Adult Burn Patients With More Than 60% TBSA Involved–Meek and Other Techniques to Overcome Restricted Skin Harvest Availability–The Viennese Concept

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Despite the fact that early excision and grafting has significantly improved outcome over the last decades, the management of severely burned adult patients with ≥60% total body surface area (% TBSA) burned still represents a challenging task for burn care specialists all over the world. In this article, we present our current treatment concept for this entity of severely burned patients and analyze its effect in a comparative cohort study. Surgical strategy comprised the use of split-thickness skin grafts (Meek, mesh) for permanent coverage, fluidized microsphere bead-beds for wound conditioning, temporary coverage (polyurethane sheets, Epigard®; nanocrystalline silver dressings, Acticoat®; synthetic copolymer sheets based on lactic acid, Suprathel®; acellular bovine derived collagen matrices, Matriderm®; allogeneic cultured keratinocyte sheets; and allogeneic split-thickness skin grafts), and negative-pressure wound therapy (vacuum-assisted closure). The autologous split-thickness skin graft expansion using the Meek technique for full-thickness burns and the delayed approach for treating dorsal burn wounds is discussed in detail. To demonstrate differences before and after the introduction of the Meek technique, we have compared patients of 2007 with ≥60% TBSA (n = 10) to those in a matched observation period (n = 7). In the first part of the comparative analysis, all patients of the two samples were analyzed with regard to age, abbreviated burn severity index, Baux, different entities of % TBSA, and survival. In the second step, only the survivors of both years were separated in two groups as follows: patients receiving skin grafts, using the Meek technique (n = 6), were compared with those without Meek grafting (n = 4). When comparing the severely burned patients of 2007 with a cohort of 2006, there were no differences for age (2007: 46.4 ± 13.4 vs. 2006: 39.1 ± 14.8 years), abbreviated burn severity index score (2007: 12.2 ± 1.0 vs. 2006: 12.1 ± 1.2) or % TBSA (2007: 72.1 ± 11.7 vs. 2006: 69.3 ± 8.7% TBSA). In these two rather small groups of severely burned patients with ≥60% TBSA, the overall survival rate of patients was 70.0% (7/10) in 2007 and 42.9% (3/7) in 2006, respectively. Almost all nonsurvivors in both years died within the first 5 days after admission. If assessing the different treatment modalities of the survivors, we found that although the Meek group patients were older (Meek 48.8 ± 13.3 vs. non-Meek 26.8 ± 11.5 years, *P* = .0381) and had consequently higher Baux scores (Meek 124.0 ± 2.9 vs. non-Meek 93.8 ± 8.5, *P* = .0095) than the non-Meek patients, this seemed to have no effect on length-of-stay (80.5 ± 9.7 vs. non-Meek 79.8 ± 33.0 days), hospital length-of-stay (85.7 ± 14.8 vs. non-meek 84.3 ± 26.1 days) or number of operations (6.5 ± 1.0 vs. non-Meek 7.0 ± 4.1 operations). The achieved results represent a combination of various treatment changes and, therefore, cannot be attributed to a single modality. The Meek technique is one of the technical options to choose from, to achieve permanent skin replacement; we think that it has its place if integrated in a whole treatment concept for management of severely burned patients. (J Burn Care Res 2009;30: 231–242)

One of the main problems encountered in extensively burned patients, ≥60% total body surface area (% TBSA), is the scarcity of harvesting areas for autologous skin grafts. The main goal of surgical treatment should be the ultimate replacement of necrotic tissue with permanent skin. Tissue-engineered skin replacements have so far not achieved a level of technical and financial feasibility because of their fragility and associated high costs.[1]

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A whole arsenal of different techniques exists to overcome common therapeutic restrictions of severely burned patients. Recent publications suggest a revival of an operative technique in this setting: a Pubmed search (December 2007) retrieved 12 clinical publications since 1993[2–14] describing different experiences with the original or modified Meek technique, since its introduction in 1958 and named after its inventor Dr. Meek.[15,16]

In some articles a favorable use of the Meek grafting technique is reported, when fewer donor sites were available,[3,7] and its use was recommended in burns with over 40 to 45% TBSA.[4,11] Although the Meek or related techniques seemed to be more time consuming and more staff was needed in the operating theatre,[4] the outcome was generally referred to be good with graft survival of above 95%,[10] a shorter duration of reepithelization[13] and satisfactory functional as well as aesthetic results.[5,9,12] Some authors also suggested the use of allograft overlay[4] and had experiences of their application in combination with dermal matrices in two-stage procedures.[7,8]

The aim of following articles is to present our current surgical treatment protocol, which is mainly based on the Meek technique, and to evaluate the clinical outcome in a comparative cohort analysis. One of the main objectives is to evaluate its place in our surgical strategy for treating severely burned adult patients.

METHODS

A total number of 10 adult patients with ≥60% TBSA were admitted in 2007 and treated according to the herein described treatment protocol.

Treatment Standards

All patients received a standardized intensive care treatment setup with central venous and arterial lines, urinary catheters placed, and early enteral feeding initiated.

Surgical Strategy

Body region topography was organized according to the probability of skin take rate and functional importance, and ultimately determined for surgical priority (Table 1 and Figure 1). Burn wounds (deep dermal and full thickness) were initially treated with silver sulfadiazine. Full-thickness burned areas, which were planned not be excised during the first operative sessions (day 3–9), were temporarily prepared with silver nitrate; in cases, where the dorsum, the dorsal aspect of the thighs, and gluteal areas were involved, a fluidized microsphere beads-bed (KCI FluidAir® Elite, KCI, Austria) was used to precondition burn wounds and served as postoperative treatment for keeping wounds dry.

Table 1. Body region organization

Definition	Body region
functional & aesthetic importance	face hands feet
superior take-rate	thorax, abdomen upper limb lower limb
inferior take-rate	flanks of torso gluteal region dorsal aspect of thighs

Surgical priority was given to areas of functional and aesthetic importance and superior take rate. Body regions with Inferior take rate were preconditioned with silver nitrate or in a fluidised microsphere bead-beds, if the patient's general condition allowed.

The aim of surgical strategy was to remove necrotic tissue within the first 3 to 9 days after injury, with exception of the dorsal aspects of the lower extremities, dorsum, gluteal, and dorsal femoral regions; these areas were preferably preconditioned in a fluidized microsphere beads-bed and debridement was not performed before days 10 to 14 after injury.

Deep dermal burns of the face were temporarily covered with nanocrystalline silver sheets (Acticoat®, Smith&Nephew, United Kingdom) and usually operated on days 10 to 14.

Permanent Coverage

Excision and grafting sessions were organized in a timeline scheme described in Table 2. In young and clinically stable adult burn patients, we aimed to remove necrotic tissue and provide cover for full-thickness burns in two operative sessions within the first 14 days after injury. Individuals aged 65 years and above usually required more than two operative sessions within the first 14 days, because the area operated on per session had to be restrained and adapted to the patient's general condition.

Unmeshed split-thickness skin grafts (STSG) were used for face and hands, all other areas were covered with either Meek grafts (expansion ratio 1:6 or 1:9) or, if respective donor sites sufficed, with mesh grafts using an expansion ratio of 1:1.5 or 1:3. Expansion ratios exceeding 1:3 to achieve sufficient coverage for full-thickness burns (Table 3) were regarded as indication for using the Meek technique (1:6 or 1:9).

Available skin harvest areas of patients with more than 75% TBSA involved were usually the occipital part of the scalp and scrotum; these regions served as reliable donor sites of autologous skin. For residual

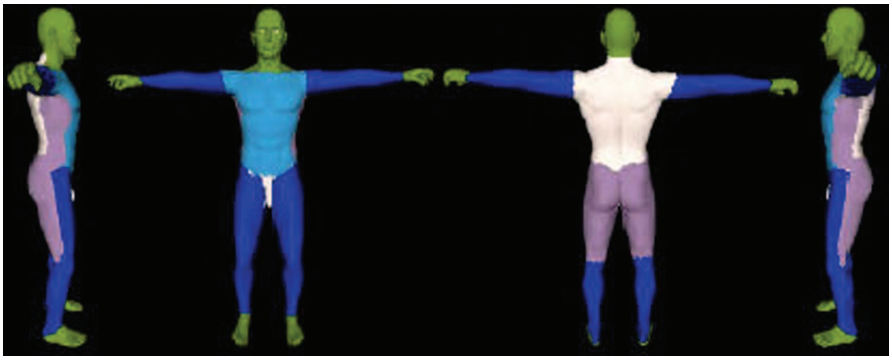

Figure 1. Body region organization. This figure illustrates the topographical organization of body regions (see also Tables 1 and 2, images generated using Burncase3D Software, UAR Upper Austrian Research GmbH, Austria).

defects, we preferred to use meshed STSG (1:1.5 or 1:3) in later stages of treatment. Table 4 describes the mesh and Meek technique and their indication in our current treatment protocol.

Meek Technique

To keep operative time within limits, surgeons worked in two teams: at the beginning of the operation split-skin grafts were harvested from available donor areas.

Table 2. Surgical timeline and priority for coverage of full-thickness burns

Timeline	Body Region	Preferred Technique
Day 3–9	Hands	Unmeshed split-thickness skin grafts (STSG)
	Thorax, abdomen, upper extremity, and ventral lower extremity	Meek (1:6 or 1:9), Mesh (1:1.5 or 1:3)
Day 10–14	Face	Unmeshed STSG
	Dorsal lower extremity, dorsum, gluteal regions, and dorsal aspect of thigh	Meek (1:6 or 1:9), Mesh (1:1.5 or 1:3)
>Day 14	Residual defects	Mesh (1:1.5 or 1:3)

In young and clinically stable adult burn patients we aimed to remove necrotic tissue and provide cover for full thickness burns in two operative sessions within the first 14 days after injury. Individuals aged 65 years and above usually required more than two operative sessions within the first 14 days, since the area operated on per session was usually smaller. Regions of functional importance (hands, upper extremity) and with superior take-rate (thorax, abdomen, and ventral aspects of lower extremities) were addressed in days 3 to 9 after injury. Preconditioning in fluidized microsphere bead-beds allowed for postponement of definite surgical treatment of dorsal body regions and areas with inferior take-rate (gluteal region, flanks of torso) to days 10 to 14 after injury. In the acute phase either Meek or mesh grafting was used, beyond day 14 for coverage of residual defects, we preferred to use mesh grafts only.

Afterwards, while the first team removed necrotic tissue, the second team prepared the micrografts.

The harvested skin grafts were tailored and positioned on a previously moistened cork plate, which reflects the future wound bed. Therefore, the grafts were placed with the dermal side facing the cork. The cork plates were then put into the cutting blocks and passed through a hand driven cutting machine (Humeca BV, The Netherlands), which contained a knives axis with round blades, each equally 3 mm apart. The knives axis only cuts the skin and a superficial part of the cork plate. After the first passage and declamping the cork plate was lifted, rotated 90 degrees on the cutting block, reclamped, and passed again through the cutting machine. This resulted in ($14 \times 14 =$) 196 square skin islands equally ($3 \times 3 =$) 9 mm^2 in size (micrografts). To facilitate detaching of freshly cut split-skin grafts from the cutting block, the serrated wedge can be used. The cork plates were finally removed from the cutting block; an adhesive dressing spray (Leukospray, Beiersdorf GmbH, Germany) was evenly applied on the epidermal side of the micrografts and allowed to leave for at least 3 minutes.

The final step is the placement of the micrografts with the now sticky epidermal side onto the gauze sheet (silk). Because all cork plates have the same size of ($42 \times 42 =$) 1764 mm^2 and contain the same

Table 3. Indication for Mesh and Meek expansion technique

	Mesh	Meek
Indication for full-thickness burns	1:1.5 up to 1:3	>1:3 (1:4, 1:6, and 1:9)

The Meek technique was used for coverage of full-thickness burns, if an expansion ratio above 1:3 was needed for treatment of freshly debrided full-thickness areas.

Table 4. Summary of patients in 2007

	Age (Years)	TBSA (Total)	TBSA (Deep)	TBSA (3)	IT	ABSI	Baux	OP (Total)	LOS (Days)	Meek	Mode of Injury	Mode of Discharge
Patient 1	58	60	60	60	1	11	118	8	78	0	Home	Dead
Patient 2	26	60	60	50	1	10	86	12	116	0	Work	Rehabilitation
Patient 3	65	61	61	51	1	13	126	5	65	1	Suicidal	Rehabilitation
Patient 4	59	65	65	36	1	12	124	6	85	1	Home	Rehabilitation
Patient 5	55	65	65	45	1	12	120	7	78	1	Work	Rehabilitation
Patient 6	51	75	75	75	1	13	126	1	3	0	Suicidal	Dead
Patient 7	36	75	75	75	1	12	111	1	3	0	Suicidal	Dead
Patient 8	47	80	80	80	1	13	127	7	94	1	Traffic	Rehabilitation
Patient 9	36	90	85	70	0	13	126	6	84	1	Leisure	Rehabilitation
Patient 10	31	90	90	75	1	13	121	8	77	1	Home	Rehabilitation

IT, inhalation trauma; **LOS,** length-of-stay.
Summary of patients in 2007 grouped by ascending total burn surface area (TBSAtot) ≥60%, total burn surface area of deep/third degree ($TBSA_{deep}/TBSA_3$) and also containing information on age, presence of inhalation trauma (IT), Abbreviated burn severity index (ABSI), Baux score, total number of operations (OP_{total}), Meek technique application, length-of-stay (LoS), and mortality (death).

number of micrografts (= 196), the chosen prefolded gauze sheet determines the actual expansion ratio. After uniform manual expansion of the micrografts with the epidermal side adherent to the gauze sheet, the aluminium foil can be removed and the micrografts (the dermal side now facing the wound) can be applied on the freshly debrided area (Figure 2).

To achieve a maximal expansion ratio, we often used 1:9 Meek sheets, resulting theoretically in an area of (126 × 126 =) 15,876 mm^2 per sheet, with each micrograft about 6.4 mm apart. In the clinical situation the actual expansion was about (120 × 120 =) 14,400 mm^2, with each micrograft about 6 mm apart (Figure 3).

Figure 4 demonstrates the theoretical skin coverage, which would be feasible in a first excision and grafting session with a 1:9 Meek expansion ratio in a patient with the occipital part of the head and the testes available for STSG harvest (as calculated with BurnCase 3D on the basis of the actual expansion ratio in the clinical situation).

Meek sheets were left on the wound surfaces for 10 days (left panel of Figure 5) and covered with antibiotic ointment coated fat gauzes. Daily superficial dressing changes with topical disinfectants accomplished local therapy.

Fluidized Microsphere Beads-Bed

Fluidized microsphere beads-beds were used for wound preconditioning, but also for postoperative wound conditioning. This method allowed for removal of moisture to keep wounds dry and permitted maintenance of constant temperature levels in areas in direct contact with the bed's superficial fabric. Only thin sterile covers were employed to shield dorsal burned areas while in these beds, and no extra ointments were applied. For wound coverage of freshly operated areas, we preferred to use fat gauzes and dry sterile compresses.

Patients with arising difficulties in respiratory management or temperature control whilst in fluidized microsphere beads-beds were temporarily transferred to standard intensive care beds.

Temporary Coverage

If harvested STSG did not suffice for coverage of full-thickness areas (third degree), we preferred to use allogeneic STSG as temporary alternative. However, if allogeneic skin was not available, we revered to a synthetic polyurethane surface with a teflon layer upside (Epigard®, Biovision GmbH, Germany) to temporarily wrap debrided full-thickness areas. Epigard was allowed to leave for 3 to 5 days, but exchange was preponed if signs of local infection evolved.

Deep dermal burned areas were covered with cytomegalovirus (CMV)-negative keratinocyte sheets.[17] A synthetic copolymer, Suprathel® (PolyMedics Innovations, Germany), was employed, if CMV negative keratinocyte sheets were not available.[18] Suprathel protected by fat gauzes was allowed to leave for 10 days.

Dermal Matrices

An acellular bovine-derived collagen matrix (Matriderm®, Dr. Otto Suwelack Skin&Health Care AG, Germany) served as dermal template for coverage of areas of functional importance in combination with unexpanded STSG (eg, hands).[19]

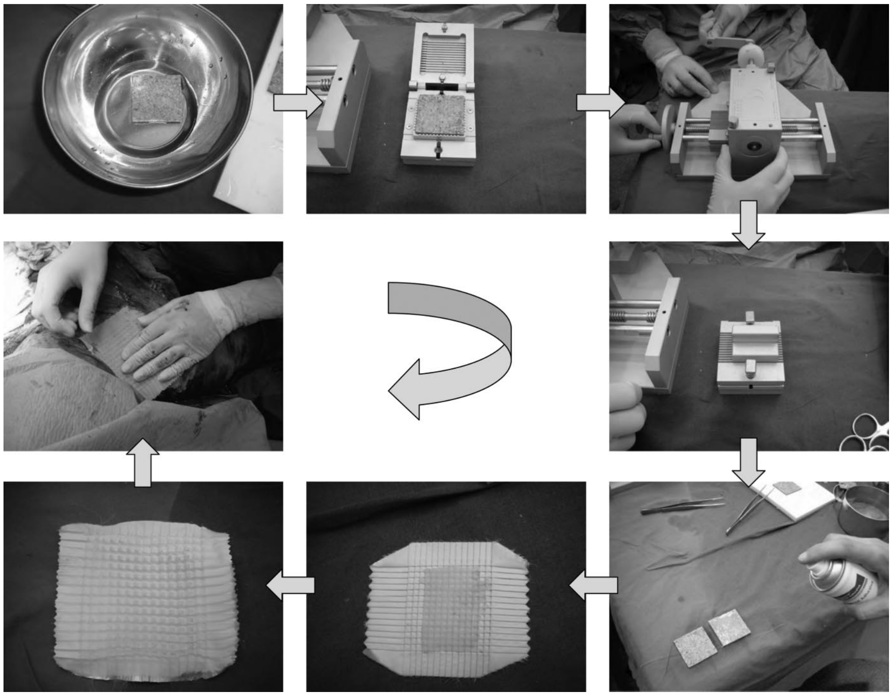

Figure 2. Meek technique and workflow steps (clockwise). The harvested skin grafts were tailored and positioned on a previously moistened cork plate, which reflects the future wound bed. Therefore, the grafts were placed with the dermal side facing the cork. The cork plates were then put into the cutting blocks and passed through a hand driven cutting machine (Humeca BV, The Netherlands), which contained a knives axis with round blades, each equally 3 mm apart. The knives axis only cuts the skin and a superficial part of the cork plate (upper three panels). After the first passage and declamping the cork plate was lifted, rotated 90 degrees on the cutting block, reclamped and passed again through the cutting machine. This resulted in ($14 \times 14 =$) 196 square skin islands equally ($3 \times 3 =$) 9 mm^2 in size (micrografts). To facilitate detaching of freshly cut split-skin grafts from the cutting block the serrated wedge can be employed (middle right panel). The cork plates were finally removed from the cutting block, an adhesive dressing spray (Leukospray, Beiersdorf GmbH, Germany) was evenly applied on the epidermal side of the micrografts and allowed to leave for at least 3 minutes (lower right panel). The final step is the placement of the micrografts with the now sticky epidermal side onto the gauze sheet (silk). Because all cork plates have the same size of ($42 \times 42 =$) 1764 mm^2 and contain the same number of micrografts (= 196), the chosen prefolded gauze sheet determines the actual expansion ratio (lower two left panels). Before and after uniform manual expansion of a 1:9 micrograft with the epidermal side adherent to the gauze sheet, the aluminium foil can be removed and the micrografts (the dermal side now facing the wound) can be applied on the freshly debrided area (middle left panel).

Negative-Pressure Wound Therapy (Vacuum-Assisted Closure)

Negative-pressure wound therapy or vacuum-assisted closure (VAC®, KCI, Austria) aided in the local therapy in STSG receiver regions of inferior take rate (see Table 1) and allowed for early mobilization in functionally important zones.

Early Mobilization

Early individual physiotherapy and ergotherapeutic splinting accomplished our therapeutic strategy.

Comparative Cohort Analysis

To demonstrate differences before and after the introduction of the Meek technique, we have compared patients of 2007 with ≥60% TBSA (n = 10) to those in a matched observation period of 2006 (n = 7).

In the first part of the comparative analysis, all patients of the two matching samples were analyzed with regard to age, abbreviated burn severity index (ABSI), Baux, different entities of % TBSA, and survival. In the second step, only the survivors of both years were separated in two groups: patients receiving skin grafts, using the Meek technique (n = 6), were compared with those without Meek grafting (n = 4).

Statistical Analysis

Statistical analysis was performed using GraphPad Prism ver. 4 (GraphPad Software Inc., La Jolla, CA). For the endpoints age, the two scores, total burn

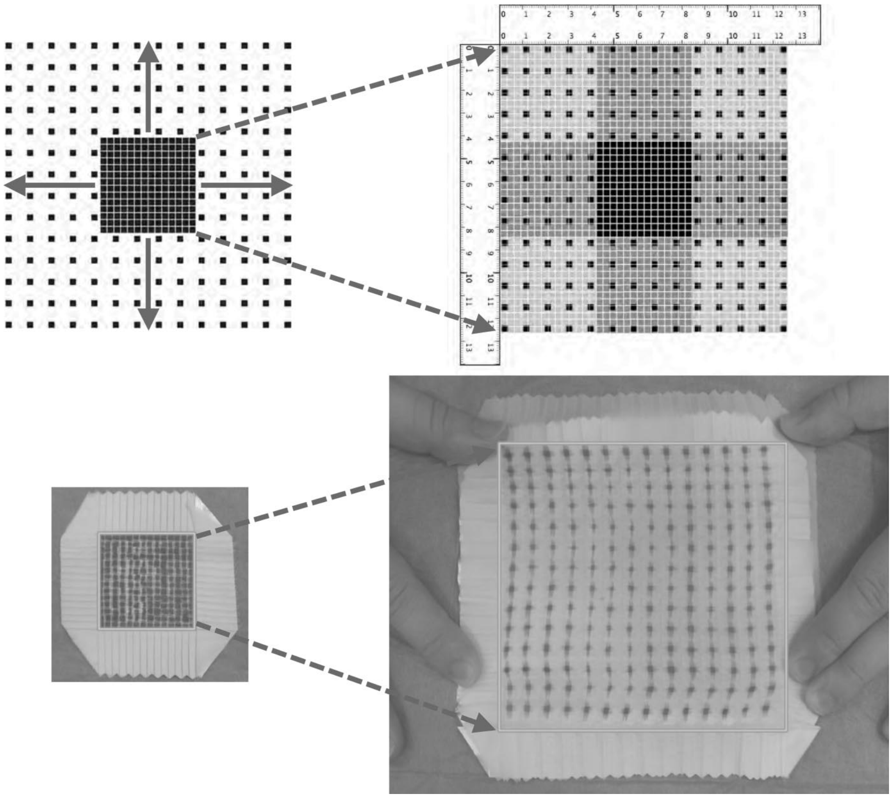

Figure 3. Theoretical and practical Meek calculations. Direction (*red arrows*, upper left) and virtual expansion (*dashed red arrows*) in a 1:9 fashion (upper right). The shaded (unexpanded) islands virtually illustrate the theoretical 1:9 expansion ratio: ($14 \times 14 =$) 196 square skin islands equally ($3 \times 3 =$) 9 mm^2 in size on a ($42 \times 42 =$) 1764 mm^2 cork plate can theoretically be 1:9 expanded to an area of ($126 \times 126 =$) 15,876 mm^2 per sheet, with each micrograft about 6.4 mm apart. The projected turquoise squares on the unexpanded (lower left) and 1:9 expanded (lower right) Meek gauze sheet demonstrate the theoretical attainable sizes. Meek islands have been mimicked with a blue marker. On the 1:9 expanded gauze sheet (lower right) the actual (clinically applicable) expansion was about ($120 \times 120 =$) 14,400 mm^2, with each micrograft about 6 mm apart.

surface area, and its entities as well as LoS, HoS, and number of operations the Mann-Whitney test were used. *P* values below .05 were considered significant.

RESULTS

In 2007, 10 patients (one woman, nine men, mean age 46.4 [26–65] years) with ≥60% TBSA were admitted to our unit (Table 4). Eight patients reached our hospital primarily after injury; two received immediate care at another institution before being admitted within 24 hours. Mean deep dermal and full-thickness body surface area (% TBSA) affected was 71.6 ± 11.0% (60–90%) and mean third-degree body surface area (% TBSA) 61.7 ± 15.4% (36–80%), respectively. Three of the 10 patients died (mortality rate 30%), two of them died within the first 72 hours after admission. Inhalation trauma was present in nine patients. Mean ABSI [20] was 12.2 ± 1.0 and Baux score [21] 118.2 ± 12.5.

Most injuries resulted from domestic accidents (3 of 10) or in a suicidal context (3 of 10), followed by two occupation-related injuries, one aerial traffic accident, and one during leisure activities. Almost all burns with inhalation trauma were caused by flame.

Three patients had a known psychiatric history, mainly explaining for the self-inflicted suicidal intent. One survivor was diagnosed with diabetes mellitus type II before admission and one succumbed patient had a history of chronic obstructive pulmonary disease. No other premorbid conditions were to be noted.

All but one patient received immediate surgical decompression (escharotomy, fasciotomy) upon admission, with the two secondary admissions having been adequately decompressed at the referring hospital. Mean number of operations was 6.1 ± 3.3. A below knee amputation was necessary in a patient with multiple traumatic injuries and several distal phalanges of the hands and feet could not be salvaged in another.

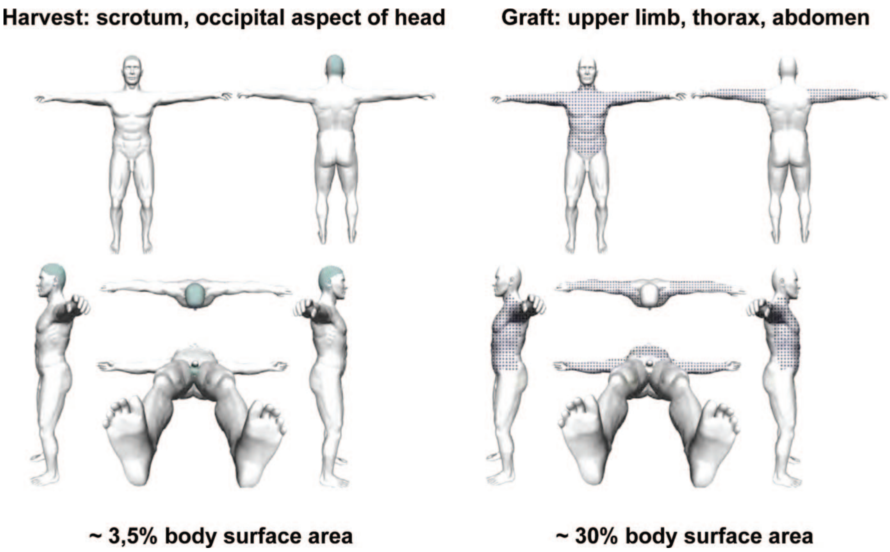

Figure 4. Meek – theoretical skin expansion (1:9 expansion example). With 3% (head, scrotum) of body surface area (BSA) available for skin harvest, a 1:9 Meek graft expansion to about 30% BSA can be achieved: suitable, for example, to cover areas of the upper limb, thorax and abdomen in one session (as shown, images generated using Burncase3D Software, UAR Upper Austrian Research GmbH, Austria).

The surviving patients' median length-of-stay (LOS) was 84 days (65–116 days) and all were discharged to a rehabilitation center thereafter. Patient data is summarized in Table 4.

Observed take rate with Meek grafts in all patients was above 85% after 10 days (see Figure 5). Common reason for graft failure was hematoma. All but one survivor have been treated with Meek grafting in the acute phase of surgical treatment. The duration for complete reepithelization was approximately 4 to 5 weeks for 1:9 expansion grafts and 3 to 4 weeks for 1:6 expansion grafts.

Preconditioning in fluidized microsphere bead-beds allowed for postponement of definite surgical treatment of dorsal wound areas for 10 to 14 days after burn trauma. This was adapted according to the overall condition and clinical necessities of a given patient.

Three burn victims have been treated with sequential superficial debridement, gradual tangential excision, and temporary coverage with nanocrystalline silver sheets after deep dermal burns of the face. We did not observe any negative effects associated with topical nanocrystalline silver application.[22]

In 2006, there were seven patients admitted to our center with ≥60% TBSA. When comparing these patients with the 2007 collective (Table 5 and Figure 6), there were no significant differences to be found for age (2007: 46.4 ± 13.4 vs. 2006: 39.1 ± 14.8 years), ABSI scores (2007: 12.2 ± 1.0 vs. 2006: 12.1 ± 1.2) or % TBSA (2007: 72.1 ± 11.7 vs. 2006: 69.3 ± 8.7% TBSA).

There was a nonsignificant trend for patients in 2007 to have higher Baux scores (2007: 118.5 ± 12.4 vs. 2006: 108.4 ± 14.2) and larger burn surface areas, with either deep partial-thickness and full-

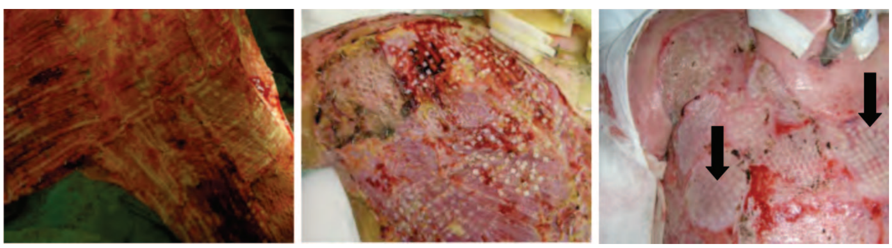

Figure 5. Meek—clinical example. 31 year old male patient with 90% TBSA after flame injury: appearance of Meek sheets intraoperatively (A), of skin islands 10 days postoperatively after removal of gauze sheets (B), and confluent growth 30 days postoperatively. In between the Meek areas (indicated by black arrows), a residual burn wound was covered using a meshed split thickness skin graft (C).

Table 5. Comparative cohort analysis: Meek (n = 6) vs. non-Meek (n = 4)

	Meek group	Non-Meek Group
Age (years)	**48.8 ± 13.3**	**26.8 ± 11.5**
ABSI	12.7 ± 0.52	11.0 ± 1.4
Baux	**124.0 ± 2.9**	**93.8 ± 8.5**
TBSA total	75.2 ± 13.2	67.0 ± 12.0
TBSA (deep partial and full thickness)	74.3 ± 12.2	59.0 ± 22.5
TBSA (full thickness only)	59.5 ± 17.9	41.8 ± 13.0
Number of operations	6.5 ± 1.0	7.0 ± 4.1
Length-of-stay	80.5 ± 9.7	79.8 ± 33.0
Hospital length-of-stay	85.7 ± 14.8	84.3 ± 26.1

No significant differences for the total TBSA or ABSI scores were noted. The Meek group had larger deep (comprising deep partial and full thickness) and full-thickness burned surface areas (TBSA) in comparison to the non-Meek group. Although the Meek group patients were significantly older (P = ill .0381, marked bold) and had consequently higher Baux scores (P = .0095, marked bold) than the non-Meek patients, this seemed to have no effect on length-of-stay, hospital length-of-stay or number of operations.

thickness burns together (2007: 71.6 ± 11.0 vs. 2006: 63.3 ± 16.7% TBSA), or full-thickness areas alone (2007: 61.7 ± 15.4 vs. 2006: 51.0 ± 15.9% TBSA), as compared with the patients in 2006. In these two rather small groups of severely burned patients with ≥60% TBSA, the overall survival rate of patients was 70.0% (7 of 10) in 2007 and 42.9% (3 of 7) in 2006, respectively. All nonsurvivors in 2006 died within the first 5 days after admission (Figure 6).

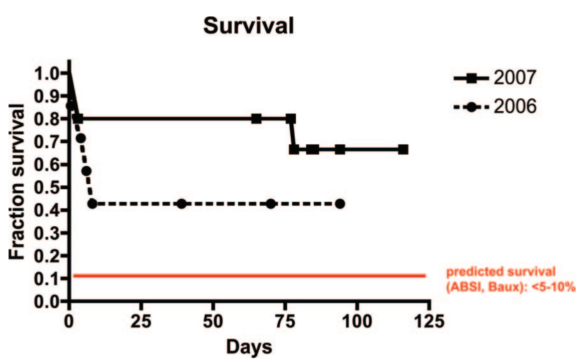

Figure 6. Survival curves for 2006 and 2007. Relative to the small number of patients, this panel should only demonstrate the evolution over time in a descriptive fashion: predicted outcome, as assessed by ABSI = 12 or Baux = 118 scores, calculates an estimated survival rate of less than 5 to 10%.[23,24] Almost all patients in 2007 (survival rate: 70.0%) or 2006 (survival rate: 42.9%) died within the first 5 days after admission, which was more likely related to the overall severe condition of the patients than the surgical techniques involved.

Of the three survivors in 2006, two have been transferred to a rehabilitation center, and one patient to another hospital.

When attempting to compare treatment outcomes in two-matched patient collectives, Meek technique (Meek group, n = 6) vs. standard grafting techniques without Meek (non-Meek group, n = 4), only survivors were included in the following analysis (all values are mean±standard deviation).

No differences for the total % TBSA or the ABSI score were noted. The Meek group exhibited larger full-thickness areas than the non-Meek patients (Meek 59.5 ± 17.9 vs. non-Meek 41.8 ± 13.0% TBSA, n.s.). Although the Meek group patients were older (Meek 48.8 ± 13.3 vs. non-Meek 26.8 ± 11.5 years, P = .0381) and had consequently higher Baux scores (Meek 124.0 ± 2.9 vs. non-Meek 93.8 ± 8.5, P = .0095) than the non-Meek patients, this seemed to have no effect on LOS (80.5 ± 9.7 vs. non-Meek 79.8 ± 33.0 days), hospital length-of-stay (HOS) (85.7 ± 14.8 vs. nonmeek 84.3 ± 26.1 days) or number of operations (6.5 ± 1.0 vs. non-Meek 7.0 ± 4.1 operations) (Table 5).

DISCUSSION

Our concept has evolved due to difficulties commonly encountered in the treatment of patients with ≥60% TBSA. Early excision and grafting has been shown to reduce mortality and costs as a result of the decreased LOS. However, donor site availability limits permanent skin replacement options in severely burned patients. Therefore, a whole set of temporary and permanent coverage options have been integrated into the current concept.

Because of the small number of patients in the comparative analysis, the level of statistical power of survival cannot reach beyond a descriptive character: predicted outcome as assessed by ABSI = 12 or Baux = 118 scores calculate an estimated survival rate of less than 5 to 10%.[23,24] The survival rate in our collective of severely burned patients (≥60% TBSA) was 42.9% in 2006. In 2007, where patients have been treated according to the described protocol, the survival rate was 70.0%. The nonsurvivors died in almost all cases within the first 5 days after admission, which was more likely related to the overall severe condition of the patients than the surgical techniques involved. Only, therefore, to better illustrate the evolution over time, a survival curve has been included in this article (Figure 6).

Body regions were defined according to aesthetic or functional importance and expected take rate (see Figure 1, Table 1 and Table 2). Therefore, hands, thorax, abdomen, upper extremity, and the ventral aspect of lower extremity were addressed operatively within 3 to 9 days after injury. Preconditioning of dorsal regions of the body, which have a thicker dermis and more viable potential, allowed time for recovery of dermal structures and encouraged definite demarcation of necrotic tissue under constant dry conditions. This approach proved to be especially useful for definite distinction between deep dermal or full-thickness burns: when operating on dorsal areas after preconditioning for 10 to 14 days, necrotic tissue in deep dermal burns could almost be excised in a "tear-off like" fashion, whereas in full-thickness burns definite demarcation considerably eased tangential or epifascial excision. However, the use of fluidized microsphere beads-beds is not entirely free of complications.[25] An adequate fluid management has to be installed to cope with increased loss of water, necessitating regular control of sodium, chloride, and hematocrit levels.[26] Problems arising with respiratory management were mainly observed in the acute phase of management. In fluidized microsphere bead-beds the body floats almost immovable,[27] and patients have to be adequately sedated or anxiolysed to tolerate the bed. But it has to be noted, that higher levels of these drugs carry the risk for development of atelectasis and subsequent pneumonia.[25,28]

But also temperature control, a typical problem in severely burned patients with loss of thermoregulation, fluid retention and protective barrier function, was difficult in the acute phase after admission. Only areas in immediate contact with the bed's superficial fabric were constantly swirled by fluidized microsphere beads; therefore, temporary relocation to standard intensive care beds was sometimes necessary, increasing the demand for nursing care. Contraindications for the use of fluidized microsphere beads-beds according to the manufacturer's manual include unstable spinal cord injury and cervical traction—factors to be noted in the multiply injured trauma patient.[25,27]

Since its introduction in the 19th century, split-thickness skin grafts have undergone various changes and modifications.[29,30] With advances in intensive care accompanied by an improved survival,[31] the Meek technique has been subject to a revival in recent years.

Either expansion technique, mesh or Meek, use STSGs, one of the main differences to be found in the way healing works. Although in meshed skin grafts cell migration occurs from the net-like transplant into the remaining "holes",[29,30] in Meek grafts sprouting starts from all the single skin islands in a circle-like fashion toward each other. All skin islands have the same size only differing in the distance from each other, as defined by the gauze sheet used (1:4, 1:6 or 1:9).[3,15,16] As a result of this distinction, the Meek expansion technique does not require a continuous (long) harvested STSG.[4,11,32,33]

Therefore, one of its main advantages is, that even smallest skin grafts and remnants, which are not suitable for a meshed skin expansion or even transplantation, can be placed on a cork plate and assembled on a whole Meek gauze sheet. Because donor site paucity plays an important role in severely burned patients, additionally, split-thickness skin grafts from "difficult to expand areas" (eg, scrotum) can also be harvested and used for coverage of large full-thickness burn areas.

However, meticulous details has to be used in handling, otherwise, for example, inversely placed grafts will not rightly attach to the wound surface and will not heal. As other authors have stated, the Meek technique is labor intensive,[34] costs time and is more expensive:[4] this can, at least partly, be overcome by using two teams of surgeons and a straight-forward operative planning. Additional improvements include mechanically driven Meek devices and larger cork plates for the use of even larger skin grafts.[11]

Most authors leave on Meek gauze sheets for 7 days postoperatively, but also 10 days have been reported to be feasible.[6] In our experience, we have achieved good results with our 10-day protocol in combination with coverage by antibiotic ointment coated fat gauzes, daily superficial dressing changes, superficial disinfectant use, and bedding in fluidized microsphere bead-beds. The take rate reported in the literature ranges from 70 to above 90% after 7 days postoperatively[2,4,6,11,32] and is comparable with our results.

According to our experience and in accordance with previous clinical reports, Meek grafts appear to be less prone to loss due to infection.[3,11] We rarely observed Meek graft failure on contaminated wound beds. If Meek graft take failed, it was restricted to a partial area without neighboring skin islands under a single gauze sheet. A possible explanation for this phenomenon is the lack of a direct interconnection between skin islands as seen in meshed skin grafts. To the best of our knowledge, no prospective studies comparing the take rate of meshed vs. Meek skin grafts currently exist, and the suggested improved healing of Meek grafts on infected wound beds is mainly based on clinical observations.

Another advantage of the Meek technique is the achievement of a true expansion ratio in the clinical situation comparable with the one calculated in theory.[35,36] This is not the case in mesh skin grafts, which have been reported not to exhibit their actual expansion ratio.[37] Although the general ease of use of meshed skin transplants has been advocated, its handling becomes difficult with expansion ratios above 1:6 and reduces take rate often because of overturn of aspects of large mesh grafts.[3] For maximum safety, we have chosen a skin expansion ratio above 1:3 as cut-off value for using Meek instead of mesh grafts for coverage of full-thickness burns. For coverage of residual burn wounds, we prefer to use meshed skin grafts with expansion ratios of 1:1.5 or 1:3. As a result of the current literature and our results, we now use the Meek technique (1:6 or 1:9) as standard operative tool in the acute phase for the treatment of severely burned patients.

No extra temporary cover for Meek grafts with, for example, allograft overlays[2] as proposed for meshed skin grafts[38] has been used. Especially, it is to be noted, that allograft overlays have been reported to produce skin contraction in animal studies[39] and in clinical reports.[40,41] Some authors recommend allograft overlay if the expansion ratio exceeds 1:4,[6] but we do not see an indication for allograft overlay and have about equal healing rates in comparison with other surgeons using Meek grafts alone.[11] We have neither used Meek transplants in combination with negative-pressure wound therapy (VAC) nor with dermal matrices.

There exist two articles on Meek grafting in combination with a dermal matrix in two-stage procedures: Papp et al reported three cases, where Meek grafts have been applied in severely burned patients (>70% TBSA) in combination with a collagen based dermal matrix and which have produced variable results: in one case, complicated by a *Pseudomonas Aeruginosa* infection, a 75% epithelization rate could be achieved with two operative sessions with 1:4 Meek sheets after removal of the dermal template's silicone layer within 4 weeks. In the second case partly graft loss due to bacterial wound colonization was observed, and in the third case multiple regrafting sessions were necessary for a patient finally succumbing due to a multiresistant *P. Aeruginosa* infection. The authors mainly used 1:3 and 1:4 Meek sheets in combination with the dermal matrix.[8] In a case after excision of a giant congenital melanocytic naevus of the entire back Kopp et al[7] could achieve a favorable aesthetic and functional outcome with Meek grafting (1:4 expansion) involving a collagen based dermal matrix for reconstruction.

Although long-term results are scarce, it seems, that according to other reports the outcome of Meek grafting was at least comparable with widely expanded meshed skin grafts,[2] have achieved a subjectively superior aesthetic appearance after 6 months follow-up[34] and resulted in a faster and more uniform reepithelization.[6,11]

When using a matched clinical cohort comparison, the Meek patients had a larger extent of full-thickness % TBSA, were significantly older and showed consequently higher Baux scores than the non-Meek patients. However, this had no effect on LOS, HOS or the overall number of operations, which are all important outcome factors, where the use of permanent coverage, like achieved with Meek grafting, has an nonnegligible influence. In a Chinese publication on burned patients with >30% TBSA, Wang et al have observed a faster wound healing, shorter stay in hospital, and reduced costs of hospitalization with Meek grafting as compared with traditional stamp grafting, which was chosen as control group. The graft survival was above 95% in both groups.[10] In accordance with our data, it seems therefore legitimate, that the argument of the Meek technique being too expensive can at least partially be refuted.

But the results have to be reviewed cautiously, since our two collectives in one single unit are rather small and therefore not entirely suitable for a generalized interpretation. Additionally, treatment changes do not comprise Meek grafting alone, but also other aspects of the surgical treatment protocol as illustrated. However, Meek grafting is an attractive option for a reliable expansion rate as defined by Vandeput et al[35,36] in severely burned patients. The technique itself does not have the same disadvantages like meshed grafts with expansion ratios beyond 1:6[37] because of the micrografts adherence to the gauze sheet and underlying wounds. It seems, also according to our experience so far, that they exhibit a reliable take rate even on difficult wound beds.[11] This study is, to the best of our current knowledge, the first approach to compare these two surgical expansion techniques in a severely burned patient collective with clinical outcome parameters like LOS, HOS or number of operations. Because our data was derived retrospectively from one single center in a traditionally small collective of severely burned patients, we have to acknowledge, that this again makes it a more attractive option to review outcome in a larger trial involving multiple centers using Meek grafting or alike. So far, for example, there exists no strong data for long-term results for clinical outcome (eg, burn contractures, number of corrective procedures) after Meek grafting. For future studies, it would be interesting to compare different techniques like Meek, mesh (both 1:6) or sandwich technique (widely meshed auto- and allografts) in larger prospective studies to evaluate the real impact of these different techniques concerning wound healing or, for example, metabolic rate. A lot of interesting questions, but to answer these questions, we have to design prospective multicenter trials.

If CMV negative allogeneic keratinocytes were not available, we revered to (artificial) temporary cover alternatives: Suprathel can be applied on freshly debrided superficial and deep dermal burns. The advantages of its use consist in achieving pain reduction[18] and postponement of deep dressing changes for about 10 days postoperatively in our treatment protocol. It can also be used for split skin harvest areas.[42] However, we did not employ the material for other indications as mentioned above. Although Suprathel is a rather costly tool for the treatment of severely burned patients, it is especially useful when no biological cover alternatives are available and early, temporary coverage is needed. Because the artificial product has no "biological" supply limit, we could show that it can be sensibly integrated in a treatment concept.

Temporary polyurethane dressings have been used for the treatment of burns since the early 1970s.[43,44] They aid in removing moisture and, if applied densely and closely on wound beds, can reduce the intrusion of microorganisms. We employed polyurethane dressings as temporary cover alternative on freshly debrided full-thickness areas, if homologous skin grafts were not available. Although they can be left for more than 3 days,[45] it is not suitable in our opinion to do so in extensive burns. Because of close proximity to possibly infected areas in large burns, contamination is likely, cannot be observed superficially and disinfectant penetration through the material is not sufficient.

Nanocrystalline silver sheets have significant properties in treating local wound infections[46] and deliver silver continuously, if remoistened daily with sterile water. Because the material can be left for 7 days, the frequency of dressing changes is reduced, while still maintaining an adequate antibacterial substance delivery. Other advantages include decreased pain sensation in comparison with other silver dressings,[47] a possible reduction of burn itching,[48] and a shorter healing time for residual burn wounds.[49,50]

Negative-pressure wound therapy (VAC) complemented our treatment protocol.[51] It has been shown to reduce edema formation, increase tissue perfusion,[52] and can affect overall skin graft take favourably.[53] In the treatment of severely burned patients, we used VAC in STSG areas of inferior take rate.

CONCLUSION

Our treatment concept is based on a whole array of wound conditioning methods (eg, fluidized microsphere bead-beds, temporary, and permanent coverage options). An integral part is the application of the Meek technique, with which we have achieved good results. Therefore, we accept higher material costs as well as an increased time demand for operating theatre personnel. In this study, we could demonstrate that although the patients in the Meek group were more severely injured in terms of age, and TBSA, they had a comparable amount of operative sessions and (hospital) LOS if checked against a matched control.

Because studies on the Meek procedure in the traditionally small collective of severely burned patients are lacking, prospective controlled multicenter trials will be needed to confirm our results in the future.

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