.039)
Overall costs ^d	8715 (13,205)	11,909 (17,344)	-350 [-742 to 41] (.079)	7576 (11,873)	8785 (15,921)	-232 [-504 to 39] (.093)

(continued »)

improved clinical outcomes is that the participating physicians are inherently different from nonparticipating physicians. There is existing evidence that the effects of voluntary participation in value-based payment programs can be partially explained by patient or provider selection.²⁵

Overall, the cost of cardiologist consultations was higher (at a negative adjusted difference of consultations between IG and CG), which may reflect greater remuneration of cardiologists enrolled in the collaborative care program, as well as a higher number of outpatient coronary interventions. As we observed fewer inpatient and more outpatient interventions and, at the same time, noted fewer emergency events and cardiovascular hospitalizations, we attribute this development to the provision of more timely care. This interpretation is in line with previous research demonstrating that early cardiologist assessments can lower hospital readmissions and cost of care.²⁶ Furthermore, the majority of readmissions of patients with chest pain are low-risk cases who do not require an intervention.²⁷

It appears plausible that improved outpatient care, including more timely management of cardiac conditions, can lead to a reduction in complications. However, as clinical information is lacking, we believe that the hypothesized association merits further study.

Current discussion of the roles of primary and specialist care does not focus on whether GPs or specialists provide better care but instead on the optimal working relationship among primary care, specialists, and allied professions.²⁸ In an ideal collaborative care system, a primary care provider would take responsibility for care coordination, and specialists would be involved when necessary.²⁹ The difficulties involved in establishing such a system are the optimization of communication and the division of responsibilities between providers. One advantage of collaborative care observed in this study is the reduction in cardiologist drug prescriptions and the increase in GP drug prescriptions (Table 3). This suggests that specialists focused on recommendations and left long-term treatment to GPs.

TABLE 4. (Continued) Costs for Health Service Utilization by Disease Cohort, 2015

Cost position (per patient) in € ^a	HRDs			VHD		
	IG n = 17,266 (mean [SD])	CG n = 15,770 (mean [SD])	Adjusted difference (95% CI); P	IG n = 12,313 (mean [SD])	CG n = 9770 (mean [SD])	Adjusted difference (95% CI); P
Cardiovascular hospitalizations ^b	1268 (5712)	1406 (6489)	-131 [-268 to 6] (.061)	1541 (7163)	1821 (8086)	-135 [-344 to 74] (.204)
Cardiologist consultations ^b	231 (544)	168 (957)	44 [26-62] ($<.001$)	231 (573)	211 (1336)	6 [-22 to 34] (.677)
GP consultations	475 (342)	599 (757)	-152 [-166 to -139] ($<.001$)	469 (332)	580 (756)	-144 [-160 to -128] ($<.001$)
Specialist (other than cardiologist) consultations	614 (2273)	810 (3102)	-108 [-169 to -48] ($<.001$)	629 (2451)	834 (3180)	-123 [-200 to -46] (.002)
Drugs prescribed by cardiologists ^b	64 (1323)	196 (2115)	-112 [-153 to -71] ($<.001$)	60 (1266)	200 (1951)	-111 [-157 to -65] ($<.001$)
Therapeutic aids prescribed by cardiologists ^b	3 (67)	11 (138)	-6 [-9 to -3] ($<.001$)	2 (41)	10 (135)	-7 [-10 to -4] ($<.001$)
Home care prescribed by cardiologists ^b	1 (97)	22 (356)	-19 [-26 to -13] ($<.001$)	2 (132)	22 (362)	-16 [-24 to -9] ($<.001$)
Remedies prescribed by cardiologists ^b	1 (14)	10 (146)	-7 [-10 to -4] ($<.001$)	1 (15)	8 (112)	-5 [-8 to -3] ($<.001$)
Summarized costs						
Specific costs ^c	1588 (5939)	1836 (7218)	-231 [-379 to -83] (.002)	1858 (7355)	2296 (8537)	-268 [-485 to -50] (.016)
Overall costs ^d	7826 (12,549)	9204 (14,384)	-163 [-432 to 107] (.236)	7779 (12,796)	9302 (15,549)	-478 [-828 to -128] (.007)

CG, control group; CHD, coronary heart disease; HF, heart failure; HRD, heart rhythm disorder; IG, intervention group; VHD, valvular heart disease.

^aLinear regression: adjusted differences are mean differences.

^bThese cost positions contribute to specific costs.

^cSpecific costs include costs of cardiovascular hospitalizations, costs of cardiologist consultations, costs of drug prescriptions by cardiologists, costs of therapeutic aids prescribed by cardiologists, costs of home care prescribed by cardiologists, costs of remedies prescribed by cardiologists, costs of emergency service utilization involving cardiovascular diagnosis, and cost of ambulatory surgery in hospital (coronary angiography, coronary intervention, implantation of cardiac stimulator).

^dOverall costs include costs of outpatient consultations (general practitioners, cardiologists, other specialists), costs of hospitalizations, costs of ambulatory surgery in hospital, costs of emergency service utilization, costs of consultations in university and psychiatric ambulances, costs of drug prescriptions, costs of remedies prescriptions, costs of therapeutic aids prescriptions, costs of home care prescriptions, and costs of nursery care.

The cardiology contract was introduced after the DMP for coronary heart disease had already been implemented. Whereas DMPs focus on single-disease management, the cardiology contract in combination with the GPCC strengthens comprehensive and continuous care for patients, taking into account all their medical problems. As the participation in DMPs is encouraged in the cardiology contract, the proportion of participating patients is much higher than in the CG (eAppendix B).

Strengths and Limitations

The evaluation is based on a large data set, and it was possible to adjust for a broad set of potential confounders. The selection of participants was based on whether patients received health care either as part of the program or usual care and did not depend only on enrollment in the program. This ensured that the sample was representative of patients with actual cardiac care needs and not just patients who decided to enroll in the program or patients who

received (by default) usual care. The analysis of claims data for health care program evaluation has the advantage that participants are not usually aware of the evaluation, which prevents interviewer bias and the Hawthorne effect. Still, because participation in the cardiology contract is voluntary, some selection bias is possible, both on a patient and physician level. For example, it is reasonable to expect physicians who are interested in adopting a new health care model to be more likely to adhere to guidelines and engage in coordinated care.

A further limitation was overlap between cohorts, as this led to dependent findings and potential residual confounding, either due to factors that were not listed in our data (eg, household income, level of education, smoking status, individual contraindications, drug intolerances) or limitations in data resolution (eg, the severity of comorbidities we adjusted for). Finally, we evaluated the cardiology contract, which is a complex intervention, as a whole. Implementation research may help identify which of the contract's specific features explain our results.

CONCLUSIONS

This evaluation of the collaborative care program involving GPs and cardiologists in Baden-Wuerttemberg, Germany, focused on quality assessment, health service utilization, and cost. Our results support existing evidence that health care service programs that strengthen collaboration between GPs and specialists can substantially improve care of patients with chronic conditions. ■

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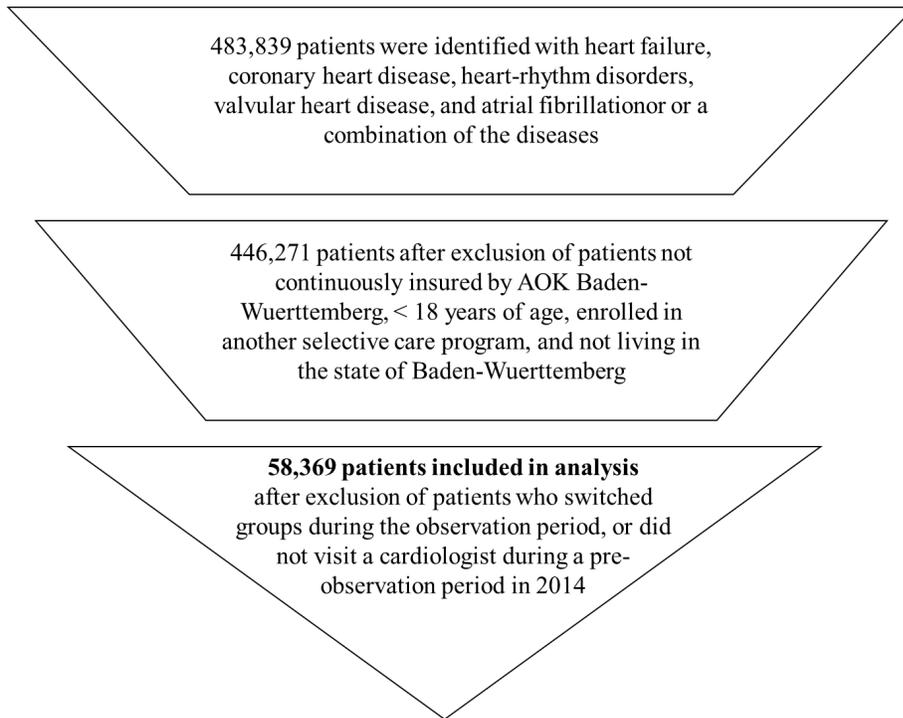
REFERENCES

- Nolte E, Knai C, Hofmarcher M, et al. Overcoming fragmentation in health care: chronic care in Austria, Germany and The Netherlands. *Health Econ Policy Law*. 2012;7(1):125-146. doi:10.1017/S1744133111000338
- Health at a glance: Europe 2018. Organisation for Economic Co-operation and Development. 2018. Accessed October 16, 2019. https://www.oecd-ilibrary.org/health-at-a-glance-europe-2018_5j8qqtK0x24.pdf?itemId=%2Fcontent%2Fpublication%2Fhealth_glance_eur-2018-en&mimeType=pdf
- Germany: country health profile 2017. Organisation for Economic Co-operation and Development. November 23, 2017. Accessed October 16, 2019. <https://read.oecd.org/10.1787/9789264283398-en?format=pdf>
- Falces C, Andrea R, Heras M, et al. Integration between cardiology and primary care: impact on clinical practice. Article in Spanish. *Rev Esp Cardiol*. 2011;64(7):564-571. doi:10.1016/j.recesp.2011.02.021
- Farmer SA, Casale PN, Gillam LD, et al. Payment reform to enhance collaboration of primary care and cardiology: a review. *JAMA Cardiol*. 2018;3(1):77-83. doi:10.1001/jamacardio.2017.4308

- Stewart S, Carrington MJ, Marwick TH, et al. Impact of home versus clinic-based management of chronic heart failure: the WHICH? (Which Heart Failure Intervention Is Most Cost-Effective & Consumer Friendly in Reducing Hospital Care) multicenter, randomized trial. *J Am Coll Cardiol*. 2012;60(14):1239-1248. doi:10.1016/j.jacc.2012.06.025
- Busse R, Blümel M, Knieps F, Bärnighausen T. Statutory health insurance in Germany: a health system shaped by 135 years of solidarity, self-governance, and competition. *Lancet*. 2017;390(10097):882-897. doi:10.1016/S0140-6736(17)31280-1
- Schlette S, Lisac M, Blum K. Integrated primary care in Germany: the road ahead. *Int J Integr Care*. 2009;9:e14. doi:10.5334/ijic.311
- Laxy M, Stark R, Meisinger C, et al. The effectiveness of German disease management programs (DMPs) in patients with type 2 diabetes mellitus and coronary heart disease: results from an observational longitudinal study. *Diabetol Metab Syndr*. 2015;7:77. doi:10.1186/s13098-015-0065-9
- Miksch A, Laux G, Ose D, et al. Is there a survival benefit within a German primary care-based disease management program? *Am J Manag Care*. 2010;16(1):49-54.
- Stock S, Drabik A, Büscher G, et al. German diabetes management programs improve quality of care and curb costs. *Health Aff (Millwood)*. 2010;29(12):2197-2205. doi:10.1377/hlthaff.2009.0799
- Mehring M, Donnachie E, Mutschler R, Hofmann F, Keller M, Schneider A. Disease management programs for patients with asthma in Germany: a longitudinal population-based study. *Respir Care*. 2013;58(7):1170-1177. doi:10.4187/respcare.01968
- Wensing M, Szecsenyi J, Stock C, Kolle PK, Laux G. Evaluation of a program to strengthen general practice care for patients with chronic disease in Germany. *BMC Health Serv Res*. 2017;17(1):62. doi:10.1186/s12913-017-2000-2
- Wensing M, Kolle PK, Szecsenyi J, Stock C, Laux G. Effects of a program to strengthen general practice care on hospitalisation rates: a comparative observational study. *Scand J Prim Health Care*. 2018;36(2):109-114. doi:10.1080/02813432.2018.1459429
- Wicke F, Karimova K, Kaufmann-Kolle P, Gerlach FM, Beyer M. Hausarztzentrierte Versorgung von Patienten mit kardiovaskulären Erkrankungen – Ergebnisse aus Baden-Württemberg. *Z Allg Med*. 2018;94(11):454-460. doi:10.3238/zfa.2018.0454-0460
- Karimova K, Uhlmann L, Hammer M, Guethlin C, Gerlach FM, Beyer M. The development of diabetes complications in GP-centered healthcare. *Am J Manag Care*. 2018;24(7):322-327.
- Freund T, Lux M. *Herzinsuffizienz – Qualitätsindikatoren für die Versorgung von Patienten mit Herzinsuffizienz*. 1st ed. AQUA-Institut für angewandte Qualitätsförderung und Forschung im Gesundheitswesen GmbH; 2012.
- Jeitler K, Semlitsch T. *Koronare Herzkrankheit – Qualitätsindikatoren für die Versorgung von Patienten mit koronarer Herzkrankheit*. 1st ed. AQUA-Institut für angewandte Qualitätsförderung und Forschung im Gesundheitswesen GmbH; 2012.
- Sundararajan V, Henderson T, Perry C, Muggivan A, Quan H, Ghali WA. New ICD-10 version of the Charlson comorbidity index predicted in-hospital mortality. *J Clin Epidemiol*. 2004;57(12):1288-1294. doi:10.1016/j.jclinepi.2004.03.012
- Braunstein JB, Anderson GF, Gerstenblith G, et al. Noncardiac comorbidity increases preventable hospitalizations and mortality among Medicare beneficiaries with chronic heart failure. *J Am Coll Cardiol*. 2003;42(7):1226-1233. doi:10.1016/s0735-1097(03)00947-1
- Gaskins M, Busse R. Morbidity-based risk adjustment in Germany: long in coming, but worth the wait? *EuroRespir*. 2009;15(3):29-32.
- Rich MW, Beckham V, Wittenberg C, Leven CL, Freedland KE, Carney RM. A multidisciplinary intervention to prevent the readmission of elderly patients with congestive heart failure. *N Engl J Med*. 1995;333(18):1190-1195. doi:10.1056/NEJM199511023331806
- Barker I, Steventon A, Deeny SR. Association between continuity of care in general practice and hospital admissions for ambulatory care sensitive conditions: cross sectional study of routinely collected, person level data. *BMJ*. 2017;356:j84. doi:10.1136/bmj.j84
- Foy R, Hempel S, Rubenstein L, et al. Meta-analysis: effect of interactive communication between collaborating primary care physicians and specialists. *Ann Intern Med*. 2010;152(4):247-258. doi:10.7326/0003-4819-152-4-201002160-00010
- Navathe AS, Emanuel EJ, Venkataramani AS, et al. Spending and quality after three years of Medicare's voluntary bundled payment for joint replacement surgery. *Health Aff (Millwood)*. 2020;39(1):58-66. doi:10.1377/hlthaff.2019.00466
- Tanguturi VK, Temin E, Yeh RW, et al. Clinical interventions to reduce preventable hospital readmission after percutaneous coronary intervention. *Circ Cardiovasc Qual Outcomes*. 2016;9(5):600-604. doi:10.1161/CIRCOUTCOMES.116.003086
- Tripathi A, Abbott JD, Fonarow GC, et al. Thirty-day readmission rate and costs after percutaneous coronary intervention in the United States: a national readmission database analysis. *Circ Cardiovasc Interv*. 2017;10(12):e005925. doi:10.1161/CIRCINTERVENTIONS.117.005925
- Katon WJ, Von Korff M, Lin E, Simon G. Rethinking practitioner roles in chronic illness: the specialist, primary care physician, and the practice nurse. *Gen Hosp Psychiatry*. 2001;23(3):138-144. doi:10.1016/s0163-8343(01)00136-0
- Rothman AA, Wagner EH. Chronic illness management: what is the role of primary care? *Ann Intern Med*. 2003;138(3):256-261. doi:10.7326/0003-4819-138-3-200302040-00034

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eAppendix A. Flow Chart Showing Inclusion and Exclusion Criteria



eAppendix B. Specifications of Covariates

Covariate	Operationalization (Comment)
Age	Age on January 1, 2015. Age-groups used for adjustment: 18-40, 41-50, 51-60, 61-70, 71-80, 81-90, ≥ 91
Sex	Male or female on January 1, 2015
Nationality	German or non-German on January 1, 2015
Insurance status	Primary member, related or retired on January 1, 2015 (in the German statutory health insurance system, insurees are either primary members or relatives of a primary member (children and non-working spouses) or retired; used for health economic outcomes analysis only
Occupational status	Employed or unemployed on January 1, 2015
Place of residence	Urban or rural (according to zip code and area classification of the Federal Institute for Research on Building, Urban Affairs and Spatial Development)
Nursing care grade	No nursing grade or registered nursing grade on January 1, 2015 (according to the official German grading system of nursing requirements)
Nursing home residence	Not residing in nursing home or residing in nursing home on January 1, 2015
Socioeconomic hardship status	Yes or no (a proxy for socioeconomic status; German health insurance grant exemption from self-payment fees if expenses exceed 2% [or 1% for chronically-ill-patients] of the yearly household income of insurees)
DMP CHD	Yes or no (participation in Disease Management Program for coronary heart disease)
DMP Diabetes	Yes or no (participation in Disease Management Program for diabetes mellitus)
NYHA-Grade	0 to 4 of the New York Heart Association Grade of Heart Failure, based on ICD-10 codes in the year 2014 (used only for the heart failure cohort)
Hospitalization with cardiac condition	Yes or no. Hospitalization in the year 2014 for any condition in ICD-10 chapter IX (diseases of the circulatory systems)
Influenza vaccination	Yes or no. Influenza vaccination in quarters 3 or 4 of the year 2014 or quarter 1 of 2015 and in quarters 3 or 4 of the year 2015 or quarter 1 of 2016 respectively
Comorbidities (for all comorbidities: at least two outpatient diagnoses in two different quarters of one year, or one inpatient diagnosis in one year, was required)	
Charlson score	0-37; based on diagnosed comorbidities in the year 2014, calculated according to Sundararajan et al. ¹⁹
Morbidity index (RSA Factor)	Measured using the morbidity weighting applied in the morbidity-based risk adjustment scheme in Germany (RSA, Risk Grouper); used for health economic outcomes analysis only

Count of HMGs	Number of hierarchical morbidity groups applied in the morbidity-based risk adjustment scheme in Germany (RSA, Risk Grouper); used for health economic outcomes analysis only
Renal insufficiency	ICD-10: N18.2, N18.3, N18.4, N18.5 , N18.8, N18.9
Diabetes	ICD-10: E10, E11
Hyperlipidemia	ICD-10: E78
Hypertension	ICD-10: I10-I15
Heart failure	ICD-10: I50
COPD	ICD-10: J44 (chronic obstructive pulmonary disease)
AF	ICD-10: I48 (atrial fibrillation)
Heart-rhythm disorder	ICD-10: I42.80, I44-I47, I49, Q24.6 (other than AF)
Myocardial infarction	ICD-10: I21, I22, I25.2
Coronary heart disease	ICD-10: I20-I25
Valvular heart disease	ICD-10: I05-I08, I34-I39, Q20-26
Depression	ICD-10: F32, F33
Pneumonia	ICD-10: J12-J18, U69.00, A40.3, J86, B95.3

eAppendix C. Baseline Characteristics of Disease Cohorts (2015)

	HF		CHD		HRD		VHD	
	IG n=13,404	CG n=8,776	IG n=19,537	CG n=16,696	IG n=17,266	CG n=15,770	IG n=12,313	CG n=9,770
Socio-economic parameters								
Sex (female)	44.8%	47.2%	37.1%	38.8%	46.5%	49.5%	50.1%	52.5%
Age (mean [SD])	72.9 [10.3]	74.2 [11.4]	72.0 [9.9]	72.1 [10.9]	72.7 [10.7]	72.9 [12.3]	72.3 [10.8]	72.0 [12.7]
Nationality (German)	91.5%	90.9%	89.1%	88.5%	92.0%	92.1%	90.2%	90.4%
Employed	13.1%	12.8%	15.4%	17.9%	14.4%	16.2%	14.6%	17.2%
Socioeconomic hardship status	30.7%	47.9%	29.4%	40.6%	27.7%	39.0%	27.6%	38.3%
Urban place of residence	46.5%	47.2%	48.9%	49.0%	46.8%	47.5%	49.7%	47.8%
Nursing home resident	0.6%	3.1%	0.3%	1.3%	0.4%	2.0%	0.4%	1.4%
Nursing care needs (nursing grade ≥ 1)	11.6%	23.0%	8.4%	12.9%	9.7%	16.2%	9.0%	13.9%
Health service utilization								
DMP Diabetes mellitus (Types I and II)	36.8%	25.7%	37.3%	25.9%	31.2%	20.5%	30.2%	20.0%
DMP CHD	41.7%	22.7%	61.3%	36.2%	32.5%	15.9%	33.6%	17.4%
Hospitalization in 2014	23.7%	37.3%	21.3%	27.6%	20.9%	27.9%	20.0%	25.5%
Influenza immunization (season 2014/2015)	49.3%	41.7%	47.3%	40.1%	47.8%	39.7%	47.6%	40.1%
Cardiovascular comorbidity								
Myocardial infarction (MI) in medical history	24.4%	21.4%	32.0%	29.4%	16.4%	13.3%	16.8%	13.3%
Hyperlipidemia	65.7%	60.2%	71.1%	68.0%	60.2%	55.1%	63.0%	58.2%
Hypertension	91.8%	90.0%	91.2%	88.1%	88.4%	84.5%	88.8%	83.7%
CHD	68.4%	63.0%	100%	100%	56.4%	47.0%	58.8%	49.5%
HF	100%	100%	47.0%	33.2%	51.4%	35.2%	53.0%	36.0%
AF	36.8%	42.1%	26.6%	26.0%	50.6%	54.7%	34.6%	34.7%
HRD	50.4%	43.3%	37.8%	31.7%	75.9%	71.1%	50.0%	38.0%
VHD	48.7%	40.1%	37.1%	29.0%	45.9%	33.7%	100%	100%
NYHA stage - not coded	23.0%	43.3%	-	-	-	-	-	-
- stage 1	13.1%	4.2%	-	-	-	-	-	-
- stage 2	30.1%	18.5%	-	-	-	-	-	-
- stage 3	26.5%	20.9%	-	-	-	-	-	-
- stage 4	7.2%	13.2%	-	-	-	-	-	-
Other comorbidities								
Depression	23.6%	23.4%	22.7%	21.5%	22.4%	21.3%	23.2%	21.0%
Chronic kidney disease	25.8%	31.3%	20.8%	20.0%	21.5%	21.4%	21.0%	20.6%
Diabetes mellitus	44.4%	43.0%	44.3%	40.4%	38.2%	34.2%	37.3%	32.0%
Chronic obstructive pulmonary disease	20.3%	21.5%	18.1%	16.6%	16.3%	14.9%	16.5%	15.0%
Pneumonia in 2014	5.5%	9.7%	4.2%	5.2%	4.5%	6.2%	4.4%	5.7%
Multimorbidity scores								
Charlson score (mean [SD])	4.6 [2.5]	4.4 [2.6]	4.0 [2.5]	3.4 [2.6]	3.7 [2.6]	3.1 [2.6]	3.7 [2.6]	3.1 [2.6]
RSA-Factor (mean [SD])	2.1 [1.6]	2.4 [2.0]	1.9 [1.5]	1.9 [1.6]	2.0 [1.5]	2.1 [1.7]	2.0 [1.5]	2.1 [1.7]
Number of occupied HMGs (mean [SD])	3.6 [2.2]	3.7 [2.4]	3.2 [2.2]	3.0 [2.2]	3.4 [2.1]	3.2 [2.2]	3.7 [2.1]	3.5 [2.2]
Mortality								
Patients deceased in 2015	5.5%	9.1%	4.0%	5.2%	4.3%	6.3%	4.4%	5.6%
Patients deceased in 2016	5.0%	8.0%	3.7%	5.1%	4.3%	5.8%	4.1%	5.6%

HF: Heart failure, CHD: Coronary heart disease, HRD: Heart rhythm disorder, VHD: Valvular heart disease, IG: Intervention group, CG: Control group, SD: Standard deviation, DMP: Disease management program, AF: Atrial fibrillation, NYHA: New York Heart Association, RSA-Factor: Morbidity Index used in the German risk adjustment scheme, HMGs: Hierarchical morbidity groups

eAppendix D. Health Service Utilization by Disease Cohort, 2016

Resource utilization (per patient)	HF			CHD			HRD			VHD		
	IG n=12,664 (mean [SD] or % [n]) ^a	CG n=7,818 (mean [SD] or % [n]) ^a	Adjusted difference (p value) [95% CI]	IG n=18,758 (mean [SD] or % [n]) ^a	CG n=15,511 (mean [SD] or % [n]) ^a	Adjusted difference (p value) [95% CI]	IG n=16,530 (mean [SD] or % [n]) ^a	CG n=14,491 (mean [SD] or % [n]) ^a	Adjusted difference (p value) [95% CI]	IG n=11,774 (mean [SD] or % [n]) ^a	CG n=9,056 (mean [SD] or % [n]) ^a	Adjusted difference (p value) [95% CI]
Outpatient care												
GP consultations (billed cases) ^b	4.63 [1.43]	6.18 [2.64]	0.73 (<0.001) [0.72; 0.74]	4.63 [1.39]	6.16 [2.53]	0.73 (<0.001) [0.72; 0.73]	4.57 [1.33]	5.21 [2.16]	0.86 (<0.001) [0.85; 0.87]	4.58 [1.38]	5.86 [2.63]	0.76 (<0.001) [0.75; 0.77]
Cardiologist consultations (billed cases) ^b	1.88 [1.54]	1.73 [1.59]	0.98 (0.082) [0.95; 1.00]	1.61 [1.35]	1.66 [1.48]	0.88 (<0.001) [0.86; 0.89]	1.73 [1.47]	1.65 [1.54]	0.92 (<0.001) [0.90; 0.94]	1.73 [1.45]	1.73 [1.52]	0.89 (<0.001) [0.87; 0.92]
Specialist (others than cardiologists) consultations (billed cases) ^b	7.64 [6.66]	8.92 [7.92]	0.85 (<0.001) [0.83; 0.87]	7.63 [6.60]	8.87 [7.62]	0.85 (<0.001) [0.83; 0.86]	7.76 [6.60]	9.06 [7.69]	0.83 (<0.001) [0.82; 0.85]	7.97 [6.82]	9.33 [7.81]	0.83 (<0.001) [0.81; 0.85]
Patients with at least 1 outpatient coronary angiography ^c	1.52 [193]	0.88 [69]	1.29 (0.099) [0.95; 1.74]	2.21 [414]	1.27 [197]	1.66 (<0.001) [1.38; 1.99]	1.40 [231]	0.84 [121]	1.41 (0.004) [1.11; 1.79]	1.69 [199]	0.99 [90]	1.62 (<0.001) [1.25; 2.12]
Patients with at least 1 outpatient coronary intervention ^c	0.26 [33]	0.13 [10]	1.35 (0.443) [0.63; 2.87]	0.45 [84]	0.25 [39]	1.52 (0.040) [1.02; 2.27]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Patients with at least 1 outpatient implantation of cardiac pacemaker ^c	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.15 [24]	0.03 [4]	4.38 (0.008) [1.46; 13.15]	n.a.	n.a.	n.a.
Medication												
Number of drug prescriptions by GP ^b	30.72 [20.83]	32.32 [23.60]	1.02 (0.055) [1.00; 1.04]	29.69 [19.66]	28.66 [21.55]	1.04 (<0.001) [1.02; 1.05]	27.89 [20.03]	26.74 [21.25]	1.04 (<0.001) [1.02; 1.05]	26.92 [19.64]	25.11 [21.02]	1.05 (<0.001) [1.03; 1.07]
Number of drug prescriptions by cardiologist ^b	0.63 [2.62]	2.15 [8.10]	0.33 (<0.001) [0.29; 0.37]	0.50 [2.23]	2.01 [7.42]	0.24 (<0.001) [0.22; 0.27]	0.49 [2.08]	1.89 [7.14]	0.25 (<0.001) [0.23; 0.28]	0.52 [2.15]	1.92 [6.86]	0.26 (<0.001) [0.23; 0.29]
Emergency care												
Patients with at least 1 outpatient emergency cardiovascular consultation (billed cases) ^c	4.69 [594]	5.97 [467]	0.96 (0.581) [0.84; 1.11]	4.35 [816]	5.14 [798]	0.91 (0.095) [0.82; 1.02]	4.57 [756]	5.59 [810]	0.87 (0.015) [0.78; 0.98]	4.09 [481]	5.08 [460]	0.84 (0.018) [0.73; 0.97]
Days involving consultation of emergency physician and rescue service followed by cardiovascular hospitalization ^b	0.03 [0.19]	0.04 [0.23]	0.94 (0.513) [0.77; 1.14]	0.02 [0.16]	0.02 [0.17]	0.89 (0.211) [0.74; 1.07]	0.02 [0.17]	0.02 [0.18]	0.92 (0.316) [0.79; 1.08]	0.02 [0.17]	0.02 [0.18]	0.93 (0.501) [0.74; 1.16]
Hospital care												
Cardiovascular hospitalizations (billed cases) ^b	0.25 [0.66]	0.30 [0.74]	0.94 (0.112) [0.87; 1.01]	0.22 [0.62]	0.25 [0.65]	0.88 (<0.001) [0.83; 0.94]	0.22 [0.62]	0.23 [0.64]	0.91 (0.006) [0.85; 0.97]	0.22 [0.63]	0.24 [0.66]	0.90 (0.009) [0.83; 0.97]
Patients with at least 1 inpatient coronary angiography ^c	5.67 [718]	5.68 [444]	0.97 (0.689) [0.85; 1.11]	6.08 [1,140]	7.01 [1,087]	0.82 (<0.001) [0.74; 0.89]	4.47 [739]	4.69 [680]	0.83 (0.002) [0.74; 0.94]	5.02 [591]	5.34 [484]	0.82 (0.003) [0.71; 0.93]
Patients with at least 1 inpatient coronary intervention ^c	2.27 [287]	2.21 [173]	0.96 (0.722) [0.78; 1.19]	3.05 [573]	3.29 [510]	0.89 (0.082) [0.78; 1.01]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Patients with at least 1 inpatient implantation of cardiac stimulator ^c	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.69 [114]	0.77 [111]	0.76 (0.058) [0.58; 1.01]	n.a.	n.a.	n.a.
Patients with at least 1 emergency cardiovascular hospitalization ^c	17.40 [2,203]	19.85 [1,552]	0.98 (0.704) [0.91; 1.07]	15.91 [2,985]	17.28 [2,681]	0.90 (0.001) [0.85; 0.96]	15.56 [2,572]	16.36 [2,371]	0.93 (0.052) [0.87; 1.00]	15.87 [1,869]	16.14 [1,462]	0.95 (0.252) [0.88; 1.04]

HF: Heart failure, CHD: Coronary heart disease, HRD: Heart rhythm disorders, VHD: Valvular heart disease, IG: Intervention group, CG: Control group, SD: Standard deviation, CL: Confidence level, GP: General practitioner, n.a. not applicable, CI: 95%;

^aDepending on the statistical model used, results are presented as mean [SD] (negative-binomial regression) or % [n] (logistic regression).

^bNegative-binomial regression: Adjusted differences are rate ratios (RR).

^cLogistic regression: Adjusted differences are odds ratios (OR).

eAppendix E. Costs for Health Service Utilization by Disease Cohort, 2016

Cost position (per patient) [€] ^a	HF			CHD			HRD			VHD		
	IG n=12,664 (mean [SD])	CG n=7,818 (mean [SD])	Adjusted difference (p value) [95% CI]	IG n=18,758 (mean [SD])	CG n=15,511 (mean [SD])	Adjusted difference (p value) [95% CI]	IG n=16,530 (mean [SD])	CG n=14,491 (mean [SD])	Adjusted difference (p value) [95% CI]	IG n=11,774 (mean [SD])	CG n=9,056 (mean [SD])	Adjusted difference (p value) [95% CI]
[#] Cardiovascular hospitalizations	1,433 [7,828]	1,624 [6,539]	-24 (0.836) [-252; 204]	1,217 [6,658]	1,313 [5,969]	-151 (0.038) [-295; -8]	1,218 [6,978]	1,214 [5,244]	-100 (0.181) [-248; 47]	1,401 [7,947]	1,462 [6,441]	-151 (0.1654) [-363; 63]
[#] Cardiologist consultations	241 [535]	197 [1,164]	29 (0.031) [2; 55]	215 [553]	175 [943]	22 (0.012) [4; 40]	216 [521]	155 [896]	38 (<0.001) [20; 55]	216 [535]	189 [1,154]	9 (0.474) [-16; 35]
GP consultations	517 [311]	544 [932]	-44 (<0.001) [-64; -24]	524 [251]	497 [732]	-11 (0.060) [-23; 1]	489 [336]	483 [721]	-23 (<0.001) [-37; -10]	489 [409]	470 [788]	-15 (0.088) [-33; 3]
Specialist (others than cardiologists) consultations	667 [2,702]	993 [3,921]	-126 (0.011) [-224; -29]	627 [2,394]	841 [3,260]	-114 (<0.001) [-177; -52]	620 [2,360]	811 [3,137]	-121 (<0.001) [-185; -57]	649 [2,498]	832 [3,185]	-109 (<0.001) [-189; -29]
[#] Drugs prescribed by cardiologist	91 [1,688]	305 [4,154]	-128 (0.006) [-219; -37]	46 [571]	136 [1,241]	-82 (<0.001) [-104; -60]	65 [1,397]	163 [1,484]	-90 (<0.001) [-125; -55]	57 [1,237]	184 [1,990]	-107 (<0.001) [-154; -59]
[#] Therapeutic aids prescribed by cardiologists	4 [89]	16 [190]	-8 (<0.001) [-13; -3]	3 [73]	8 [135]	-3 (0.006) [-6; -1]	2 [66]	10 [158]	-6 (<0.001) [-9; -3]	1 [29]	10 [166]	-7 (<0.001) [-11; -3]
[#] Homecare prescribed by cardiologists	5 [221]	33 [448]	-22 (<0.001) [-33; -12]	2 [152]	14 [287]	-10 (<0.001) [-15; -4]	2 [129]	21 [348]	-17 (<0.001) [-24; -11]	3 [173]	21 [349]	-13 (0.001) [-22; -5]
[#] Remedies prescribed by cardiologists	1 [40]	8 [106]	-4 (<0.001) [-7; -2]	1 [33]	6 [97]	-4 (<0.001) [-6; -2]	1 [24]	7 [94]	-5 (<0.001) [-7; -3]	1 [25]	7 [109]	-5 (<0.001) [-8; -3]
Summarized costs												
Specific costs^b	1,800 [8,105]	2,217 [8,540]	-158 (0.225) [-415; 98]	1,504 [6,752]	1,677 [6,293]	-231 (0.002) [-378; -83]	1,525 [7,210]	1,593 [5,624]	-184 (0.019) [-338; -30]	1,701 [8,126]	1,896 [6,956]	-276 (0.014) [-498; -54]
Overall costs^c	9,072 [14,789]	11,929 [17,187]	-450 (0.048) [-897; -3]	7,996 [13,684]	9,026 [15,976]	-393 (0.011) [-697; -89]	8,266 [13,871]	9,280 [14,006]	-249 (0.102) [-548; 50]	8,213 [14,467]	9,223 [15,322]	-457 (0.022) [-847; -66]

HF: Heart failure, CHD: Coronary heart disease, HRD: Heart rhythm disorders, VHD: Valvular heart disease, IG: Intervention group, CG: Control group, SD: standard deviation, CL: confidence level; CI: 95%;

[#]These cost positions contribute to specific costs.

^aLinear regression: Adjusted differences are mean differences.

^bSpecific costs include: costs of cardiovascular hospitalizations, costs of cardiologist consultations, costs of drug prescriptions by cardiologists, costs of therapeutic aids prescribed by cardiologists, costs of homecare prescribed by cardiologists, costs of remedies prescribed by cardiologists, costs of emergency service utilization involving cardiovascular diagnosis, and cost of ambulatory surgery in hospital (coronary angiography, coronary intervention, implantation of cardiac stimulator).

°Overall costs include: costs of outpatient consultations (GPs, cardiologists, other specialists), costs of hospitalizations, costs of ambulatory surgery in hospital, costs of emergency service utilization, costs of consultations in university and psychiatric ambulances, costs of drug prescriptions, costs of remedies prescriptions, costs of therapeutic aids prescriptions, costs of homecare prescriptions and costs of nursery care.