Contractures in Burn Injury: Defining the Problem

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This study prospectively examined the incidence and severity of large joint contractures after burn injury and determined predictors of contracture development. Data were collected prospectively from 1993 to 2002 for consecutive adult burn survivors admitted to a regional burn center. Demographic and medical data were collected on each subject. The primary outcome measures included the presence of contractures, number of contractures per patient, and severity of contractures at each of four joints (shoulder, elbow, hip, knee) at time of hospital discharge. Logistic regression analysis was performed to determine predictors of the presence and severity of contractures and a negative binomial regression was performed to determine predictors of the number of contractures. Of the 985 study patients, 381 (38.7%) developed at least one contracture at hospital discharge. Among those with at least one contracture, the mean is three contractures per person. The shoulder was the most frequently contracted joint (38%), followed by the elbow (34%) and knee (22%). Most contractures were mild (60%) or moderate (32%) in severity. Statistically significant predictors of contracture development were length of stay ($P < .005$) and extent of burn ($P = .033$) and graft ($P < .005$). Predictors of the severity of contracture include graft size ($P < .005$), amputation ($P = .034$), and inhalation injury ($P = .036$). More than one third of the patients with a major burn injury developed a contracture at hospital discharge, which highlights the importance of therapeutic positioning and intensive therapy intervention during acute hospitalization. Furthermore, this challenges the burn care community to find new and better ways of preventing contractures after burn injury. (J Burn Care Res 2006;27:508–514)

Contractures from burn injury were first documented in Ebers' Papyrus in 1500 BC, describing the use of copper splints to treat burns.[1] Contractures are defined as an inability to perform full range of motion of a joint.[2] They result from a combination of possible factors—limb positioning, duration of immobilization and muscle, soft tissue, and bony pathology. Individuals with burn injuries are at risk for developing contractures. Patients with burns often are immobilized, both globally, as a result of critical illness in the severely burned, and focally, as a result of the burn itself because of pain, splinting, and positioning. Burns, by definition, damage the skin and also may involve damage to the underlying soft tissue, muscle, and bone. All of these factors contribute to contracture formation in burn injury.

Contractures place patients at risk for additional medical problems and functional deficits. Contractures interfere with skin and graft healing. Functionally, contractures of the lower extremities interfere with transfers, seating, and ambulation. Contractures of the upper extremities may affect activities of daily living, such as grooming, dressing, eating, and bathing, as well as fine motor tasks.[3,4]

As burn survival rates have increased significantly in the past few decades,[5] attention is shifting to issues of morbidity and function. Clinicians devote significant time and energy to preventing and treating contractures. Investigators have examined contracture prevention[6–9] and treatment options, including splinting,[8,10–19] serial casting,[14,20–23] ultrasound,[24] silicon gel,[25,26] iontophoresis,[27] exercise,[14,28] and surgical correction.[29–38]

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Despite serious clinical and academic interest in burn contractures, little is known of the scope of the problem. Dobbs and Curreri[39] retrospectively reviewed 681 patients who received physical therapy for burn injury and found that 28% developed contractures. The hand, elbow, and shoulder were the most frequently affected joints. TBSA and burn depth were associated with the development of contractures. A retrospective review of burn contractures by Kraemer found that 3.7% of burn patients underwent surgical contracture release. The hand and axilla were the most frequently affected joints, and wound size was directly related to the number of contractures.[40] In another retrospective chart review of 52 burn patients with contractures, Richard found elbow flexion (21%), ankle plantarflexion (19%), and shoulder extension/adduction (17%) contractures were most common.[14] In a published abstract, Kowalske et al[41] reported contractures in 42% of 1749 adult burn patients with American Burn Association criteria for major burn injury at time of discharge. The shoulder, elbow and hand were most commonly affected. In addition, flame burns and larger burns had a higher incidence of contracture.

There exists no published prospective study on the incidence and severity of contractures in burn injury. Therefore, the main purpose of this study was to determine the incidence of contractures in burn patients at discharge from the acute-care hospital and to describe the most frequently contracted joints. A secondary purpose was to determine predictors of the presence, number and severity of contractures.

METHODS

Data were collected prospectively from 1993 to 2002 for consecutive burn patients admitted to a regional burn center. Inclusion criteria are major burn injury as defined by American Burn Association guidelines[42] and age older than or equal to 18 years. All study subjects signed an informed consent to participate in the study. Those with pre-existing physical disability were excluded. The primary outcome measures included the presence and severity of contracture and number of contractures per patient (detailed herein). Demographic (age, sex, and ethnicity) and medical data were collected. Medical data included length of hospital stay, length of intensive care unit stay, presence of concomitant medical problems (defined as medical problems that might alter the course of recovery from the burn, eg, diabetes, chronic obstructive pulmonary disease, heart disease, asthma), burn etiology, inhalation injury, neuropathy, heterotopic ossification, amputation as the result of the burn injury, and TBSA burned and grafted (recorded as whole number percentile and by quintile).

The joints of interest included the shoulder, elbow, hip, and knee. At the time of discharge from the hospital, the specified joints were examined bilaterally for a total of eight studied joints per subject. The subjects' active range of motion at each joint was measured using a goniometer and inclinometer with a standardized technique.[43] Multiple planes of motion (ie, flexion/extension) were investigated at each joint. The specific methodology for range of motion measurements at each joint is detailed in the Model System for Burn Injury Rehabilitation National Database Data Dictionary.[44] Joint muscle action in each plane is assigned a normal range of motion based on physical examination conventions.[43,45] Each impaired joint muscle action is assigned a severity rating. Such ratings are determined by dividing the normal range of motion value equally in thirds (mild, moderate, and severe; Table 1).

For the purposes of analysis, a limitation in the range of motion in at least one plane of motion at a specified joint was considered to be a contracture at that joint. Furthermore, if more than one muscle action was limited at a joint, the severity of the worst muscle action at that joint was considered to represent the severity of contracture at that joint.

Analogous data were collected for the joints of the hand, ankle, neck, trunk, as well as the presence of eyelid and nasolabial contractures and microstomia. These data will be discussed separately in a subsequent report.

Statistical Analysis

The frequency and severity of contractures at each joint and number of contractures per patient at hospital discharge were calculated. Logistic regression analysis was used to determine predictors of the presence and severity of contractures and a negative binomial regression was used to determine predictors of the number of contractures. Negative binomial regression was used because the variance assumption underlying Poisson regression was violated. The negative binomial regression model adjusts for the overdispersion. The potential predictors were the demographic and medical data (as detailed previously). Violations of statistical assumptions and goodness of fit were analyzed.

RESULTS

During the study period, 1090 patients met inclusion criteria. A pre-existing physical disability was documented in 105 patients, resulting in 985 study pa-

Table 1. Range of motion severity ratings by joint muscle action

		Contracture Severity		
Joint	Muscle Action	Mild	Moderate	Severe
Shoulder	Flexion	120–180	60–119	<60
	Extension	32–50	16–31	<16
	Abduction	120–180	60–119	<60
	Adduction	32–50	16–31	<16
Elbow	Flexion	93–140	46–92	<46
	Extension	−140–93	−46–92	>−46
	Pronation	53–80	26–52	<26
	Supination	53–80	26–52	<26
Hip	Flexion	67–100	34–66	<34
	Extension	20–30	10–19	<10
	Abduction	26–40	13–25	<13
	Adduction	13–20	7–12	<7
Knee	Flexion	100–150	50–99	<50
	Extension	−150–100	−99–50	>–50

Table 2. Demographic and medical characteristics of the study population

Total number of study patients	985
Male, percent	78.1
Age at injury, mean (SD) years	42.5 (17.1)
Ethnicity, percent	
Caucasian	60.3
Black	20.4
Hispanic	16.6
Other	2.7
Length of stay, mean (SD) days	21.7 (22.9)
Inhalation injury, percent	12.5
Percent TBSA burned, mean (SD)	25.1 (19.7)
Etiology, percent	
Fire/flame	60.7
Electricity	8.8
Flash	8.1
Scald	6.5
Grease	5.5
Other	10.4

tients. The demographic and medical data of the study population are presented in Table 2.

The frequency and severity of limitations by joint muscle action is presented in Table 3.

Shoulder flexion (n = 336) and abduction (n = 329), knee flexion (n = 209), and elbow flexion (n = 206) were the most frequent contractures. Using the methodology described previously, contracture frequency and severity at each joint was tabulated and is presented in Table 4. The shoulder (38%) was the most frequently contracted joint, followed by the elbow (34%), knee (22%), and hip (5%). Most contractures were mild (60%) or moderate (32%) in severity.

Among the study population, 381 patients (39%) demonstrated at least one contracture at hospital discharge. In total, 953 joints were contracted resulting in an average of three contractures per person (among those with at least one contracture). The mode is two joint contractures per patient (frequency, 136). These analyses apply only to those joints detailed in this report (shoulder, elbow, hip, and knee). The frequency of contractures is detailed in Table 5.

Statistically significant predictors of contracture development are length of stay ($p < .005$), TBSA grafted ($P < .005$), and TBSA burned ($P = .033$; Table 6). Predictors of the severity of contracture include TBSA grafted ($P < .005$), amputation ($P = .034$), and inhalation injury ($P = .036$; Table 7). The number of contractures is associated with length of stay ($P < .005$), TBSA grafted ($P < .005$), and TBSA burned ($P = .004$; Table 8). There was no violations of statistical assumptions or goodness of fit for these analyses.

DISCUSSION

Contractures are a common problem (39%) after a major burn injury. A significant number of contractures occurred despite receiving treatment at a major burn center that provides specialized occupational and physical therapy services for all burn patients.

Table 3. Severity and frequency of range of motion limitation by joint muscle action

Joint	Muscle Action	Severity			Total
		Mild	Moderate	Severe	
Shoulder	Flexion	196	126	14	336
	Extension	16	6	1	23
	Abduction	179	137	13	329
	Adduction	4	0	0	4
Elbow	Flexion	177	24	5	206
	Extension	160	20	0	180
	Pronation	43	8	13	64
	Supination	88	33	26	147
Hip	Flexion	28	6	0	34
	Extension	4	6	10	20
	Abduction	3	5	0	8
	Adduction	2	2	2	6
Knee	Flexion	125	77	7	209
	Extension	25	0	0	25
Total (%)		1050 (66)	450 (28)	91 (6)	1591

Table 4. Contracture severity and frequency by joint

Joint	Contracture Severity			Total (%)
	Mild	Moderate	Severe	
Shoulder	197	147	21	365 (38)
Elbow	224	66	34	324 (34)
Hip	24	16	12	52 (5)
Knee	128	77	7	212 (22)
Total (%)	573 (60)	306 (32)	74 (8)	953

Table 5. Contracture frequency

Patients with at least one contracture	381 (N = 985)
Total number of contractures	953
Average number of contractures per person	3
Patients with one contracture	98
Patients with two contractures	136
Patients with three contractures	39
Patients with four contractures	92
Patients with more than four contractures	16

There are multiple reasons why burn survivors develop contractures despite receiving specialized care at a burn center. Regional burn centers act as referral centers for the sickest and most severely injured burn patients. With this in mind, our data suggest that the patient's general medical condition correlates with one's risk of developing contractures. Those patients with longer length of stays, higher TBSA, and inhalation injury confer a greater risk of contracture development. In addition, our data demonstrate that those with amputations are at risk for developing more severe contractures. This evidence is not surprising given that amputees are at risk for developing contractures independent of the presence of burn injury.[46] Also, burn injuries that cross a major joint likely result in a greater risk of contracture development at that joint. The timing of surgical interventions and postoperative healing may result in a period of mandatory immobilization that puts patients at risk for contracture development. Additional contributing factors include patients who do not cooperate with therapy and positioning interventions and those who refuse therapy treatment altogether.

Given the frequency of contractures and having considered the multiple factors contributing to con-

Table 6. Logistic regression analysis of predictors of the presence of contractures

Variable	Odds Ratio	SE	Z	*P* Value	95% Confidence Interval
Age	0.988	0.005	−2.37	.018	0.978–0.997
Sex	0.692	0.133	−1.92	.055	0.474–1.008
Length of stay	1.044	0.011	3.84	.000	1.021–1.067
Inhalation injury	0.581	0.148	−2.14	.033	0.353–0.956
Medical problem	1.344	0.221	1.80	.072	0.974–1.855
TBSA burn	1.031	0.015	2.13	.033	1.002–1.060
TBSA graft	1.070	0.012	6.05	.000	1.047–1.094

Table 7. Logistic regression analysis of predictors of the severity of contractures

Variable	Odds Ratio	SE	Z	*P* Value	95% Confidence Interval
Sex	0.603	0.160	−1.90	0.057	0.0359–1.015
Inhalation injury	1.893	0.577	2.10	0.036	1.042–3.440
Medical problem	1.429	0.292	1.74	0.081	0.957–2.134
Amputation	2.480	1.060	2.13	0.034	1.073–5.731
TBSA graft	1.046	0.010	4.80	0.000	1.027–1.066

Table 8. Negative binomial regression of predictors of the number of contractures

Variable	Incidence Rate Ratio	SE	Z	*P* Value	95% Confidence Interval
Gender	0.777	0.099	−1.99	0.047	0.606–0.996
Inhalation injury	0.732	0.116	−1.97	0.049	0.537–0.999
Medical problem	1.205	0.132	1.71	0.088	0.973–1.493
TBSA burn	1.027	0.010	2.84	0.004	1.008–1.046
TBSA graft	1.036	0.007	5.41	0.000	1.023–1.050
Age	0.991	0.003	−2.69	0.007	0.984–0.997
Length of stay	1.036	0.007	4.95	0.000	1.021–1.051

tracture development, this study underscores the importance of positioning and intensive therapy intervention in hospitalized burn patients. Furthermore, this presents a challenge to the burn treatment team to find new and better ways of preventing contractures.

Despite the frequency of contractures, very few contractures were severe (8%). This rate may be viewed as a success of therapy and positioning efforts. Also, one should consider that the subjects in this study were only followed for the duration of their acute hospitalization (mean length of stay, 22 days). Therefore, the natural history of contracture development beyond this time period is not addressed in this study.

Most moderate severity contractures, which are defined as a limitation in the range of motion in the middle third of the range, are clinically significant. For example, a contracture at the shoulder (the most commonly affected joint) with a range of motion of 90° (in the middle of the moderate severity range) is associated with significant functional limitations. Such contractures limit overhead activities involved in grooming, bathing, dressing and occupational tasks. Although the severity ratings are logical and useful for statistical analysis, clinical perspective is needed to draw meaningful practical insights from the data. Of note, this study does not examine measures of quality of life or functional outcome, which is a limitation of this study. Future research may examine the affect of contracture severity on quality of life and function.

Armed with data from this report, clinicians can identify burn survivors at risk for developing contractures. Those with extended hospital stays and large burns are at risk for developing contractures. Additionally, the extent of burn injury, amputation and inhalation injury are predictors of contracture severity. An ability to identify early those at highest risk for contracture development will enable clinicians to focus preventative efforts on those most in need. In such patients, vigilant positioning and aggressive therapy is warranted. In addition, future experimental interventions aimed at preventing contractures should target this high risk subpopulation.

Contractures have a disproportionate affect on the upper extremities, with the shoulder and elbow comprising the vast majority of contractures (72%). This evidence has implications for how we think about the impact of contractures on patients' function. Activities of daily living, instrumental activities of daily living, and occupational tasks are more affected with upper-extremity impairments, thereby reinforcing the need for outpatient therapy after burn injury. Future studies may investigate the efficacy of outpatient physical and occupational therapy in treating upper-extremity contractures. Investigators also may examine the correlation between contractures and return to work outcomes. In contrast, less frequent lower extremity contractures translates into fewer mobility issues after hospitalization. A knowledge of affected joint frequency helps in planning resource allocation for the treatment of hospitalized burn patients and forecasting outpatient needs of burn survivors as it applies to contracture management. Likewise, such information is useful to insurance companies, enabling them to better plan for costs related to future therapy and surgical care related to contracture management.

A careful understanding of the methodology enables one to extract the most meaning out of the data. This study treats limitations in multiple planes of motion at one joint as one contracture at that joint (Tables 3 and 4). This method of calculation was chosen to present the data in a clinically relevant manner. One should keep in mind that this methodology effectively compresses the data by potentially representing limitations in multiple planes of motion at one joint as one contracture. Additionally, a joint with limitations in multiple planes motion was assigned a contracture severity of the most severe limitation. Again, this method was chosen as the most useful clinical representation of the data. For example, if a shoulder exhibits mild limitations in flexion, extension and adduction but a severe limitation in abduction, the joint is assigned a severe contracture rating and likewise is considered clinically severe by the authors.

Tables 6 and 7 summarize results of logistic regression analyses, whereas Table 8 presents results of a negative binomial regression. The main column of interest for Tables 6 and 7 is headed "odds ratio." An odds ratio of 1 is a null value, meaning that the predictor has no effect on the outcome of interest. An odds ratio greater or less than 1 is associated with an increase or decrease, respectively, in the odds of the outcome of interest. To compare odds ratios greater than 1 to odds ratios less than 1, we need to compare one value with its multiplicative inverse; thus, an odds ratio of 0.5 is the same size effect as an odds ratio of 2. For example, in Table 6 the odds ratio associated with having an inhalation injury is 0.58, meaning that the odds of having a contracture decrease by 42% ($= 1 - 0.58$) for those who have an inhalation injury compared with those who don't have an inhalation injury. As another example, the odds ratio associated with having a medical problem is 1.344, meaning that the odds of having a contracture are 34% higher for those with a medical problem than for those without a medical problem. The incidence rate ratio in Table 8 is interpreted in a similar manner; however, because this regression has number of contractures as the output, the ratio applies to the chances of developing an additional contracture. For example, the coefficient for "medical problem" is 1.2, meaning that the presence of a medical problem increases the rate of contracture by 20% compared to someone who does not have a medical problem.

CONCLUSION

Despite being at a major burn center with integrated therapy services, more than one third of patients with a major burn injury exhibited a contracture at hospital discharge. Those with more extensive burns, amputations and inhalation injuries are more likely to develop severe contractures. The frequency and severity of contractures highlights the need and importance of physical and occupational therapy services during the acute hospitalization and in the outpatient clinic. Informed with a more detailed understanding of contracture development, clinicians are better able to identify those at highest risk for contracture development and managers are better able to provide appropriate therapy staffing for burn centers and outpatient clinics. Furthermore, this challenges the burn care community to find new and better ways of preventing contractures after burn injury.

REFERENCES

1. Robotti EB. The treatment of burns: an historial perspective with emphasis on the hand. Hand Clin 1990;6:163–90.
2. Mosby's Dictionary. 6th ed. St. Louis: Mosby, Inc.; 2002.
3. Palmieri TL, Petuskey K, Bagley A, et al. Alterations in func-

tional movement after axillary burn scar contracture: a motion analysis study. J Burn Care Rehabil 2003;24:104–8.
4. Kowalske KJ, Voege JR, Cromes GF Jr., et al. The relationship between upper extremity contractures and functional outcome after burn injury (abstr). Proc Am Burn Assoc 1996; 28:55.
5. Ryan CM, Schoenfeld DA, Thorpe WT, et al. Objective estimates of the probability of death from burn injuries. N Eng J Med 1998;338:362–6.
6. Cooper S, Paul EO. An effective method of positioning the burn patient. J Burn Care Rehabil 1988;9:288–9.
7. Helm PA, Kevorkian CG, Lushbaugh M, et al. Burn injury: rehabilitation management in 1982. Arch Phys Med Rehabil 1982;63:6–16.
8. Serghiou MA, McLaughlin A, Herndon DN. Alternative splinting methods for the prevention and correction of burn scar torticollis. J Burn Care Rehabil 2003;24:336–40.
9. Bunchman HH, Huang TT II, Larson DL, et al. Prevention and management of contractures in patients with burns of the neck. Am J Surg 1975;130:700–3.
10. Richard R, Staley M, Miller S, et al. To Splint or not to splint—past philosophy and present practice: part I. J Burn Care Rehabil 1996;17:444–53.
11. Richard R, Staley M, Miller S, et al. To splint or not to splint—past philosophy and present practice: part II. J Burn Care Rehabil 1997;18:64–71.
12. Richard R, Staley M, Miller S, et al. To splint or not to splint—past philosophy and present practice: part III. J Burn Care Rehabil 1997;18:251–5.
13. Fujimori R. Effect of adhesive splint in preventing scar contracture. J Burn Care Rehabil 1984;5:50–4.
14. Richard R, Miller S, Staley M, et al. Multimodal versus progressive treatment techniques to correct burn scar contractures. J Burn Care Rehabil 2000;21:506–12.
15. Manigandan C, Gupta AK, Venugopal K, et al. A multipurpose, self-adjustable aeroplane splint for the splinting of axillary burns. Burns 2003;29:276–9.
16. Van Straten O, Sagi A. "Supersplint": a new dynamic combination splint for the burned hand. J Burn Care Rehabil 2000;21:71–3.
17. Forsyth-Brown E. The slot-through splint. Physiotherapy 1983;69:43–4.
18. Guild S. A new splinting approach for dorsal foot burns. J Burn Care Rehabil 2001;22:454–6.
19. Bhattacharya S, Bhatnagar SK, Chandra R. Postburn contracture of the neck– our experience with a new dynamic extension splint. Burns 1991;17:65–7.
20. Ridgway CL, Daugherty MB, Warden GD. Serial casting as a technique to correct burn scar contractures: a case report. J Burn Care Rehabil 1991;12:67–72.
21. Johnson J, Silverberg R. Serial casting of the lower extremity to correct contractures during the acute phase of burn care. Phys Ther 1995;75:262–6.
22. Bennett GB, Helm P, Purdue GF, Hunt JL. Serial casting: a method for treating burn contractures. J Burn Care Rehabil 1989;10:543–5.
23. Staley M, Serghiou M. Casting guideline, tips, and techniques: proceedings from the 1997 American Burn Association PT/OT casting workshop. J Burn Care Rehabil 1998;19:254–60.
24. Ward RS, Hayes-Lundy C, Reddy R, et al. Evaluation of topical therapeutic ultrasound to improve response to physical therapy and lessen scar contracture after burn injury. J Burn Care Rehabil 1994;15:74–9.
25. Wessling N, Ehleben CM, Chapman V, et al. Evidence that use of a silicone gel sheet increases range of motion after burn wound contractures. J Burn Care Rehabil 1985;6:503–5.
26. Perkins K, Davery RB, Wallis KA. Silicone gel: a new treatment for burn scars and contractures. Burns 1982;9:201–4.
27. Driscoll JB, Plunkett K, Tamari A. The effect of potassium iodide iontophoresis on range of motion and scar maturation following burn injury. Phys Ther Case Rep 1999;2:13–8.
28. Celis MM, Suman OE, Huang TT, et al. Effect of a supervised exercise and physiotherapy program on surgical interventions in children with thermal injury. J Burn Care Rehabil 2003; 24:57–61.
29. Greenhalgh DG, Gaboury T, Warden GD. The early release of axillary contractures in pediatric patients with burns. J Burn Care Rehabil 1993;14:39–42.
30. Hallock GG. A systematic approach to flap selection for the axillary burn contracture. J Burn Care Rehabil 1993;14: 343–7.
31. Tanaka A, Hatoko M, Tada H, et al. An evaluation of functional improvement following surgical corrections of severe burn scar contracture in the axilla. Burns 2003;29:153–7.
32. Nisanci M, Er E, Isik S, et al. Treatment modalities for postburn axillary contractures and the versatility of the scapular flap. Burns 2002;28:177–80.
33. Madhuri V, Dhanraj P. Correction of post burns contracture of wrist with Ilizarov method. Burns 1998;24:576–8.
34. Ertas NM, Bozdogan N, Erbas O, et al. The use of subcutaneous pedicle rhomboid flap in the treatment of postburn scar contractures. Ann Plast Surg 2004;53:235–9.
35. Suliman MT. Experience with the seven flap-plasty for the release of burns contractures. Burns 2004;30:374–9.
36. Wilson IF, Lokeh A, Schubert W, et al. Latissimus dorsi myocutaneous flap reconstruction of neck and axillary burn contractures. Plast Reconstr Surg 2000;105:27–33.
37. Iwuagwu FC, Wilson D, Bailie F. The use of skin grafts in postburn contracture release: a 10-year review. Plast Reconstr Surg 1999;103:1198–204.
38. Frame JD, Still J, Lakhel-LeCoadou A, et al. Use of dermal regeneration template in contracture release procedures: a multicenter evaluation. Plast Reconstr Surg 2004;113: 1330–8.
39. Dobbs ER, Curreri PW. Burns: analysis of results of physical therapy in 681 patients. J Trauma 1972;12:242–8.
40. Kraemer MD, Jones T, Deitch EA. Burn contractures: incidence, predisposing factors, and results of surgical therapy. J Burn Care Rehabil 1988;9:261–5.
41. Kowalske K, Holavanahalli R, Serghio M, et al. Contractures following burn injury in children and adults—a multicenter report (abstr). J Burn Care Rehabil 2003;24:S85.
42. Organization and delivery of burn care. J Burn Care Rehabil 2001; 1S–4S.
43. Norkin CC, White DJ. Measurement of Joint Motion: A Guide to Goniometry. Philadelphia: FA Davis; 1985.
44. Model System for Burn Injury Rehabilitation National Database Data Dictionary. Version 8.0. October 1, 2001. Available at: http://bms-dcc.uchsc.edu/; Internet; accessed May 8, 2006.
45. Magee DJ. Orthopedic Physical Assessment. Philadelphia: Saunders; 2002.
46. Frontera WR, Silver JK. Essentials of physical medicine and rehabilitation. Philadelphia: Hanley & Belfus, Inc; 2002.