

# Cardiac Rehabilitation and Survival of Dialysis Patients after Coronary Bypass

Nancy G. Kutner, Rebecca Zhang, Yijian Huang, and Charles A. Herzog

*Rehabilitation/Quality of Life Special Studies Center, United States Renal Data System, Atlanta, Georgia, and Cardiovascular Special Studies Center, United States Renal Data System, Minneapolis, Minnesota*

Patients who are on renal dialysis are at high risk for cardiac death and have a large burden of cardiovascular disease and cardiovascular disease risk factors. Cardiac rehabilitation can promote improved survival of nondialysis patients after coronary artery bypass grafting (CABG) surgery and is covered by Medicare, but no previous studies have investigated whether dialysis patients' survival after CABG may be improved as a function of cardiac rehabilitation. A prospective cohort study was conducted using Medicare claims (1998 to 2002) for CABG and cardiac rehabilitation and patient information from the United States Renal Data System database for 6215 renal patients who initiated hemodialysis and underwent CABG between January 1, 1998, and December 31, 2002, with mortality follow-up to December 31, 2003. Cardiac rehabilitation was defined by Current Procedural Terminology codes for monitored and nonmonitored exercise in Medicare claims data. Dialysis patients who received cardiac rehabilitation after CABG had a 35% reduced risk for all-cause mortality and a 36% reduced risk for cardiac death compared with dialysis patients who did not receive cardiac rehabilitation, independent of sociodemographic and clinical risk factors, including recent hospitalization. Only 10% of patients received cardiac rehabilitation after CABG, compared with an estimated 23.4% of patients in the general population, and lower income patients of all ages as well as women and black patients who were aged 65+ were significantly less likely to receive cardiac rehabilitation services. This observational study suggests a survival benefit of cardiac rehabilitation for dialysis patients after CABG.

*J Am Soc Nephrol* 17: 1175–1180, 2006. doi: 10.1681/ASN.2005101027

Every year in the United States, approximately 100,000 patients with ESRD start chronic dialysis, and the annual death rate of patients who undergo dialysis is approximately 20% (1). Cardiovascular mortality, the largest contributor to patient death, is almost 40 times greater among dialysis patients than in the general population (2). There is evidence that cardiovascular disease (CVD) and CVD risk factors are undertreated in the dialysis population (3,4). Dialysis patients are less likely than nondialysis patients to receive interventions such as coronary revascularization procedures and medications with proven efficacy for treating CVD. Possible reasons range from lack of clinical trial evidence in dialysis patients to therapeutic nihilism (3,4).

Medicare covers cardiac rehabilitation for patients who have undergone coronary artery bypass grafting (CABG) and for patients who have had an acute myocardial infarction (AMI) in the past 12 mo or have stable angina (5). Cardiac rehabilitation has been shown to reduce coronary heart disease risk factors in the general population (6). Participation in a cardiac rehabili-

tation program also may promote lower mortality from coronary heart disease (7–11). No information exists, however, about cardiac rehabilitation and survival in dialysis-dependent patients with ESRD or about how likely eligible patients who are on dialysis are to receive cardiac rehabilitation.

Evidence to date indicates that both CABG and percutaneous coronary intervention (PCI) in dialysis patients are associated with lower risk for death compared with no revascularization (12), and it seems that CABG compared with PCI provides better long-term results in dialysis patients (4,13). The primary purpose of our study was to investigate whether cardiac rehabilitation was associated with improved survival in dialysis patients who had undergone CABG. A secondary purpose of our study was to identify patient characteristics that were associated with receipt of cardiac rehabilitation in the study population.

## Materials and Methods

### Patients

In this study, we examined survival after cardiac rehabilitation in a large cohort of dialysis patients, using United States Renal Data System (USRDS) files that contained information on deaths and Medicare inpatient and outpatient claims during the most recent period for which these data were available. We focused on patients who initiated hemodialysis (HD) in 1998 to 2002 and subsequently underwent CABG. ESRD patients who initiated chronic HD and were hospitalized during the period from January 1, 1998, to December 31, 2002, for a CABG procedure while still undergoing chronic dialysis (*i.e.*, had not received a kidney transplant) were identified retrospectively from the USRDS database. This period represents the most recent 5 yr of hospital claims

---

Received October 4, 2005. Accepted January 12, 2006.

Published online ahead of print. Publication date available at [www.jasn.org](http://www.jasn.org).

The interpretation and reporting of the data presented here are the responsibility of the authors and in no way should be seen as an official policy or interpretation of the US government.

**Address correspondence to:** Dr. Nancy Kutner, Department of Rehabilitation Medicine, Emory University, Atlanta, GA 30322. Phone: 404-712-5561; Fax: 404-712-5895; E-mail: [nkutner@emory.edu](mailto:nkutner@emory.edu)

data that were available for analysis. The patients identified were those who had procedure codes 36.10 to 36.19 of the *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* in Part A and/or Part B Medicare claims. For patients who were younger than 65 yr, only those with CABG procedure dates that occurred day 90 or later of ESRD were included, because many patients who are younger than 65 yr do not become eligible for Medicare for up to 90 d after initiating dialysis and therefore may have incomplete claims data before this.

### *Determination of Cardiac Rehabilitation, Patient Characteristics and Medical History, and Vital Status*

Cardiac rehabilitation, the primary independent variable in this study, was identified by Current Procedural Terminology codes 93797 for nonmonitored exercise and 93798 for monitored exercise. These are Health Care Financing Administration Common Procedure Coding Standard codes. Code 93797 indicates physician services for outpatient cardiac rehabilitation without continuous electrocardiogram monitoring per session, whereas code 93798 indicates physician services for outpatient cardiac rehabilitation with continuous electrocardiogram monitoring per session. Medicare coverage of participation by eligible patients in up to 36 sessions of a cardiac rehabilitation exercise program is considered reasonable and necessary, with three sessions a week in a single 12-wk period of therapy (5).

Patient age, gender, race, and dialysis start date were obtained from the USRDS Patient Standard Analysis File (SAF), along with Medicaid coverage at treatment start (yes/no), which was included as an indicator of socioeconomic status (Medicaid is a federal/state health insurance entitlement program for low-income people). Clinical characteristics that were documented at treatment start (primary diagnosis of diabetes, number of existing cardiovascular conditions [congestive heart failure, coronary artery disease, history of AMI, cardiac arrest, dysrhythmia, cerebral vascular disease, peripheral vascular disease], ambulation status [yes/no], chronic obstructive pulmonary disease, serum albumin [g/dl], and hemoglobin [g/dl]) were also obtained from the USRDS Patient SAF. AMI that occurred before CABG but after dialysis start was identified by the appearance of ICD-9-CM diagnosis codes 410, 410.X0, and 410.X1 in Part A or Part B Medicare claims.

Type of dialysis facility (hospital-based, non-hospital-based) in which the patient initiated dialysis was identified from USRDS Patient History Files (RXHIST and RXHIST60) that are constructed by the USRDS Coordinating Center and contain information about patients' original Centers for Medicare and Medicaid Services dialysis providers. Although approximate, this measure was the best indicator of the patient's probable type of dialysis facility when cardiac rehabilitation services were received. A transplant event that occurred after CABG was identified from the USRDS Transplant SAF.

Patient mortality data for up to 6 yr were obtained from USRDS Patient Files that contained information through December 31, 2003, on date of death and primary cause of death. Cardiac causes of death were AMI, hyperkalemia, pericarditis, atherosclerotic heart disease, cardiomyopathy, cardiac arrhythmia, cardiac arrest, valvular heart disease, and pulmonary edema. Data for individual patients from the various USRDS files were linked using the unique patient identifier that was assigned to each patient by the USRDS Data Coordinating Center.

### *Statistical Analyses*

The hazard function of cardiac rehabilitation, among alive patients, was modeled as a time-to-event outcome using the Cox proportional hazards model. The study start date was defined as the CABG procedure date. Separate models were estimated for patients who were aged 65+ and patients who were younger than age 65. Predictors in these

models included patient demographics and clinical measures, as well as type of facility in which the patient initiated dialysis (hospital-based/non-hospital-based).

To explore the effect of cardiac rehabilitation on survival, we analyzed both all-cause death and cardiac death using the Cox proportional hazards model. The analyses were restricted to patients who survived at least 90 d after CABG to minimize the effect on patient survival of postsurgery complications that are likely to be associated with early death. For patients who received a transplant, the follow-up time was censored at the time of transplantation. Cardiac rehabilitation as a time-varying indicator was included in these models, along with time-independent patient demographic and clinical predictors. To address concern about the potential confounding effect of a patient's health status at the initiation of cardiac rehabilitation, we further considered two additional sets of models. The first set added an indicator of hospitalization during the past 30 d. The second set included cardiac rehabilitation within 6 mo of CABG only, which was treated as a time-independent indicator; approximately 90% of observed cardiac rehabilitation occurred within 6 mo of CABG surgery. Statistical analyses were performed using SAS (SAS Institute, Cary, NC).

## **Results**

Demographic and medical characteristics of the study cohort are shown in Table 1. More patients who underwent CABG were male (61%) than female, and the average patient age was almost 68 yr. More than three fourths of patients in the cohort were white. The average number of documented cardiovascular conditions at dialysis start was  $1.4 \pm 1.4$  (range 0 to 7); 79% of patients had zero to two documented conditions, and the remainder had three or more documented conditions. Half of the patients who underwent CABG had developed ESRD as a result of diabetes, and 41% sustained an AMI after starting dialysis. The average number of months on dialysis at the time of CABG surgery was  $11.6 \pm 13.1$ .

Approximately 10% of dialysis patients who underwent CABG subsequently received cardiac rehabilitation (10.4% of patients aged <65, 9.9% of patients aged 65+). The mean  $\pm$  SD number of days between CABG and cardiac rehabilitation was  $88 \pm 100$  d; 50% of patients who received cardiac rehabilitation did so within 60 d after CABG, and 90% of patients who received cardiac rehabilitation did so within 183 d after CABG, *i.e.*, 6 mo. The majority of patients who received cardiac rehabilitation received monitored exercise.

Lower income patients of all ages, as measured by Medicaid coverage at treatment start, were less likely to receive cardiac rehabilitation (Table 2). Among patients who were aged 65 and older, men were significantly more likely than women to receive cardiac rehabilitation, whereas black patients and patients who were nonambulatory were less likely to receive cardiac rehabilitation. There was a trend for older patients with diabetic ESRD to be less likely to receive cardiac rehabilitation and for older patients with higher serum albumin to be more likely to receive cardiac rehabilitation (Table 2).

To investigate the effect of cardiac rehabilitation on all-cause and cardiac death, several sets of models were adopted to address the potential confounding effect of a patient's health status at the initiation of cardiac rehabilitation. All models provided similar results. The results for the model with cardiac

**Table 1.** Characteristics of 6215 patients with ESRD who started hemodialysis and underwent CABG surgery between January 1, 1998, and December 31, 2002<sup>a</sup>

Characteristic	Value
Age (yr; mean [SD])	67.9 (10.3)
Male (%)	61.4
Race (%)	
Asian	3.4
black	17.5
Native American	1.3
white	76.9
other	0.9
Medicaid coverage at HD start (%)	19.7
No. of cardiovascular conditions at HD start (mean [SD])	1.4 (1.4)
congestive heart failure (%)	39.9
coronary artery disease (%)	44.9
history of AMI (%)	18.9
cardiac arrest (%)	1.2
dysrhythmia, (%)	8.8
cerebral vascular disease (%)	11.0
peripheral vascular disease (%)	20.0
Hemoglobin (g/dl; mean [SD])	9.9 (1.6)
Serum albumin (g/dl; mean [SD])	3.1 (0.6)
Diabetic ESRD (%)	50.8
AMI before CABG (%)	41.1
COPD (%)	9.1
Nonambulatory (%)	3.4
Vintage (mo receiving dialysis when underwent CABG; mean [SD])	11.6 (13.1)
Started HD in hospital-based facility (%)	29.6

<sup>a</sup>CABG, coronary artery bypass grafting; HD, hemodialysis; AMI, acute myocardial infarction; COPD, chronic obstructive pulmonary disease.

rehabilitation and hospitalization within 30 d as time-varying indicators are given in Table 3.

Only patients who survived at least 90 d beyond CABG were included in the survival analysis, to exclude in-hospital and other early deaths after surgery. Cardiac death accounted for 45% of all deaths that were observed in the study cohort. Cardiac rehabilitation was a significant predictor of reduced risk for all-cause death (hazard ratio 0.65; 95% confidence interval 0.56 to 0.76;  $P < 0.001$ ) and risk for cardiac death (hazard ratio 0.64; 95% confidence interval 0.51 to 0.81;  $P < 0.001$ ). In addition, older patient age ( $\geq 65$ ), higher number of cardiovascular conditions at dialysis start, AMI before undergoing CABG, chronic obstructive pulmonary disease, nonambulatory status, longer time since starting dialysis, and recent hospitalization were associated with increased risk for both all-cause and cardiac death. Black race and higher serum albumin were associated with reduced risk for all-cause death, and lower income, as measured by Medicaid coverage, was associated with reduced risk for cardiac death.

## Discussion

Cardiac rehabilitation is recommended as a standard component of care for patients who are recovering from CABG (6). A national survey of 500 randomly selected cardiac rehabilitation programs found that 23.4% of CABG survivors enrolled in these programs (6), a rate more than twice as high as the rate that we observed (10%) among CABG survivors who were on dialysis. In addition, in the dialysis cohort that we studied, lower income patients were less likely to receive cardiac rehabilitation, and older women and older black patients were less likely to receive cardiac rehabilitation after CABG.

Determinants of participation in cardiac rehabilitation can be classified broadly as patient-related factors, including ease of transportation, severity of disease, personal preferences, and family support; physician-related factors, including perception of benefit for the patient and strength of recommendation to enroll in cardiac rehabilitation; and program-related factors, including location/availability and facility desirability (6). Lack of insurance reimbursement can be a barrier for cardiac patients in the general population, but dialysis patients are already Medicare entitled. A recent study in Canada found that in the context of an automatic referral system, perceived need for and benefits from cardiac rehabilitation and fewer logistical barriers (e.g., distance) in gaining access to programs were much more influential on program participation than any sociodemographic characteristics of patients, such as age, gender, ethnic group, or educational level (14). It is possible that dialysis patients may be more likely to participate in cardiac rehabilitation when they receive dialysis in a hospital-based dialysis facility, where an outpatient cardiac rehabilitation program may be physically located. Whether programs are conducted in specialized, free-standing clinics or in outpatient hospital departments, a physician must be available to perform medical duties, the program must be staffed by personnel who are trained in basic and advanced life support techniques and in exercise therapy for coronary disease, and medically necessary cardiopulmonary emergency diagnostic and therapeutic life-saving equipment must be available (5).

Exercise, which is prescribed individually for each patient, is the key component of cardiac rehabilitation programs that are covered by Medicare (5). The National Kidney Foundation Kidney Disease Outcomes Quality Initiative Cardiovascular Disease Work Group was not able to identify any randomized clinical trials in dialysis patients that had assessed the effects of exercise on cardiovascular risk profile, but the work group noted that randomized trials in dialysis patients have demonstrated effects of exercise training on physical functioning (15). Improvements in HD patients' physical fitness as measured by reaction time and lower extremity muscle strength (16), left ventricular systolic function (17), and psychosocial functioning (18) have been demonstrated in randomized clinical trials. Other studies of exercise interventions in patients who were on HD have provided evidence to support improvement in arterial stiffness (19), decrease in pulse pressure (20), increase in aerobic capacity (21–26), reduced need for antihypertensive medications (23,27,28), increase in hemoglobin concentration and hematocrit levels (28), and improved lipid metabolism (28).

Table 2. Multivariable Cox proportional hazards models predicting receipt of cardiac rehabilitation after CABG in HD patients younger than 65 yr and in HD patients 65 yr and older<sup>a</sup>

Risk Factor	Patients Aged <65 Yr <sup>b</sup> (n = 1855)		Patients Aged 65 Yr and Older (n = 4353)	
	Hazard Ratio (95% CI)	P Value	Hazard Ratio (95% CI)	P Value
Male gender	1.10 (0.74 to 1.38)	0.97	2.04 (1.62 to 2.58)	<0.0001
Race (referent = white)				
Asian	0.73 (0.34 to 1.58)	0.43	0.54 (0.24 to 1.21)	0.13
black	0.71 (0.49 to 1.03)	0.07	0.50 (0.34 to 0.72)	0.0002
Native American	1.82 (0.89 to 3.72)	0.10	0.64 (0.16 to 2.59)	0.53
other	0.42 (0.06 to 3.02)	0.39	0.41 (0.06 to 2.94)	0.38
Medicaid coverage at HD start	0.59 (0.42 to 0.85)	0.004	0.49 (0.33 to 0.73)	0.0005
No. of cardiovascular conditions at HD start	0.91 (0.79 to 1.05)	0.21	0.95 (0.88 to 1.02)	0.13
Hemoglobin	0.98 (0.90 to 1.07)	0.70	1.01 (0.95 to 1.07)	0.81
Serum albumin	1.08 (0.87 to 1.36)	0.48	1.16 (0.99 to 1.36)	0.07
Diabetic ESRD	0.89 (0.66 to 1.19)	0.41	0.82 (0.67 to 1.00)	0.05
AMI before CABG	0.80 (0.58 to 1.09)	0.15	0.88 (0.72 to 1.07)	0.20
COPD	0.70 (0.32 to 1.50)	0.36	0.89 (0.63 to 1.24)	0.49
Nonambulatory	0.27 (0.04 to 1.93)	0.19	0.35 (0.14 to 0.85)	0.02
Vintage	1.00 (0.99 to 1.01)	0.83	1.01 (1.00 to 1.01)	0.26
Started HD in hospital-based facility	1.25 (0.92 to 1.70)	0.15	1.16 (0.95 to 1.42)	0.14

<sup>a</sup>CI, confidence interval.

<sup>b</sup>Restricted to patients who underwent coronary bypass >90 d after start of ESRD treatment.

The National Kidney Foundation Kidney Disease Outcomes Quality Initiative Clinical Practice Guidelines for Cardiovascular Disease that were released in 2005 recommend that chronic kidney disease patients who qualify for cardiac rehabilitation be referred to a specialist (15). It is not known how likely dialysis patients are to be referred for cardiac rehabilitation and what impact this practice guideline may have on referral. Once the patient is referred, the potential benefits of cardiac rehabilitation must be valued by patients, and feasible opportunities for participating in cardiac rehabilitation must be available.

Our study indicates that dialysis patients who received cardiac rehabilitation after CABG had reduced risk for both all-cause and cardiac death, compared with patients who did not receive cardiac rehabilitation, but it is important to consider potential limitations of our data sources and interpretation of results. First, the survival benefit that was observed in this study may reflect patient selection effects instead of or in addition to therapeutic benefit. Patients who are referred to and participate in cardiac rehabilitation may differ in disease severity or prognosis from patients who are not referred and do not participate. We did endeavor to control for patients' health status by including recent hospitalization in the Cox models. Second, no information was available in the database to indicate whether patients were referred by their physician for cardiac rehabilitation services. Patients may have been referred but did not participate, a recognized issue in the general population (29). The strength and the content of the physician's recommendation may be an important variable. Eligible patients in the general population who fail to attend cardiac rehabilitation programs are less likely to perceive that their physician recommends cardiac rehabilitation (6,30,31) and are less likely to understand how cardiac rehabilitation can help them (32).

We chose to focus on dialysis patients who had undergone CABG because Medicare coverage of cardiac rehabilitation programs is considered reasonable and necessary for all patients who have had CABG, and CABG may be the optimal therapy for CVD in patients with ESRD (33). In addition, there is evidence from the general population that enrollment in cardiac rehabilitation is higher among CABG survivors than among patients who have had PCI or AMI (6). Medicare coverage of cardiac rehabilitation also is considered reasonable and necessary for patients who have a documented diagnosis of AMI within the past 12 mo or have stable angina, and those diagnoses also may characterize dialysis patients who undergo CABG. Two fifths (41%) of the patients whom we studied sustained an AMI after starting dialysis, and 25% had a diagnosis of angina.

Because patients who are on renal dialysis are at high risk for cardiac death and have a large burden of CVD risk factors, increasing attention is being given to outcomes that are associated with use of coronary revascularization and other cardiovascular interventional therapies in patients with ESRD (2,3,15,34,35). There is evidence that cardiac rehabilitation can promote improved survival of nondialysis patients after CABG surgery, but no previous studies have investigated whether the survival of dialysis patients after CABG may be improved as a function of cardiac rehabilitation. Our study showed that dialysis patients who received cardiac rehabilitation after CABG had a 35% reduced risk for all-cause mortality and a 36% reduced risk for cardiac death compared with dialysis patients who did not receive cardiac rehabilitation, independent of sociodemographic and clinical risk factors, including recent hospitalization. Studies that are based on administrative data such



Table 3. Multivariable Cox proportional hazards models predicting all-cause and cardiac mortality risk of 5274 incident HD patients after CABG<sup>a</sup>

Risk Factor	All-Cause Mortality Hazard Ratio (95% CI)	P Value	Cardiac Mortality Hazard Ratio (95% CI)	P Value
Age ≥ 65 y	1.56 (1.40 to 1.74)	<0.0001	1.37 (1.17 to 1.61)	<0.0001
Male gender	0.98 (0.90 to 1.07)	0.69	0.98 (0.86 to 1.11)	0.70
Race (referent = white)				
Asian	0.99 (0.77 to 1.26)	0.90	1.29 (0.93 to 1.79)	0.13
black	0.84 (0.75 to 0.95)	0.004	0.87 (0.73 to 1.03)	0.11
Native American	0.80 (0.53 to 1.21)	0.29	0.59 (0.30 to 1.20)	0.14
other	1.08 (0.67 to 1.75)	0.75	0.97 (0.46 to 2.05)	0.94
Medicaid coverage at HD start	0.92 (0.82 to 1.02)	0.11	0.83 (0.70 to 0.97)	0.02
No. of cardiovascular conditions at HD start	1.05 (1.02 to 1.09)	0.001	1.07 (1.02 to 1.12)	0.004
Hemoglobin	1.02 (0.99 to 1.05)	0.21	1.02 (0.98 to 1.06)	0.44
Serum albumin	0.91 (0.85 to 0.97)	0.006	1.02 (0.92 to 1.13)	0.78
Diabetic ESRD	0.95 (0.87 to 1.03)	0.20	1.07 (0.94 to 1.21)	0.33
AMI before CABG	1.11 (1.02 to 1.20)	0.02	1.29 (1.14 to 1.46)	<0.0001
COPD	1.27 (1.12 to 1.45)	0.0003	1.25 (1.03 to 1.52)	0.03
Nonambulatory	1.70 (1.40 to 2.06)	<0.0001	1.60 (1.19 to 2.16)	0.002
Vintage	1.01 (1.01 to 1.02)	<0.0001	1.01 (1.00 to 1.01)	0.01
Recent hospitalization <sup>b</sup>	7.76 (7.13 to 8.44)	<0.0001	8.11 (7.16 to 9.20)	<0.0001
Cardiac rehabilitation <sup>b</sup>	0.65 (0.56 to 0.76)	<0.0001	0.64 (0.51 to 0.81)	0.0002

<sup>a</sup>Restricted to patients who survived at least 90 d after undergoing CABG.

<sup>b</sup>Time-varying covariate.

as Medicare claims are necessarily exploratory in nature. Randomized clinical trials are needed to study the effects of exercise training on cardiovascular risk in dialysis patients (15) and to provide definitive evidence about the effect of dialysis patients' participation in cardiac rehabilitation after CABG.

## Acknowledgments

This study was supported by National Institutes of Health contract N01-DK-1-2471.

A preliminary version of this study was presented at the American Society of Nephrology annual meeting; October 31, 2004; St. Louis, MO.

## References

1. United States Renal Data System: *USRDS 2005 Annual Data Report*, Bethesda, National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health, 2005
2. Collins AJ: Cardiovascular mortality in end-stage renal disease. *Am J Med Sci* 325: 163–167, 2003
3. Culeton BF, Hemmelgarn B: Inadequate treatment of cardiovascular disease and cardiovascular disease risk factors in dialysis patients: A commentary. *Semin Dial* 17: 342–345, 2004
4. Herzog CA: Cardiovascular disease and dialysis patients: Is therapeutic nihilism justified? *Semin Dial* 12: 285–287, 1999
5. Centers for Medicare & Medicaid Services (CMS): *Medicare National Coverage Determinations Manual*. Available: [www.cms.hhs.gov/manuals/103\\_cov\\_determ/ncd103c1\\_Part\\_1.pdf](http://www.cms.hhs.gov/manuals/103_cov_determ/ncd103c1_Part_1.pdf). Accessed August 31, 2005
6. Thomas RJ, Miller NH, Lamendola C, Berra K, Hedback B, Durstine JL, Haskell W: National survey on gender differences in cardiac rehabilitation programs: Patient characteristics and enrollment patterns. *J Cardiopulm Rehabil* 16: 402–412, 1996
7. Dalal H, Evans PH, Campbell JL: Recent developments in secondary prevention and cardiac rehabilitation after acute myocardial infarction. *BMJ* 328: 693–697, 2004
8. Belardinelli R, Georgiou D, Cianci G, Purcaro A: Randomized, controlled trial of long-term moderate exercise training in chronic heart failure: Effects on functional capacity, quality of life, and clinical outcome. *Circulation* 99: 1173–1182, 1999
9. Hedback B, Perk J, Wodlin P: Long-term reduction of cardiac mortality after myocardial infarction: 10-year results of a comprehensive rehabilitation programme. *Eur Heart J* 14: 831–835, 1993
10. Lau A, Antman EM, Jimenez-Silva J, Kupelnick B, Mosteller F, Chalmers TC: Cumulative meta-analysis of therapeutic trials for myocardial infarction. *N Engl J Med* 327: 248–254, 1992
11. Oldridge NB, Guyatt GH, Fischer ME, Rimm AA: Cardiac rehabilitation after myocardial infarction: Combined experience of randomized clinical trials. *JAMA* 260: 945–950, 1988
12. Hemmelgarn BR, Southern D, Culeton BF, Mitchell LB, Knudtson ML, Ghali WA, for Alberta Provincial Project for

- Outcomes Assessment in Coronary Heart Disease (APPROACH) Investigators: Survival after coronary revascularization among patients with kidney disease. *Circulation* 110: 1890–1895, 2004
13. Tadros GM, Herzog CA: Percutaneous coronary intervention in chronic kidney disease patients. *J Nephrol* 17: 364–368, 2004
  14. Grace SL, Evindar A, Kung TN, Scholey PE, Stewart DE: Automatic referral to cardiac rehabilitation. *Med Care* 42: 661–669, 2004
  15. National Kidney Foundation (NKF), K/DOQI Work Group: K/DOQI clinical practice guidelines for cardiovascular disease in dialysis patients. *Am J Kidney Dis* 45[Suppl 3]: S1–S153, 2005
  16. van Vilsteren MC, de Greef MH, Huisman RM: The effects of a low-to-moderate intensity pre-conditioning exercise programme linked with exercise counselling for sedentary haemodialysis patients in The Netherlands: Results of a randomized clinical trial. *Nephrol Dial Transplant* 20: 141–146, 2005
  17. Deligiannis A, Kouidi E, Tassoulas E, Gigis P, Tourkantonis A, Coats A: Cardiac effects of exercise rehabilitation in hemodialysis patients. *Int J Cardiol* 70: 253–266, 1999
  18. Kouidi E, Iacovides A, Iordanidis P, Vassiliou S, Deligiannis A, Ierodiakonou C, Tourkantonis A: Exercise renal rehabilitation program: Psychosocial effects. *Nephron* 77: 152–158, 1997
  19. Mustata S, Chan C, Lai V, Miller JA: Impact of an exercise program on arterial stiffness and insulin resistance in hemodialysis patients. *J Am Soc Nephrol* 15: 2713–2718, 2004
  20. Parsons TL, Toffelmire EB, King-VanVlack CE: The effect of an exercise program during hemodialysis on dialysis efficacy, blood pressure and quality of life in end-stage renal disease (ESRD) patients. *Clin Nephrol* 61: 261–274, 2004
  21. Macdonald JH, Marcora SM, Jibani M, Phanish MK, Holly J, Lemmey AB: Intradialytic exercise as anabolic therapy in haemodialysis patients—A pilot study. *Clin Physiol Funct Imaging* 25: 113–118, 2005
  22. Storer TW, Casaburi R, Sawelson S, Kopple JD: Endurance exercise training during haemodialysis improves strength, power, fatigability and physical performance in maintenance haemodialysis patients. *Nephrol Dial Transplant* 20: 1429–1437, 2005
  23. Levendoglu F, Altintepe L, Okudan N, Ugurlu H, Gokbel H, Tonbul Z, Guney I, Turk S: A twelve week exercise program improves the psychological status, quality of life and work capacity in hemodialysis patients. *J Nephrol* 17: 826–832, 2004
  24. Kouidi E, Albani M, Natsis K, Megalopoulos A, Gigis P, Guiba-Tziampiri O, Tourkantonis A, Deligiannis A: The effects of exercise training on muscle atrophy in haemodialysis patients. *Nephrol Dial Transplant* 13: 685–699, 1998
  25. Painter PL, Nelson-Worel JN, Hill MM, Thornberry DR, Shelp WR, Harrington AR, Weinstein AB: Effects of exercise training during hemodialysis. *Nephron* 43: 87–92, 1986
  26. Zabetakis PM, Gleim GW, Pasternack FL, Saraniti A, Nicholas JA, Michelis MF: Long-duration submaximal exercise conditioning in hemodialysis patients. *Clin Nephrol* 18: 17–22, 1982
  27. Miller BW, Cress CL, Johnson ME, Nichols DH, Schnitzler MA: Exercise during hemodialysis decreases the use of antihypertensive medications. *Am J Kidney Dis* 39: 828–833, 2002
  28. Goldberg AP, Hagberg JM, Delmez JA, Haynes ME, Harter HR: Metabolic effects of exercise training in hemodialysis patients. *Kidney Int* 18: 754–761, 1980
  29. Daly J, Sindone AP, Thompson DR, Hancock K, Chang E, Davidson P: Barriers to participation in and adherence to cardiac rehabilitation programs; a critical literature review. *Prog Cardiovasc Nurs* 17: 8–17, 2002
  30. Jones LW, Farrell JM, Jamieson J, Dorsch KD: Factors influencing enrollment in a cardiac rehabilitation exercise program. *Can J Cardiovasc Nurs* 13: 11–15, 2003
  31. Cooper AF, Jackson G, Weinman J, Horne R: Factors associated with cardiac rehabilitation attendance: A systematic review of the literature. *Clin Rehabil* 16: 541–552, 2002
  32. Cooper AF, Jackson G, Weinman J, Horne R: A qualitative study investigating patients' beliefs about cardiac rehabilitation. *Clin Rehabil* 19: 87–96, 2005
  33. Chertow GM, Normand SL, Silva LR, McNeil BJ: Survival after acute myocardial infarction in patients with end-stage renal disease: Results from the Cooperative Cardiovascular Project. *Am J Kidney Dis* 35: 1217–1220, 2000
  34. Herzog CA, Li S, Weinhandl ED, Strief JW, Collins AJ, Gilbertson DT: Survival of dialysis patients after cardiac arrest and the impact of implantable cardioverter defibrillators. *Kidney Int* 68: 818–825, 2005
  35. Herzog CA, Ma JZ, Collins AJ: Poor long-term survival after acute myocardial infarction among patients on long-term dialysis. *N Engl J Med* 339: 799–805, 1998

Access to UpToDate on-line is available for additional clinical information  
at <http://www.jasn.org/>