Early Inpatient Rehabilitation After Elective Hip and Knee Arthroplasty

Michael C. Munin, MD; Thomas E. Rudy, PhD; Nancy W. Glynn, PhD; Lawrence S. Crossett, MD; Harry E. Rubash, MD

Context.—Inpatient rehabilitation after elective hip and knee arthroplasty is often necessary for patients who cannot function at home soon after surgery, but how soon after surgery inpatient rehabilitation can be initiated has not been studied.

Objective.—To test the hypothesis that high-risk patients undergoing elective hip and knee arthroplasty would incur less total cost and experience more rapid functional improvement if inpatient rehabilitation began on postoperative day 3 rather than day 7, without adverse consequences to the patients.

Design.—Randomized controlled trial conducted from 1994 to 1996.

Setting.—Tertiary care center.

Participants.—A total of 86 patients undergoing elective hip or knee arthroplasty and who met the following criteria for being high risk: 70 years of age or older and living alone, 70 years of age or older with 2 or more comorbid conditions, or any age with 3 or more comorbid conditions. Of the 86 patients, 71 completed the study.

Interventions.—Random assignment to begin inpatient rehabilitation on postoperative day 3 vs postoperative day 7.

Main Outcome Measures.—Total length of stay and cost from orthopedic and rehabilitation hospital admissions, functional performance in hospitals using a subset of the functional independence measure, and 4-month follow-up assessment using the RAND 36-item health survey I and the functional status index.

Results.—Patients who completed the study and began inpatient rehabilitation on postoperative day 3 exhibited shorter mean (±SD) total length of stay (11.7±2.3 days vs 14.5±1.9, $P<.001$), lower mean (±SD) total cost ($25 891±$3648 vs $27 762±$3626, $P<.03$), more rapid attainment of short-term functional milestones between days 6 and 10 (36.2±14.4 m ambulated vs 21.4±13.3 m, $P<.001$; 4.8±0.8 mean transfer functional independence measure score vs 4.3±0.7, $P<.01$), and equivalent functional outcome at 4-month follow-up.

Conclusion.—These data showed that high-risk individuals were able to tolerate early intensive rehabilitation, and this intervention yielded faster attainment of short-term functional milestones in fewer days using less total cost.

JAMA. 1998;279:847-852

TOTAL JOINT replacements for the hip and knee are among the most common surgical procedures in the United States. Rehabilitation is essential to minimize disability after surgery, yet pressure on clinicians to reduce length of stay has limited the use of hospital rehabilitation services. Most patients can be discharged directly home in 5 to 7 days if they are medically stable and have completed a postoperative rehabilitation program.[1] Those who were significantly older, lived alone, and had an increased number of comorbid conditions were at high risk for requiring further inpatient rehabilitation services before returning home.[2] However, there are no practice parameters to determine how best to treat high-risk patients who are unable to go directly home after joint replacement surgery.

Two factors that influence the type of rehabilitation program selected for high-risk individuals include the timing of when to begin inpatient rehabilitation and the intensity of therapy services needed to attain good outcomes. Some rehabilitation facilities accept patients as early as the third postoperative day to reduce patients' length of stay. However, it is unknown if elderly patients can benefit from intensive therapy this early after surgery. If patients are transferred to a rehabilitation facility prematurely, rehabilitation costs could be increased if patients are unable to participate in intensive physical and occupational therapies, or if they are transferred out of rehabilitation because of acute medical or surgical complications. It has not been determined if more intensive therapy for high-risk joint replacement patients produces a faster rate of improvement, or if outcome is independent of the amount of delivered therapy.[3]

For editorial comment see p 880.

Using an acute inpatient rehabilitation setting, this study randomized high-risk patients to either begin inpatient rehabilitation on postoperative day 3 (day 3 treatment group) or to delay inpatient rehabilitation until 7 days after surgery (day 7 treatment group). Since the acute care hospital provides some rehabilitation services at a lower intensity compared with inpatient rehabilitation, and most patients who go home can be discharged within 7 days, this time interval was used as the control. Total length of stay, total cost, complications, and functional outcomes were measured. We tested the hypothesis that the day 3 group would demonstrate less total cost and a faster rate of functional improvement because intensive therapy was delivered earlier after surgery. Additionally, we hypothesized that beginning rehabilitation efforts earlier following surgery would not be detrimental to long-term outcomes.

METHODS

Subjects

All patients evaluated for total-hip arthroplasty or total-knee arthroplasty at the University of Pittsburgh orthopedics office were considered for inclusion

From the Division of Physical Medicine and Rehabilitation (Drs Munin and Glynn), Department of Orthopaedic Surgery (Drs Munin, Crossett, and Rubash), and the Departments of Anesthesiology and Biostatistics (Dr Rudy), University of Pittsburgh, Pittsburgh, Pa.

Reprints: Michael C. Munin, MD, Division of Physical Medicine and Rehabilitation, Suite 901, Kaufmann Bldg, 3471 Fifth Ave, Pittsburgh, PA 15213 (e-mail: muninmc@msx.upmc.edu).

between August 1994 and November 1995. Eligible subjects included patients at high risk for requiring inpatient rehabilitation after elective hip and knee arthroplasty: (1) 70 years of age or older and living alone, (2) 70 years of age or older with 2 or more comorbid conditions, or (3) any age with 3 or more comorbid conditions.[2] A comorbidity checklist that assessed 11 major conditions was developed to extract significant medical history from both the clinical record and patient interviews. The surgical procedure could be a primary arthroplasty or a revision of a previous arthroplasty. Individuals were excluded if the indication for surgery included stabilization for tumor, acute fracture, femoral osteonecrosis, or hemophilic arthropathy. Additionally, patients were excluded if medical or surgical complications occurred postoperatively and precluded scheduled rehabilitation transfer. Each patient who met the criteria for inclusion read and signed the institutional review board informed consent form before data collection began.

Assignment

Eighty-six subjects met the inclusion criteria. These patients were assigned randomly to begin inpatient rehabilitation on postoperative day 3 (day 3 group) or remain on the orthopedic service until postoperative day 7 (day 7 group) and then pursue inpatient rehabilitation. A random listing of 100 numbers, using 0 to equal day 3 group and 1 to equal day 7 group, was generated in blocks of 10. Separate lists were used for hip and knee patients to maintain balance of the randomized design. The codes were administered by a blinded executor who kept them in a locked filing cabinet that was inaccessible to the principle investigator and research coordinator. Randomization occurred preoperatively in the orthopedic office after patient eligibility was established and the consent form was signed. Based on our previous data,[2] a sample size of 40 patients per group was determined to have adequate statistical power ($\beta = .80$) to detect major effect sizes (SD = 0.8) for length of stay and total costs.

Rehabilitation

Patients were treated at a university medical center for all aspects of the study, which included an orthopedic surgery floor and a 20-bed inpatient rehabilitation unit. Patients in the day 3 group had earlier exposure to the inpatient rehabilitation unit, even though both treatment groups started therapy at the same time.

While in the acute care orthopedic surgery service, patients were scheduled to receive two 30-minute physical therapy sessions beginning on postoperative day 2 and one 30-minute occupational therapy session beginning no later than postoperative day 3 during weekdays only. The comprehensive inpatient rehabilitation program included two 60-minute physical therapy and two 60-minute occupational therapy sessions daily, as well as recreational therapy and clinical psychology services as needed. One 30-minute physical therapy session was given to all patients, regardless of location, on Saturday.

The rehabilitation and orthopedic units both used clinical pathways, and several practical considerations were routinely used. Pain was aggressively treated with ice packs applied to the incision, and narcotic analgesia was always given before morning and afternoon therapy sessions. The surgical wound was monitored for drainage and prophylactic antibiotic coverage with a first-generation cephalosporin instituted when needed, although therapy was infrequently withheld because of wound drainage. Discharge from the rehabilitation unit was determined by the interdisciplinary team of clinicians, some of whom were not blinded to randomization. However, standardized, objective criteria were used for discharge. All patients had to be ambulating greater than 45 m, performing transfers and all self-care independently with adaptive equipment, and demonstrating the ability to safely return home.

Table 1.—Subject Demographics and Presurgical Information for Patients Completing the Rehabilitation Component of the Study

Variable	Hip Replacement Group		Knee Replacement Group		Total Sample
	Day 3	Day 7	Day 3	Day 7	
Sample size	14	12	24	21	71
Age, y					
Mean	75.7	74	72.2	73.2	73.5
SD	5.4	5.8	6.5	7.7	6.6
Gender, %					
Male	14.3	16.7	8.3	4.8	9.9
Female	85.7	83.3	91.7	95.2	90.1
Ethnicity, %					
White	81.8	100	83.3	85	86.6
African American	18.2	0	16.7	15	13.4
Major insurance, %					
Medicare	100	91.7	91.7	100	95.8
Medicaid	0	0	4.2	0	1.4
Commercial	0	8.3	4.2	0	2.8
Osteoarthritis, %	92.9	83.3	79.2	100	88.7
Rheumatoid arthritis, %	7.1	16.7	20.8	0	11.3
Revision surgery, %	28.6	41.6	25	19	26.8
Live alone, %	71.4	41.6	75	66.7	66.2
No. of comorbid conditions, mean (SD)*	2.4 (0.9)	3.1 (1.2)	2.1 (1.1)	2.5 (1.5)	2.5 (1.3)
RAND health survey, physical domain, scale score (SD)†					
Physical functioning	23.6 (11.5)	17.1 (11.8)	20.2 (12.1)	16.2 (14.7)	19.2 (12.8)
Role functioning, physical	14.3 (21.3)	16.6 (18.4)	10.4 (19.4)	11.9 (24.5)	12.7 (20.9)
Bodily pain	31.3 (14.8)	27.5 (10.7)	31.9 (10.7)	25.4 (16.3)	29.1 (13.4)

*Comorbid conditions included diabetes requiring medication, coronary artery disease or prior myocardial infarction, asthma requiring medication, stroke with residual neurologic deficit, cancer, renal disease requiring dialysis, hypertension requiring medication, peripheral vascular disease with claudication, other neurologic disorders (eg, Parkinson disease), systemic arthritis, and active psychiatric disorders.
†RAND health survey scale scores range from 0 to 100.

Outcome Measures

Length of Stay and Cost Analysis.— The total hospital length of stay, which included the days in the orthopedic and rehabilitation units, was compared between treatment groups. All physical and occupational therapy sessions were counted throughout the orthopedic and rehabilitation admissions. Data were collected by the Medical Archival System (MARS) database.[4]

Charges were retrieved from the individual transaction detail, including transaction code, department code, quantity, date of service, and charge. Charge data were converted to cost using total-loaded ratios of cost to charge, which are hospital-specific, government-mandated standards used to estimate cost in prior joint replacement studies.[5,6] The ratios of cost to charge have been shown to have good reliability for comparing the relative costs of patients with the same diagnosis in different institutions.[7] Each department's unique fiscal year 1995 ratios of cost to charge were applied to arrive at the total-loaded cost for each transaction. The total-loaded costs were aggregated to arrive at the department costs for day-

Table 2.—Description of Patients Not Completing the Rehabilitation Component of the Study*

Variable	Treatment Group	
	Day 3 (n=7)	Day 7 (n=8)
Complications		
Deep vein thrombosis	4	1
Elevated prothrombin time	1	0
Ileus	1	0
Infected knee	0	1
Deconditioned (nursing home placement)	0	1
Noncomplications		
Administrative	1	0
Went home	0	4
Insurance denial	0	1
Age, mean (SD), y	72.7 (7.5)	71.1 (8.5)
Gender, % female	85.7	75
Type of replacement, hip:knee	5:2	4:4
Revision surgery	2	3
No. of comorbid conditions, mean (SD)†	3 (1.7)	2.2 (0.9)
Length of stay, mean (SD), d	13.1 (5.2)	11.4 (5.6)
Total costs, mean (SD), $	30 335 (6208)	23 245 (4655)
RAND health survey, physical domain, scale score (SD)‡		
Physical functioning	17.8 (9.9)	15 (15.5)
Role functioning, physical	14.2 (37.8)	9.4 (26.5)
Bodily pain	33.2 (22.1)	25 (12.9)

*Statistical analyses indicated no significant differences between groups, with the exception that day 3 total costs were significantly higher than day 7 ($P<.02$).
†See footnote in Table 1 for a list of comorbid conditions included in this index.
‡RAND health survey scale scores range from 0 to 100.

of-surgery costs, hospital postoperative costs, and rehabilitation costs for physical and occupational therapy. Physician costs were derived from average Medicare reimbursement for the type of surgical procedure and physiatric evaluation and management.

Functional and Health Status Assessments.—Baseline data were obtained approximately 4 weeks before surgery to assess general health status and function. General health status was obtained with the RAND 36-item health survey I (RAND-36) and data were confined to 2 primary health constructs, physical and mental domains.[8,9] The functional status index (FSI)[10] was used to assess overall function based on important tasks that are needed to complete activities of daily living. The FSI has 3 dimensions that measure difficulty, pain, and assistance. Both of these self-report instruments have been validated in prior hip and knee arthroplasty studies.[11-13]

A subset of the functional independence measure (FIM)[14] was used daily in both the orthopedic and rehabilitation units to measure immediate postoperative function. The therapists in the study were trained to use the FIM, and we have previously demonstrated excellent interrater reliability using a FIM-based measurement system in the acute care hospital after joint replacement.[15] To assess the perceived benefit of the rehabilitation program, follow-up data using the RAND-36 and FSI were mailed at 16 weeks[16] from the date of hospital discharge.

Data Analyses.—Analysis of variance, using the general linear model because of unequal sample sizes, was used for length of stay and cost data. To provide better protection against type I error, a multivariate analysis of variance (MANOVA) approach was used to analyze RAND-36 and FSI change scores. Repeated-measures MANOVA was used for the FIM data that were divided into 3 periods. Power or square-root transformations were applied to 3 variables to achieve adequate normality for the analysis of variance and MANOVA analyses. Raw means and SDs for all variables are reported here for clarity. Exact probability χ^2 analyses, computed with the StatXact program,[17] were used to analyze dichotomous and ordinal measures. A P value of $<.05$ was used as statistically significant, and Bonferroni correction was applied to post hoc analyses when the primary analyses were significant.

The intention-to-treat principle was maintained in this study whenever possible. Because of differences in study dropouts between the day 3 and day 7 groups, efficacy analyses that included only subjects completing the rehabilitation arm of the study also were computed for length of stay and cost data.

RESULTS

Of the 86 patients randomized to the study, 71 patients (83%) completed the rehabilitation arm of the study following replacement surgery (Table 1). Fifteen patients were excluded or dropped out after surgery (Table 2), with no exclusions occurring before randomization. The number of patient exclusions was not significantly different between the 2 rehabilitation conditions (χ^2 [1 df]=0.47, P=.57). A MANOVA analysis between those excluded and those completing treatment for FSI and RAND-36 presurgery scores indicated no significant differences. Analysis of variance data indicated no significant differences with respect to age and the number of comorbid conditions, and χ^2 analyses indicated no significant differences with respect to gender.

As displayed in Table 1, the baseline characteristics for subjects completing the rehabilitation component were similar between the 2 treatment conditions (day 3 vs day 7) and the 2 types of replacement surgeries (hip vs knee). Analysis of variance and χ^2 analyses for the variables listed in Table 1 indicated that for knee patients, a higher proportion of rheumatoid arthritis patients were randomized to the day 3 group (χ^2 [1 df]=4.92, $P<.05$). For all other pretreatment measures, no significant differences were found between groups, indicating that the randomization procedure was successful in producing comparable groups.

Length of Stay and Cost Analyses

Both intention-to-treat and efficacy analyses of total length-of-stay data indicated that patients assigned to the day 3 protocol stayed in the hospital significantly fewer days than day 7 patients (both with $P<.04$). This conclusion was not significantly influenced or modified by the type of replacement received. The length-of-stay data for patients who completed rehabilitation are presented in Table 3. When dropouts were included, patients assigned to day 3 had a mean length of stay of 11.9 days (SD, 2.9) and day 7 had 13.8 days (SD, 3.1), which remained significantly different ($P<.004$). The slight reduction in length-of-stay differences between day 3 and day 7 patients when dropouts were included is because of the longer stay of excluded day 3 patients compared with those day 3 patients completing rehabilitation, coupled with the 4 patients in the day 7 dropout group (Table 2) who stayed an average of only 8.5 days because they elected to go home rather than complete the rehabilitation component of the study.

Intention-to-treat grand total cost analyses indicated no significant differences between patients assigned to the day 3 and day 7 treatment conditions. Day 3 patients had a mean cost of $26 582 (SD, $4370) and day 7 had a mean cost of $26 880 (SD, $4194). An efficacy cost

Table 3.—Length of Stay and Costs for Patients Completing Rehabilitation by Type of Postoperative Rehabilitation and Replacement

Variable	Treatment Group		Day 3 Group vs Day 7 Group, *P* Value	Hip Replacement Group		Knee Replacement Group	
	Day 3 (n=38)	Day 7 (n=33)		Day 3 (n=14)	Day 7 (n=12)	Day 3 (n=24)	Day 7 (n=21)
Length of stay, d (median [SD], range)	11.7 (11 [2.3], 8-16)	14.5 (14 [1.9], 11-20)	<.001	12.2 (13 [2.8], 9-16)	14.8 (14 [2.2], 12-20)	11.4 (11 [2.1], 8-16)	14.2 (14 [1.7], 11-18)
Costs, mean (SD), $							
Day of surgery	12 056 (3140)	11 326 (3458)	.35	13 556 (3270)	12 776 (4296)	11 180 (2764)	10 497 (2645)
Hospital postoperation	9361 (3359)	11 773 (3363)	<.008	9738 (4140)	11 465 (3885)	9142 (2886)	11 949 (3116)
Rehabilitation							
Physiatrist	366 (79)	321 (60)	<.008	382 (92)	332 (70)	357 (70)	316 (54)
Physical therapy	2581 (701)	2974 (689)	<.008	2663 (746)	3078 (787)	2533 (686)	2915 (639)
Occupational therapy	1526 (622)	1367 (583)	.25	1916 (644)	1786 (668)	1299 (492)	1128 (363)
Physical therapist and occupational therapist*	347 (56)	298 (59)	<.008	375 (56)	326 (74)	331 (51)	282 (44)
Total costs†	25 891 (3648)	27 762 (3626)	<.03	28 256 (3545)	29 437 (4352)	24 512 (2985)	26 804 (2824)

*Costs for physical therapist and occupational therapist are per day.
†Total costs include all costs except daily physical therapist and occupational therapist.

Table 4.—Physical Therapy Functional Independence Measures (FIM) Scores by Type of Postoperative Rehabilitation and Replacement*

Variable	Treatment Group		Post Hoc *P* Value†	Hip Replacement Group		Knee Replacement Group	
	Day 3 (n=37/29)	Day 7 (n=31/30)		Day 3 (n=14/10)	Day 7 (n=11/11)	Day 3 (n=23/19)	Day 7 (n=20/19)
Transfers, mean (SD), FIM							
Days 1-5	3.61 (1.05)	3.37 (0.82)	.52	3.2 (1.25)	3.33 (0.87)	3.85 (0.86)	3.39 (0.83)
Days 6-10	4.8 (0.80)	4.26 (0.74)	<.01	4.59 (0.97)	4.16 (0.43)	4.92 (0.68)	4.31 (0.88)
Days ≥11	5.5 (0.65)	5.47 (0.53)	.46	5.12 (0.77)	5.72 (0.29)	5.7 (0.48)	5.32 (0.58)
Ambulation, mean (SD), FIM							
Days 1-5	1.43 (0.40)	1.18 (0.35)	<.01	1.54 (0.53)	1.17 (0.35)	1.36 (0.30)	1.19 (0.36)
Days 6-10	3.63 (1.51)	2.08 (1.02)	<.001	3.46 (1.58)	1.81 (0.81)	3.72 (1.49)	2.23 (1.11)
Days ≥11	5.01 (1.32)	4.33 (1.43)	.13	4.87 (1.51)	4.65 (1.32)	5.08 (1.25)	4.15 (1.5)
Distance walked, mean (SD), m							
Days 1-5	12.62 (8.34)	5.89 (4.2)	<.001	12.95 (9.39)	5.11 (3.84)	12.44 (7.9)	6.33 (4.45)
Days 6-10	36.18 (14.36)	21.41 (13.3)	<.001	31.79 (15.14)	17.7 (8.76)	38.55 (13.66)	23.36 (14.98)
Days ≥11	44.06 (15.4)	40.88 (9.29)	.7	39.14 (12.73)	43.13 (8.57)	46.39 (16.09)	39.63 (9.66)
Stairs, mean (SD), FIM							
Days 1-5	1.04 (0.12)	1 (0)	.2	1.07 (0.17)	1 (0)	1.02 (0.07)	1 (0)
Days 6-10	2.12 (1.32)	1.27 (0.45)	<.01	2.11 (1.34)	1.17 (0.33)	2.13 (1.34)	1.34 (0.51)
Days ≥11	2.98 (1.79)	2.58 (1.4)	.32	2.83 (1.85)	2.22 (1.33)	3.07 (1.81)	2.79 (1.43)

*The 2 sample sizes presented for each patient group represent the available sample size for the days 1 to 5 and days 6 to 10 FIM scores (numbers before the virgule) and the available sample for FIM scores during days 11 or higher (numbers following the virgule). Data for 3 patients were unavailable during the first 2 time frames. Additionally, data for days 11 or higher were not available for all patients because of the earlier discharge of some patients. A separate multivariate analysis of variance for day 11 or higher FIM scores was computed because of this reduced sample size.
†Post hoc tests for day 3 vs day 7 treatment groups for significant interactions of days by treatment group, which indicated the treatment groups were significantly different for 1 or more of the 3-day ranges. Bonferroni correction was applied to control type I errors.

analysis of those completing rehabilitation showed the grand total costs were significantly lower for day 3 compared with day 7 (Table 3). To further delineate these differences, Bonferroni-adjusted post hoc analyses were conducted for major components of the grand total cost. These analyses indicated that hospital postoperative costs were significantly less for day 3 patients and that hip replacements were more expensive than knee replacements for day-of-surgery costs. Other analyses stratified by type of surgery were not significant. For rehabilitation costs (Table 3), physician costs were significantly higher for inpatient rehabilitation that was begun sooner for day 3 patients compared with day 7 patients and the daily average for physical therapist plus occupational therapist costs indicated a higher daily fee for day 3 vs day 7 patients. This finding demonstrates that the day 3 group actually received more therapy per day than the day 7 group.

Physical Therapist– and Occupational Therapist–Assessed FIM Scores During Hospital Rehabilitation

The daily FIM scores were analyzed to determine the rate of functional change during hospitalization. Because of the differing lengths of stay among patients, the distributional characteristics of patients' lengths of stay were evaluated and lower-, middle-, and upper-quartile values were computed.[18] This statistical approach created 3 postoperative periods: days 1 through 5, days 6 through 10, and days 11 or higher. Mean FIM scores were computed for each of these periods for each patient.[19] Data for days 11 or higher were not available for all patients because of the earlier discharge of some patients, as noted in Tables 4 and 5.

As displayed in Table 4, significant differences in physical therapist–assessed FIM scores were found between the day 3 vs day 7 groups, although no differences were noted when the data were stratified by surgery type. Specifically, transfers, ambulation, distance walked, and stair climbing scores were significantly higher (better) for the day 3 patients during days 6 to 10 of hospitalization. Additionally, day 3 patients compared with day 7 patients displayed significantly better scores on ambulation and distance walked during days 1 to 5 of hospitalization. Results for the occupational therapist–assessed scores were similar to those of the physical therapist–assessed scores (Table 5), with the day 3 patients demonstrating signifi-

Table 5.—Occupational Therapy Functional Independence Measure (FIM) Scores by Type of Postoperative Rehabilitation and Replacement*

Variable	Treatment Group		*P* Value†	Hip Replacement Group		Knee Replacement Group	
	Day 3 (n=34/24)	Day 7 (n=30/30)		Day 3 (n=13/9)	Day 7 (n=11/11)	Day 3 (n=21/15)	Day 7 (n=19/19)
Bathing, mean (SD), FIM							
Days 6-10	4.76 (0.73)	4.1 (0.92)	<.01	4.64 (0.84)	4.05 (0.96)	4.83 (0.65)	4.13 (0.93)
Days ≥11	5.51 (0.5)	5.28 (0.53)	.17	5.4 (0.47)	5.26 (0.55)	5.57 (0.52)	5.3 (0.54)
Lower-extremity dressing, mean (SD), FIM							
Days 6-10	4.67 (0.81)	4.07 (0.85)	<.01	4.54 (0.81)	4.02 (1.12)	4.74 (0.82)	4.1 (0.71)
Days ≥11	5.46 (0.6)	5.28 (0.61)	.41	5.21 (0.64)	5.22 (0.7)	5.61 (0.53)	5.31 (0.58)
Toilet transfers, mean (SD), FIM							
Days 6-10	4.69 (0.74)	4.38 (0.82)	.19	4.63 (0.87)	4.5 (0.67)	4.73 (0.66)	4.31 (0.9)
Days ≥11	5.55 (0.51)	5.37 (0.48)	.48	5.34 (0.54)	5.54 (0.42)	5.67 (0.45)	5.28 (0.5)
Tub or shower transfers, mean (SD), FIM							
Days 6-10	3.57 (1.63)	3.78 (1.29)	.54	3.15 (1.64)	3.42 (1.59)	3.8 (1.61)	4.01 (1.04)
Days ≥11	4.97 (1.4)	4.99 (1.04)	.72	4.54 (1.46)	5.15 (0.75)	5.25 (1.34)	4.89 (1.19)

*In contrast to physical therapy–assessed scores (Table 4), too few occupational therapy–assessed scores were conducted during days 1 to 5 of hospitalization to compute reliable analyses and, therefore, are not displayed in this table. The 2 sample sizes presented for each patient group represent the available sample size for the days 6 to 10 FIM scores (numbers before the virgule) and the available sample for FIM scores during days 11 or higher (numbers following the virgule). Data for 7 patients were unavailable during the first 2 time frames. Additionally, data for days 11 or higher were not available for all patients because of the earlier discharge of some patients. A separate multivariate analysis of variance for days 11 or higher FIM scores was computed because of this reduced sample size.
†Bonferroni correction was applied to control type I errors.

Table 6.—Change Scores Between Pretreatment and Follow-up Functional Status Index Scores by Type of Postoperative Rehabilitation and Replacement*

Variable	Treatment Group		Hip Replacement		Knee Replacement	
	Day 3 (n=40)	Day 7 (n=31)	Day 3 (n=16)	Day 7 (n=12)	Day 3 (n=24)	Day 7 (n=19)
Pain	10.23 (9.4)	9.48 (9.61)	8.07 (9.51)	9.25 (12.17)	11.58 (9.27)	9.63 (7.95)
Difficulty	8.51 (9.07)	6.45 (10.31)	8.73 (6.98)	6.92 (10.52)	8.38 (10.3)	6.16 (10.46)
Assistance	2.21 (9.06)	3.55 (10.73)	2.33 (8.3)	4.75 (13.48)	2.13 (9.68)	2.79 (8.91)

*Data are reported as mean (SD). Positive change scores indicate improvement from pretreatment to 4-month follow-up.

cantly higher scores during days 6 to 10 of hospitalization for bathing and lower-extremity dressing.

Follow-up Analyses for Standardized Self-report Measures

Of the 86 patients randomized to the study, 71 patients (83%, 62 who completed rehabilitation and 9 dropouts) could be reached and returned the standardized questionnaires at the time of the 4-month follow-up. Separate MANOVA analyses for pretreatment FSI and RAND-36 scores between those completing the follow-up questionnaires and those lost to follow-up indicated no significant differences.

Change scores for the FSI between the 4-month follow-up and pretreatment values are presented in Table 6. A MANOVA analysis indicated no significant differences in the magnitude of these FSI changes between rehabilitation groups or between type of replacement surgery. A separate MANOVA indicated patients displayed significant changes from pretreatment to the 4-month follow-up for the FSI pain and difficulty scales ($P<.001$), but not for the assistance scale.

Change scores for the 5 RAND-36 scales used in this study are displayed in Table 7.[4] All 3 physical domain scales displayed significant improvements from pretreatment values at the time of the 4-month follow-up (both $P<.001$), but significant differences in the change scores were not found between rehabilitation groups or replacement type. Similarly, change scores for the 2 mental domain scales were not significantly different between groups or replacements.

Follow-up Complications

Within the follow-up interval, 2 patients had hip dislocation (1 day 3 and 1 day 7), while another hip replacement patient (day 3) was ruled out for deep vein thrombosis at a local emergency department. Three knee arthroplasty patients (all day 7) were readmitted to the hospital with diagnoses of deep vein thrombosis in 2 individuals and congestive heart failure was ruled out in another. The χ^2 analyses indicated no significant differences between day 3 and day 7 groups with respect to follow-up complications (χ^2 [1 *df*]=1.44, $P=.30$).

COMMENT

The results from this randomized trial indicate that high-risk individuals undergoing elective hip and knee arthroplasty had shorter total length of stay, faster attainment of short-term functional milestones, and equivalent functional outcome at 4-month follow-up if they completed an inpatient rehabilitation program that began on the third rather than the seventh postoperative day. Patients in this cohort were primarily female, lived alone, had increased comorbidities, and were typical of elderly patients receiving total joint replacement.[20] More important, the data showed that this group could tolerate and benefit from early, intensive rehabilitation, which allowed a more rapid emphasis on physical independence and comprehensive assessment of functional problems.[11] Patients in the day 3 group did not have a higher rate of complications requiring transfer from the rehabilitation unit or increased hospital readmissions once sent home. In addition, the day 3 group demonstrated longer ambulation distance walked and superior FIM scores for mobility and self-care measures during postoperative days 6 to 11. The increased therapy attended per day by the day 3 group appears to be responsible for shorter total length of stay, since functional milestones were attained sooner than for the day 7 patients.

Few studies have examined cost in relation to functional outcome after hip and knee arthroplasty. Healy and Finn[5] and Barber and Healy[6] examined the differences in acute care costs pertaining to total-hip arthroplasty and total-knee arthroplasty during a 10-year follow-up period and found significant price increases related mostly to the cost of the surgical implant. Liang et al[13] reported an average cost of $22 730 per patient with significant improvements in global health and functional status at 6 months postoperatively. Chang et al[21] found total-hip arthroplasty to be cost-effective in improving quality-adjusted life years for both short- and long-term outcomes. While these studies support the benefits of joint replacement, all patients were

Table 7.—Change Scores Between Pretreatment and Follow-up RAND 36-Item Health Survey Scores by Type of Postoperative Rehabilitation and Replacement*

Variable	Treatment Group		Hip Replacement		Knee Replacement	
	Day 3 (n=40)	Day 7 (n=31)	Day 3 (n=16)	Day 7 (n=12)	Day 3 (n=24)	Day 7 (n=19)
Physical domain, mean (SD)						
Physical functioning	13.5 (24.86)	16.43 (23.86)	14.06 (27.7)	19.58 (16.3)	13.13 (23.4)	14.43 (27.85)
Role functioning, physical	13.13 (30.48)	16.94 (34.39)	20.31 (38.96)	25 (33.71)	8.33 (22.92)	11.84 (34.73)
Bodily pain	21.81 (27.03)	24.11 (21.72)	39.22 (22.26)	29.79 (24.04)	12.01 (23.76)	20.53 (19.96)
Mental domain, mean (SD)						
Emotional well-being	6.2 (14.52)	2.19 (12.89)	3.75 (10.38)	5 (10.39)	7.83 (16.74)	0.42 (14.23)
Role functioning, emotional	−1.67 (42.67)	7.53 (61.89)	2.08 (35.42)	5.56 (69.39)	−4.17 (47.46)	8.77 (58.63)

*Positive change scores indicate improvement from pretreatment to 4-month follow-up.

included rather than focusing solely on high-risk individuals who have higher hospitalization costs. In our earlier work, treatment algorithms differed significantly depending on whether patients were at low or high risk for requiring prolonged inpatient rehabilitation services after total-hip arthroplasty and total-knee arthroplasty.[2]

Similar to our results, Cameron and colleagues[16] randomized hip fracture survivors to receive either accelerated rehabilitation or standard care and found significant total cost reductions for the accelerated group. In this study, decreased length of stay accounted for differences in cost between groups even though the therapy cost per day was higher in the accelerated treatment group.

Although 15 patients (17%) randomized to the study did not complete the rehabilitation arm because of dropouts or complications, there were no significant differences between day 3 vs day 7 exclusions for basic demographic and health status measures or in the composition of those excluded as compared with the remaining high-risk patients whose postoperative health status did not interfere with rehabilitation transfer. An intention-to-treat analysis indicated that day 3 patients had a significantly shorter total length of hospital stay compared with day 7 patients. However, an intention-to-treat total cost analysis indicated no significant cost differences, even though an efficacy cost analysis of patients who completed rehabilitation demonstrated a mean cost savings of $1871 in favor of early rehabilitation. The reason for the different conclusions is that day 7–excluded patients had significantly lower total costs than day 3 exclusions, primarily because 4 of the 8 patients in the day 7 exclusion group elected not to participate in the rehabilitation component of the study even though this was deemed appropriate. Thus, if the early inpatient rehabilitation program was generalized, it is likely that overall costs would, in the worst case, not increase and probably would decrease.

In conclusion, this study supports acute inpatient rehabilitation services beginning on postoperative day 3 for high-risk patients unable to make transitions to home after total joint replacement. These data also support the notion that the rate of recovery can be hastened by settings that provide intensive therapy services early after surgery.

This study was supported by a grant from the Competitive Medical Research Fund of the University of Pittsburgh Medical Center.

The authors are indebted to Jeannine Valentino, BS, and Meenakshi Malhotra, MBA, as well as the other physical and occupational therapists at the University of Pittsburgh Medical Center who participated in this study. In addition, we gratefully acknowledge Melissa Saul, MS, for her expertise in retrieving information from the MARS database.[4]

References

1. Weingarten S, Riedinger M, Conner L, et al. Hip replacement and hip hemiarthroplasty surgery: potential opportunities to shorten lengths of hospital stay. *Am J Med.* 1994;97:208-213.
2. Munin MC, Kwoh CK, Glynn N, Crossett L, Rubash HE. Predicting discharge outcome after elective hip and knee arthroplasty. *Am J Phys Med Rehabil.* 1995;74:294-301.
3. Kim PR. Cost-effectiveness of physiotherapy versus no physiotherapy in patients undergoing total knee arthroplasty. Presented at: Annual Meeting of the American Academy of Orthopedic Surgeons; February 26, 1996; Atlanta, Ga.
4. Medical Archival System [database]. Pittsburgh, Pa: Information Processing and Management; 1991.
5. Healy WL, Finn D. The hospital cost and the cost of the implant for total knee arthroplasty. *J Bone Joint Surg Am.* 1994;76:801-806.
6. Barber TC, Healy WL. The hospital cost of total hip arthroplasty. *J Bone Joint Surg Am.* 1994;75:321-325.
7. Shwartz M, Young DW, Siegrist R. The ratio of costs to charges: how good a basis for estimating costs? *Inquiry.* 1995/1996;32:476-481.
8. Ware JE, Sherbourne CD. The MOS 36-item short form health survey (SF-36), I: conceptual framework and item selection. *Med Care.* 1992;30:473.
9. McHorney CA, Ware JE, Raczek AE. The MOS 36-item short-form health survey (SF-36), II: psychometric and clinical tests of validity in measuring physical and mental health constructs. *Med Care.* 1993;31:247-263.
10. Jette AM. The functional status index: reliability and validity of a self-report functional disability measure. *J Rheumatol.* 1987;14(suppl 15):15-21.
11. Bayley KB, London MR, Grunkemeier GL, Lansky DJ. Measuring the success of treatment in patient terms. *Med Care.* 1995;33(suppl):AS226-AS235.
12. Katz JN, Larson MG, Phillips CB, Fossel AH, Liang MH. Comparative measurement sensitivity of short and longer health status instruments. *Med Care.* 1990;28:632-641.
13. Liang MH, Cullen KE, Larson MG, et al. Cost-effectiveness of total joint arthroplasty in osteoarthritis. *Arthritis Rheum.* 1986;29:937-943.
14. Hamilton B, Granger C, Sherwin F, et al. A uniform national data system for medical rehabilitation. In: Fuhrer M, ed. *Rehabilitation Outcomes: Analysis and Measurement.* Baltimore, Md: Brookes; 1987:137-147.
15. Kwoh CK, Petrick MA, Munin MC. Inter-rater reliability for function and strength measurements in the acute care hopsital after elective hip and knee arthroplasty. *Arthritis Care Res.* 1997;10:128-134.
16. Cameron ID, Lyle DM, Quine S. Cost effectiveness of accelerated rehabilitation after proximal femoral fracture. *J Clin Epidemiol.* 1994;47:1307-1313.
17. Mehta C, Patel N. StatXact: statistical software for exact nonparametric inference. Cambridge, Mass: CYTEL Software Corp; 1991.
18. Mosteller F, Tukey JW. *Data Analysis and Regression.* Reading, Mass: Addison-Wesley; 1977.
19. Stineman MG, Shea JA, Jette A, et al. The functional independence measure: tests of scaling assumptions, structure, and reliability across 20 diverse impairment categories. *Arch Phys Med Rehabil.* 1996;77:1101-1108.
20. Baron JA, Barrett J, Katz JN, Liang MH. Total hip arthroplasty: use and select complications in the US Medicare population. *Am J Public Health.* 1996;86:70-72.
21. Chang RW, Pellissier JM, Hazen GB. A cost-effectiveness analysis of total hip arthroplasty for osteoarthritis of the hip. *JAMA.* 1996;275:858-865.