Cardiac Rehabilitation and Resting Blood Pressure

MONTANA OUTCOMES PROJECT CARDIAC REHABILITATION REGISTRY FINDINGS

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Purpose: Exercise-based cardiac rehabilitation (CR) is essential for treating cardiovascular disease, and modifying risk factor modification, including hypertension. Because the causes of hypertension and benefits of CR are faceted, we examined the influence of phase II CR on resting blood pressure (BP).

Methods: Outcomes straddle the release of the updated BP guidelines, and study emphases included CR session number, sex, race/ethnicity, insurance provider, and referring diagnosis.

Results: Patient files of 31 885 individuals uploaded to the Montana Outcomes Project registry indicated that lowered systolic and diastolic BP were further improved after the release of the revised BP guidelines. The CR session number was proportional to improvements in diastolic BP. Blood pressure improved independent of sex, although female patients exhibited lower diastolic BP before and after CR. Race/ethnicity analyses indicated that Asian and White patients experienced drops in systolic and diastolic BP, while diastolic BP was improved in Hispanic patients. Neither American Indian nor Black patients exhibited statistically altered BP. Medicare, Veterans Administration, and privately insured patients had lowered systolic and diastolic BP, while Medicaid patients had lower diastolic BP, and the uninsured had lower systolic BP. Blood pressure outcomes were generally improved independent of the primary referring diagnosis, while those with peripheral artery disease showed no improvements.

Conclusions: Findings demonstrate that phase II CR is highly effective in the control of BP, although improvements are not equally distributed to all individuals according to differences in sex, race/ethnicity, and access to insurance-funded health care.

Key Words: cardioprotection • exercise • hypertension

Cardiovascular disease (CVD) remains a leading cause of morbidity and mortality in industrialized nations.[1] Prevention of recurrent CVD is linked to healthy lifestyles and risk factor mitigation. Notably, regular exercise prevents disease, but given the frequency of CVD diagnoses, exercise-based cardiac rehabilitation (CR) is essential for preventing disease recurrence.[2-5] The benefits of exercise extend to CVD risk factor management, including the control of blood pressure (BP), one of the most well-established benefits experienced by active individuals.[6]

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DOI: 10.1097/HCR.0000000000000638

Hypertension contributes directly to many cardiac pathologies (eg, ischemic heart disease, heart failure), and hypertension is among the most modifiable CVD risk factors, whereas a 10-mm Hg drop in BP is associated with 50% lower rates in all-cause mortality.[7] Accordingly, recent Global Burden of Disease Study findings demonstrate that elevated systolic blood pressure (SBP) is among the most important contributing factors to all-cause disability.[8]

Given need to improve BP management in at-risk persons, the American College of Cardiology (ACC)/American Heart Association (AHA) released revised hypertension guidelines in 2017, lowering diagnostic hypertension thresholds from 140/90 mm Hg to 130/80 mm Hg.[9] The revised guidelines reclassify the pernicious effects of hypertension by delineating pre-hypertension from stage 1 and stage 2 hypertension according to more rigorous standards, lowered in 10 mm Hg increments.

Accordingly, lowering BP through comprehensive CR approaches is among the most impactful first-line treatments[10]; however, the impact of the new BP guidelines is incomplete. Preliminary findings from a retrospective study indicated that CR reduces all-cause mortality in the approximately 6 yr of follow-up investigation, but the contribution of rehabilitative exercise to risk factor modifications, including BP, was not delineated. Successful control of SBP is nonetheless recognized as essential to long-term cardiovascular health in that CR participation is linked to declines in visit-to-visit SBP.[11]

Based on this rationale, it is clear that exercise rehabilitation improves cardiovascular health, at least in part due to improvements in BP[2,10,12]; however, several fundamental questions remain unresolved. For instance, (1) how much does rehabilitative exercise alter BP in the average CR patient? (2) Since phase II CR visits typically range between 12 and 36 visits, is there a dose response effect on BP? In addition, (3) do demographic factors (sex, race, etc), referring diagnoses, or the influence of the insurance provider alter BP? Finally, (4) it is unknown whether institution of the new ACC/AHA guidelines[12] has impacted BP in patients referred to CR. According to this rationale, we sought to answer these questions about the influence of CR on BP.

METHODS

CR REGISTRY AND PATIENT DATA COLLECTION

These data were collected from the Montana Outcomes Project, a data registry developed and coordinated by the Cardiovascular Health Program within the Montana Department of Public Health and Human Services. The registry was created in 2006 and includes >100 submitting programs within the United States. A data use agreement was formalized between the Cardioprotection Laboratory/International Heart Institute of St Patrick's Hospital/Providence Health Care System in collaboration with the

Table 1

Participant Characteristics (N = 31 885)[a]

Phase II visits, d	26.6 ± 8.9
Age, yr	67.7 ± 11.0
Sex	
Female	9283 (29.1)
Male	22 602 (70.9)
Race	
American Indian	302 (1.0)
Asian	364 (1.1)
Black	633 (2.0)
Other	13 (0)
White	29 926 (93.9)
Ethnicity	
Hispanic	717 (2.3)
Referring diagnoses	
MI	1538 (4.8)
MI/CABG	1362 (4.3)
MI/PCI	6488 (20.4)
CABG	6266 (19.7)
PCI	8660 (27.2)
Angina	1029 (3.2)
Heart failure	3410 (10.7)
Systolic type	2299 (7.2)
Diastolic/right side	583 (1.8)
Valve replacement/repair	5129 (16.1)
Transplant	79 (0.2)
LVAD	12 (0)
PAD	148 (0.5)
TAVR	475 (1.5)
Other	831 (2.6)
Diabetic status	
Diabetic	9725 (30.5)
Nondiabetic	22160 (69.5)

Abbreviations: CABG, coronary artery bypass graft; LVAD, left ventricular assist device; MI, myocardial infarction; PAD, peripheral artery disease; PCI, percutaneous coronary intervention; TAVR, transthoracic aortic valve replacement.
[a]Data are presented as mean ± SD or n (%).

University of Montana. The University of Montana Institutional Review Board issued an exemption letter for use of the anonymized rehabilitation registry data.

BP DATA COLLECTION

Blood pressure values represent that averaged SBP and diastolic blood pressure (DBP) measures were determined as the average resting BP recorded prior to the first three consecutive (pre-) exercise sessions and last three consecutive (post-) outpatient exercise visits. The BP measures were obtained by trained staff members employed by participating CR programs as a standard practice within health care.

PATIENT DATA COLLATION AND SUBCLASSIFICATIONS

Patient demographic data were recorded for sex, race (White, American Indian, Black, Asian, and Other), Hispanic ethnicity, number of phase II visits completed, insurance-provided classifications and, referring diagnoses of diabetes and CVD. Patients completing 12-36 phase II sessions were included and were stratified by completion of 12-23, 24-35, and 36 sessions. Rehabilitation session break points were based on the observations that when clustered for the number of exercise sessions completed, patient tertials span 1-23, 24-35, and 36 sessions. In the former instance, we took an approximate average of 12 sessions to be the lower limit for inclusion in the current study. These tertial observations of patient session number completion are confirmed by independent efforts to track CR participation.[13,14] With respect to disease classifications, the patients were classified on the basis of the primary referring diagnoses.

Quarterly BP values from 2016 to 2017 and 2018 to 2019

For the entire data collection, the patients were designated as achieving the BP goal when SBP/DBP values were collectively lower than 130/80 mm Hg.

STATISTICAL ANALYSES

Data are reported as mean ± SD. Statistical tests were performed using SPSS (26.0) software package (IBM). Pre- and post-BP data for the group, sex, race, ethnicity, referring diagnoses, insurance providers, and reporting quartiles were examined by analysis of variance, with protected *t* tests being performed to counter the potential for alpha inflation. Because of group sample size differences producing instances of unequal variance, the Kruskal-Wallis test was used to determine *post hoc* differences for pre- and post-values between session numbers, race, and insurance designations. Mann-Whitney *U* tests were used to determine sex-specific differences. Patients meeting the recommended BP goals were analyzed by analysis of variance. Statistical significance was determined when *P* values exceeded the *a priori* threshold of ≤0.05 unless otherwise stated.

RESULTS

According to the inclusion/exclusion methodology, 31 885 patients completing 12-36 CR sessions are reported. Patient characteristic data are presented in Table 1. Patients averaged 67.7 yr and completed 26.6 CR sessions. Males (n = 22 602) represented approximately 70% of the patient records, while the most patients were White (n = 29 926). Of the referring diagnoses, most included revascularization and/or repair procedures (myocardial infarction [MI]/percutaneous coronary intervention [PCI] = 6488, coronary artery bypass graft [CABG] = 6266, PCI = 8660, and valve replacement/repair = 5129). Finally, 9725 of the patient files uploaded to the data registry included individuals with diabetes.

SEX, RACE, AND ETHNICITY

Blood pressure values pre- and post-CR number of phase II visits, sex, race, and ethnicity distributions are presented for the group in Table 2. Both SBP (−1.0 mm Hg, $P < .0001$) and DBP (−1.0 mm Hg, $P < .0001$) were lower following CR. Stratification for the number of phase II CR visits (12-23, 24-35, and 36) revealed that SBP and DBP were improved in all tiers. Specifically, patients completing 12-23

visits (SBP: −1.0 mm Hg, $P < .001$; DBP: −0.8 mm Hg, $P < .001$), 24-35 visits (SBP: −1.1 mm Hg, $P < .001$; SBP: −1.0 mm Hg, $P < .001$), and 36 visits (SBP: −1.4 mm Hg, $P < .001$; DBP: −1.3 mm Hg, $P < .001$) exhibited BP improvements. *Post hoc* analyses of post-DBP indicated that session number was proportional to lower DBP (36 sessions was −0.8 mm Hg lower than 24-35 sessions, $P < .001$; 12-23 sessions was +0.5 mm Hg higher than 24-35 sessions, $P < .001$). When separated by sex, females (SBP: −1.4 mm Hg, $P < .0001$; DBP: −1.0 mm Hg, $P < .0001$) and males (SBP: −1.0 mm Hg, $P < .0001$; DBP: −1.0 mm Hg, $P < .0001$) exhibited lower BP values post-CR. *Post hoc* analyses indicated that females had lower DBP at both pre- ($P < .001$) and post- ($P < .001$) CR than males.

White patients represented approximately 94% of the uploaded data records, exhibiting lower SBP (−1.2 mm Hg, $P < .0001$) and DBP (−1.0 mm Hg, $P < .0001$). Similarly, discharged patients identified as Asian demonstrated lower SBP (−1.3 mm Hg, $P = .032$) and DBP (−1.0 mm Hg, $P = .006$). Black patients did not exhibit changes in SBP (−0.2 mm Hg, $P = .683$), or DBP (−0.5 mm Hg, $P = .078$) when comparing pre- with post-CR values. Moreover, post-CR BP values were unchanged from pre values in the 302 American Indian patients. American Indian BP did not change between pre- and post-CR, with SBP exhibiting a nonsignificant increase of +1.2 mm Hg ($P = .092$), while DBP values were also unchanged (±0.0 mm Hg, $P = .832$). Finally, patients identified as ethnically Hispanic or "Other" experienced an identical −1.0 mm Hg decrease in DBP ($P < .0001$) but not in SBP (Hispanic: ±0.0 mm Hg, $P = .899$; Other: −0.5 mm Hg, $P = .256$).

When examining racial differences, Black patients had higher pre-CR SBP than Asian and Other categorized patients. Pre-rehabilitation DBP differences were also higher in Asian and Black patients than in White and American Indian patients. In post-CR analyses, Black patients exhibited elevated SBP as compared with Asian, Other, and White patients. Similarly, American Indian patients had higher SBP values than Asian patients. Finally, Asian and Black patients had higher DBP values than White and Other patients.

CARDIOVASCULAR AND DIABETIC DIAGNOSES

Blood pressure values are reported pre- and post-CR for the primary referring cardiac and diabetes diagnoses (Table 3). When stratified on the basis of their primary referring diagnosis, cardiovascular diagnoses, MI, PCI, MI/PCI, and angina patients experienced decreased SBP (MI: −1.1 mm Hg, PCI: −2.0 mm Hg, and MI/PCI: −1.2 mm Hg; $P < .0001$) and DBP (MI: −1.2 mm Hg, PCI: −1.3 mm Hg, and MI/PCI: −1.2 mm Hg; $P < .0001$). Alternately, post-CR DBP was improved in patients referred following CABG (−0.5 mm Hg, $P < .0001$) or MI/CABG (−0.7 mm Hg, $P < .0001$), while SBP was unchanged between pre- and post-CR (CABG: +0.2 mm Hg, $P = .348$; MI/CABG: −0.1 mm Hg, $P = .892$).

Patients diagnosed with heart failure also exhibited post-CR drops in both SBP (−1.0 mm Hg, $P < .0001$) and DBP (−1.2 mm Hg, $P < .0001$). Systolic heart failure patients experienced lower SBP (−1.2 mm Hg, $P < .0001$) and DBP (−1.2 mm Hg, $P < .0001$). In similar fashion, diastolic heart failure patients exhibited −1.1 mm Hg drop in SBP ($P = .030$) and −1.3 mm Hg drop in DBP ($P < .0001$).

Valve replacement/repair patients (SBP: −0.5 mm Hg, $P = .003$; diastolic: −0.4 mm Hg, $P < .0001$), transthoracic aortic valve replacement (TAVR) (SBP: −1.5 mm Hg, $P < .0001$; DBP: −0.8 mm Hg, $P = .008$), and other diagnoses (SBP: −1.6 mm Hg, $P < .0001$; DBP: −1.4 mm Hg, $P = .008$) were also improved. Peripheral artery disease (PAD) patients were the only diagnostic group that did not exhibit decreased post-CR values (SBP: −1.4 mm Hg, $P = .179$; DBP: −0.6 mm Hg, $P = .320$). The concomitant diagnosis of diabetes revealed a lowering in SBP (−0.6 mm Hg, $P < .0001$) and in DBP (−0.6 mm Hg, $P < .0001$).

INSURANCE PROVIDERS

Data were subdivided according to insurance coverage or a lack thereof (Table 4). Systolic blood pressure and DBP were lower for post-CR in Medicare, Medicaid, and privately insured patients. Medicare-covered patients experienced lower SBP (−1.1 mm Hg, $P < .0001$) and DBP (−0.9 mm Hg, $P < .0001$). Similarly, patients with Medicaid coverage had lower SBP (−1.2 mm Hg, $P = .001$) and DBP (−1.1 mm Hg, $P < .0001$). Those with private insurance (other) had lower SBP (−1.1 mm Hg, $P < .0001$) and DBP (−1.1 mm Hg, $P < .0001$).

When comparing across insurance providers, post-CR values were higher for patients receiving Medicare, VA health coverage, and uninsured patients, as compared with Medicaid or other/private insurance options. Notably, Medicare/VA/uninsured patients had higher SBP and DBP, both pre- and post-CR, save for DBP when exhibited a −1.1 mm Hg ($P < .0001$) drop in post-CR values of VA-insured patients.

QUARTERLY REPORTING AND REVISED BP RECOMMENDATIONS

Data were stratified as received before and after the release of the updated BP guidelines, averaging 1993 ± 305 records/quarter. Of the data received, 15 848 (1981 ± 241/quarter) came prior to the new recommendations, and 16 037 (2005 ± 375/quarter) came after. Pre-rehabilitation SBP values were higher in the quarters before the release of the new recommendations than in the quarters after (Q1-Q8 122.5 ± 14.0 mm Hg vs Q9-Q16 122.1±13.6 mm Hg; $P = .009$). Similarly, post-CR SBP values were higher in the quarters before the new recommendations than the corresponding quarters after (Q1-Q8 121.4 ± 13.3 mm Hg vs Q9-Q16 121.0 ± 12.8 mm Hg; $P = .005$). In contrast, DBP values averaged over the quarters before and after the new recommendations were unchanged pre- (Q1-Q8 69.8 ± 8.1 mm Hg vs Q9-Q16 69.8 ± 7.9 mm Hg; $P = .384$) or post- (Q1-Q8 68.8 ± 7.9 mm Hg vs Q9-Q16 68.8 ± 7.7 mm Hg; $P = .607$) CR.

Quarterly SBP and DBP values are presented for pre- and post-CR in Figure. Systolic blood pressure was improved in 5/8 quarterly reporting periods prior to the release of the new BP guidelines, while DBP values were improved in 7/8. In contrast, both SBP and DBP values were improved in 8/8 quarters after the implementation of the new BP guidelines.

PATIENTS MEETING BP GOALS

Patient records were examined for the percentage of individuals who met the most recent BP goals at the post-CR time point (Table 5). Findings indicate that 74% achieved the goal of BP 130/80 mm Hg values. Stratification for CR session number indicated that the percentage of at goal patients was similar between 12-23, 24-35, or 36 sessions (12-23 = 73%, 24-25 =74%, and 36 = 74%). Similarly, the percentage of females (74%) at goal was similar to males (73%). When examining for race and ethnicity, patients identified as Asian (77%), White (74%), and Other (74%) classifications had higher rates of at goal BP than American Indian (65%), Black (65%), and Hispanic (67%) patients.

Table 2

Resting Blood Pressure Values Pre and Post 12-36 Sessions of Cardiac Rehabilitation for Total Group, Sex, Race, and Ethnic Distributions[a]

Total Sample (n = 31 885)	Pre	Post	*P* Value
SBP, mm Hg	122.3 ± 0.53	121.3 ± 0.57	*<.0001*
DBP, mm Hg	69.8 ± 0.31	68.8 ± 0.28	*<.0001*
Number of phase II cardiac rehabilitation visits			
12-23 (n = 12 381)			
SBP, mm Hg	122.3 ± 13.7	121.3 ± 13.0	*<.0001*
DBP, mm Hg	70.2 ± 8.0[b]	69.4 ± 7.9[b]	*<.0001*
24-35 (n = 8572)			
SBP, mm Hg	122.3 ± 13.7	121.2 ± 13.0	*<.0001*
DBP, mm Hg	69.9 ± 8.0[b]	68.9 ± 7.7[b,c]	*<.0001*
36 (n = 10 932)			
SBP, mm Hg	122.5 ± 13.9	121.1 ± 13.2	*<.0001*
DBP, mm Hg	69.4 ± 8.0	68.1 ± 7.7	*<.0001*
Sex			
Female (n = 9283)			
SBP, mm Hg	122.6 ± 14.1	121.2 ± 13.2	*<.0001*
DBP, mm Hg	68.9 ± 7.7[d]	67.9 ± 7.5[d]	*<.0001*
Male (n = 22 602)			
SBP, mm Hg	122.2 ± 13.6	121.2 ± 13.0	*<.0001*
DBP, mm Hg	70.2 ± 8.1	69.2 ± 7.9	*<.0001*
Race and ethnicity			
American Indian (n = 302)			
SBP, mm Hg	121.9 ± 14.3	123.1 ± 14.6[e]	.092
DBP, mm Hg	69.7 ± 8.9[e,f]	69.7 ± 8.9	.832
Asian (n = 364)			
SBP, mm Hg	120.7 ± 14.7[f]	119.4 ± 13.6[f]	*.032*
DBP, mm Hg	71.6 ± 8.0	70.6 ± 7.8	*.006*
Black (n = 633)			
SBP, mm Hg	123.7 ± 14.4	123.5 ± 14.0	.683
DBP, mm Hg	71.9 ± 8.6	71.4 ± 8.1	.078
Other (n = 660)			
SBP, mm Hg	121.2 ± 13.9[f]	120.7 ± 13.5[f]	.256
DBP, mm Hg	70.1 ± 7.8[e]	69.1 ± 7.6[e,f]	*<.0001*
White (n = 29 926)			
SBP, mm Hg	122.4 ± 13.7	121.2 ± 13.0[f]	*<.0001*
DBP, mm Hg	69.7 ± 8.0[e,f]	68.7 ± 7.8[e,f]	*<.0001*
Ethnicity			
Hispanic (n = 717)			
SBP, mm Hg	123.8 ± 14.4	123.8 ± 14.8	.899
DBP, mm Hg	71.2 ± 8.3	70.2 ± 7.7	*<.0001*

Abbreviations: DBP, diastolic blood pressure, SBP, systolic blood pressure.

[a]Data are presented as means ± SD.

[b]Significantly different from 36 phase II sessions.

[c]Significantly different from 12 to 23 phase II sessions.

[d]Significantly different from males.

[e]Significantly different from Asian.

[f]Significantly different from Black.

Table 3

Resting Blood Pressure Values Pre and Post 12-36 Sessions of Cardiac Rehabilitation for the Referring Diagnosis and Diabetes[a]

Referring Diagnosis	Pre	Post	*P* Value
MI (n = 1538)			
SBP, mm Hg	121.1 ± 14.3	120.0 ± 13.3	*<.0001*
DBP, mm Hg	69.3 ± 8.3	68.1 ± 8.0	*<.0001*
MI/CABG (n = 1362)			
SBP, mm Hg	121.8 ± 14.0	121.7 ± 13.3	.892
DBP, mm Hg	70.3 ± 7.9	69.6 ± 7.9	*<.0001*
MI/PCI (n = 6488)			
SBP, mm Hg	120.9 ± 13.6	119.7 ± 12.8	*<.0001*
DBP, mm Hg	69.7 ± 7.9	68.5 ± 7.6	*<.0001*
CABG (n = 6266)			
SBP, mm Hg	122.7 ± 13.4	122.9 ± 12.8	.348
DBP, mm Hg	70.2 ± 8.0	69.7 ± 7.8	*<.0001*
PCI (n = 8660)			
SBP, mm Hg	124.1 ± 13.4	122.1 ± 12.7	*<.0001*
DBP, mm Hg	69.6 ± 7.8	68.3 ± 7.6	*<.0001*
Angina (n = 1029)			
SBP, mm Hg	123.8 ± 13.2	121.3 ± 12.6	*<.0001*
DBP, mm Hg	70.1 ± 7.9	68.4 ± 7.6	*<.0001*
Heart failure (n = 3410)			
SBP, mm Hg	117.4 ± 14.4	116.4 ± 13.8	*<.0001*
DBP, mm Hg	67.9 ± 8.2	66.7 ± 7.8	*<.0001*
Systolic heart failure (n = 2299)			
SBP, mm Hg	116.0 ± 14.4	114.8 ± 13.5	*<.0001*
DBP, mm Hg	67.7 ± 8.1	66.5 ± 7.7	*<.0001*
Diastolic/right heart failure (n = 583)			
SBP, mm Hg	122.5 ± 13.5	121.4 ± 13.3	*.030*
DBP, mm Hg	68.1 ± 8.3	66.8 ± 7.7	*<.0001*
Valve replacement/repair (n = 5129)			
SBP, mm Hg	122.6 ± 13.7	122.1 ± 13.2	*.003*
DBP, mm Hg	70.0 ± 8.3	69.6 ± 8.2	*<.0001*
PAD (n = 148)			
SBP, mm Hg	125.6 ± 13.7	124.2 ± 13.1	.179
DBP, mm Hg	67.3 ± 7.1	66.7 ± 7.8	.320
TAVR (n = 475)			
SBP, mm Hg	128.2 ± 14.0	126.7 ± 13.0	*<.0001*
DBP, mm Hg	67.4 ± 8.2	66.6 ± 7.5	*.008*
Other (n = 831)			
SBP, mm Hg	122.1 ± 13.6	120.5 ± 13.2	*<.0001*
DBP, mm Hg	70.4 ± 8.5	69.0 ± 8.4	*<.0001*
Diabetic (n = 9725)			
SBP, mm Hg	123.9 ± 14.0	123.3 ± 13.4	*<.0001*
DBP, mm Hg	68.8 ± 7.9	68.2 ± 7.8	*<.0001*

Abbreviations: CABG, coronary artery bypass graft; DBP, diastolic blood pressure; MI, myocardial infarction; PAD, peripheral artery disease; PCI, percutaneous coronary intervention; SBP, systolic blood pressure; TAVR, transthoracic aortic valve replacement.

[a]Data are presented as mean ± SD.

Table 4

Resting Blood Pressure Values Pre and Post 12-36 Sessions of Cardiac Rehabilitation for the Insurance Provider[a]

Insurance Provider	Pre	Post	*P* Value
Medicare (n = 17 417)			
SBP, mm Hg	123.3 ± 13.7[b,c]	122.1 ± 13.1[b,c]	*<.0001*
DBP, mm Hg	68.5 ± 7.7[b,c,d,e]	67.6 ± 7.6[b]	*<.0001*
Medicaid (n = 781)			
SBP, mm Hg	119.2 ± 14.4	119.0 ± 14.0	.577
DBP, mm Hg	71.1 ± 8.8[d]	70.5 ± 8.3[d]	*.019*
Veterans Administration (n = 1041)			
SBP, mm Hg	122.6 ± 13.5[b,c]	121.4 ± 13.2[b,c]	*.001*
DBP, mm Hg	69.7 ± 8.3[b,c]	68.6 ± 8.1[b]	*<.0001*
Other/private (n = 12 368)			
SBP, mm Hg	121.2 ± 13.7[b]	120.1 ± 12.9	*<.0001*
DBP, mm Hg	71.5 ± 8.0[d]	70.4 ± 7.8[d]	*<.0001*
Uninsured (n = 206)			
SBP, mm Hg	124.4 ± 13.5[b,c]	122.7 ± 10.8[b,c]	*.043*
DBP, mm Hg	71.7 ± 7.4[d]	71.0 ± 6.4[d]	.095

[a]Data are presented as mean ± SD.
[b]Significantly different from Medicaid.
[c]Significantly different from Other/Private.
[d]Significantly different from Veterans.
[e]Significantly different from Medicare.

In reference to the referring diagnoses, MI/CABG (69%) exhibited lower rates of patients at goal as compared with MI (78%), MI/PCI (80%), CABG (72%), and angina (74%). Similarly, those with PAD (68%) had lower success rates in post-rehabilitation. Interestingly, conditions related to systolic and diastolic heart failure had higher (eg, heart failure = 82%) rates of at goal patients. In contrast, lower rates of at goal patients were observed for TAVR (67%). Finally, the type of insurance provider did not correspond to the percentage of patients at goal by the end of CR, with at BP goal rates between 72 and 75%.

DISCUSSION

The key finding is that CR benefits resting SBP and DBP by an average of −1 mm Hg. The impact of lowering BP is reflected by the fact that 74% of our 31 885 discharged patients met the 2018 ACC/AHA BP goal of <130 mm Hg systolic and <80 mm Hg diastolic.[9] The number of rehabilitation sessions ranged from 12 to 36 and was linked to dose-dependent improvements in DBP. These findings confirm that supervised exercise is essential to the treatment of newly diagnosed CVD. The importance of these findings cannot be overstated because CVD recurrence is highly dependent upon modification of risk factors. Moreover, the control of BP is among the most impactful variables in the prevention of secondary CVD events.[8] This understanding of BP control and risk factor modification suggests that implementation of phase II CR is foundational for preventing future CVD events. Unfortunately, this study also revealed that the BP-lowering effects of phase II CR were not distributed equally across all patients when considering sex, race, and insurance providers.

THE NEW ACC/AHA BP GUIDELINES

A recent National Health and Nutrition Survey revealed that population control of hypertension peaked between 2008 and 2013 and has since worsened.[15] In this regard, release of the stringent ACC/AHA guidelines bisected the current 4-yr investigation, revealing that BP values collected after release of the revised standards were associated with improved BP control.[9] Indeed, the more ambitious BP goals were associated with lower SBP pre- (−1.4 mm Hg) and post- (−0.4 mm Hg) rehabilitation, although corresponding drops in DBP values were not observed. While maintenance of goal SBP is faceted and influenced by variables other than physical activity, the contributory role of phase II CR is apparent. Nonetheless, implementing stringent health care expectations for BP appears to have improved patient outcomes. In support, prior observations from the SBP intervention trial (SPRINT) indicated that the implementation of a more rigorous BP goal (120 mm Hg vs 140 mm Hg) corresponded to a −15 mm Hg drop in SBP, justifying early conclusion of the study due to the fact that all-cause mortality was lower in treated patients.[16]

SEX

Female records in this investigation exhibited −1.3 mm Hg DBP both pre- and post-CR as compared with male records. While we cannot determine the causative nature of this difference, findings may reflect the fact that males out represented females by a factor of 2.4-fold.[17,18] Sex-based disparities did not, however, extend to CR efficacy in that females and males experienced similar drops in SBP (females: −1.4 mm Hg, males: −1.0 mm Hg) and DBP (females: −1.0 mm Hg, males: −1.0 mm Hg). In support,

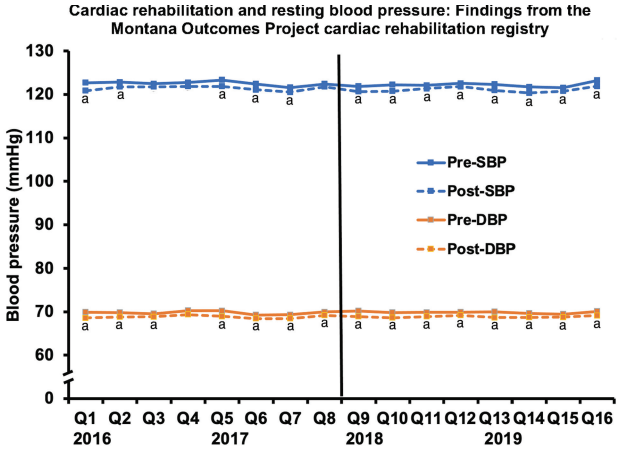

Figure. Quarterly reporting of resting systolic and diastolic blood pressure pre– and post–cardiac rehabilitation. Resting systolic (blue) and diastolic (orange) blood pressure values are plotted at the beginning ("pre," solid line) and at the conclusion ("post," dashed line) of CR. The vertical black line between 2017 Q4 and 2018 Q1 represents the release of the updated American College of Cardiology/American Heart Association updated resting blood pressure guidelines. [a]Significant difference between pre and post values for a given quarterly value ($P < .05$). DBP indicates diastolic blood pressure; SBP, systolic blood pressure. This figure is available in color online (www.jcrpjournal.com).

we observed comparable percentages of females (74%) and males (73%) with at goal pressures <130/80 mm Hg.

RACE/ETHNICITY

Blood pressure outcomes were stratified for race and ethnicity, revealing discordant findings. White patients constituted 94% of the records (vs 60.1% US[19]), a trend that confirms prior evidence of racial and ethnic inequity in rehabilitation referral rates.[18] Based on disproportionate representation, it was not surprising that the most consistent improvements in BP were observed in White patients (SBP: −1.2 mm Hg, DBP: −1.0 mm Hg). Post-rehabilitation BP also improved in Asian patients (SBP: −1.3 mm Hg, DBP: −1.0 mm Hg). While Asian patients were 1.14% the current study (vs 5.9% US[19]), prior investigations of 1-yr post-CR mortality rates also demonstrated improved outcomes in Asian patients despite underrepresentation.[18]

In contrast, Hispanic or "Other" patients exhibited identical −1.0 mm Hg improvements in DBP only. Raising further concern about racial and ethnic inequities, American Indian and Black patients did not exhibit improvements in either SBP or DBP. Moreover, American Indian patients experienced a +1.2 mm Hg (nonsignificant) increase in pre- and post-SBP. Thus, Asian, Other, and White classified patients met the ACC/AHA BP goals at higher rates (77-74%) than American Indian, Black, and Hispanic patients (67-65%). As a possible explanation, Li et al[18] quantified the influence of CR referral rates on race-related death rates. When adjusted for race-dependent differences in sociodemographic and lifestyle factors, 1-yr mortality rates were 18% higher for Black patients as compared with White patients. White patients in the prior study by Li et al[18] out represented Black patients by 15:1 (vs 4.5:1 US[19]): a ratio that was 47:1 in the current investigation. While referral rates are only part of the problem in treating CVD patients, race and ethnicity are disparately linked to outcomes that include hypertension.[20] Moreover, prior investigations link the clustering of CVD risk factors, including hypertension, as a race- and ethnic-dependent factor.[21]

INSURANCE PROVIDERS

The current investigation examined relationships between insurance providers and BP outcomes. Relative to CR, managed care is poorly defined.[22] Medicare, Veterans Administration, and privately insured patients accounted for 97% of our database and exhibited marked improvements in both SBP and DBP. Alternately, Medicaid patients exhibited a significant, but clinically modest, −0.6 mm Hg improvement in DBP and no improvement in SBP. Interestingly, Medicaid patients had the lowest SBP values pre- and post-rehabilitation; an observation that likely reflects a subset age of 57 yr, as compared with the study average of 67.7 yr. Finally, uninsured patients (0.6% of patient records) presented with the highest SBP and DBP, both pre- and post-CR. Moreover, while post-CR SBP values were improved by −1.7 mm Hg, DBP changes (−0.7 mm Hg) were not different from pre-values. As a consideration for future study, the impact of dual medical coverage on the control of hypertension is needed. Preliminary findings indicate that instances of dual coverage are associated with a −4.2% drop in complicated hypertension in patients with both VA coverage and Medicare.[23] Additional study is also needed to understand possible links between the insurance provider, BP control, and intervening relationships with sex, race/ethnicity, and sociodemographic status.[22]

PRIMARY DIAGNOSES

An important aspect of this investigation was the influence of cardiovascular and diabetes diagnoses. While CR is an established treatment for a host of CVD diagnoses, including MI[12] and PCI[24], the independent relationship on BP is not well defined. Indeed, a preliminary investigation demonstrated that MI is associated with improvements in SBP (−1.4 mm Hg)[12]; the impact of CR on BP in those with many other referring diagnoses has not been well described prior to this study.

In the current study, we observed that CR was associated with improvements in both SBP and DBP for MI, MI/PCI, PCI, angina, heart failure, valve replacement, TAVR, and diabetes: a collective observation that encompasses most referring diagnoses for CR patients. For MI/CABG and CABG patients, we found that DBP was improved, even if SBP was not. Moreover, PAD was the only diagnosis that did not yield improvements in either SBP or DBP. While the nature of the current data set prevents causative interpretation, it is tempting to speculate about the fact that diagnoses with the most diffuse pathological vascular remodeling (MI/CABG, CABG, and PAD) were the only diagnoses without BP improvements. Follow-up study is needed to delineate the potential mechanistic underpinnings of vascular dysfunction and BP control following phase II CR. Moreover, the nature of the current database did not enable subanalyses of comorbidities. Given the undeniable clustering of multiple cardiovascular, metabolic, and other pathologies in many CR patients, additional research is needed to better quantify the impact of multiple diagnoses on BP outcomes, a fact that is not independent from sex, race/ethnicity, and access to medical coverage.[25]

STUDY LIMITATIONS

Among the limiting factors not already highlighted, the Montana Outcomes Project data registry records only the use of statins and antiplatelet/coagulant medications. Accordingly, subanalyses to delineate the potential influence of exercise versus the combined effects of exercise and antihypertensive medications cannot be addressed. Nonetheless, within hypertensive CR patients, the majority are treated with medications housed within a handful of drug

Table 5

Percentage of Patients Meeting Both 130 mm Hg Systolic and 80 mm Hg Diastolic Blood Pressure Goals—Stratified for Number of Rehabilitation Visits, Sex, Race, Ethnicity, Referring Diagnosis, Diabetes, and Insurance Provider[a]

	Percentage at BP Goal	Percentage Not at BP Goal	*P* Value
Total sample (n = 31 885)	73.5	26.5	*<.0001*
Number of phase II cardiac rehabilitation visits			
12-23 (n = 12 381)	72.7	27.3	*<.0001*
24-35 (n = 8572)	73.9	26.1	*<.0001*
36 (n = 10 932)	73.9	26.1	*<.0001*
Sex			
Females (n = 9283)	74.1	25.9	*<.0001*
Males (n = 22 602)	73.2	26.8	*<.0001*
Race			
American Indian (n = 302)	64.6	35.4	*<.0001*
Asian (n = 364)	76.6	23.4	*<.0001*
Black (n = 633)	64.6	35.4	*<.0001*
Other (n = 660)	73.9	26.1	*<.0001*
White (n = 29 926)	73.7	26.3	*<.0001*
Ethnicity			
Hispanic (n = 717)	67.1	32.9	*<.0001*
Referring diagnosis			
MI (n = 1538)	77.5	22.5	*.002*
MI/CABG (n = 1362)	69.3	30.7	*.011*
MI/PCI (n = 6488)	79.6	20.4	*<.0001*
CABG (6266)	71.6	28.4	*<.0001*
PCI (8660)	73.8	26.2	*<.0001*
Angina (1029)	74.1	25.9	*.005*
Heart failure (n = 3410)	81.9	18.1	*<.0001*
Systolic heart failure (n = 2299)	84.2	15.8	*<.0001*
Diastolic/right-sided heart failure (n = 583)	75.1	24.9	*<.0001*
Valve replacement/repair (n = 5129)	72.5	27.5	*<.0001*
PAD (n = 148)	68.5	31.5	*<.0001*
TAVR (n = 475)	67.4	32.6	*<.0001*
Other (n = 831)	73.6	26.4	*<.0001*
Metabolic derangement			
Diabetic (n = 9725)	71.0	29.0	*<.0001*
Insurance provider			
Medicare (n = 17 417)	72.4	27.6	*<.0001*
Medicaid (n = 781)	73.4	25.7	*<.0001*
Veterans Administration (n = 1041)	72.4	27.6	*<.0001*
Other/private (n = 12 368)	74.9	25.1	*<.0001*
Uninsured (n = 206)	72.8	27.2	*<.0001*

Abbreviations: BP, blood pressure; CABG, coronary artery bypass graft; MI, myocardial infarction; PAD, peripheral artery disease; PCI, percutaneous coronary intervention; TAVR, transthoracic aortic valve replacement.

[a]Data are presented as percentage.

classifications.[26] Moreover, several careful studies have demonstrated that in those with diagnosed or suspected CVD, hypertensive medications are among the most potent interventions,[27] a fact that supports our observation that 74% of our discharged patients met the BP goal. Moreover, pharmacologic treatment considerations for hypertension reinforce sex and race/ethnic disparities in BP observed in this investigation in that women and White patients appear to receive better pharmacologic care than male and non-White Hispanic and Black patients.[27] Finally, these data did not delineate between non-Black and Black Hispanic patients. Future investigations should explore potentially important relationships between treatment access and outcome responses in non-Black and Black Hispanic patients.[28]

CONCLUSION

The revised 2017 ACC/AHA guidelines recommend risk stratification of patients with BP >130/80 mm Hg prior to hypertensive pharmacotherapy.[9] In the context of supervised phase II CR, we observed notable improvements in both SBP and DBP, with the latter measure being improved as a function of increasing the phase II CR session number. The importance of BP control in newly diagnosed CVD patients cannot be overstated in light of the fact that it is among the most modifiable and influential factors in presenting disease recurrence.[9,15,27,29] Furthermore, our demographic data indicate that new approaches are needed for improving the referral rates for American Indian, Asian, Black, and Hispanic patients, in addition to females of all race and ethnic groups. Moreover, our findings suggest that improvements in BP due to phase II CR are related to the nature of the referring diagnosis. Accordingly, additional research is needed to identify strategies through which exercise rehabilitation, potentially combined with adjuvant therapies, can be used to reverse or slow the atherosclerotic process in patients with advanced vascular disease. Finally, future research efforts should be directed at understanding the influence of insurance coverage on BP and other CVD risk factors in phase II CR patients, especially as these factors may cluster with sex, race, and ethnic demographics resulting in untoward patient outcomes.

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