Changing trends in pediatric upper extremity electrical burns

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Abstract

Background Upper extremity electrical burns are a cause of major morbidity and disability in affected individuals. Anecdotally, we have noted changes in the presentation of cases to our institution. We sought to compare current data on upper extremity electrical burns in children with our previously published historical data.

Methods Using the Shriners Hospital Boston and American Burn Association databases, we retrospectively analyzed electrical upper extremity burns in patients aged 21 years or younger. Data regarding demographics, etiology, and reconstruction were collated and analyzed.

Results In our institutional cohort, patients were most commonly males (37/48, 77%) aged 10–15 years (19/48, 40%). We have seen a rise in the proportion of female, younger patients, with burns attributed to domestic wiring, indicative of a reduction in the number of high-voltage injuries in males due to demonstrations of bravado. High-voltage injuries correlate with severity of injury and tended to be transferred to our institution from foreign countries (9/48, 19%). We have also seen a reduction in the need to amputate extremities.

Conclusions Changes in upper extremity electrical burn demographics and etiology since the 1970s may be indicative of effective education and safety campaigns. Consequently, reconstructive requirements have also changed. We hope that similar ongoing efforts in the developing world may bring about comparable positive results.

Keywords Burns · Pediatric · Upper extremity · Electrical

Introduction

Burn injuries of the upper extremity may cause significant morbidity and disability in those affected. Electrical burns of the upper extremity add another level of complexity with tissue injury, rhabdomyolysis, and neurolysis occurring due to thermal mechanisms (joule heating), non-thermal mechanisms (cell lysis by electroporation), and associated flame burns [9, 10]. Arcing at points of entry and exit combined with severe tissue destruction at narrow “choke” points commonly causes destruction to key structures, particularly in the volar wrist [5, 6, 17]. Furthermore, in the hand and wrist, even a small surface area burn can result in major morbidity due to the functional consequences of nerve injury, tendon dysfunction, and contractures. While we have made large advances in reconstructive options including microsurgery and free tissue transfer allowing better soft tissue coverage and motion, recovery after burn injuries to major peripheral nerves remains limited. As a result, electrical burns of the upper extremity frequently result in the need for significant limb reconstructive surgery or amputation [7, 8, 15, 16].

Throughout the USA from 1999 to 2008, there were 127,016 burns including 3,812 electrical burns (3.0%) reported to the American Burn Association (ABA) [2]. Shriners Hospital Boston is the major referral center for all pediatric burns in New England, and during a similar time period (July 1, 1998 and July 1, 2008) at Shriners Hospital, we have taken care of 48 upper extremity electrical burns. In 1976, McLoughlin et al. [12] published a paper detailing the epidemiology of high-voltage electrical injuries in children from our institution.

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Since this time, we have seen considerable regulation in electrical safety [13], and it is widely believed that public policy and education has changed the epidemiology of electrical burn injuries. Current prevention strategies include both active measures (education) and passive measures (product design, environmental change, legislation, and regulation [11]. These have included changes such as redesign of electrical plugs, burying power lines, making high-voltage sources less accessible, and undertaking educational, such as the “stop, drop, and roll” message. US regulations have been enforced concerning the placement and security of high-voltage electrical sources; children receive education about risk taking; and parents are educated about preventing access to electricity (such as covering electrical outlets) [13]. Moreover, the social correlates of burns (poverty, overcrowding, and educational deficits) have been changed substantially over decades [11]. However, few direct comparisons have clearly evaluated the changes in case presentations. Our goal was to compare current data on the demographics and severity of upper extremity electrical burns in children from within our institution and the American Burn Association with our own previously published historical data. Here, we report our results with electrical injuries of the upper extremity in children treated at Shriners Hospital Boston.

Patients and Methods

After institutional review board approval, a retrospective review of pediatric electrical upper extremity burn data was performed. Patients were selected using computerized databases kept by Shriners Hospital Boston. Given the bias of our data to include both complex burns and transfers from other hospitals (and overseas), data were also requested from the American Burn Association to serve as a comparison group.

The Shriners database consists of all patients admitted to Shriners Hospital Boston for evaluation, acute treatment, or reconstructive procedures related to burns (restricted to age 21 years or younger). All burn patients coded with an electrical etiology between July 1, 1998 and July 1, 2008 were included. The ABA database consists of voluntarily submitted data from 79 hospitals across 33 states plus the District of Columbia. This database was queried for all electrical burns of the hand and forearm in patients aged 21 years or younger between 1998 and 2007, inclusive. Where possible, patients included in the Shriners Hospital database were removed from the ABA database to prevent duplication in each cohort. Due to a lack of data, this was not possible for all patients, but they represent a relatively small number and their inclusion serves to reduce the differences found between the two groups.

For each dataset, data regarding demographics, burn details, and reconstruction (where applicable) were entered into a spreadsheet (Microsoft® Office Excel® 2007 SP2, Microsoft Corporation), and basic data analysis was performed using pivot tables. Statistical analysis was performed using computer analysis (JMP 4.0.0, SAS Institute Inc, Cary, NC, USA). All statistical tests were two-tailed with data considered statistically significant where $p < 0.05$. No patient was excluded from our analysis; however, where data were inadequate, these were categorized as “unknown.”

Results

Patient Demographics

Between July 1, 1998 and July 1, 2008, 48 children aged 21 years or younger (mean age 10.7 years) were admitted to Shriners Hospital Boston for injuries related to electrical burns of the upper extremity. Of these, 37 (77%) were male and 11 (33%) were female. The peak incidence of injury occurred at ages 10–15 years (19/48, 40%), with the next most common ages being 1–5 years (15/48, 31%) and 5–10 years (8/48, 17%). Twenty-four patients (50%) were from the USA, 13 patients (27%) were from the Dominican Republic, and the remaining 11 patients (23%) came from a variety of countries in Central and South America and Eastern Europe. Of the 48 patients, estimated burn total body surface area was 1–10% in 23 patients (48%), 11–20% in 5 patients (10%), 21–30% in 5 patients (10%), 31–40% in 2 patients (4%), 51–60% in 4 patients (8%), 71–90% in 2 patients (4%), and unknown in 7 patients (15%). Twenty-five patients (52%) were admitted for acute burn management, with the remainder being admitted for delayed management and reconstruction. Of those transferred for delayed management, 22/23 (95%) were from outside the USA.

During a similar 10-year period (1998 through 2007, inclusive), 357 children younger than 21 years (mean age 10.6 years) were included in the American Burn Association database, of which 79% were male and 20% female. One-hundred and fifteen patients (32%) were aged under 5 years, 55 (15%) aged 5 to 10 years, 74 (21%) aged 10 to 15 years, 93 (26%) aged 15 to 20 years, and 22 (6%) aged 20 to 21 years. The vast majority (272/357, 76%) suffered burns of 10% or less total body surface area.

Etiology

The etiology of electrical burn mechanism is variably classified. Using the classification system used by the American Burn Association, the majority of injuries in our

institutional series (21/48, 44%) occurred from electric power plants and lines, closely followed by domestic wiring and appliances (17/48, 35%). As may be expected, there is a striking difference in the etiology of burns dependent on the patient's country of origin. Patients living in the USA were significantly more likely to have an etiology of domestic wiring and appliances versus foreign patients who most commonly presented with burns related to electric power plants and lines (chi-square, $p=0.04$) (Table 1). Furthermore, where data were known, all patients who received burns from domestic wiring and appliances suffered 1–10% total body surface area burns, while all of the burns over 10% total body surface area were attributed to electric power plants and industrial causes.

In comparison, when examining the American Burn Association database, the most common source of burns was from domestic wiring and appliances (159/357, 45%). In addition, assuming that non-domestic sources are generally high voltage, we see a slightly higher (but not statistically significant) proportion of high-voltage burns (26/48, 54%) than the American Burn Association database average (147/357, 41%) (Table 1).

Injury

Patients present to Shriners Hospital Boston with injuries varying from small first and second degree burns to complete limb amputations. Given the absence of a standard injury classification system, we categorized these based on burn depth and exposure/injury to critical structures: 11/48 (23%) suffered first/second degree burns to the hand(s) and forearm (s), 18/48 (38%) patients second/third degree burns, and 11/48 (23%) exposure or destruction of vessels, tendons, and/or nerves (Table 2). There is a significant difference between countries of origin with 2/24 (8%) US patients suffering from exposure or loss of vital structures, compared with 9/24 (38%) foreign patients (Fisher's exact test, $p<0.04$).

Reconstruction

Methods of reconstruction varied considerably, dependent on the degree of injury. Of our 48 patients, 23 patients

(48%) required no surgery, 9 (19%) underwent primary excision and grafting, 2 (5%) required local tissue rearrangement, 3 (6%) required release and grafting, and 9 (19%) required flap coverage (Table 2). Where flap coverage was required, this was achieved with either a fillet flap, chest flap, groin flap, or anterolateral thigh flap. Those patients requiring flap coverage typically underwent delayed tendon and nerve grafting and two patients underwent toe-to-thumb transfers.

Discussion

In a prior review from our institution including 7 years of data prior to publication in 1976, McLoughlin et al. [12] examined their patients with high-voltage electrical injuries. They identified 27 patients, all male, and the majority in their early teens. The mechanism of injury was classified into pole climbing (9/27, 33%), trespassing (9/27, 33%), other climbing (7/27, 26%), and target practice (2/27, 7%). Burke et al. [4] published a series of 29 patients in 1977, ranging in ages from 7 to 16 years. Eleven of these patients suffered only surface burns from 28% to 80% total body surface area. Eighteen suffered from deep tissue destruction. Twenty-five were recorded as being “engaged in essentially mischievous activity that involved climbing.”

In contrast to these prior data, we report significantly more electrical burns in female patients, and there is a striking difference in the etiology of burns whereby burns in US residents are typically from domestic wiring while those in foreign patients are often from electric power plants and power lines. These altered demographics likely represent three trends. First, increased safety mechanisms and education may have reduced the number of adolescent males receiving electrical burns while undertaking acts of “bravado,” thus increasing the *proportion* of very young male and female patients suffering from injuries due to lack of awareness such as placing objects into domestic electrical outlets. This is supported by data from Shriners Hospital Galveston where 77% of their low-voltage burns occur in children aged 0–5 years, despite a decline in low-voltage injuries [14]. Second, policies to prevent public

Table 1 Burn etiology

	US resident (Shriners Hospital)	Foreign (Shriners Hospital)	Total (Shriners Hospital)	ABA total
Domestic wiring/appliances	16	1	17 (35%)	159 (45%)
Industrial wiring/machinery	2	3	5 (10%)	36 (10%)
Electric power plants/wiring	6	15	21 (44%)	111 (31%)
Unknown [or lightning]	0	5	5 (10%)	47 [3] (14%) [1%]
Total	24	24	48 (100%)	357 (100%)

Table 2 Burn severity and reconstruction

	No surgery	Excision and graft	Release and graft	Local tissue rearrangement	Pedicled or free flap	Surgery prior to transfer	Total
First/second degree burns	11						11
Second/third degree burns	9	8	1				18
Exposed tendon/vessel/nerve				1			1
Loss of nerves/vessels/tendons		1			9	1	10
Delayed contracture			1	1			2
Unknown	3		1			1	6
Total	23	9	3	2	9	2	48

contact with high-voltage distribution devices and industrial sources of electricity may have reduced the number of high-voltage injuries in the USA, but the lack of such policies and safety mechanisms in the developing world has maintained these sources as a significant danger to children growing up outside of the developed world. Third, public education and specialization with centralization of resources may have increased the number of referrals with minor electrical injuries that would have previously not been seen at our tertiary referral center.

Rai et al. [14] examined 30 years of data from Galveston, TX, reporting burns from 1987 to 1997 in detail. They similarly find that, during this more recent time period, while low-voltage injuries predominate in the 0–5-year age group, high-voltage injuries (most commonly from power lines) occurred most frequently in the 11–18-year age group and most commonly in boys. Importantly, high-voltage injuries must remain an important focus when considering the morbidity of these injuries; other authors have published that of those injuries requiring graft and/or flap coverage 90% were due to high-voltage burns [1].

This effect of public policy and education is interesting when our data are segregated according to the country of origin. While the typical American “high-voltage electrical burn patient” has not changed over the years (teenage boys testing “physical prowess, fearlessness, or a spirit of adventure”) [12], our influx of outside patients has increased the number of accidental electrical burn injuries being admitted for delayed management or devastating injuries due to high voltages from exposed electrical transmission systems or industrial sources. Due to the voluntary reporting of data to the American Burn Association’s National Burns Registry and the variable referral practice to our institution, it is not possible to accurately and directly compare numbers. However, in the 10-year period of this study, 6/24 (33%) US patients received upper extremity electrical burns from non-domestic sources. In 1977, Burke et al. [4] from our institution report 29 high-voltage burns in children in an 8-year period. These data

may represent a decline in devastating injuries. Furthermore, while there is a clear referral bias, only a small number (2/24, 8%) of our US resident patients suffered injuries involving exposure or destruction of vital structures (and far fewer than in 1976 when 2 patients died and 48% received some form of amputation), suggesting that the severity of burn injuries has decreased, likely due to less exposure to high-voltage electrical sources.

Reconstruction of the upper extremity remains a complex topic. Management with early excision and grafting followed by splinting is well-known to reduce deformity, decrease the need for later reconstruction (by approximately 50%), and optimize functional outcomes, but optimal management after devastating injuries is less clear-cut [3]. With a goal of limb salvage, we now commonly undertake more complex reconstructive attempts than in 1976, at which time approximately half of patients with high-voltage injuries underwent amputation, often losing more than one limb [8, 12, 14]. Our data are not directly comparable with other published series nor our own historic data. However, 9 of the 25 patients (36%) requiring procedures and 9 of our 31 patients (29%) with electrical burns from non-domestic sources required flap closure of wounds, commonly using groin or free flaps. Most commonly, we have employed the pedicled groin flap. Similar to other published series, many of these patients will go on to need delayed tendon and nerve grafting with possible free toe transfer [1]. In our series, no patient required limb amputation (although one patient had an amputation prior to transfer to our facility and others suffered auto-amputation during their injury requiring delayed reconstruction).

Conclusions

Upper extremity electrical burns constitute a relatively small number of injuries in the USA. However, for those affected, they are a source of significant morbidity and disability. Our experience over the past 10 years has shown

a significant change in the demographics of those affected. We are now seeing a higher proportion of very young male and female children with domestic wiring electrical burns and fewer teenage males with injuries related to power lines and industrial sources. This has resulted in us seeing a relatively higher proportion of low-voltage, low mortality injuries from within the USA, with a consequent increase in overseas referrals of devastating high-voltage injuries. We believe that this change may be due to better education and safety within the USA causing a change in presentation and referral patterns.

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