Management of Major Burns in 37 Casualties of a Colored Powder Explosion

Experience of the Linkou Burn Center in Taiwan

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Background: On June 27, 2015, a colored powder explosion occurred in Taiwan. As a result, 499 people were injured, and over 200 people were in critical condition because of severe burns. Forty-nine casualties were transported to the Chang Gung Memorial Hospital.

Methods: We undertook a single-center retrospective observational study using clinical data for 37 patients with major burns with more than 20% total burn surface area (TBSA). We describe the experience of managing patients with acute burn injuries in these patients. Patient-specific data were analyzed and expressed as mean ± standard deviation.

Results: Thirty-seven major burn patients were admitted to our hospital. The mean ± SD age was 22.5 ± 5 years. The mean ± SD TBSA was 48.9% ± 20%. All patients were stabilized within 6 hours after admission, and no patient experienced hypothermia or hypovolemia. We performed 95 debridement procedures and 88 skin grafts. A mean of 5.6 surgeries were performed for each patient. The mean ± SD hospital stay was 62 ± 32 days. The ratio for hospital days/%TBSA was 1.36, and hospital charges/hospital days ratio was US $973 a day for surviving patients. Two mortalities (2/37, 5.4%) were reported: one was related to cardiac insult, and another was caused by sepsis.

Conclusions: We share our experience in managing 37 major burn patients in a colored powder explosion to improve the holistic care in modern mass burn casualties. Aggressive early debridement and skin grafting reduced hospital stay and costs.

Key Words: colored powder explosion, major burns management

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Mass casualty incidents from terrorist attacks and other man-made or natural disasters remain a constant global threat. Adequate preparation and appropriate alignment of resources with immediate needs remain the key to optimal outcomes.

On Saturday, June 27, 2015, a flammable starch-based color powder explosion occurred in New Taipei City, Taiwan. Overall, 499 individuals were injured during the incident and more than 200 were in critical condition with severe burns. Forty-nine casualties were transported to the Chang Gung Memorial Hospital (CGMH). Most casualties were healthy young adults.

Herein, we report our experience with acute burn management in this homogenous group of young patients, according to a modern standardized burn care protocol at a tertiary medical center. All physicians had received comprehensive training from the same faculty and center, which allowed us to conduct a single-center retrospective observational study.

This study differs from previous studies because (1) the subjects were a homogenous group of young adults, (2) the injuries involved flame burns from an open-space explosion of starch-based powder, (3) the study design was a cross-sectional analysis of a single-center admission course, and (4) the training background of plastic surgeons and the treatment protocol were homogenous.

This article describes the details of how we treated patients, the challenges we faced during treatment, and how we managed these challenges. Our aim was to share our experience to help improve holistic care for modern mass burn casualties.

METHODS

On the evening of June 27, 2015, at the Color Play Asia party, a flammable starch-based color powder explosion occurred at 8:30 PM. The triage took place at the scene by emergency medical technician personnel who classified patient injury severity as mild, moderate, or severe.[1] The Ministry of Health and Welfare of Taiwan initiated a mass casualty management system protocol immediately, and the Emergency Operation Center coordinated with hospitals in the surrounding area.[2] The CGMH is located approximately 11.6 km from the accident scene. The Emergency Operation Center notified the CGMH to prepare for an expected influx of severe burn patients (estimated time of arrival, 9 PM).

The CGMH, located in Linkou, Taoyuan, is a tertiary medical center with a 3700-bed facility that serves 10,000 outpatients per day. Currently, it is the largest medical facility and is 1 of 19 hospitals accredited by the Joint Commission International in Taiwan. The Linkou Burn Center in CGMH was originally designed by Professor Nordhoff to accommodate patients with major burns. It is equipped with 17 intensive care unit (ICU) beds, 9 general beds, a hydrotherapy room, and 2 operating rooms. The incidence of major burns, defined as more than 20% of the total burn surface area (TBSA), in patients admitted to the Linkou Burn Center per year was 14.1% (range, 7.6%–22.3%, for 2008–2017). All staff members at the Linkou Burn Center are plastic surgeons.

Although the CGMH initially received 49 burn victims, only 37 were diagnosed with a major burn more than 20% TBSA and were thereby included in this study. We undertook an institutional review board–reviewed single-center retrospective observational study using the clinical data of these 37 patients.

We describe our acute management experience in these patients. Demographic data included patient age, sex, TBSA, incidence of inhalation injury, abbreviated burn severity index (ABSI),[3] intubations, surgical debridement and skin graft, hospital days, cost per patient, and survival rate. Patient-specific data were analyzed and expressed as mean ± standard deviation.

RESULTS

Once the Emergency Operation Center notified the CGMH, the hospital's Critical Event and Preparedness and Emergency Management

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Code 333 protocol was initiated. A total of 336 medical personnel, including 19 plastic surgeons, were called and reported to the emergency room (ER) to manage the patient flow. Forty-nine patients were transferred to the CGMH within 4 hours.[1] Of these 49 patients, 37 presented with burns with more than 20% TBSA, 7 had less than 20% TBSA burns, and 5 patients were discharged from the ER with superficial secondary burns of less than 5% TBSA (Fig. 1). Overall, 37 patients (17 men and 20 women) with burns more than 20% TBSA (17 patients with >50% TBSA and 20 patients with 20%–50% TBSA) were included in the study. Most patients were healthy young adults without any major systemic disease. Mean ± SD patient age was 22.5 ± 5 years (range, 15–38 years). The mean ± SD TBSA was 48.9% ± 20% (range, 21%–95% TBSA).

Twenty-five patients (67.5%) suspected of inhalation injury were intubated immediately in the ER. All 25 patients were examined and evaluated by chest specialists using a bronchoscope on day 3, and variable inhalation injuries were reported (16 level I and 9 level II inhalation injuries). Bronchoscopy was repeated the next day for these patients. Only 1 patient received multiple bronchoscopy examinations, irrigation, and lavage for pneumonia treatment. Neither acute respiratory distress syndrome nor pulmonary edema developed in these patients. No patient received a tracheostomy. The average intubation period (SD) was 16.9 (8.7) days.

None of the patients had an ocular injury. Twenty-three patients (62%) underwent immediate extremity escharotomy (Fig. 2). All patients were stabilized within 6 hours after admission. There were no cases of hypothermia or hypovolemia. Only 1 patient experienced transient acute renal injury, and this patient recovered after resuscitation and debridement. None of the patients required renal dialysis throughout treatment.

Any routine plastic surgeries scheduled at our hospital were postponed for 2 weeks to manage these casualties, and 11 operating rooms were engaged. Overall, 206 operations were performed including 23 escharotomies, 95 debridements (average, 2.5 debridements/patient), and 88 skin grafts (average, 2.4 skin grafts/patient). An average of 5.6 operations (range, 1–14 operations) were performed for each patient. For this disaster, 639,805 cm^2 of cadaveric skin was imported from the United States and Europe by the Ministry of Health and Welfare. Based on the daily needs, 34,480 cm^2 of cadaveric skin was distributed to the CGMH to cover the patients after debridement.[1]

Before debridement, intravenous morphine for pain control was administered to the 25 intubated patients. However, considering that wound pain may progress postsurgical debridement, all 37 patients, including those without intubation, were provided with patient-controlled analgesia (PCA) for pain control in our practice. The average duration of PCA use was 17.7 days (range, 5–30 days).

The overall mean ± SD hospital stay was 62 ± 32 days (range, 19–139 days), with mean ± SD stay of 65.7 ± 30 days (range, 19–139 days) for living patients and a mean stay of 17.5 days for patients who died in hospital. The ratio of hospital days to %TBSA was 1.36 and 0.28 for living and dead patients, respectively. The mean ± SD cost for each patient was US $61,550 ± $38,221 (range, US $9327–157,499); mean ± SD cost for each living patient was US $63,947.6 ± $37,952.3, whereas the cost for dead patients was US $47,841 (US $1–32 Taiwan dollars). The hospital charge per hospital day was US $973 and $2734 for living and dead patients, respectively.

The mean ± SD ABSI score was 7.86 ± 2.12, and the estimated probability of survival was 70% to 80%. Two mortalities (of 37, 5.4%) were observed. One death was related to cardiac insult, whereas the other patient died of sepsis after refusing limb amputation for fourth-degree burn injuries (Table 1).

DISCUSSION

Acute Management on Day 1

All primary resuscitations, wound management procedures, escharotomies, and patient allocations to the burn center and different ICUs were completed within 6 hours. By 3:00 AM on June 28, all patients were well settled at the hospital.

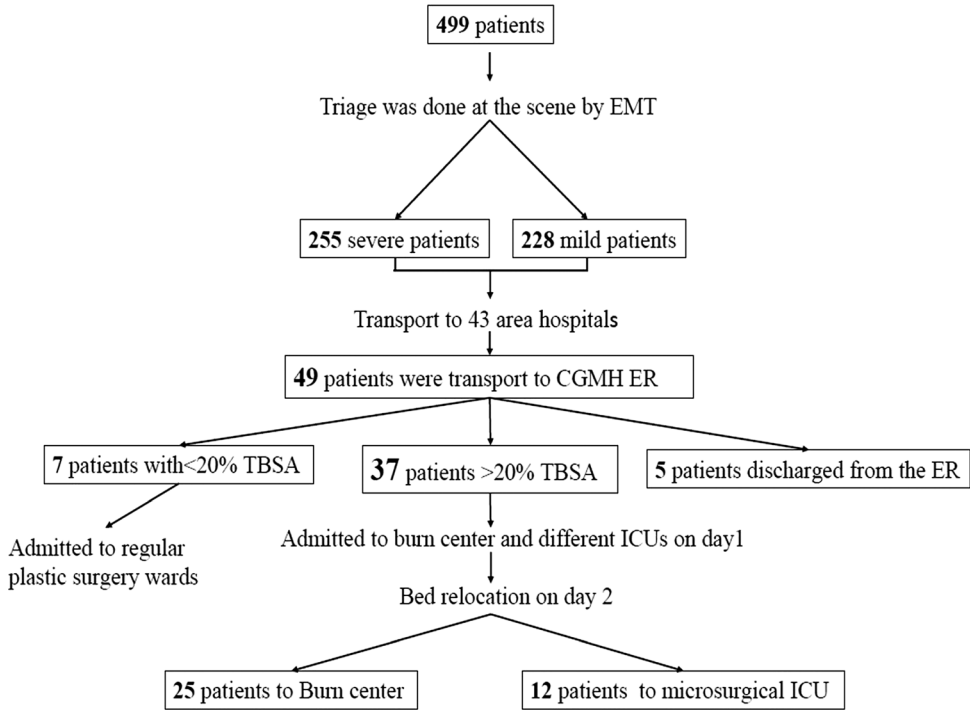

FIGURE 1. Flowchart of the triage at the scene and admission and bed allocation at the Chang Gung Memorial Hospital.[1] EMT, emergency medical technician personnel.

FIGURE 2. A 19-year-old woman with 95% TBSA on day 1: (A, B) preescharotomy; (C, D) posteschar otomy.

Emergency Management and Primary Resuscitation

Both ER physicians and plastic surgeons assessed the patients, including evaluation of extent of TBSA and depth of burn injury, as well as application of intubation, and decided on admission of the patient to the ICU or a general ward. The Lund and Browder chart was used to assess the patient's TBSA. Adult patients with more than 20% TBSA and children with more than 10% TBSA warranted fluid resuscitation. The Parkland formula was used for fluid resuscitation in the first 24 hours, and the lactated Ringer's solution was the preferred resuscitation fluid. Children also received maintenance fluid in addition to the resuscitation fluid. The goal of ongoing fluid therapy was to maintain end-organ perfusion and prevent shock. Fluid resuscitation with intravenous crystalloid solution was adjusted to maintain urine output at 0.5 to 1 mL/kg per hour for adults and 1 mL/kg per hour for children. At 24 hours postburn injury, we initiated colloid infusion and reduced the crystalloid infusion rate by an equal volume. The only colloid therapy we used included albumin and fresh frozen plasma.

Many patients were wearing plastic facial tattoo stickers as entry identification for the party. More severe facial burns were noted in patients with stickers. The nature of these plastic stickers aggravated the injuries.

Inhalation Injury

Twenty-five patients with suspected inhalation injury were intubated on day 1. No carbon monoxide intoxication was noted. All patients were examined and evaluated by chest specialists using a bronchoscope on day 3. Indications for extubation were a clear chest radiograph, proper weaning profile, subsidence of facial swelling, clear expectoration from the endotracheal tube, and stabilized general conditions. Of the 25 intubated patients, 3 reintubations were needed after a relatively early extubation (within 7 days). Our experience showed that early extubation within 7 days is not advisable, as the tracheal epithelium and surfactant may not yet be adequately recovered within this time.

Hypothermia Prevention and Wound Care

Hypothermia has been associated with increased mortality in patients with burn injuries.[4] To prevent hypothermia (body temperature, ≤35°C) and save time in wound care, the patients were quickly admitted to the burn center, different ICUs, and the general ward as soon as possible.

Part of our routine consisted of performing hydrotherapy upon each admission. Hydrotherapy and wound change usually required about 1 hour per patient; however, the risk of potential hypothermia was underestimated. Hydrotherapy was not performed for this incident owing to the massive influx of patients and to allow timely actions. All patients were treated in a temperature-regulated environment considering the risk of hypothermia. Generally, we (1) use a radiator to increase the ambient temperature to a comfortable level; (2) use a heating lamp; (3) warm the bed sheets; (4) adjust the indoor temperature to 24°C to 28°C, with a humidity of 40% to 50%; (5) use a fluid warmer to provide intravenous fluids close to body temperature; and (7) provide sufficient preheated blankets for cover and an insulating warmer (Temperature Management Unit, Model 775, Bair Hugger Therapy; Arizant Healthcare Inc., Eden Prairie, Minn). All wound care procedures were conducted at bedside by using silver sulfadiazine cream first. None of the patients experienced hypothermia.

Escharotomy

Escharotomy was performed for third-degree circumferential burn injuries to prevent compartment syndrome after fluid resuscitation. No compartment syndrome occurred in all 37 cases managed.

Acute Management on Day 2

Bed Relocation and Operating Room Prioritization (Augmentation of Existing Resources)

Twelve hours after the incident (9 AM, June 28), plastic surgeons took charge of the first ward round and visited all patients in the different ICUs and wards and assessed relocation possibilities. Under the current standard protocol, early debridement and skin grafting are key factors for early wound closure, which increases the survival rate. Considering future needs for early debridement and skin grafting, changes in operating room availability, and schedules were discussed extensively. Because of the large number of burn victims,

TABLE 1. Patient Demographic Data

No. patients, N	37
Sex, male/female	17/20
Age, Mean ± SD (range), y	22.5 ± 5 (15–38)
TBSA, Mean ± SD (range), %	48.9 ± 20 (21–95)
20%–50% TBSA, n	20
>50% TBSA, n	17
Inhalation injury, n (%)	25 (67.5)
Operations, n (average per patient)	
Debridement	95 (2.5)
Skin grafts	88 (2.4)
Fasciotomy	23
Total	206 (5.6)
Hospital days, Mean ± SD (range)	62 ± 32 (19–139)
Living patients	65.7 ± 30
Dead patients	17.5
Hospital days to %TBSA ratio	
Living patients	1.36
Dead patients	0.28
Mean hospital charge for each patient, US $ (range)	61,550 ± 38,221 (9327–157,499)
Living patients	63,947.6 ± 37,952.3
Dead patients	47,841
Hospital charges per hospital day, US $	
Living patients	973
Dead patients	2734
Complications, n (%)	
Pneumonia	1 (2.7)
Transient acute renal injury	1 (2.7)
Adverse effects of PCA	16 (43)
Distal digit amputation	3 (8.1)
Mortalities, n (%)	2 (5)

Exchange rate: US $1 to 32 Taiwan dollars.

all medical resources were triaged. All routine reconstructive surgeries were postponed for 2 weeks to prioritize the management of patients with severe burns. Eleven operating rooms were engaged (2 rooms in the burn ICU and 9 central operating rooms). Twenty-five patients had severe burn injuries requiring transfer to the burn center (capacity, 26 beds); 12 patients were admitted to the microsurgical ICU (capacity, 20 beds); and 7 patients with mild burn injuries were sent to regular plastic surgery wards (capacity, 50 beds) (Fig. 1). Experienced medical personnel are essential for repeated evaluations and estimations of the wound condition. Up to 4 times more frequent ward inspection is conducted for more critical cases.

Fluid Resuscitation on Day 2

Based on urine output, we gradually decreased the amount of crystalloid solution and increased the amount of colloid solution on postburn day 2. The colloid can increase intravascular oncotic pressure and draw fluid back intravascularly. Colloid is typically not used until 12 to 24 hours after a burn injury, when the capillary leak has started to seal.[5] Albumin is the most oncotically active solution, and we used it only when the laboratory albumin level was less than 2.5 mg/dL. Taiwan's National Health Insurance Policy states the following: (1) patients with major burns with albumin level of less than 2.5 mg/dL may start the supplement; (2) 2 bottles (albumin 20%, 50 mL/vial, intravenous fluid) per day with a complete course of 5 bottles per patient are allowed. We conducted follow-up measurements of albumin level twice weekly. Two units of fresh frozen plasma was used for patients with major burn injuries (>20% TBSA) twice daily from postinjury day 2 until the TBSA was reduced to less than 20%. There were no occurrences of renal failure in the resuscitated cases. Only 1 patient experienced transient acute renal injury, which resolved within 1 week after the debridement procedure. No cases required renal dialysis during our treatment course.

Ocular Examination

Because we highly suspected ocular insults owing to the explosive flame burns and many cases of facial involvement, we surveyed all patients on admission. All patients underwent eye examinations conducted by ophthalmologists. Fortunately, none of the patients exhibited an ocular injury. We speculated that reflexive eye closure provided protection, and the short duration of the flash flame as well as the open environment setting contributed to zero cases of eye involvement.

Nutrition

Whether oral or enteral, nutrition should be initiated as soon as possible after admission. Because of a combination of (1) major burn (37 patients, >20%) and (2) facial involvement, we inserted a nasogastric tube for feeding. If the previous 2 criteria along with decreased bowel motility or posttraumatic gastric atony were present, nasoduodenal (ND) tube insertion was indicated. Twenty-six patients underwent endoscopy-assisted ND feeding tube insertion on the third day. The health of the gastrointestinal tract was examined simultaneously. The estimated energy requirements were based on the modified Schofield equation. The timing for ND tube and nasogastric tube removal was determined based on the healing of the facial wound and the return to normal bowel mobility.

Amino acid supplementation was indicated when the blood urine nitrogen level was less than 20 mg/dL.

Pain Control

The importance of pain control could not be overestimated owing to the frequent operations and wound changes. All 37 patients received PCA for pain control after debridement. Two PCA combinations were used: (1) 0.0003% fentanyl plus 0.023% morphine pain cocktail solution (350 mL) and (2) 0.00015% fentanyl plus 0.0165% morphine pain cocktail solution (340 mL). The anesthesiologist responsible for the pain control team visited the patients twice daily and adjusted the dosage on-site after discussions with the plastic surgeon. The target of pain control was a numerical rating scale score of less than 4, and the evaluation frequency was per nursing shift. The adverse effects of PCA included 8 cases of dizziness, 4 cases of nausea, 3 cases of vomiting, and 1 case of lethargy and allergy. Because the adverse effects of nausea, vomiting, and decreased peristalsis were mainly attributable to morphine, if the patient could not tolerate such gastrointestinal disturbance, we stopped PCA and used intravenous fentanyl for pain control. One patient experienced skin rash after fentanyl use, thereby prompting us to use only morphine for pain control.

Acute Management From Day 3

Early Debridement

Early debridement and skin grafting are the 2 cornerstones for the survival of patients with burns. To deal with the large number of casualties and to complete early aggressive tangential excision and skin grafting, a large team of plastic surgeons was brought together. Overall, it was estimated that 10% of all trained plastic surgeons in the United Kingdom attended to the casualties of the Bradford City Football Club stadium fire (1985), Kings Cross Underground fire (1987), and the Piper Alpha offshore oil rig disaster (1988).[6] In our experience, from

the third to the fifth day after the incident, the 37 patients underwent their first tangential excision under a team of 23 plastic surgeons and 12 residents across 11 operating rooms. Twenty patients required a second debridement 3 to 4 days after the first debridement, owing to aggravating wound conditions.

In adults, blood loss may reach 117 mL for every 1% TBSA of skin debrided.[7] According to the literature, other institutes prefer to debride 10% to 20% burn area per surgery to limit blood loss.[8] However, we routinely perform debridement of the entire burn area in a single surgical procedure (Fig. 3). Our objective is to reduce the number of surgical procedures, speed up the process of skin graft and wound closure, and reduce the hospital stay. Consequently, extensive blood loss during surgery is expected; therefore, we transfused blood from the beginning of the operation. Hemoglobin level was checked during surgery to decide whether further blood transfusion was needed.

Our debridement procedure started at the patient's back and proceeded to the 4 limbs and the chest area. The major advantage of starting with the back in decubitus position is timely hemostasis compression when the patient is repositioned supine for debridement of other parts. If debridement of the limbs and anterior chest wall is prioritized, large blood loss can be expected. Further change of position to address the back may lead to orthostatic hypotensive crisis. Each limb was debrided from the distal to the proximal part. Each debrided part was packed with warmed epinephrine gauze (50 mL norepinephrine in 1 L injectable normal saline) accompanied by elastic bandage compression sequentially from the distal to proximal part to prevent blood loss. Tourniquet on the extremities was not routinely used during tangential excision because we needed to check for wound bed bleeding to determine the adequacy of debridement. Meticulous electrocautery hemostasis was performed at the end of debridement.

Suprafascial excision of burn wounds was of limited use at our institution because soft tissue loss leads to subsequent poor functional and cosmetic recovery, even after reconstruction.

An intimate cooperation between plastic surgeons and anesthesiologists was the key to successful debridement. When patients' systolic pressure was less than 80 mm Hg, we used epinephrine packing for the wound and elastic bandage compression.

During the surgery, to maintain the optimal temperature, the following conditions were set: (1) indoor temperature of up to 24°C to 28°C, with humidity of 40% to 50%, (2) use of 1 or 2 heating lamps, (3) use of warmed bed sheets, and (4) use of fluid warmer to provide intravenous and blood supplements close to the body temperature.

When the body temperature (monitored with a nasothermometer by the anesthesiologist) was less than 35°C, we halted surgery and covered the patient with sterilized preheated blankets and an insulating warmer (Temperature Management Unit, Model 775, Bair Hugger Therapy). When the body temperature started to increase, a small surgical field was opened and the debridement continued.

According to standard practice in these cases, between the time of wound debridement and skin grafting, the wounds were covered with a biologic dressing (cadaver skin) or a topical wound dressing.

Cadaver Skin

The use of cadaveric skin has been controversial. According to an 11-year retrospective review (1993–2003) of 102 patients with burn injury (TBSA >40%) by the Singapore General Hospital Burn Center, there was no significant reduction in mortality. However, the length of hospital stay decreased by 15.7 days during the post–skin-banking period.[9] In this mass causality incident, our experience showed no differences in the total frequencies of surgeries and the ICU and hospital stay durations between the cadaveric and the noncadaveric skin groups.

FIGURE 3. A 19-year-old woman with 95% TBSA status after the first debridement, day 3.

Topical Wound Dressing

After each debridement, neomycin ointment was applied first over the wound bed, and then the wound was covered with DuoDERM Extra Thin Dressing or Comfeel Plus Transparent to keep it moist with septic prophylaxis. We punctured these dressings evenly for discharge drainage and changed the dressing every 2 days. In some patients, Biobrane or Acticoat (Smith and Nephew plc, London, UK) was used, and the wound dressing was changed weekly.

Early Skin Graft

In our routine practice, patients receive early wound excision and skin graft within 7 days after burn injury. However, to manage the high number of causalities, skin graft was delayed to the second week. Thirty-seven patients underwent wound debridement and autologous split thickness skin graft in a single procedure on the second week thereafter. Because of the local inflammatory response in the debrided wound bed, significant blood loss may occur. The autologous skin graft was expanded using the MEEK technique (Meek micrografting 1:6) and MESH grafting (meshed autograft 1:4) and was applied to the healthy wound bed after hemostasis. However, a high risk of wound oozing was not infrequently noted after surgery, and bedside coagulation and suture ligation were potentially required. The most important factor for patient survival is to decrease the surface area of the injury. However, some injured area present better potential for secondary healing, such as the back and face. Thus, treatment for these areas can be delayed while prioritizing difficult-to-heal regions. In such circumstances, the time for wound healing can be shortened. A logical algorithm is recommended in skin grafting for patients with major burns. Because most of the victims who survived the colored powder explosion had deep extremity burns, the 4 limbs were prioritized for skin grafting.[2] When the TBSA was less than 20% after skin grafting, we prioritized the hands, neck, and face for skin grafting to prevent excessive functional impairment. We suggest harvesting thick split thickness skin graft (18–20/1000 in. from the back to cover the hand, neck, or axilla, to achieve better functional and esthetic outcomes. The donor site of the back healed spontaneously without any complications.

The scalp, lower back, and medial thigh are common autologous skin graft donor sites in our practice. In this incident, the most common burn locations were the extremities (90% lower limb, 71% upper limb), with the scalp (6%) relatively spared.[1] The scalp has been our most preferred skin donor site. Because of the short recovery time of the scalp (within 2–3 weeks), repetitive harvest is possible. Furthermore, any scar is easily concealed by hair. However, the advantages come with pitfalls. Secondary harvest of the scalp provides lesser quality graft and tends to cause heavy bleeding owing to newly formed scar.

Cultured Autologous Epidermis

Cultured autologous epidermis (CEA) is helpful for patients with more than 50% TBSA, as these patients have limited donor sites.[10] In the disaster described herein, a Japanese CEA manufacturer donated

FIGURE 4. A 19-year-old woman with 95% TBSA status after 3 procedures of MEEK skin grafting with residual wound less than 5%, 2 months after burn injury.

CEA as part of international medical assistance. Seven skin biopsies were collected from different hospitals, with an average of 81% TBSA approximately 1 month after the disaster.[10] One female patient with 90% TBSA was initially selected for CEA grafting. However, after 3 attempts of MEEK skin grafting, the TBSA of this patient was reduced to less than 5% within a 2-month interval; thereby, there was no further need for CEA grafting (Fig. 4).

We suggest that the timing of skin biopsy be within a week after injury onset, preferably after the first to second surgery, to enable timely use of CEA in the patient by about 1 month.

Antimicrobial Therapy

Currently, infection is the leading cause of deaths after initial resuscitation. However, the use of prophylactic antibiotics is controversial.[11] In our regular practice, we do not use prophylactic antibiotics except for cases of inhalation injury. Systemic antimicrobial therapy is indicated for patients with burn wound infection or sepsis. Wound culture is performed upon admission and then twice weekly. If there are positive clinical signs such as fever, lethargy, change of vital signs, accompanying abnormal laboratory data (eg, lowered platelet numbers, thrombocytopenia, hypocalcemia, hypophosphemia, hyperglycemia, and elevated creatinine and procalcitonin levels), and pending culture results, empirical intravenous antibiotics (cefazolin and gentamycin) are given immediately. Laboratory tests are performed regularly upon admission and every day (some tests are checked weekly, others daily, and a change of clinical status prompts a change in evaluation frequency). However, antibiotic escalation between the window period of the next culture results and deterioration of clinical condition has posed considerable clinical challenges; however, the controversy remains currently unresolved despite advances in total burn care. The balance between the life-saving use and deescalation use of antibiotics requires additional study as the fast pace of life profile may easily go beyond the point of no return.

Rehabilitation

The influx of patients with major burn injuries reached our full capacity from the third day of the colored powder explosion. The need to expand our rehabilitation team was unavoidable. Our routine burn rehabilitation team, originally comprising 3 staff (1 physiatrist, 1 occupational therapist, and 1 physical therapist), was expanded into a team of 6 (1 physiatrist, 3 occupational therapists, and 2 physical therapists) to cover the myriad of clinical needs. Patient positioning, edema control, education, splinting manufacturing, and exercises were all well-coordinated with the surgical schedules and the overall medical presentations. Because fluid challenges and repeated debridement left the patient with a wet wound bed, the benefits of use of splints were weighed against their risks. Use of towel rolls and wedges early in resuscitation provided better flexibility to address edema control, discharge, and anticontracture postures. Because changes of wound and dressing types may vary widely, especially after splinting removal and refitting, heightened awareness and frequent splint check postrefitting was a major challenge. In our experience, posterior ankle-foot orthoses manufactured at 100° provides better patient tolerance and less calcaneal stress than those manufactured at 90°.

Hospital Stay and Cost

From the American Burn Association National Burn Repository Advisory Committee 2016 report, in patients aged 20 to 29.9 years, the hospital days to %TBSA ratio was 2.37 and 0.5 for living and dead patients, respectively, and the hospital charge per hospital day was US $7682 and $29,757 for living and dead patients, respectively.[12]

In this colored powder explosion, we managed 37 patients with major burn injuries simultaneously. The hospital days to %TBSA ratio was 1.36 and 0.28 for living and dead patients, respectively, and the hospital charge per hospital day was US $973 and $2734 for living and dead patients, respectively. Our indication for discharge was healing of the wound to less than 2% TBSA and stable clinical conditions. We believe that our aggressive early debridement and skin graft strategy reduced the hospital days and cost.

Mortality

Modern developments in burn care have improved resuscitation, wound coverage, and infection control. Most importantly, the emphasis on a multidisciplinary burn team has contributed to a higher survival rate. According to a cohort study by Kraft et al[13] between January 1, 1998, and September 6, 2008, at the University of Texas Medical Branch (Galveston, Tex), the overall mortality of burn injury in pediatric patients ranged from 3% to 55%, depending on the TBSA and the presence of inhalation injuries. In the American Burn Association National Burn Repository Advisory Committee 2016 report, the mortality rate was 9.6% in the age group 20 to 29.9 years with burn injury size of 40% to 49.9% TBSA.[12]

Longitudinal studies of burn survival from individual facilities are well suited to demonstrate advances in care. However, the applicability of extrapolating this experience to other burn centers through cross-sectional evaluation remains unclear.

In the disaster that occurred in New York City at the World Trade Center on September 11, 2001, a regional burn center reported a 39% mortality rate in an entire group of 18 patients with mean age of 43.7 years and a mean burn injury size of 51.9% TBSA.[14] In a major kerosene explosion disaster that occurred in Nigeria in October 2001, a total of 123 patients with an average age of 25 years and mean injury size of 47% TBSA were attended to at the Lagos State University Teaching Hospital during a 25-day period. Twelve (9.7%) of the 123 patients died.[15]

In the colored powder explosion described herein, we simultaneously managed 37 patients with major burn injuries and yielded a survival rate of 94.6%, which was higher than the probability of survival (70%–80%) estimated by the ABSI. Two mortalities were observed at the CGMH. One 20-year-old male patient with 50% TBSA burns died because of cardiac insult on day 9 and another 18-year-old male patient with 65% TBSA burns died of sepsis on day 26. The cardiac insult was related to an unknown premorbid congenital cardiomegaly of the patient. He died despite receiving extracorporeal membrane oxygenation. The second patient rejected below-the-knee amputation despite a series of bilateral debridement for the lower limbs with fourth-degree burns. He died of sepsis.

CONCLUSIONS

We share our experience of managing 37 patients with major burns arising from a colored powder explosion accident. Reconstructive plastic surgeons played a critical role in both the acute and ongoing management. Hydrotherapy was not provided in this mass casualty incident to prevent hypothermia and to accelerate the patient admission process. We do not recommend early extubation within 7 days for patients with inhalation injury. Aggressive early debridement and skin graft can reduce hospital stay and cost. Skin biopsy for CEA is better performed within a week of injury onset so that CEA can be used timely on the patient at about one month.

No differences were observed in mortality, total frequencies of surgeries, and ICU and hospital stays between the cadaveric skin and noncadaveric skin use groups.

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