Clinical Characteristics of Hypertension in Burned Children

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Although systemic arterial hypertension has been recognized as a common complication of thermal injury in children, its clinical characteristics have not been defined. This review of 987 burned children, treated over an 11-year period, documents development of hypertension in 195 patients (19.8%). The problem occurs most frequently in males and in the 7–10-year age group, but does not correlate with racial origin. Incidence increases with burn severity up to a 40% total surface burn. The incidence did not vary with the year of treatment when changes in patient population were eliminated. Fifteen of the 195 patients had hypertensive encephalopathy and seizure problems. No other complication or change in mortality could be related to hypertension. The problem could not be related to location of the burn wound, drug treatment, or differences in transfusion and fluid therapy. Comparison of the highest daily blood pressure measurements between matched hypertensive and normotensive groups demonstrated that the hypertension is limited to the acute phase of burn wound treatment and that blood pressures are normal after complete autografting. The encephalopathy and seizure problems indicate the need for careful blood pressure monitoring and effective antihypertensive therapy in the treatment of burned children.

A SYNDROME CONSISTING OF systemic arterial hypertension, mental lethargy, disorientation, central nervous system irritability, and sometimes seizures in burned children was first described by Lowrey in 1967.[7] This syndrome was described after a review of 53 burned children and study of the 13 patients who became hypertensive. Douglas and Broadfoot further studied the problem in 43 burned children, and noted an incidence of 37%.[1] More recently, Falkner et al. evaluated 54 burned children and found 32% to have sustained hypertension and 57% to have episodic hypertension.[2] Only two seizures have been described as related to hypertension.[1,7] All of these studies clearly document the existence of this problem and suggest that it is one of the most common complications of thermal injury in children. None of them, however, reports large numbers of hypertensive burned patients. Correlation of the hypertension with the many factors which complicate thermal injury is difficult. The extent to which this complication contributes to the morbidity of thermal injury and the need for treatment is unknown.

This syndrome has been recognized at the Cincinnati Unit of the Shriners Burns Institute from 1968 through 1978, during which 987 children were treated for acute thermal burn injury. It has been clinically associated with a serious seizure and encephalopathy problem and treated with an aggressive blood pressure monitoring and antihypertensive program. This retrospective review of 195 patients with hypertension documents the clinical characteristics of this problem and suggests the need for treatment.

Methods

The hospital records of 987 acutely burned children were available for review and included extensive data from the blood pressure monitoring program. Blood pressures for most patients during the acute phase of their illness, prior to complete autografting, were measured either every hour or every six hours. During the convalescent phase, after autografting and before discharge, blood pressures were determined as frequently as several times daily and at least every three days. In the first two years of this period, the syndrome was recognized with less frequency and, therefore, monitoring was not as aggressive and records not so complete as suggested above.

Blood pressure data was that routinely obtained by nursing personnel. The techniques used were consistent with the recommendations of Kirkendall et al.[4] An assortment of appropriately sized blood pressure cuffs for pediatric use was maintained on the wards throughout the time of the study. Personnel were instructed in their proper use during this time, and the same personnel obtained the acute, convalescent and the long-term follow-up data used in these studies. Blood pressures were frequently taken with a sterile nonad-

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herent dressing (Telfa®, manufactured by Kendall Company) over either burn wounds or fresh donor sites and under the blood pressure cuff. Leg pressures were occasionally the only pressures available and were corrected by subtracting 10 mmHg from measured values when used in calculations.

Patients were classified as hypertensive on the basis of a diastolic blood pressure over 90 mmHg sustained for at least 24 hours, or treatment with antihypertensive agents. The latter classification was necessary as some patients had a labile hypertension with high intermittent systolic and diastolic blood pressures which were felt to require antihypertensive treatment. Records of all patients were reviewed to obtain sex, race, age, burn size and year of treatment. Data from all patients classified as hypertensive were related to that of the entire burned group to obtain the incidence of hypertension in subpopulations segregated according to the above factors.

The magnitude of blood pressure elevation, the influence of location of burn, the incidence of complications during therapy, specific drug therapy, and fluid therapy as factors in the origin and morbidity of the hypertensive problem were evaluated by comparing records of a group of hypertensive patients with those of a closely matched group of normotensive patients. Forty-one hypertensive patients were matched with 41 normotensive patients as having the same burn size (±5% burn index), year of treatment (±one year), age (±one year), race, and sex. Burn index was calculated as the per cent of full thickness burn plus one-half the per cent of partial thickness burn. All patients in these two groups were used to compare location of burn, complications, mortality and specific drug therapy.

Data from 21 of these hypertensive patients and their 21 matched controls were used for calculations of mean highest daily, mean maximal, mean convalescent, and mean long-term blood pressure values for groups of normotensive and hypertensive patients. Mean values of the highest daily blood pressures for each patient were determined during periods of hypertension and during identical periods of acute treatment in the normotensive controls. Maximal blood pressure was the highest pressure recorded on each patient's chart. Mean convalescent blood pressures were determined after complete autografting of the burn wound, after ambulation and before discharge. Mean long-term blood pressure measurements were compiled from measurements taken on return clinic visits and during admissions for reconstructive surgical procedures over periods of four to eight years postburn.

Twelve hypertensive patients and 12 normotensive control patients had records satisfactory for evaluation of fluid and transfusion therapy. This included records of red cell and plasma transfusion, total fluid intake, and total fluid output (exclusive of burn wound and respiratory losses) measurements from the time of burn injury until diagnosis of hypertension. Mean values for these measurements could be calculated for the entire burn injury period prior to onset of hypertension and for the five days preceding onset of hypertension, and then be compared with similar values calculated for the matched normotensive control patients.

The relationship between elevated blood pressures, seizures, and encephalopathy was evaluated by reviewing the records of all patients known to have had a seizure during the hospitalization for treatment of acute thermal injury. Seizures were classified as related to hypertension by the following criteria as suggested by Gifford and Westbrook:[3] a) documented major motor seizures; b) marked hypertension during and after the event; c) encephalopathic symptoms of irritability, headache, lethargy, or coma before, during and after the event; d) no other demonstrable etiology; e) response to antihypertensive therapy; and f) no prior nor further history of seizure disorder.

Antihypertensive therapy was variable during the initial years of this study, but became more aggressive as the encephalopathic potential of this problem was appreciated. Initial treatment has consisted of hydralazine hydrochloride 0.15 mg/kg intramuscularly every six hours with other antihypertensive drugs used as necessary. Thirty-one of the 41 hypertensive patients matched with normotensive patients and 11 of the 21 hypertensive patients selected for review of blood pressure data received some form of therapy. None of the 21 hypertensive patients providing blood pressure data received any antihypertensive medication during the convalescent phase of his treatment and none of the patients with hypertension attributed to burn injury has required long-term antihypertensive therapy.

Data was analyzed by calculation of chi square values with the contingency table method and with the use of Student's t-test for paired data.[9]

Results

Relationship to Sex, Race, Age, Burn Size, and Year of Treatment

One hundred ninety-five of 987 total patients admitted for treatment of acute thermal injury were hypertensive, giving an overall incidence of 19.8% (Table 1). Males had a higher incidence than females (23.3 vs 14%, $p < 0.001$). The difference between Caucasian (19.2%) and non-Caucasian (23.8%) patients was not significant. There was a relationship to age ($p < 0.001$) with patients aged seven to ten years having a higher incidence (30.2–32.3%) than either younger

or older patients (8.7–21.6%). Statistical analysis of the age data with removal of the 0–2 year age group indicated the same relationship to age ($p < 0.02$).

A significant relationship to the magnitude of burn injury was observed ($p < 0.001$) (Table 2). The incidence of hypertension increased with the size of burn until the 40% total surface burn level was reached. At this point, all burns of 40% and larger had approximately a 40% incidence of hypertension. The smaller incidences in the 71–80% and the 91% and over burns can be attributed to a number of patients with large burns who were extremely ill and died with hypotensive crises before ever completely stabilizing.

The relationship of the incidence of hypertension to the year of treatment demonstrated a relatively constant rate for the first seven years with a drop during the last four years (Table 3). Analysis of the populations at risk, however, indicated a marked increase in burns of less than 20% total surface during the last four years and a shift of patients into the higher and lower age ranges. The incidence of hypertension in a high-risk group of patients (males, >20% total surface burn, age seven to ten years) has remained relatively constant (Table 3).

Relationship to Location of Burn, Complications, Mortality, and Drug Therapy

A comparison of the anatomic areas burned in 41 hypertensive patients and their matched controls (Table 4) reveals a slight preponderance of face and head, and of bilateral arm burns in the hypertensive group. Involvement of one arm, trunk or legs was similar in both groups.

The only difference in major complications in the 41 hypertensive patients and their 41 matched controls was six seizures in the hypertensive group versus none in the normotensive group. All six of the seizures met the criteria previously mentioned for seizures secondary to hypertensive encephalopathy. In addition to these six patients, nine other patients not included in these matched series had seizure episodes which met the criteria to be of hypertensive etiology. Eight of these 15 patients had clearly defined hypertension before the seizure activity occurred. In the other seven patients, blood pressures were not adequately measured prior to the onset of seizure for definition of hypertension. Clinical data used to eliminate the cases of metabolic seizure are summarized in Table 5. Each patient was also followed by a pediatric and/or neurologic consultant and no clinical finding other than hypertension was evident to explain the seizure and encephalopathy.

Hypertensive and normotensive patients from the matched series had similar numbers of septic episodes, 13 and 15, respectively. There was no preponderance of any specific organism responsible in either group. Two of 41 patients in both the hypertensive and normotensive groups developed pulmonary edema and one of 41 patients in both groups developed electrolyte imbalances. The only renal dysfunction in either group was one episode of uremia in a hypertensive patient which became evident after the hypertension and was associated with a multiple organ failure syndrome secondary to terminal sepsis. Deaths were almost identically distributed between the two groups with six in the hypertensive group and five in the normotensive group.

The frequency of individual drug use was similar in both the hypertensive and normotensive groups. Only diphenylhydantoin, phenobarbital, and antihy-

TABLE 1. *Incidence of Hypertension Related to Sex, Race, and Age*

	Total Admissions	Number Hypertensive	Incidence Hypertension (%)
Entire Series	987	195	19.8
Sex			
male	622	144	23.3
female	365	51	14.0
Race			
Caucasian	865	166	19.2
non-Caucasian	122	29	23.8
Age (years)			
0–2	229	20	8.7
3–4	129	26	20.2
5–6	134	25	18.7
7–8	133	43	32.3
9–10	116	35	30.2
11–12	116	24	21.6
13–14	110	18	16.4
15–16	20	4	20.0

Contingency table analysis: Relation of hypertension to sex—$p < 0.001$; relation of hypertension to race—$p > 0.25$ (NS); relation of hypertension to age—$p < 0.001$; relation of hypertension to age with 0–2 yr. group excluded—$p < 0.020$.

TABLE 2. *Incidence of Hypertension Related to Burn Size*

Burn Size (% Total Surface)	Total Admissions	Number Hypertensive	Incidence Hypertension (%)
0–5	99	0	—
6–20	352	26	7.4
21–30	150	36	24.0
31–40	150	42	28.0
41–50	84	36	42.9
51–60	61	23	37.7
61–70	42	18	42.9
71–80	30	8	26.7
81–90	15	5	33.3
91–100	4	1	25.0

Contingency table analysis: Relation of hypertension to burn size: $p < 0.001$.

TABLE 3. *Incidence of Hypertension Related to Year of Treatment and to Other Risk Factors*

Year	Incidence of Total Admissions Hypertensive (%)	Incidence of "High Risk" Patients Hypertensive (%)
1968	28	80
1969	23	64
1970	21	75
1971	16	33
1972	39	88
1973	22	56
1974	30	55
1975	11	14
1976	14	71
1977	5	20
1978	7	60

Contingency table analysis: Relation of incidence to year of treatment for total admissions: $p < 0.001$; relation of incidence to year of treatment for "high risk" group (males, 7–10 years, >20% total surface burn): $p > 0.09$, NS.

pertensive agents were used to a larger extent in the hypertensive group for the treatment of the hypertension and seizures which occurred in that group.

Blood Pressure Data

The mean of the highest daily blood pressures and the mean maximal blood pressures were both elevated when the values from the 21 hypertensive patients were compared with their 21 matched normotensive controls ($p < 0.001$) (Table 6). Both systolic and diastolic pressures were elevated. There were no differences in the mean convalescent blood pressures or the mean long-term blood pressures between the hypertensive and normotensive patients.

Relation to Fluid and Transfusion Therapy

Mean values for red blood cell, plasma, and total fluid intake, and total fluid output measurements were almost identical for 12 hypertensive patients and 12 matched normotensive patients (Table 7). No significant difference in fluid or transfusion therapy was evident when either mean values for the entire hypertensive period or for the five-day period preceding diagnosis of hypertension were compared.

TABLE 4. *Relation of Hypertension to Anatomic Areas Burned in 41 Hypertensive Patients and 41 Matched Normotensive Patients*

Locations	Hypertensive (%)	Normotensive (%)
Face and head	44	32
One arm	17	17
Both arms	70	54
Trunk	100	95
Legs	80	83

TABLE 5. *Available Data from 15 Patients at the Time of Hypertensive Seizure*

		Number	Mean	Range
Postburn day		15	34	6–59
Blood pressure	(mmHg)	15	179/118	144/110–196/160
Temperature	(C)	15	38.2	37.8–38.9
Hematocrit	(%)	15	37	34–46
Serum Na	(mEq/L)	15	140	136–146
Serum K	(mEq/L)	15	4.1	3.0–5.5
Serum Cl	(mEq/L)	15	98	92–105
Serum CO_2	(mEq/L)	15	24	18–30
BUN	(mg/100 ml)	15	13	8–29
Blood glucose	(mg/100 ml)	10	121	66–288
Serum Ca	(mg/100 ml)	11	9.5	8.7–10.8
Serum Mg	(mEq/L)	11	1.9	1.8–2.3
Serum P	(mg/100 ml)	11	4.5	2.1–6.5
Osmolality	(mOsm)	13	286	275–300
P_{O_2}	(mmHg)	6	92	73–101
P_{CO_2}	(mmHg)	6	33	32–36
pH		6	7.41	7.39–7.45
Blood cultures		11		11/11 Sterile

Discussion

The overall incidence of hypertension in burned children of 19.8% reported in this study is lower than the incidence of 24–89% reported by other authors.[1,2,7] The 19.8% incidence would be higher if the criterion of an elevation above two standard deviations over the mean pressure for a given age as described by Moss and Adams, or by Londe, had been used to define hypertension.[6,8] These age-related hypertensive levels are consistently below 90 mmHg diastolic in the age ranges studied here, and use of these lower levels in defining hypertension, as was done in the previous burn hypertension studies, would elevate the incidence of hypertension found in this study. The incidence of 19.8% reported here is a conservative estimate, but does indicate that hypertension is one of the most common complications of thermal injury in children.

This study further defines this hypertensive syndrome by suggesting that it is most prominent in the 7–10-year age group, predominates in males, and is clearly related to the magnitude of thermal injury. A high-risk group of patients (males, aged seven to ten, greater than 20% burn) can be identified and should be monitored closely for development of this problem. The relative consistency of the incidence of hypertension (mean: 57%) in this high-risk group also makes an etiologic relationship of hypertension to many specific modes of therapy which have varied in use during this 11-year period unlikely.

The risk factors of age and burn size strongly influence the clinical course of the injury including development of complications, therapy and final outcome. It is, therefore, important to compare only

TABLE 6. *Blood Pressure Data*

Patient Group (n)	Mean of the Highest Daily Blood Pressure (mmHg)	p	Mean Maximal Blood Pressure (mmHg)	p	Mean Duration (days)	Mean Convalescent Blood Pressure (mmHg)	p	Mean Long-term Blood Pressure (mmHg)	p
Normotensive (21)	123/78		142/91			114/73		106/64	
Hypertensive (21)	145/100	*/*	168/125	*/*	36.1	118/76	NS	107/68	NS

* $p < 0.001$ different from normotensive (p values determined by Student's t-test for paired data).

21 normotensive patients—mean burn index 39.5.
21 hypertensive patients—mean burn index 40.7.

groups of hypertensive patients with groups of normotensive patients who are similar with regard to the above factors to determine the influence of the development of hypertension on the subsequent clinical course. This is accomplished, in this study, by comparing 41 hypertensive patients with 41 normotensive patients who have been closely matched with regard to age, sex, year of treatment, and burn size.

The result of the comparison of anatomic areas burned is of interest because of the possibility that the elevation in blood pressure could be stimulated by the measurement of blood pressure in a painful, burned extremity, or be artifact from measurements taken on edematous extremities. The increase in bilateral arm involvement in the hypertensive group would support these hypotheses. Blood pressures, however, were measured in unburned, nonedematous extremities whenever possible, and when burned extremities were used, blood pressure cuffs were kept in place and simply inflated for measurement. This later technique and the use of nonadherent dressings caused little pain in most patients. These factors, the common findings of extremely high blood pressures in patients with small burns and normal extremities (*e.g.*, 196/160 mmHg in a 5-year-old with a 21% burn), and the confirmation of most of the blood pressures in this series by one of the authors (D.F.) make artifact in blood pressure measurement from edema or pain an unlikely explanation for hypertension associated with thermal injury.

Comparison of complication rates between the two groups indicates that seizure problems are the only identifiable complication of burn hypertension. The finding of 15 patients with seizures, which can be related to the hypertension by the previously outlined criteria, suggests that a total of 15 of the 195 hypertensive patients had episodes of hypertensive encephalopathy. Most of these seizures occurred during the early years of this experience (1968–1969) before the hypertension problem was recognized and treated aggressively (Table 8). Encephalopathy consisting of lethargy, irritability, headache, or somnolence occurred with all of the seizures and appears related to this syndrome, as suggested by Lowrey.[7] The monitoring of blood pressures during this acute phase and the use of hydralazine and other antihypertensive medications to control hypertension appear to have eliminated hypertensive seizures over the past five years (Table 8).

The relatively equal frequency of major drug use in both groups tends to eliminate an idiosyncratic reaction to a drug as a possible cause. The drugs monitored in the matched series included the majority of drugs commonly used in the burn unit, and it is unlikely that an unrecognized agent is causing the problem. No hexachlorophene soaps, which have been implicated in causing encephalopathy, have been used on the unit at any time during this study.[5]

Blood pressure data contained in Table 6 gives mean values over a prolonged period of time and illustrate both how high pressures go and the relatively long time period, mean 36.1 days, over which the problem was observed. The sampling techniques used clearly define the hypertensive population as having blood pressure elevations in the range of 145/100 mmHg at least once daily and in the range of 168/125 mmHg

TABLE 7. *Fluid and Transfusion Therapy (ml/m²/24 hrs ± SEM)*

	Hypertensive (12)				Normotensive (12)			
	RBC	Plasma	Intake	Output	RBC	Plasma	Intake	Output
Entire prehypertensive period	69 ± 9	111 ± 12	2750 ± 113	1366 ± 100	55 ± 12	139 ± 12	2865 ± 194	1327 ± 127
5 Days pre-hypertensive period	79 ± 19	121 ± 29	3041 ± 213	1606 ± 148	56 ± 21	113 ± 30	2744 ± 206	1403 ± 180

12 hypertensive patients—mean burn index 46.

12 normotensive patients—mean burn index 43.

TABLE 8. *Seizures and Treatments by Years*

Year	Per Cent Hypertensives Treated	Hypertensive Seizures	Other Seizures
1968	24	6	2
1969	72	4	1
1970	71	1	1
1971	76	2	3
1972	77	0	2
1973	100	2	1
1974	100	0	2
1975	100	0	0
1976	100	0	1
1977	100	0	1
1978	100	0	0
		15	14

during the hospitalization, which are both markedly abnormal. Further, the convalescent and long-term pressures are normal, which indicates that the problem is limited to the acute phase of burn treatment.

The fluid and transfusion data from Table 7 demonstrate no significant difference in fluid or transfusion therapy in 12 hypertensive patients and 12 closely matched normotensive controls. This type of analysis, based on nursing records, would only detect a relatively large and systematic difference in fluid therapy and would not detect several liters of fluid being retained by a child over several days of therapy. No comment from these data can, therefore, be made as to whether or not this is a volume-related form of hypertension.

This retrospective review of this hypertensive problem defines its origin only to the extent of eliminating burn treatment modes or specific burn complications such as gross renal disease as possible causes. It does, however, define a high-risk group of patients and confirms the presence of a syndrome of burn-related hypertension which includes a serious hypertensive encephalopathy problem. Although no other increase in morbidity is associated with this syndrome, the encephalopathy problem indicates the need for careful monitoring of blood pressure in burned children and effective antihypertensive therapy to prevent seizures once hypertension is detected.

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