HHS Public Access
Author manuscript
J Burn Care Res. Author manuscript; available in PMC 2022 July 22.

Published in final edited form as:
J Burn Care Res. 2017 ; 38(1): e192–e199. doi:10.1097/BCR.0000000000000341.

Pediatric Contractures in Burn Injury: A Burn Model System National Database Study

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Abstract

Joint contractures are a major cause of morbidity and functional deficit. The incidence of postburn contractures and their associated risk factors in the pediatric population has not yet been reported. This study examines the incidence and severity of contractures in a large, multicenter, pediatric burn population. Associated risk factors for the development of contractures are determined. Data from the National Institute on Disability and Rehabilitation Research Burn Model System database, for pediatric (younger than 18 years) burn survivors from 1994 to 2003, were analyzed. 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 nine locations (shoulder, elbow, hip, knee, ankle, wrist, neck, lumbar, and thoracic) at time of hospital discharge. Regression analysis was performed to determine predictors of the presence, severity, and numbers of contractures, with $P < .05$ used for statistical significance. Of the 1031 study patients, 237 (23%) developed at least 1 contracture at hospital discharge. Among those with at least one contracture, the mean was three (3.3) contractures per person. The shoulder was the most frequently contracted joint (27.9%), followed by the

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elbow (17.6%), wrist (14.2%), knee (13.3%), and ankle (11.9%). Most contractures were mild (38.5%) or moderate (36.3%) in severity. The statistically significant predictors of contracture development were age and intensive care unit (ICU) length of stay. The statistically significant predictors of severity of contracture were age, ICU length of stay, presence of amputation, and black race. Predictors of the number of contractures included total age, length of stay, length of ICU stay, presence of amputation, TBSA burned, and TBSA grafted. This is the first study to report the epidemiology of postburn contractures in the pediatric population. Approximately one quarter of children with a major burn injury developed a contracture at hospital discharge, and this could potentially increase as the child grows. Contractures develop despite early therapeutic interventions such as positioning and splinting; therefore, it is essential that we identify novel and more effective prevention strategies.

Survival after burn injury in the pediatric population is now the rule, with average mortality rates for all burns less than 2% in modern U.S. burn centers.[1,2] Significant emphasis is placed on improving quality of life for pediatric burn survivors through the optimization of functional, aesthetic, psychological, and social outcomes. Pathological scarring and postburn contractures continue to be a major source of morbidity and can have a devastating impact on quality of life.[3–8] Conservative measures such as stretching, splinting, and range of motion exercises are helpful, but surgical correction with skin grafting, adjacent tissue rearrangement, or local and distant flaps is typically required. Nevertheless, surgical correction still carries a significant rate of recurrence with often undesirable cosmetic outcomes. Furthermore, postburn contractures, even those not requiring surgical treatment, often require additional postoperative physical and occupational therapy, increase the financial burden of burn care, and limit patients from returning to school and normal activity.

The cause of postburn contracture formation is multifactorial: 1) injury-related factors include the depth, extent, etiology, and location of burn; 2) patient-related factors include genetic inheritance, race, skin color, age, gender, nutritional status, and compliance with therapy; and 3) treatment-related factors including the type and timing of wound closure, the wound bed, and prevention strategies utilized.[9–13] Furthermore, and specific to the pediatric population, it remains unclear precisely how the burn scar responds to the normal growth and development of the pediatric patient into adulthood. Although the cellular and biological basis of wound, scar, and skin graft contracture, as well as hypertrophic scarring, has been extensively researched,[14,15] burn clinicians have no specific epidemiological data with respect to burn contractures in the pediatric population.

Of the few publications to date, which have evaluated the epidemiology of burn contractures, only one included pediatric burn patients.[16] Kraemer et al retrospectively reviewed all patients presenting for surgical correction of postburn contractures over a 6-year period (1980–1986, n = 31). They further stratified these patients into pediatric and adults and calculated contracture incidence based on the total number of patients treated for burns at their institution during this time period (n = 839). The incidence of pediatric burn contractures was noted to be significantly greater than that of adults (7.8%, n = 19 vs 2%, n = 12). Significant methodological discrepancies and small sample size, however, limit the generalizability and utility of this study. Three studies have more clearly documented the incidence of contracture after burn injury in the adult population, which has been reported to be between 20 and 40%.[17–19] Therefore, this study aims to be the first published comprehensive analysis of postburn contractures in the pediatric population.

METHODS

From 1994 through 2003, the National Institute on Disability and Rehabilitation Research (NIDRR) Burn Model System (BMS) database collected detailed data on contractures. These prospectively collected data for pediatric (younger than 18 years) burn survivors were analyzed. The NIDRR BMS database comprises pediatric patients who meet at least one of the following inclusion criteria:

1. Burn injury greater than or equal to 20% TBSA, which required surgery for at least some portion of wound closure (defined as autografting).

2. Electrical high voltage/lightning injury, which required surgery for at least some portion of wound closure.

3. Burn injury of any size to critical area(s): face and/or hands and/or feet and/or genitals, which required surgery for at least some portion of wound closure.

During the 10 years of this study, and the 20 years of the NIDRR BMS database, minor modifications have been made to the inclusion/exclusion criteria. These modifications can be found at http://burndata.washington.edu/standard-operating-procedures, and the complete detailed inclusion and exclusion criteria have been previously described.[20] Primary outcome measures included the presence, severity, and number of contractures. Demographic (age, sex, and ethnicity [white, black, Hispanic, and other]) and medical data were collected. If demographic data cannot be collected through patient report, it is collected from the medical record. Medical data included burn etiology, inhalation injury, neuropathy, heterotopic ossification, amputation of digit or limb as the result of the burn injury, TBSA burned and grafted (recorded as a whole number percentile), total length of hospital stay, length of intensive care unit (ICU) stay, and concomitant medical problems (defined as medical problems that might alter the course of recovery from the burn, such as diabetes mellitus, chronic obstructive pulmonary disease, heart disease, asthma). We chose to report on all contractures recorded in the NIDRR database, except for that of the hand, as contractures of the hand will be reported in a separate manuscript. This included musculoskeletal contractures (eg, joint) and non-joint contractures. These areas of interest included the shoulder (typically as a result of axillary contractures), elbow, hip, knee, ankle, wrist, neck, and the lumbar and thoracic areas. At the time of discharge from the hospital, specified areas were examined for a total of 15 studied sites per subject (neck, lumbar, and thoracic were unilateral). The subjects' active range of motion at each joint was measured using a goniometer and inclinometer with a standardized technique.[21] Multiple planes of motion (ie, flexion/extension) were investigated at each area of interest. The specific methodology for range of motion measurements at each site is detailed in the Model System for Burn Injury Rehabilitation National Database Data Dictionary.[22] Joint muscle action in each plane is assigned a normal range of motion based on physical examination conventions.[21,23] As in a similar study by Schneider et al,[18] 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; Appendix, Table 1, Supplemental Digital Content 1, at http://links.lww.com/BCR/A43). For the purposes of this analysis, a limitation in the range of motion in at least one plane of motion at a specified site was considered to be a contracture at that site. Furthermore, if more than one muscle action was limited at a joint, the severity of the worst muscle action at that site was considered to represent the severity of contracture at that site. Data were also collected for the presence of ectropion, microstomia, and nasolabial contractures. These contractures contributed to analyses of frequency and number, but not to the severity of contracture.

Statistical Analysis

The frequency and severity of contractures at each site, and number of contractures per patient at hospital discharge, were tabulated. Logistic regression analysis was used to determine predictors of the presence of contractures. Ordered logistic regression was used to determine the severity of contractures. Negative binomial regression, one form of a multivariate analysis, 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 this overdispersion. The potential predictors were the demographic and medical data (as detailed previously). Violations of statistical assumptions and goodness-of-fit test were analyzed. A $P < .05$ was used for statistical significance. The data analysis package used was Stata, version 13.1 (www.stata.com; StataCorp, College Station, TX).

RESULTS

The demographic and medical data of the study population are presented in Table 1, and the frequency and severity of limitations by joint muscle action is presented in Table 2. Shoulder flexion (n = 187) and abduction (n = 135), elbow flexion (n = 111), and knee flexion (n = 99) were the most frequent muscle action limitations. Using the methodology described previously,[17] contracture frequency and severity at each site was tabulated (Table 3). The shoulder (27.9%) was the most frequently contracted site, followed by the elbow (17.6%), wrist (14.2%), knee (13.2%), and ankle (11.9%). Most contractures were mild (38.5%) or moderate (36.3%) in severity. Among the study population, 237 patients (23.0%) demonstrated at least one contracture at hospital discharge.

In total, 787 contractures were found resulting in an average of 3 (3.3) contractures per person (among those with at least 1 contracture). The frequency of contractures is presented in Table 4. The frequency of microstomia (0.2%), ectropion (2.4%), and nasolabial contractures (0.3%) was also determined. Regression analysis was used to identify predictors of postburn contracture development (Table 5), contracture severity (Table 6), and number of contractures (Table 7). The statistically significant predictors of contracture development were greater age and ICU length of stay. The statistically significant predictors of severity of contracture were greater age, ICU length of stay, presence of amputation, and black race. Predictors of the number of contractures included total age, length of stay, length of ICU stay, presence of amputation, TBSA burned, and

TBSA grafted. There were no violations of statistical assumptions or goodness-of-fit test for these analyses.

DISCUSSION

This work represents the first published review describing the epidemiology of pediatric postburn contracture and their associated risk factors. Not only are these data useful for benchmarking one's own center's results, but by knowing risk factors typically associated with severity of injury for both contracture frequency and severity, clinicians can aim physical and occupational therapy services at those most in need, both during acute hospitalization and at outpatient clinics.

With a 1 to 2% overall mortality for pediatric burns, emphasis is placed on decreasing morbidity and improving the long-term quality of life for burn survivors.[24] This includes devoting significant time and research to the prevention and treatment of postburn contractures.[25–46] Although the past 4 decades have seen a general trend from treatment to prevention of postburn contractures, studies examining the efficacy, or optimum methodology, for prevention are still needed, and therefore, evidence-based guidelines are lacking. In fact even in the area of surgical treatment of contractures, quality evidence and sound guidelines are needed.

Pediatric burn contractures remain a common morbidity after a severe burn injury and occur despite early interventions of aggressive occupational and physical therapy. A few studies have been published on the surgical treatment of pediatric burn contractures; however, there are no publications describing the epidemiology of pediatric burn contractures and the scope of the problem.[47,48] Therefore, we can only compare these data with that of the adult population. Although previous reports have shown that younger age is an independent risk factor for pathological scarring, including contracture, these studies did not include the pediatric population (younger than 18 years).[49] In the current study, we note an incidence of contracture in the pediatric population (23%) that is slightly lower than that previously reported for adults. Dobbs and Curreri[17] (28%), Schneider et al[18] (39%), and Goverman et al[19] (33%) all logged incidence of adult contracture to be between 20 and 40%. Perhaps the physiology of children may be different than that of adults, and thus, we cannot assume that what we learn in adults with burn injuries directly applies to children.[50] Similar to the adult population, however,[18,19] shoulder and elbow were the most commonly involved sites, with wrist and knee coming third and fourth, and followed closely by ankle. Severity of contracture was similar to that of Goverman et al's study of adults, and again, most ankle contractures were severe.

Overall, limited research has been completed in the area of contracture prevention, and the research that has been performed has not examined children; this is an area of great need. Current prevention strategies are primarily composed of static splinting and active/passive range of motion exercises. However, static splinting has the potential to cause excessive scar tension, which theoretically increases hypertrophic scarring and therefore contracture. In fact a prospective randomized trial on shoulder splinting and a literature review on static splinting for burns were unable to demonstrate strong support for this modality.[51,52] In addition, aggressive passive range of motion exercises have the potential to increase generalized and local inflammatory mediators and may be involved in the development of heterotopic ossification.[53] The dilemma remains, however, as to what level and forms of therapy are considered to be “aggressive” enough to incite detrimental levels of inflammation. As our understanding of the molecular basis of hypertrophic scarring and contracture improves, we will better understand the pediatric host response to various forms of physical and occupational therapy; at which time we could pinpoint which therapy may be most beneficial for a particular patient.

Risk factors were identified for the presence, severity, and number of contractures; however, as this was only an epidemiological study, the determination of causality is beyond the scope of this analysis. For example, black race was noted to be a risk factor for more severe contractures. Although it has been previously shown that skin pigmentation and ethnicity is associated with increased risk for hypertrophic scaring, and thus the potential increase risk for contracture severity, this is only speculation.

As stated previously, the criteria for inclusion into the NIDRR BMS database selects those with more severe burns and, therefore, may not be representative of all burn patients and burn centers. The fact that this data set is 12 years old is a limitation of this study; however, detailed contracture data were only collected in this data set during the period represented in this study; nonetheless, this is a valuable contribution as it represents the largest and most detailed pediatric burn contracture data set in the literature to date. We did not explore measures of quality of life or functional outcome. Hence, the significance of these contractures on disability is unknown. Future research may examine the effect of contracture severity on quality of life and function, as well as the correlation between contractures and return to school status. The database does not specify details of operative interventions for contractures, the impact of surgery on contracture development, nor the ultimate cost of contractures. These data will serve as a foundation for future investigations in which these important issues can be addressed. In addition, the range of motion data reported in this article does not specify the etiology of the loss of range of motion. Therefore, those with neuropathies, soft tissue and skin contractures, and preexisting contractures for various reasons were all included in the analysis.

Furthermore, details of physical and occupational therapy sessions, splinting techniques, time to full active range of motion, time of immobilization, and time to complete wound closure were not recorded and are all valuable data points for future analyses. In addition, we included only one time point, discharge, in this analysis, and the results should be interpreted as contractures at the end of acute hospitalization. This does not take into account the effects of acute pain, anxiety, scar maturation, or edema, which likely improve in the rehabilitation phase and may result in increased range of motion. Moreover, this time point does not allow us to measure the contribution of physical and occupational therapy in the postacute phase, nor can we assess the impact of a child’s growth on the occurrence of a contracture. This concept definitely deserves further investigation. Finally, we are unable to separate the influence of a prolonged ICU stay, which is a known risk factor for contractures even in the absence of a burn, from that of the burn injury itself.[54]

CONCLUSION

Approximately one quarter of pediatric burn patients admitted to one of five burn centers with a severe burn injury exhibited a contracture at discharge. This study highlights the importance of early therapeutic interventions during acute hospitalization targeted to those at high risk for contractures. Which forms of therapy are most effective in prevention and treatment of contractures after burn injury and standardization of practice is a needed area of future inquiry.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Supported by a grant from the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR grant number 90DP0035). NIDILRR is a Center within the Administration for Community Living (ACL), Department of Health and Human Services (HHS). The contents of this manuscript do not necessarily represent the policy of NIDILRR, ACL, HHS, and you should not assume endorsement by the Federal Government.

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Table 1.

Demographic and medical characteristics of the study population

Total number of study patients	1031
Male (%)	66.1
Age at injury (yr), mean (SD)	7.4 (5.4)
Age at injury (yr), median	6.1
Ethnicity (%)	
Caucasian	35.1
Black	15.0
Hispanic	45.2
Other	4.1
Length of stay (d), mean (SD)	24.3 (27.0)
Inhalation injury (%)	15.4
Percent TBSA burned, mean (SD)	29.5 (22.1)
Percent TBSA burned, median	24.0
Etiology (%)	
Fire/flame	57.1
Electrical	5.7
Flash	0.9
Scald	25.1
Grease	5.2
Other	4.4

Table 2.

Severity and frequency of range of motion limitation by joint muscle action (degrees)

Joint	Muscle Action	Severity			Total (%)
		Mild	Moderate	Severe	
Shoulder	Flexion	95	70	22	187 (13)
	Extension	6	24	19	49 (4)
	Abduction	62	65	8	135 (10)
	Adduction	5	19	26	50 (4)
Hip	Flexion	20	14	1	35 (3)
	Extension	12	16	9	37 (3)
	Abduction	7	18	2	27 (2)
	Adduction	0	5	3	8 (1)
Elbow	Flexion	74	28	9	111 (8)
	Extension	68	6	0	74 (5)
	Pronation	12	11	7	30 (2)
	Supination	19	20	12	51 (4)
Knee	Flexion	50	35	14	99 (7)
	Extension	49	0	0	49 (4)
Wrist	Flexion	27	5	4	36 (3)
	Extension	27	13	2	42 (3)
	Radial deviation	3	4	3	10 (1)
	Ulnar deviation	6	12	3	21 (2)
Ankle	Dorsiflexion	7	27	44	78 (6)
	Plantarflexion	14	5	14	33 (2)
	Inversion	5	12	11	28 (2)
	Eversion	5	7	11	23 (2)
Neck	Forward flexion	14	4	1	19 (1)
	Right rotation	8	17	6	31 (2)
	Left rotation	9	13	8	31 (2)
	Extension	5	15	5	25 (2)
	Right lateral flexion	9	9	5	23 (2)

		Severity			
Joint	**Muscle Action**	**Mild**	**Moderate**	**Severe**	**Total (%)**
	Left lateral flexion	11	9	3	23 (2)
Lumbar	Forward flexion	3	1	3	7 (1)
	Right lateral flexion	4	2	2	8 (1)
	Left lateral flexion	4	3	1	8 (1)
Thoracic	Forward flexion	4	4	1	9 (1)
	Right rotation	0	0	0	0 (0)
	Left rotation	0	0	0	0 (0)
Total (%)		644 (46)	493 (35)	259 (19)	1396

Each impaired joint muscle action is assigned a severity rating determined by dividing the normal range of motion value equally in thirds (mild, moderate, and severe).

Table 3.

Contracture severity and frequency by joint (degrees)

Joint	Contracture Severity			Total (%)
	Mild	Moderate	Severe	
Shoulder	88	77	54	219 (27.9)
Elbow	74	44	20	138 (17.6)
Hip	17	36	12	65 (8.3)
Knee	55	35	14	104 (13.2)
Ankle	6	30	58	91 (11.9)
Wrist	51	40	21	112 (14.2)
Neck	5	17	14	36 (4.6)
Lumbar	3	3	4	10 (1.3)
Thoracic	4	4	1	9 (1.1)
Total (%)	303 (38.5)	286 (36.3)	198 (25.1)	787

Each impaired joint muscle action is assigned a severity rating determined by dividing the normal range of motion value equally in thirds (mild, moderate, and severe).

Table 4.

Contracture frequency (N = 1031)

Patients with at least one contracture (%)	237 (23)
Total number of contractures	787
Mean number of contractures per person if at least 1	3.32
Patients with one contracture (%)	72 (7.0)
Patients with two contractures (%)	64 (6.2)
Patients with three contractures (%)	19 (1.8)
Patients with four contractures (%)	24 (2.3)
Patients with more than four contractures (%)	58 (5.6)

Table 5.

Logistic regression analysis of predictors of the presence of contractures

Variable	Odds Ratio	SE	*T*	*P* > |*t*|	95% Confidence Interval
Age	1.06	0.129	4.94	.000	1.037–1.087
ICU **d**ays	1.012	0.007	2.47	.013	1.004–1.033

ICU, intensive care unit.

Pseudo R^2 over imputed data = .04160638. C statistic over imputed data = 0.65433175.

Table 6.

Ordered logistic regression analysis of predictors of the severity of contractures

Variable	Odds Ratio	SE	t	*P* > |t|	95% Confidence Interval
Age	1.22	0.071	3.39	.001	1.086–1.364
ICU **d**ays	1.02	0.008	2.34	.019	1.003–1.035
Amputation	1.58	0.284	2.53	.012	1.107–2.246
Black	1.40	0.188	2.49	.013	1.074–1.821
Hispanic	0.81	0.194	−0.89	.375	0.506–1.293
Other **e**thnicity (not **w**hite, **b**lack, or Hispanic)	1.13	0.326	0.41	.683	0.638–1.987

ICU, intensive care unit.

Table 7.

Negative binomial regression analysis of predictors of the number of contractures

Variable	**IRR**	**SE**	***t***	***P* > |*t*|**	**95% Confidence Interval**
Age	1.261	0.062	4.71	<.001	1.145–1.389
Length of **s**tay	1.002	0.001	2.24	.025	1.000–1.003
ICU **d**ays	1.017	0.004	4.40	<.001	1.009–1.025
Amputation	1.512	0.189	3.31	.001	1.182–1.933
TBSA **b**urn	1.050	0.019	2.59	.010	1.012–1.088
TBSA **g**raft	1.014	0.004	3.29	.001	1.006–1.023

ICU, intensive care unit; *IRR*, inter-rater reliability.