Available online at www.sciencedirect.com

SciVerse ScienceDirect

journal homepage: www.elsevier.com/locate/burns

Complex chemical burns following a mass casualty chemical plant incident: How optimal planning and organisation can make a difference

Tomás B. O'Neill *, *Jeremy Rawlins*, *Suzanne Rea*, *Fiona Wood*

Burns Service of Western Australia, Royal Perth Hospital, Perth, Western Australia, Australia

ARTICLE INFO

Article history:
Accepted 10 December 2011

Keywords:
Mass casualty
Chemical burns
Disaster management
Communication
Planning

ABSTRACT

Introduction: Four employees at a chemical plant sustained extensive chemical burns following the explosion of a pipeline containing 100% sulphuric acid. We describe the management of these patients from the initial ED triage through to discharge from hospital in life and limb threatening chemical burns.

Methods: Four patients who sustained chemical burns to the torso and extremities are reviewed. Data was retrieved from patient case notes and operating theatre logbooks.

Results: Four patients sustained chemical burns during the blast and were immediately transferred to a local ED where a prompt referral was made to the burns service. All patients were male aged 25–59 years (mean 46.5). Burn size was 2–50% BSA (mean 22.5). Following RFDS transfer to the state burns service two patients required immediate excisional surgery. In these patients the chemical burn involved full thickness skin loss with extensive underlying muscle and neurovascular damage. One patient required immediate above knee amputation of one leg and fascial burn excision of the other. The other patient required fascial burn excision of both legs followed by Integra placement 24 h later. Both patients had prolonged hospital stays due to the complex nature of their injuries requiring multiple trips to theatre and lengthy rehabilitation. The two patients with smaller burns had straightforward surgery and an unremarkable recovery.

Conclusion: Early communication following this mass casualty incident allowed for organisation of tertiary services and early radical surgery which was life saving. Management lessons were learnt following this mass casualty chemical burn incident.

1. Introduction

Mass burn casualty management, has been extensively examined in the international literature since 1964 [1]. Many lessons were learned following the September 11th attack in New York, 2001 [2,3], the Bali Bombings in Kuta, 2002 [4–6], and the Madrid train bombings, 2004 [7], where large numbers of burn-casualties were generated from terrorist attacks. The Bali bombings alone culminated in a rapid influx of 62 burn-casualties to Australia, which resulted in every adult burn bed on the continent being occupied [4]. Unforeseen surges in patient numbers can cripple a unit, which occur in the context of normal routine daily operations and standard burns admissions. In reality however the number of casualties required to stretch a burns unit to its resource limit, is far less than those generated by terrorist attacks or natural disasters.

* *Corresponding author*. Tel.: +61 404103366.
E-mail address: tomasoneill@gmail.com (T.B. O'Neill).
0305-4179/$36.00
doi:10.1016/j.burns.2011.12.010

We describe a four-victim mass burn-casualty incident in which our hospital was placed on code 'brown', anticipating mass casualties for an external event. We describe the timeline of events and communication, which resulted optimal resuscitation, triage, transport and intervention for the chemical burn casualties, and almost certainly contributed to two casualties surviving what were undoubtedly life-threatening injuries. We also discuss the health and safety implications that this incident had on the chemical manufacturing industry worldwide.

2. Methods

Data pertaining to the four casualties from an industrial chemical plant incident were retrieved and examined. Information from the patient's individual medical notes and theatre logbooks were cross-referenced. Senior burns team members were asked to document and recall the events as they unfolded. Finally, health and safety experts were consulted in collaboration with the chemical plant owner/operators.

3. Incident

On February 25, 2010 at 11.00 h, the director of the Burns Service of Western Australia (BSWA), based in Perth, received a direct phone call from the Emergency Department (ED) consultant in Bunbury Hospital (180 km away), informing her of a mass casualty incident at an industrial chemical plant, which had resulted in four burns casualties. Digital photographs illustrating the injuries were emailed from Bunbury ED to the Director of the BSWA clarifying the natureof the injuries. A pipe containing 100% sulphuric acid had burst in the plant and had showered four workers with the concentrated acid. The four workers were immediately taken to safety showers, however the lower garments of clothing were not removed. The closest safety shower was still in the zone of the spraying acid and therefore the workers had to move across the plant to another shower to escape the continuing acid flow. Thinking that the call for help had not yet been made, one of the victims left the emergency shower to raise the alarm.

Whilst the patients continued to be stabilised in Bunbury ED pending transfer, a code 'brown' call was instigated at Royal Perth Hospital (RPH) at 11.25 h. A code brown call corresponds to an external event, and the RPH ED, State Trauma Unit, and Intensive Care Unit (ICU) were placed on alert.

The burns unit, ICU, State Trauma Unit and Operating Theatre (OT) staff, were all aware of the code brown call and immediately prepared for incoming casualties. The Director of the BSWA along with senior and experienced members of the burns team including medical, anaesthetic and nursing staff convened, discussed the injuries and prepared for urgent and radical debridement in multiple simultaneous theatres. The resuscitation bay in the ED was prepared and two burns theatres were warmed. All necessary equipment and staff for radical and simultaneous debridement were prepared. Our Burns ICU was informed of the anticipated need for two beds and extra staff were allocated. The agreed plan was for the Burns and Anaesthetic teams to review the casualties in the ED and transfer straight to the OT suite once satisfactorily stabilised.

The Royal Flying Doctors Service (RFDS) transported all four victims to Perth via fixed wing aircraft. The first two casualties arrived at RPH ED at 14.00 h, only two and a half hours after the initial referral.

The four victims were all male aged 59, 54, 48 and 25 years (Table 1).

The first patient was a 59-year-old male. He received 45% TBSA burns to his bilateral lower limbs, hands and back. His lower limb burns were extensive and deep and had penetrated the fascia and underlying muscle on the left leg (Fig. 1). The burns on his right leg were also extensive and full thickness for the most part (Fig. 2). He was transferred directly from the ET to the OT at 14:30 h. An above knee amputation was performed on the left leg and a fascial excision of the burns to his right leg were performed (Fig. 3). Both legs were dressed with Jelonet (Smith and Nephew, Hull, UK) and betadine soaked gauze and he was transferred to the Intensive Care Unit (ICU) where he remained intubated and ventilated overnight. The following morning a V.A.C.® dressing was applied to the left AKA stump. Split thickness skin grafts (SSG) were meshed 1:3 and applied to his right lower limb. In addition ReCell® non-cultured autologous cells were sprayed over the right leg to augment wound healing. ReCell® was also used to treat his burns to the upper extremities and to the skin graft donor sites. He required ICU support for 8 days and subsequent trips to the OT for VAC

Table 1 – Summary of the casualties and their injuries.

Patient No.	Age	TBSA%	Body site	Timing of surgery	Initial procedure	LoS	Total no. Sx's	Subsequent procedures	LoS per % TBSA
1	59	45	Bilateral legs and hands. Back	Immediate	Left AKA fascial excision burns right leg	114	2	SSG and ReCell® to right leg. ReCell® to upper limb VAC to AKA stump.	2.5
2	54	1	Bilateral legs	Delayed	None	4	1	SSg and ReCell®	4
3	48	2.5	Right flank	Delayed (6 days)	None	11	1	SSG and ReCell® to right flank	4.4
4	25	38	Bilateral legs and hands	Immediate	Fascial excision of bilateral lower limb burns	79	2	Integra to lower limbs @ 24 h. SSG and ReCell® to upper limbs	2

Fig. 1 – Left lower limb chemical burn necessitating amputation.

changes and further skin grafting to achieve wound closure. The remainder of his inpatient stay was complicated by intermittent atrial fibrillation and sepsis. He was discharged on day 114, and continues to receive rehabilitation (Fig. 4).

The second patient was a 54-year-old male. He received small burns to his bilateral lower limbs totalling 1% TBSA. He did not require immediate surgery for his burns but was admitted to the burns unit for analgesia, dressings and psychosocial care. He was discharged 4 days following his admission. After 12 days of conservative management his wounds had failed to close satisfactorily and he was re-admitted for SSG and ReCell® application. He was subsequently discharged following an unremarkable post-operative recovery (Fig. 5).

The third patient was a 48-year-old male with a 2.5% TBSA burn to his right flank. He underwent surgery (SSG and ReCell®) on day 6 of his admission, had a satisfactory post-operative recovery and was subsequently discharged 11 days following his admission (Fig. 6).

The final patient was a 25-year-old male. He had full-thickness burns to both lower limbs and deep dermal injuries to both his hands totalling 38% TBSA. (Fig. 7.) He was taken to the OT following stabilisation in the ED (approximately 30 min following patient 1). He underwent fascial excision to both

Fig. 2 – Bilateral lower limbs demonstrating extent of injuries. Note myoglobinuria in catheter bag from extensive myonecrosis.

Fig. 3 – Left AKA and fascial excision of right lower limb burns.

Fig. 4 – Patient 1 in OPD following discharge.

lower limbs and dermabrasion of his hand burns and application of ReCell®. The common peroneal nerve of his left leg was noted at surgery to be partially burnt but was preserved to act as a conduit to facilitate nerve growth (Fig. 8). His legs were dressed with Jelonet and betadine soaked gauze. The following day he was returned to the OT. Minimal further debridement was required and Integra® was applied to both lower limbs (Fig. 9). His post-operative recovery was hampered by an episode of sepsis and partial loss of the Integra (30% lost) and a profound depressive illness. He subsequently had SSG and ReCell® applied to the vascularised Integra over three further trips to the OT. He continues to attend for rehabilitation and scar management (Fig. 9).

Fig. 5 – Patient 2 pre-op and 6 months post-operatively.

4. Discussion

A well-devised and communicated management plan, instigated for as few as four burn casualties, can result in optimal intervention and ensure adequate and necessary care delivery. The burns service of Western Australia has been called-upon to treat several mass-casualty burns in the past. In the senior authors 20 years experience of providing this service, there have been at least 14 mass casualty incidents. In 2002 for example, it responded to the Bali bombings by accepting 28 of the patients into the burns unit at Royal Perth Hospital [4]. More recently in 2009, 23 patients were transferred to Perth following a fire onboard a vessel off the coast of Ashmore Reef in the Indian Ocean [8]. On both of these occasions the burns service of Western Australia responded appropriately by

Fig. 7 – Bilateral lower limb and hand burns in the fourth patient, a 25-year-old male.

Fig. 6 – Patient 3 pre-op and 6 months post-operatively.

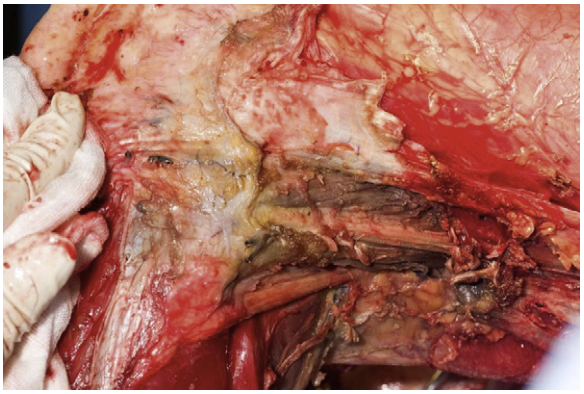

Fig. 8 – Fascial excision of burn revealing involved common peroneal nerve (preserved).

increasing bed capacity on the burns unit, calling-up additional nursing and medical staff, and rostering theatre personnel to allow multiple surgeries simultaneously. Good communication and meticulous planning was paramount to successful operations in both 2002 and 2009, and such was the case following this chemical plant incident. The initial call to the burns service was between the receiving emergency consultant and the director of the burns service on-call for burns admissions that day. This direct communication avoided a lot of unnecessary passing things 'up and down the line' and ensured a prompt response. Following the Bali bombs and Ashmore reef we had 24–48 h to prepare for patients arriving into Perth; on this occasion we had just 3 h.

Technology certainly expedited our response on this occasion. Digital photographs of the patients taken in the admitting emergency department were emailed directly to the on-call burns consultant in Perth before the patients had left the department. This detailed information clarified the extent of the injuries, allowing us to prepare two operating theatres for radical surgery involving amputation and fascial burn excision.

Large body surface area deep chemical injuries require early (and aggressive) surgery to save life [9]. With deep structures involved amputation and fascial excision is lifesaving and certainly proved to be the case in this situation. Whilst some of the Integra was lost due to infection the fact that the majority was salvaged suggests that it was worth doing and that the benefits of using the dermal matrix will be evident for many years. Integra was not used in the patient requiring the amputation for the main reason that we felt any additional sepsis (from the Integra) would not be tolerated by the older patient with medical co-morbidities.

Much was learnt from the management of these complex chemical burn patients – not only at the burns unit. Immediately following the incident the chemical plant halted operations (for approximately 1 week) to allow a full investigation of the event to be carried out. Prior to this event the plant (and indeed the company managing the plant) had not recorded an injury since 2007, and no lost work days since 2003 [10]. The investigation reported that it was a combination of factors that led to such deep injuries to the legs including the employees being too close to the malfunctioning pipes and valve, and a failure to remove the acid soaked lower garments and boots prior to entering the safety shower. The injuries may have been less severe had the employees showered their burns with the neutralising agent Diphoterine® immediately following the incident [12]. Diphoterine® is an amphoteric and chelating solution that can be applied to a chemical burn to help stop the irritating and corrosive actions on the skin. Compared to water it is thought to have an improved rinsing effect and reduces the penetration of tissues due to its hypertonicity [11]. Following on from this incident, all employees at Cristal Global chemical manufacturing plants (including the plant where this incident occurred) now have access to Diphoterine® for use following a chemical burn.

Fig. 9 – Patient 4, 24 h following fascial excision of bilateral lower limb burns and 6 months post-op. Integra was applied to both lower limbs.

5. Conclusion

Mass casualty incidents involving burns can very rapidly overwhelm a burns service. With early involvement of senior clinicians, rapid assessment of the injuries, and prompt communication across health networks, even the most devastating of injuries may be salvaged and lives saved. The use of digital photography was certainly an advantage in this case, and proved an efficient and accurate method of communicating the extent and severity of the injuries. With the help of the multidisciplinary burn care team all of our patients (including the two men who underwent radical excision/amputation were rehabilitated back to their homes and to work. Key to any incident such as this, lessons must be learnt. It is hoped that now employees have access to Diphoterine® on site, any further chemical incidents will result in far less serious injuries requiring far less mutilating surgery.

Conflict of interest statement

The authors have no conflict of interest to declare.

REFERENCES

[1] Pessereau G, Monteil R, Morvan R. Treatment of mass burn casualities. Gaz Med Fr 1964;71:2237–50.

[2] Jordan MH, Hollowed KA, Turner DG, Wang DS, Jeng JC. The Pentagon attack of September 11, 2001: a burn center's experience. J Burn Care Rehabil 2005;26:109–16.

[3] Yurt RW, Bessey PQ, Alden NE, Meisels D, Delaney JJ, Rabbitts A, et al. Burn-injured patients in a disaster: September 11th revisited. J Burn Care Res 2006;27:635–41.

[4] Edgar D, Wood F, Goodwin-Walters A. Maintaining physical therapy standards in an emergency situation: solutions after the Bali bombing disaster. Burns 2005;31:555–7.

[5] Fisher D, Burrow J. The Bali bombings of 12 October, 2002: lessons in disaster management for physicians. Intern Med J 2003;33:125–6.

[6] Palmer DJ, Stephens D, Fisher DA, Spain B, Read DJ, Notaras L. The Bali bombing: the Royal Darwin Hospital response. Med J Aust 2003;179:358–61.

[7] Carresi AL. The 2004 Madrid train bombings: an analysis of pre-hospital management. Disasters 2008;32:41–65.

[8] Satterthwaite PS, Atkinson CJ. Using 'reverse triage' to create hospital surge capacity: Royal Darwin Hospital's response to the Ashmore Reef disaster. Emerg Med J 2010.

[9] Sanford A. Chemical burns. In: Herndon D, editor. 2nd ed., Total burn care, London: Saunders; 2002.

[10] Cristalglobal. Bunbury operations [online]; 2009, Available: www.cristalglobal.com/AboutCristalGlobal_Resources/Bunbury_6_15.pdf [accessed 17.04.11].

[11] Cavallini M, Casati A. A prospective, randomized, blind comparison between saline, calcium gluconate and diphoterine for washing skin acid injuries in rats: effects on substance P and beta-endorphin release. Eur J Anaesthesiol 2004;21:389–92.

[12] Mathieu L, Burgher F, Blomet J. Comparative evaluation of the active eye and skin chemical splash decontamination solutions diphoterine and hexafluorine with water and other rinsing solutions: effects on burn severity and healing. J Chem Health Safety 2007.