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Prevalence and Risk Factors for Hypertrophic Scarring of Split Thickness Autograft Donor Sites in a Pediatric Burn Population

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ABSTRACT

Title: Prevalence and Risk Factors for Hypertrophic Scarring of Split Thickness Autograft Donor Sites in a Pediatric Burn Population.

Objective: The split-thickness autograft remains a fundamental treatment for burn injuries; however, donor sites may remain hypersensitive, hyperemic, less pliable, and develop hypertrophic scarring. This study sought to assess the long-term scarring of donor sites after pediatric burns.

Methods: A retrospective review of pediatric burn patients treated at a single institution (2010-2016) was performed. Primary outcomes were prevalence of donor site hypertrophic scarring, scarring time course, and risk factor assessment.

Results: 237 pediatric burn patients were identified. Mean age at burn was 7 yrs., mean %TBSA was 26% with 17% being Full Thickness. Mean follow-up was 2.4 yrs. Hypertrophic scarring was observed in 152 (64%) patients with 81 (34%) patients having persistent hypertrophic scarring through long-term follow-up. Patient-specific risk factors for hypertrophic scarring were Hispanic ethnicity ($P=0.03$), increased %TBSA ($P=0.03$), %Full Thickness burn ($P=0.02$) and total autograft amount ($P=0.03$). Donor site factors for hypertrophic scarring were longer time to epithelialization ($P<0.0001$), increased donor site harvest depth ($P<0.0001$), autografts harvested in the acute burn setting ($P=0.008$), and thigh donor site location (vs. all other sites; $P<0.0001$). The scalp, arm, foot, and lower leg donor sites (vs. all other sites) were less likely to develop HTS ($P<0.0001$, 0.02, 0.005, 0.002, respectively), along with a history of previous donor site harvest ($P=0.04$).

Conclusions: Hypertrophic scarring is a prominent burden in donor site wounds of pediatric burn patients. Knowledge of pertinent risk factors can assist with guiding management and expectations.

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1. Background

While burn survival has improved dramatically in the last half century, pathologic scarring after burns remains one of the greatest challenges for burn-injured patients [1]. Hypertrophic scarring and debilitating contractures after burns affect 32–72% [2] and 38-54% of patients [3], respectively, with up to 46% patients undergoing at least one reconstructive procedure after their acute stay [4]. Risk factors for development of pathologic scarring in the setting of burns have been reported to include darker skin color [5,6], female sex [7], young age [7], burns to the neck or upper limb, [7] multiple surgical procedures, [7] meshed skin graft, [7] increased time to healing [6-8], and burn severity [7] There, however, remains a limited knowledge about the etiology of pathologic scarring, its incidence, risk factors, and time course. Furthermore, despite a multitude of treatment modalities, consensus for scar reduction protocols has been limited by few adequately powered studies [9,10].

The split-thickness autograft (STAG) remains a fundamental means of treatment for deep partial thickness and full thickness burn wounds. In concept, because the donor site wound is superficial (typically 0.010–0.015 inches in depth), epidermal progenitor cells present in deeper adnexal structures remain and can repopulate the epidermis with minimal morbidity and scarring. However, in reality, wounds from donor sites can cause considerable discomfort for the patient especially with regards to pain and aesthetics. Many clinical trials have looked at interventions to reduce donor-site pain [11] and accelerate the average 7–14 day re-epithelialization rate to allow for shorter hospital stays or quicker re-use of the same site for further grafting [12]. Despite efforts toward improved acute healing, STAG donor sites can remain painful [12] and have been noted to leave lasting evidence of differences in pliability and erythema [13,14]; however, unlike the burn scar, there exists little to no data analyzing the prevalence of hypertrophic scarring or the variables associated with this process in STAG donor site wounds. Due to the large area that a STAG donor site typically encompasses, an abnormal healing response could understandably cause significant distress for patients, prompting them to seek scar reduction therapy.

We sought to identify the frequency of pathologic scarring in the surgical donor sites of split-thickness skin grafts, define the time course for pathologic scarring in donor sites from epithelialization to scar to resolution, and elucidate the risk factors for the development and resolution of hypertrophic scarring (HTS).

2. Methods

2.1. Study Population and Design

University of Cincinnati Institutional Review Board approval (protocol #2016-3803) was obtained prior to initiation of the study. All pediatric patients treated for an acute burn from January of 2010 to September of 2016 were identified and their charts were retrospectively reviewed. Inclusion criteria were children age 0–21 at the time of burn who received excision and grafting at The Shriners Hospitals for Children – Cincinnati burn hospital for their acute burn. Exclusion criteria were patients who died within 6 months after burn, did not receive STAG for their burn or did not return for follow-up at our hospital, and those who had inadequate follow-up (donor sites were not epithelialized at date of last follow-up visit).

2.2. Treatment Protocols

Each patient's donor site was cleaned with a chlorhexidine wash and allowed to dry prior to harvest. Donor sites were infiltrated subcutaneously to distention with lactated Ringer's solution containing 2cc 1:100,000 epinephrine per liter to decrease blood loss [15]. Grafts were harvested at a depth determined by the primary surgeon with an electric dermatome (Padgett Instruments, Kansas City, Missouri). Epinephrine-soaked pads were placed on the donor sites immediately to further minimize blood loss. Donor sites were then dressed with calcium-alginate dressing (Kaltostat, Convatee, Princeton, New Jersey), transparent film dressing (Tegaderm, 3M, Maplewood, Minnesota), or silver-impregnated dressing (Silvercel, Acelity, San Antonio, Texas), and wrapped in dry burn gauze and elastic bandages (in feasible locations). On post-operative day 5, dressings were removed. The donor site was cleaned, and then dressings were replaced. This process occurred any time the wound developed discolored exudate. After dressings fell off from re-epithelialization, the remaining open areas were treated with bacitracin, 3:1 (Bacitracin: Silvadene) or 1:1:1 (Bacitracin:Silvadene:Nystatin) topical ointments, as dictated by colonization cultures, and covered with a non-stick dressing of Adaptic (Johnson & Johnson, New Brunswick, New Jersey), dry gauze, and elastic bandages. After discharge, patients were followed up every 2 weeks regularly until donor site and graft epithelialization. Patients then were followed at least every three to six months in the first year after burn and yearly afterwards, with more frequent visits depending on patient course. Once fully epithelialized or epithelialized enough to withstand shear forces, donor sites were fitted and covered with pressure garments custom made in-house. Patients and families were instructed to wear garments at all times except when bathing and to massage scars using lotion three times daily.

2.3. Variables Assessed

Preoperative variables assessed included age at time of burn, sex, race, ethnicity, cause of burn wound, percent total body surface area (%TBSA), percent full thickness burn (%FT), and prior medical comorbidities. A full-thickness wound was defined as undergoing excision and grafting, i.e., this was a combination of some deep dermal and all full thickness burns as the definition included any burns that underwent grafting. A partial-thickness wound encompassed burn wounds healing within 3 weeks with conservative treatment. Operative variables collected were total STAG area for the entire operation (measured intra-operatively), donor site locations and area (calculated based on area grafted and mesh ratio), depth of donor site based on documented dermatome setting, whether the donor site was previously harvested, and whether autograft harvest occurred during the acute or reconstructive

setting. Acute setting was defined as during initial hospitalization, while reconstructive admission was defined as thereafter. Donor site locations were divided into scalp, chest and abdomen, back including the flanks, buttocks, hip and thigh, lower leg, foot, arm and forearm, and scrotum. Postoperative variables collected were initial donor site dressing, time to at least 99.9% epithelialization, time to hypertrophic scarring, time to resolution of HTS, if applicable, and length of follow-up. HTS was defined as "raised" or "hypertrophic" upon assessment by the clinical team (physician, wound care nurse, occupational therapist, physical therapist). Resolution was defined as "flat" by the clinical team. Donor site scars were determined to be persistent if present at the patient's last clinic visit or if deemed refractory to long-term pressure garments, lotion and massage and thus treated with laser therapy.

2.4. *Statistical Analysis*

Initially, patients were divided into three groups: those who had no HTS, those who had HTS that resolved during their follow-up, and those who showed no resolution of HTS during the time of the study. Variables were assessed using analysis of variance, the Kruskal–Wallis test and χ^2 tests. Subsequently, pooled comparisons between two groups were made first looking at those that never had HTS versus all HTS scarring, and then looking at no long-term HTS versus long-term HTS. Those comparisons between two groups were made by Student's t-tests, the Wilcoxon rank sum test, and χ^2 tests.

3. Results

3.1. *Inclusions*

Between January 2010 and September 2016, a total of 259 patients received split-thickness autografts during their acute stay at our hospital. Twenty-two patients were excluded from analysis, including 1 for death within 6 months after burn, 12 for no follow-up at our hospital, and 9 for inadequate follow-up (Fig. 1). Thus, 237 patients were included.

3.2. *Prevalence of Hypertrophic Scarring and Patient Predictors*

In 85 (36%) patients, no HTS was observed (Table 1). HTS was observed in at least one donor site in 151 (63.7%) patients during follow-up, with 71 (30%) patients experiencing resolution of their HTS and 81 (34%) patients with hypertrophic scars that persisted through their last follow-up visit (mean 2.4 years).

Patient risk factors for hypertrophic scarring were Hispanic ethnicity (P=0.03), increased %TBSA and %Full Thickness (P=0.03 and 0.02, respectively), length of follow-up (P=0.007) and total amount of autograft received (P=0.03). In pooled analysis, many of these risk factors demonstrated increased risk for prevalence of HTS but not long-term persistence of HTS. Risk factors for persistent HTS demonstrated associations with %TBSA (P=0.02) and %Full Thickness (P=0.009).

3.3. *Prevalence of Hypertrophic Scarring and Donor Site/Surgical Predictors*

Based on our anatomic classification of donor sites, the 237 patients had a total of 1,358 donor sites harvested (Table 2). Four hundred fifteen (31%) donor sites were re-harvested, and thus were not included in risk factor analysis. Five hundred fifty-seven (41%) donor sites never demonstrated HTS, while 198 (15%) had hypertrophic scarring that resolved, 163 (12%) had hypertrophic scarring that persisted, and 16 (1%) donor sites were non-healing and undergoing grafting.

Nine hundred eighteen donor sites were followed for HTS (Table 3). Donor site risk factors for HTS included mean donor site depth (P<0.0001), donor site location (P<0.0001), autograft harvest in the acute burn setting (P=0.008), and time to full re-epithelialization (P<0.0001). Additionally, pooled analysis demonstrated differences in HTS with the donor site dressing (P=0.04). Donor sites with a previous history of harvest displayed less HTS (P=0.04). Thigh donor sites had increased risk for HTS compared to all other locations (P<0.0001), while the lower leg, arm, foot, and scalp donor sites, versus all others, were less likely to experience HTS (P=0.002, 0.02, 0005, <0.0001, respectively). Long-term, this finding held true for lower leg and scalp donor sites with significantly less persistent scarring (P=0.01 and 0.01).

Post-hoc analysis of autograft harvest depth divided into groups, ≤0.010 in., 0.010–0.015 in., and ≥0.015 in., noted a decreased predilection for the development (P<0.0001) and persistence (P=0.049) of HTS in harvest depths of ≤0.010 in. compared to deeper harvest depths (Table 4).

3.4. *Donor Site Time Course for Healing, Scarring, and Resolution*

Average time to full re-epithelialization of donor sites occurred by 29 days (median 21 days) with significantly longer durations noted in donor sites that experienced HTS (P<0.0001) (Table 5). Mean time to development of HTS occurred at 5 months (median 4 months). A significantly longer incubation period for HTS development was noted in donor sites with persistent HTS. When a hypertrophic scar resolved, scar resolution occurred on average at 14 months (median 11 months).

4. Discussion

The long-term prevalence of HTS, though well documented for burns that heal with or without grafting, is often overlooked in skin graft donor sites in the setting of burns. We utilized a binary definition, rather than a scar scale, in this study because any raised scar in a donor site is considered abnormal and pathologic. We found that the majority of patients (64%) experienced HTS in one of their split-thickness skin graft donor sites at some point during follow-up, and that one-third patients (34%) experienced persistent HTS at their donor site (s). The average time to development of HTS was 5 months with resolution occurring at 14 months after donor site harvest.

Risk factors for HTS of donor sites were Hispanic ethnicity, increased %TBSA and %Full Thickness, and a greater amount

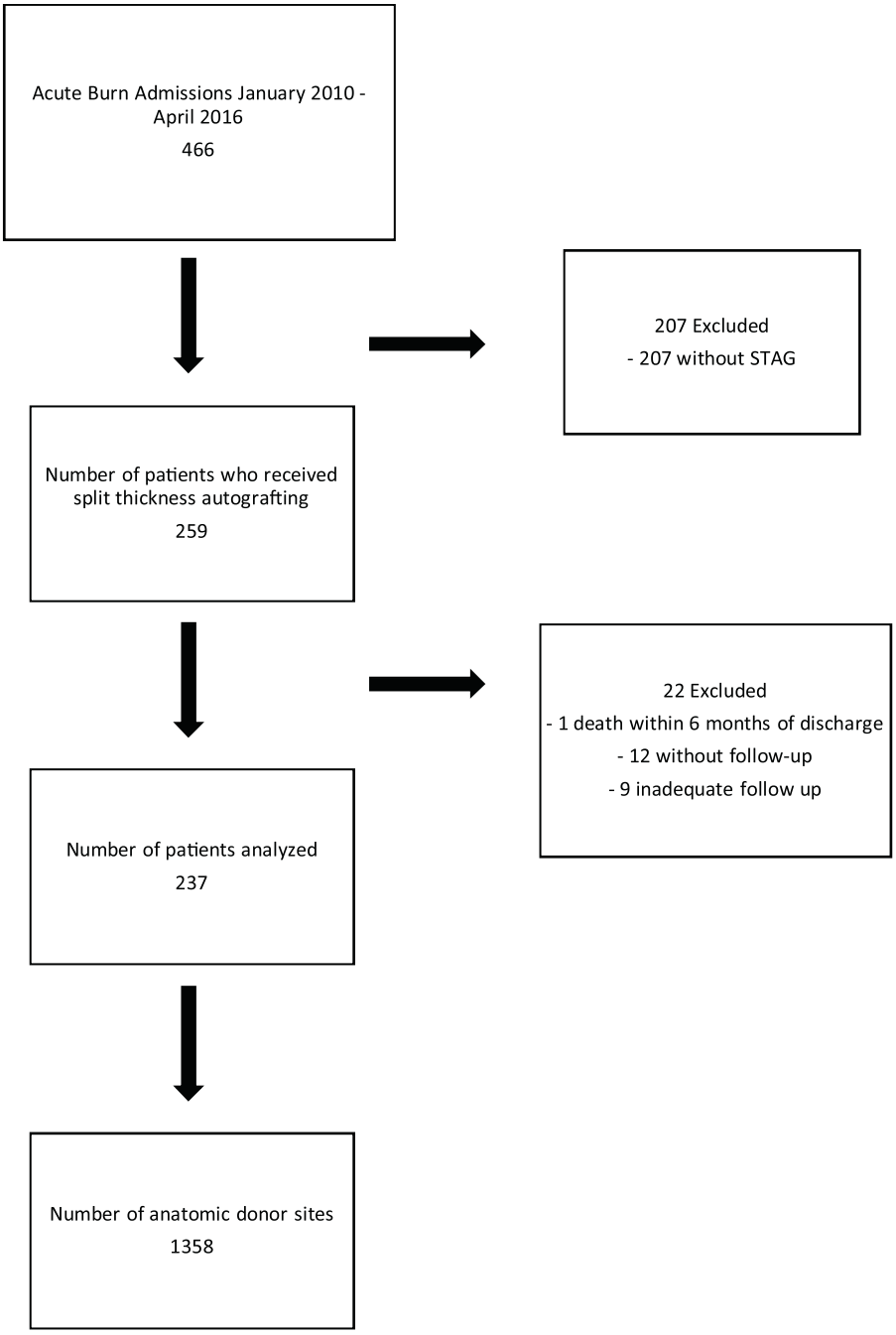

Fig. 1 – Flow chart of patient inclusion and exclusion.

of autograft received. As described in the methods section, we defined any burn that underwent graft as full thickness, which included some deep dermal burns. We considered this a reasonable way to collate that data as a deep dermal burn that undergoes autograft is likely to contribute to healing response more similar to that of a full thickness burn. Additional risk factors included deeper autograft harvest depth, thigh donor sites, autograft harvest in the acute burn setting, and delayed re-epithelialization. Protective factors were scalp, lower leg, arm, and foot donor sites, calcium alginate post-operative dressing, and previous history of donor site harvest. To our knowledge, this is one of the largest studies looking at the hypertrophic scar response in donor sites of pediatric burn patients.

The current literature examining pathologic scarring in the donor sites of burn patients is sparse with the exception of scalp donor sites. Multiples studies have advocated for the use of scalp donor sites due to its quick re-epithelialization time with reports ranging from 6.8 to 9.5 days and its limited morbidity [16]. The most common complications observed are scalp alopecia (0–5%) [17]. and scalp folliculitis (0–2%) [18], which can commonly contribute to the future development of alopecia, [19] with HTS being a rarity [20]. Of 42 patients in our population with scalp donor sites, 2 patients (5%)

Table 1 – Hypertrophic Scar Prevalence and Patient Risk Factors.

Characteristic[a,b]	All Patients (%)	Never HTS (%)	Resolved HTS (%)	Persistent HTS (%)	*P – All groups*[d]	*P – HTS anytime*[e]	*P –Persistent HTS only*[f]
Total	237	85 (36)	71 (30)	81 (34)			
Sex					0.3	0.5	0.2
Male	158 (67)	54 (34)	45 (29)	59 (37)			
Female	79 (33)	31 (39)	26 (33)	22 (28)			
Race					0.2	0.4	0.2
American Indian or Native Alaskan	3 (1)	0 (0)	0 (0)	3 (100)			
Asian	2 (1)	0 (0)	1 (50)	1 (50)			
Black or African American	59 (25)	18 (31)	23 (39)	18 (31)			
White	153 (65)	60 (39)	42 (27)	51 (33)			
Other	18 (8)	7 (39)	4 (22)	7 (39)			
Ethnicity					0.03	0.02	0.1
Hispanic, Latino	16 (7)	1 (6)	6 (38)	9 (56)			
Not Hispanic, Latino	214 (90)	80 (37)	64 (30)	70 (33)			
Other	5 (2)	4 (80)	0 (0)	1 (20)			
Fitzpatrick[c] (n=172)					0.04	0.2	0.2
1	10 (6)	5 (50)	1 (10)	4 (40)			
2	82 (48)	33 (40)	21 (26)	28 (34)			
3	12 (7)	3 (25)	1 (8)	8 (67)			
4	14 (8)	4 (29)	3 (21)	7 (50)			
5	33 (19)	14 (43)	9 (27)	10 (30)			
6	21 (12)	3 (14)	12 (57)	6 (29)			
Age at Burn, yrs (SD)	7 (5)	7 (5)	7 (5)	6 (4)	0.4	0.4	0.2
F/U length, yrs (SD)	2.4 (1.6)	2.0 (1.6)	2.7 (1.6)	2.6 (1.5)	0.007	0.002	0.2
%TBSA (SD)	26 (22)	22 (22)	25 (18)	30 (23)	0.03	0.03	0.02
%Full Thickness (SD)	17 (19)	13 (20)	17 (16)	22 (19)	0.02	0.02	0.009
Type of Burn					0.4	0.3	0.1
Flame	146 (62)	47 (32)	42 (29)	57 (39)			
Scald	61 (26)	23 (38)	20 (33)	18 (30)			
Contact	19 (8)	11 (58)	5 (26)	3 (16)			
Friction	8 (3)	3 (38)	3 (38)	2 (25)			
Electrical	2 (1)	1 (50)	1 (50)	0 (0)			
Chemical	1 (<1)	0 (0)	0 (0)	1 (100)			
Total Autograft Amount, cm^2 (SD)	1157 (1273)	858 (1250)	1287 (1248)	1354 (1275)	0.03	0.007	0.09

Abbreviations: HTS, Hypertrophic Scar; F/U, Follow Up; SD, Standard Deviation; yrs, years; TBSA, Total Body Surface Area.
[a]Unless otherwise indicated, data are reported as number and (percentage) of patients.
[b]Unless otherwise indicated, the total number of patients included in the analysis of a given group is 237.
[c]Fitzpatrick skin type was determined retrospectively based on analysis of patient photographs and descriptors in the medical record.
[d]ANOVA or Kruskal–Wallis of Never HTS, Resolved HTS, Persistent HTS.
[e]Chi-squared or T-test of Never HTS versus pooled Resolved HTS and Persistent HTS.
[f]Chi-squared or T-test of Persistent HTS versus pooled Never HTS and Resolved HTS.

Table 2 – Donor Site Outcomes.

	No. of Donor Sites (n=1358)	%
Never HTS	557	41%
HTS at some point	361	27%
– Resolved HTS	– 198	– 15%
– Persistent HTS	– 163	– 12%
Donor Site reused	415	31%
Donor Site non-healing, grafted	16	1%

Abbreviations: HTS, Hypertrophic Scar; No., number; f/u, follow up.

demonstrated hypertrophic scarring; one resolved and the other resulted in chronic alopecia. In a prospective study comparing scalp to thigh donor sites, Martinot et al. found thigh donor sites to have long-term dyschromic scarring in 22 of 29 patients and hypertrophic or keloidal scarring in 5 of 29 patients, yet no morbidity of scalp donor sites ($P<0.0001$) [21]. In a cross-sectional study previously performed by Greenhalgh et al., back and thigh donor sites were compared for pathologic scarring using the Vancouver Scar Scale (VSS). Donor sites examined less than or equal to 1 year after harvest showed significantly better scores for color, suppleness, edema, and cosmetic outcome in back donor sites compared to thigh donor sites; however, no significant differences existed in donor sites greater than 1 year after harvest. A subset evaluation of 32 patients with both back and thigh donor sites, demonstrated significantly better height, color, edema, and patient preference for back donor sites compared

Table 3 – Donor Site Risk Factors.

Characteristic[a]	Donor Sites[b] (%) (n=918)	Never HTS (%) (n=557)	Resolved HTS (%) (n=361)	Persistent HTS (%) (n=163)	*P – All groups*[c]	*P – HTS anytime*[d]	*P – Persistent HTS only*[e]
Hx previous harvest					**0.04**	**0.02**	0.4
No	591 (64)	341 (58)	140 (24)	110 (19)			
Yes	327 (36)	216 (66)	58 (18)	53 (16)			
Mean donor site depth, inches (SD)	0.0130 (0.002)	0.0127 (0.002)	0.0135 (0.002)	0.0131 (0.002)	<**0.0001**	<**0.0001**	0.2
DSW Location					<**0.0001**	<**0.0001**	**0.005**
Thigh	368 (40)	190 (52)	105 (28)	73 (20)		<**0.0001**	0.2
Back	174 (19)	96 (55)	45 (26)	33 (19)		0.1	0.7
Buttock	143 (15)	83 (58)	27 (19)	33 (23)		0.5	0.09
Chest/abdomen	63 (7)	43 (68)	8 (13)	12 (19)		0.3	0.9
Lower Leg	77 (8)	60 (78)	12 (15)	5 (7)		**0.002**	**0.01**
Arm	30 (3)	25 (83)	0 (0)	5 (17)		**0.02**	1.0
Foot	19 (2)	18 (95)	0 (0)	1 (5)		**0.005**	0.3
Scalp	44 (5)	42 (96)	1 (2)	1 (2)		<**0.0001**	**0.01**
Scrotum	5 (1)	5 (100)	0 (0)	0 (0)		n/a	n/a
Autograft Setting					**0.008**	**0.003**	0.09
Acute	806 (88)	474 (59)	182 (22)	150 (19)			
Reconstructive	112 (12)	83 (74)	16 (14)	13 (12)			
Post-operative Dressing					0.1	**0.04**	0.3
Kaltostat	884 (98)	538 (61)	189 (21)	157 (18)			
Tegaderm	12 (1)	4 (33)	4 (33)	4 (33)			
Silvercel	7 (1)	2 (29)	3 (42)	2 (29)			
100% epithelialization, days (SD)	34 (29)	29 (25)	44 (45)	39 (35)	<**0.0001**	<**0.0001**	0.08
PG Compliance					0.5	0.9	0.5
Good	554 (79)	327 (59)	126 (23)	101 (18)			
Poor	146 (21)	88 (60)	27 (18)	31 (21)			
Massage Compliance					0.3	0.7	0.5
Good	558 (82)	334 (60)	126 (23)	98 (17)			
Poor	125 (18)	78 (62)	21 (17)	26 (21)			

Abbreviations: HTS, Hypertrophic Scar; Hx, History; PG, Pressure Garmet; n/a; not applicable (too small to calculate P value).
[a]Unless otherwise indicated, data are reported as number and (percentage) of patients.
[b]Does not include donor sites that were reused or non-healing.
[c]ANOVA or Kruskal-Wallis of Never HTS, Resolved HTS, Persistent HTS.
[d]Chi-squared or T-test of Never HTS versus pooled Resolved HTS and Persistent HTS.
[e]Chi-squared or T-test of Persistent HTS versus pooled Never HTS and Resolved HTS.

to thigh donor sites at an average of 14 months after harvest [22]. They believed this observation was likely due to skin thickness being greater in the back than the thigh as has been demonstrated by anatomic studies [23]. We surmise that another contributing factor may be that back donor sites experience incidental compression therapy when patients are lying down, compared to thigh donor sites.

In this study, longer time to epithelialization was a risk factor associated with HTS. This relationship has been frequently reported in previous studies looking at HTS in burn wounds that heal with or without surgical interventions in both pediatric [5,8,24] and adult populations [7]. Notably, our definition of epithelialization was 99.9%; we acknowledge that many studies use 95%. The reason for the extreme was an

Table 4 – Donor Site Autograft Harvest Depth.

Donor Site Depth (inches)	Never HTS[a] (%)	Resolved HTS[a] (%)	Persistent HTS[a] (%)	*P – HTS anytime*[b]	*P – Persistent HTS only*[c]
≤0.010	147 (75)	25 (13)	23 (12)		
0.010-0.015	193 (55)	85 (26)	72 (19)	<0.0001	0.049
≥0.015	217 (58)	89 (23)	68 (19)		

Abbreviations: HTS, Hypertrophic Scar.
[a] Data are reported as number and (percentage) of donor sites.
[b] Chi-squared of Never HTS versus pooled Resolved HTS and Persistent HTS.
[c] Chi-squared of Persistent HTS versus pooled Never HTS and Resolved HTS.

Table 5 – Time Course for Healing, Scarring, Resolution.

Donor Site Outcome	Mean Time to Epithelialization, days (SD)	Mean Time to HTS, days (SD)	Mean Time to Scar Resolution, days (SD)	Mean Length of Time as HTS, days (SD)
All groups	29 (29)	150 (152)	419 (336)	302 (336)
– Never HTS	29 (25)*	–	–	–
– Resolved HTS	44 (45)*	117 (75)**	419 (336)	302 (336)
– Persistent HTS	39 (35)*	192 (203)**	–	–

Abbreviations: HTS, Hypertrophic Scar; SD, Standard Deviation.
* $P < 0.0001$, Kruskal-Wallis of Never HTS, Resolved HTS, Persistent HTS.
** $P < 0.0001$, T-test of HTS Resolved vs. HTS persisted.

insistence on having a healed donor site documented and partial or 95% healing was not frequently documented in our charts. Therefore, the documented time to epithelialization is likely relatively longer in our study than others which use a 95% definition. One cause of prolonged healing time, and thus worse scar outcomes, is depth of injury. At greater depths there exist fewer epidermal appendages, hair follicles in particular, to provide epithelial regeneration [25]. In the setting of burn injury, determination of depth is the primary crux in the decision of whether to pursue excision and grafting or to allow healing secondarily. With regards to incisional wounds, Dunkin et al. used a dermal scratch model in healthy adults to demonstrate a scarring response at a critical depth of greater than 0.022 in. the lateral hips of patients [26]. Our study noticed a difference in hypertrophic scarring within a small range of donor site depths, of which the majority were between 0.010 and 0.015 in.; however, thickness of skin can vary based on anatomic location [23] and even within anatomic location, as demonstrated by Chan et al. who found differing epidermal and skin thickness between anterior, anteromedial, and anterolateral aspects of the thigh [27]. The desire for providing excised burns with thick split-thickness grafts, while limiting the amount of scarring left at the donor site, prompted some to explore the efficacy of graft-back techniques, where thin STAGs are used to cover the donor sites of thick STAGs [28,29]. or dermal auto-grafts, in which the epidermis is raised and then left at the donor site [30,31]. These techniques in addition to other surgical techniques to limit or altogether eliminate donor site size provide options for overcoming the associated pitfalls of STAGs [32,33]. A cultural norm at our institution for many years has been to harvest thicker grafts to minimize contracture at the grafted site. While recorded dermatome depths are not necessarily accurate due to frequent miscalibration of the device and the alteration in depth depending on the pressure applied during harvest, on a relative scale, an intentional harvest of 0.015 inch has a high probability of being a deeper harvest than an intentional thin harvest, i.e., <0.010 inch. The only accurate way to define thickness of harvest is measurement after harvest with microscopy, which is not an option in a retrospective study of this type. This is a limitation of our study.

Understanding the natural time course for development and resolution of HTS precedes the ability to accurately comment on the benefit of scar reducing therapies. In our population, the average time to development of HTS was 5 months and the average time to resolution was 14 months after donor site harvest. Previous studies have noted the development of HTS in burn scars to occur anywhere from 2 to 6 months and scar maturation to occur thereafter up to 13 months [34,35]. Oliviera et al. used the Patient and Observer Scar Assessment Scar Scale and Vancouver Scar Scale scores in addition to objective measurements and found hypertrophy to develop between 2 and 6 months after burn, reach a maximum between 6 and 12 months after burn, and regress between 18 and 24 months after burn [36]. Although the longitudinal follow-up with a mean of 2.4 years allowed us to assess the full process of scarring for the majority of patients, further follow-up would be able to better determine whether some hypertrophic scars resolved at a later time. In addition, consideration should be made as to how persistent HTS responds to the rapid increases in growth and hormonal changes associated with puberty.

In contrast to previous publications, our study found history of a previous donor site harvest to be associated with less HTS. Mimoun et al. highlighted in a study of 757 patients (74.6% burns) with 945 STAGs from scalp donor sites that repeat donor site use had longer healing time (10.2 days vs. 6.8 days for first time donor sites) and an increased prevalence of morbidity (9.0% in patients with multiple donor site harvests vs. 0.4% in patients with a single donor site harvest) [16]. Our finding may reflect an inherent bias of re-harvested donor sites for re-epithelializing in a timely manner for secondary use.

The vast majority of patients in this study received calcium-alginate dressings (Kaltostat) on their donor sites post-operatively with few exceptions based on physician preference. The finding of increased risk of HTS donor sites not dressed with a calcium-alginate dressing is likely due to the small sample size of these alternative donor site dressings. The majority of studies in the literature comparing donor site dressings focus on time to epithelialization, pain, and short-term scar outcomes [37]. Overall, the evidence is contradictory, yet demonstrates a slight benefit for moist dressings [37]. In comparative studies specifically looking at calcium alginate dressings, decreased time to epithelialization has been noted [12,38]. Without clear consensus for donor site care, dressing choice is likely based on clinical experience with institution-specific patient outcomes and satisfaction, ease of use, and cost.

Our standard post-operative protocol utilizes scar reduction therapies of pressure garments and massage. While the published evidence for both is mostly anecdotal and controversial [39], there is a growing amount of evidence for pressure

garment therapy grounded in animal studies [40] and randomized clinical trials [41,42]. Our binary assessment of massage and pressure garment protocol adherence does not capture the complexity of individual use– proper wear, massage technique, or adequate amount and distribution of pressure– and thus may account for a lack of difference seen in our patient sample.

As a retrospective observational study, many limitations were evident. Notably, our results were limited by the differing techniques of multiple surgeons with respect to tension on the donor site skin or pressure placed on the dermatome when harvesting, as these can alter the true depth of harvest. While this may present theoretical variability, the utilization of an iatrogenic donor wound presents greater uniformity and control of depth compared to the burn wound itself, providing opportunities for future studies of scar interventions.

Scarring occurs on a spectrum, thus a dichotomous outcome of hypertrophic or non-hypertrophic does not capture the greater complexity of the scar response; however, the value of dichotic scale is its simplicity and its clinical relevance by sharing the decision of whether to treat with invasive therapies (laser, surgery). In our institution, the decision to continue pressure garments and massage is made based a multidisciplinary team's evaluation that weighs the potential benefit and the scar's inconvenience to the patient and his/her family.

5. Conclusion

In conclusion, we sought to identify the frequency and risk factors associated with HTS in the surgical donor sites of split thickness skin grafts in a pediatric burn population. The new information identified by this study provides tremendous insights about our practice and warrants reassessment of the philosophy of procuring thicker grafts (in a pediatric population) at the expense of poor donor site outcomes. We were able to quantify the number of pediatric patients who experience hypertrophic scarring long-term, which is higher than has been previously reported. In addition, we were surprised to find that lower leg donor sites to have better scarring outcomes long-term compared to other donor sites. This study adds to the growing knowledge of HTS by characterizing the burden that donor sites pose. There exists a need for further improvement in alleviating the burden of scarring both from burns and from the sequelae in treating burns, and this study serves as a reference for future studies to improve upon.

Declarations of Interest

None.

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