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The West Australian surgical approach to massive burn injury

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Summary Massive burn injuries (> 50% total body surface area) remain challenging for survival and reconstructive management. In Western Australia (WA), the dermal template used for massive burns was changed from Integra® to Novosorb® Biodegradable Temporising Matrix in 2019. Short-term outcomes in massive burns were examined in two groups before and after this change: 2015-2019 and 2020-2024. Comparison between these groups revealed that mortality of actively treated patients decreased in the latter group (from 22% to 14%), the mean length of stay reduced (from 82 days to 74 days) and the mean time to healing reduced dramatically (4.1 months compared to 6.8 months). A protocol-driven surgical approach to massive burns was developed in WA over the past decade which may have contributed to these improved outcomes along with the change in the dermal template used. Lessons learned over time and details of this surgical strategy are presented.

Parts of this article have been presented at the following meetings/conferences:

1. International Society for Burn Injury meeting in August 2024 in Birmingham, UK.
2. Australian and New Zealand Burns Association meeting in October 2024 in Auckland, New Zealand.

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Foreword/personal reflection

When asked by the Deputy Editor Chris Lewis to submit an article for the *JPRAS Burns* special edition, I was delighted and uneasy. It has been over ten years since I passed my FRCS(Plast), but I have nowhere near the experience or research accolades as several of my burns colleagues. Then, I remembered something I hold as a core truth and relaxed at once; burns is a team specialty and I work with an incredible team of consultants.

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The surgical approach to massive burns (> 50% TBSA) that we, as a team, have crafted will be the focus of this article. Some data, but mostly the combined experience and opinions of the burns plastic surgeons who work in Western Australia (WA) and what works for us in these challenging injuries are presented. For this, I make no apology; this is the foundation upon which I believe many of us base our entire working lives—data which makes sense to us and opinions from people we trust.

I presented some of the findings and learnings in this paper at the Australia and New Zealand Burns Association (ANZBA) meeting in Auckland in 2024, and the first question from the audience was "And…all the surgical team manage these patients generally in this way? No disagreement?" I could honestly tell them that yes, whilst we all have differences in our practice, our consultant team are largely uniform in the way we treat massive burns. The admitting consultant leads the plan and directs operations in theatre, but we all hold to the overall strategy and respect the prepared plans when we operate on each other's patients. This requires a level of trust that is built over time and shared experiences. Similar to several consultant teams, we meet regularly to discuss our clinical outcomes; monthly M&M meetings, 3-monthly safety and quality meetings and 3-monthly consultant meetings, where we discuss everything from workforce planning, staffing, research and disaster plans. For the past few years, we have also made a huge effort to meet as a team socially, with our partners, for dinner evenings. We manage this on an average twice a year, but the benefits of investing time by socialising together cannot be underestimated. Your work relationships, like your house plants, need attention or they will wither and die. You do not need to be best friends, but taking time outside of work to spend together means that you feel invested in your colleagues; you are more likely to let any minor annoyances go and feel benevolent towards them if they need help with a massive burn debridement at 6 p.m. on a Friday.

I have enjoyed putting this article together and on behalf of myself and the rest of the team of burns plastic surgeons of WA, we hope you enjoy reading it.

Introduction

Keeping massive burns alive is difficult. It has always been difficult, and it will probably always be difficult. When Ms. Sian Falder, now the Clinical Lead for burns at Alder Hey, was the burns fellow in Western Australia (WA) in 2006, she reviewed all our acute burn Integra® data and found that in adult major burns 35% of all Integra applied completely failed and was removed owing to infection, and 50% of those patients whose Integra failed went on to die. This was a tragic finding, but when donor sites are limited, there were few other options. Since 2019, we have exclusively used Novosorb® Biodegradable Temporising Matrix (BTM) as a 2-stage dermal template for massive burns.

In WA, we do not use allograft and have not used it since the early noughties. It is our opinion that the temporary nature of cadaveric skin, its creation of HLA sensitivity[1] (complicating future transplantation), requirement of tissue license, special storage and overall cost are factors which cannot be outweighed by any benefits now that BTM is available.

From 2015 to 2024, 30 massive adult burns were admitted to the State Adult Burns Unit in WA with a mean age of 45 years (range 19–93 years) and mean %TBSA burn of 73% (range 53–98%). Our overall mortality was 55%, which conforms with the literature in Australasia and Europe[2,3]; however, among the patients who died, 82% were palliated within 24 h of their admission on grounds of futility. Of the remaining 16 actively treated patients, the mean mortality was much lower at 18%.

Sub-group analysis of this cohort of massive burn patients was performed. The cohort was split into 2015–2019 (when Integra was used exclusively as a dermal template) and after 2019 (when BTM was used exclusively as a dermal template) and some differences were observed in the short-term outcome data (Table 1).

The number of patients presenting with massive burn injuries did not change, nor did the number of patients palliated for futility. The mean number of operations each patient required through their journey in the burns unit was also similar.

However, the mortality of the actively treated patients reduced from 22% in the earlier group to 14% in our later cohort which is a sizeable difference in a relatively short time. The later cohort also had a lower mean length of stay at 74 days compared to 82 days. This is a true length of stay in hospital with discharge to residence; at The State Adult Burns Unit, we perform our rehabilitation in-house on the Burns Unit or if specialist services are required (e.g. amputee services), they are still on-site at the State Rehabilitation Service. This is located in the same hospital, meaning they can attend the burns unit for dressings, physiotherapy, occupational therapy and specialist dietician and clinical psychology input.

Perhaps the most intriguing change in the data between the earlier and later groups is the time to healing, measured indirectly as total time in dressings. This was considerably reduced in the latter group at a mean of 4.1 months compared to 6.8 months in the earlier cohort, indicating that these patients are healed and out of dressings earlier and remaining healed.

The presented data are all raw and descriptive. Further interrogation and statistical analysis of our massive burns database is planned for later this year; however, these changes are promising and appear to confirm that the reported short-term clinical outcomes are indeed improving. A possible reason for this, as we have indicated, is that we have changed our dermal template to BTM for massive burns. BTM is now accepted as a far more resistant template to infection than the others used previously,[4,5] and a recent review of our own paediatric acute major burn data confirmed that we have an almost zero rate of template loss due to infection.[6]

Surgical strategy in massive burn injury

Immediate

Most of our massive burns arrive intubated or are intubated in the Emergency Department, with Acticoat silver dressings applied to all areas of their burns and are taken for a scrub in theatre. Western Australia is over 2.5 million square kilometres in size, meaning that transfers are frequently via aeromedical teams over vast distances and can take several hours and even days. We request Acticoat to be applied to all burns before

Table 1 Massive burn patient outcomes.

	Patients palliated (n)	Patients actively treated (n)	Mean age (y)	Mean TBSA (%)	Mean mortality of actively treated (%)	Mean LOS of survivors (days)	Mean operations in survivors (n)	Mean time to healing (months)
2015–2019	7	9	37 (19–75)	64 (53–92)	22	82 (55–136)	6.4 (3–10)	6.8 (3.2–10.5)
2020–2024	7	7	43 (23–93)	66 (55–98)	14	74 (32–146)	6.6 (3–10)	4.1 (2.0–8.1)

transfer, as it reduces the burn wound infection which is especially important in delayed transfers.[7]

Most massive burns require escharotomies by virtue of their anatomical extent and we make sure that the patient's core temperature is as close to 36 °C as possible before starting any escharotomy. This is not universally accepted as an independent risk for intra- and post-operative bleeding, but most people agree that hypothermia is bad for burns.[8–10] Therefore, in an acidotic, catabolic and critically unwell patient we try to avoid it. Senior authors in this article have observed cardiac arrythmias on the monitor at core temperatures below 34 °C, despite using under-patient warmer, Bairhuggers and warmed fluids. We employ 400 ml intra-vesical instillation of warmed Hartmann's changed every 3 min with a 3-way tap which raises the core temperature quickly.

Since 2022, we have used Nexobrid® (Nexobrid) to debride deep facial burns of intubated patients. Figures 1 and 2 show a male patient with a 78% flame burn, with mostly deep dermal burns to his face on day 2 of his injury. He had Nexobrid applied day 4 post-injury and then any unhealed areas were treated with autologous cells using ReCell® (ReCell) spray at one-week post-Nexobrid removal. He required split-thickness skin graft (SSG) to only his lateral forehead and temples at 4 weeks post-injury. We now believe, as do several of our European colleagues,[11] that the removal of the pro-inflammatory burn tissue at an earlier stage of the facial burn facilitates accurate assessment, removal of the toxic load of the burn and reduces the hypertrophic scars and contractures observed in facial burns which have been left longer to heal and grafted at a later date. As Nexobrid is incredibly painful when applied, we only use it for intubated or perioperative patients. We use Nexobrid in the intensive care unit (ICU), at the bedside, or at the start of a supine debridement operation (which usually takes 3-4 h in a massive burn—the duration for which the Nexobrid needs to be applied) which means it will work whilst you address other areas of burn and saves time. It is a useful technique for faces and we have recently treated our first paediatric deep facial burn using this technique as well with great success. Expanding our use of Nexobrid to treat other anatomical areas where dermal preservation is key, such as the hand, is next.

Figure 1 Our patient's facial burns at 48 h post-injury, prior to Nexobrid application.

Figure 2 Same patient at 2 years post-injury, displaying the healed areas of split skin grafts on the temples, upper cheeks, forehead and the remainder of the face which healed with ReCell alone.

First debridement operation – 48–72 h post-injury

Total burn debridement (not necessarily total burn skin excision to fat or fascia) is performed at the first debridement operation whenever possible. This can mean total excision of the skin, but any areas of dermis which can be preserved will be considered. The back, for instance, is often an area where you can set the dermatome to 25 and in a pre-infiltrated state achieve good debridement to clean white dermis, which we would then ReCell and dress with Surfasoft® non-adherent polyamide dressings and gauze (Figures 3 and 4). This area can then often heal before BTM delamination is completed, which in a massive burn is considerably advantageous and can let you address more functional areas with the available donor sites.

If debridement is possible under tourniquet, then tangential sharp debridement (Humby or dermatome) is considered, especially on limbs and cosmetic areas to preserve the dermis; however, if the burn is evidently full thickness on a test-shave or not amenable to tourniquet, then a subdermal excision with monopolar to healthy fat is a safe, quick and relatively bloodless technique. If the patient is unstable and the operation is required to be as quick as

Figure 3 A massive burn patient's back which was debrided to the deep dermis using the dermatome, ReCell was sprayed and Surfasoft dressings applied.

Figure 4 The same back 4 weeks later with good evidence of healing without any formal split skin grafting.

possible then a fascial excision with monopolar is considered for speed and reduction of blood loss. Ensuring haemostasis, we apply BTM tightly with multiple adhering staples to healthy dermis, fat or fascia with Acticoat, gauze and crepe firmly wrapped around on top. It is our experience that BTM applied tightly to a healthy wound bed will integrate to fat as well as it does to fascia, which reduces contour abnormalities, improves aesthetics and reduces graft loss at fat/fascial junctions which are often challenging areas to achieve graft take.

At this first debridement operation, the only areas routinely considered for grafting would be tracheostomy and line sites. Donor sites are crucial in massive burns and if the noradrenaline goes high and the donors deepen then outcomes become bleak, thus, any donor sites taken at this operation are minimised and ReCell is routinely sprayed back onto them.

Timing of initial debridement varies between units; however, a recent multivariable analysis of thousands of burns surgical patients in WA examined timing of initial debridement surgery.[12] This huge data analysis found that length of stay, length of ICU stay and time to healing significantly improved in our patient cohort when we performed the first debridement operation between 3–5 days post-injury. The proposed reasons for this are that it facilitates intensivists to optimise patients prior to their massive operation and gives time for fluid shifts to settle, which we believe allows better adherence of the BTM to a less oedematous wound bed. As previously mentioned, our transfer times in WA can be measured in days and not hours, which lends itself to a later starting point on debridement. By aiming to debride at 48–72 h post-injury, we also have time for surgical and personnel planning in our burns-dedicated theatre and have found that this achieves good outcomes in our patient cohort.

Day 1–2 post-debridement

Our patients are mobilised as early as day one post-operatively, even if they are ventilated in ICU and this requires 4 staff and a tilt-table. Prof. Dale Edgar and his therapy team in WA demonstrated that achieving these functional vertical milestones improves nearly all outcomes in ICU burn patients.[13] Splinting is performed for functional positioning but there is no splinting or restricted movement for the BTM, and we start functional ranging at 48 h post-operatively when all outer dressings are changed in ICU by our senior nursing team. The medical team will examine the BTM for any haematoma or oedema reduction causing 'baggy' BTM that does not adhere to the wound bed. This can be cut, stretched and re-stapled down in ICU if needed, to ensure BTM is in contact with the wound bed. The BTM is then redressed with Acticoat, gauze and firm crepe bandages and this dressing change regime is repeated every 48 h in ICU with adequate analgesia.

Week 1–2 post-debridement

We consider the use of Oxandrolone 10 mg BD from day 5 post-injury until less than 5% unhealed; this guideline was amalgamated from those shared with us by our previous fellow Ms. Sarah Bache, who is now a burns consultant in Birmingham, and Dr. Paul Baker, Director of burns in Auckland. The oxandrolone is paused if liver transaminases are >100 IU/L. Concerns have been recently raised regarding safety in patients with hepatic and cholesterol risk factors; however, in the face of a massive burn injury, we believe that these risks are often outweighed by the improvement in donor site healing, reduction in weight loss and reduced catabolic effects.[14,15]

We employ skin grafting functional areas such as the hands within the first 5–10 days, if the patient is stable and not on large amounts of noradrenaline (to protect the donor sites and not waste precious skin). In deep hand injuries debrided to paratenon, we would use 1-mm MatriDerm® (MatriDerm) with immediate split-skin grafting as this provides a functional gliding layer (Figures 5 and 6). If there is graft loss or early breakdown, then vascularised layer from underneath can be re-grafted, rather than at bare tendon or joint. The other advantage of removing BTM and applying MatriDerm and immediate skin grafts to hands in this early

Figure 5 Deep dorsal hand burns 48 h post-65% flame burns.

Figure 6 The same hand three months after MatriDerm and immediate grafting on day 5 post-injury, showing pliable graft dorsally.

period is that it can be functionally ranged similar to a normal graft from 48 h post-operatively. This does not necessitate a second operation and is healed quickly allowing early occupational therapy, garments, functional adaptations and physiotherapy.

BTM, as a side note at this point, is incredibly robust. A learning curve exists, where the surgeon is required to hold their nerve with infection. Even the thick, yellow fluid under the BTM can be treated by making holes in the template, milking and culturing it, followed by re-stretch and re-stapling so that it contacts the wound bed. The correct antibiotics and microbiology advice will often save the template, though the condition of the wound bed can be checked through the holes made. Removing large pieces of BTM should be avoided if possible as this invariably results in die-back. Even when the BTM has not adhered to the wound bed, it can be removed, the wound bed debrided with Versajet and a new piece can be immediately reapplied (Figures 7–10), which would not be possible with Integra.

Figure 7 Patient with oedema reduction, resulting in BTM not contacting the wound bed. A large section was removed from the abdomen due to concern regarding infection.

Figure 8 Immediate preoperative photograph post-removal of BTM-the wound bed had evidently dried out and died back where the BTM is removed, versus a moist and healthy wound bed where the unintegrated BTM was left on. All wounds were lightly debrided with Versajet and BTM was immediately re-applied.

Figure 9 Good integration of BTM at 2-weeks post-re-application.

Figure 10 Good graft take post-delamination and grafting.

Weeks 2–4 post-debridement

From week 2 onwards, BTM delamination and grafting is commenced and a surgical tracheostomy considered at 14 days post-intubation. In massive burns in WA, BTM is applied to all debrided deep dermal and full thickness injuries to

Figure 11 Healed split-skin grafts at 1:1.5 over chest and upper arms with 1:3 on abdomen.

reduce grafting at the first debridement operation for the reasons stated. Selection of the first areas of BTM to delaminate and graft will frequently target the deep dermal areas, as template integration is less relevant and dermis is easier to graft than fat or fascia. This means that in massive burns, we use BTM as a partial and full-thickness skin substitute, a temporary dressing and to convert a non-graftable bed to one which will take a graft. It is a one-size fits all for massive burns and the cost of 'wasting' the template becomes less relevant when considering our dataset indications of lower mortality, lower length of stay and time in dressings for the BTM cohort.

After the dermal areas, anterior body surfaces are considered for delamination and grafting; these areas are not influenced by gravity, fluid accumulation and shear forces unlike the posterior thighs, buttocks, shoulders and back. If the hands have not already been addressed, then these are prioritised, followed by the face, neck, upper limbs, lower legs, then the anterior surfaces of thighs, chest, abdomen and flanks. This results in posterior surfaces left to heal with the applied ReCell® or BTM and can be grafted last when the patient is mobile, awake and can spend more time in a vertical position to reduce graft loss.

In terms of meshing SSG, we use 1:1.5 for functional and cosmetic areas (hands, neck, arms, joints and chest) and 1:3 for thighs, buttocks, abdomen, flanks and back. ReCell® is routinely applied to all SSG areas to assist healing the gaps between the mesh interstices (Figure 11).

When discussing timing and donor sites it is worth acknowledging that a massive burn of 51% is very different to a massive burn of 85%, but in the context of any massive burn in WA, after 2 weeks of BTM integration has elapsed, the patient is taken to theatre for delamination and grafting on an average every 10 days (with ICU dressing changes every 48 h in between).

Figure 12 Inferior wound shows freshly harvested ultra-thin SSG site; superior wound shows a donor site which is allowed to heal (taken 10 days prior) and will be ready for the next re-crop.

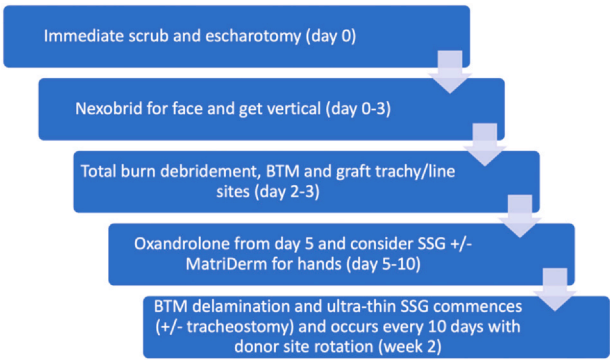

Figure 13 Flowchart of WA surgical approach to massive burns.

At each operation delamination and grafting of 10–15% TBSA is performed and only half of the available donor site is cropped at each operation. This ensures that one donor area is allowed over 20 days to heal between re-cropping, but still permits moving the patient forward incrementally by 10–15% healing every 10 days. Rotating the donor sites, taking them ultra-thin and allowing each donor area 2–3 weeks to heal results in less deepening of the donor sites which can be disastrous in a massive burn. Split skin grafts are taken ultra-thin in WA, at 4-6/1000″ on the dermatome and we have previously published this in reference to what we believe are excellent outcomes.[16] We routinely apply ReCell® to the donor sites each time they are cropped to aid healing (Figure 12).

Whilst BTM is robust to infection, antimicrobials are still required to treat the inevitable infections and in a massive burn organisms, it can develop resistance before wound coverage is achieved, resulting in overwhelming sepsis. Progressing the wounds on a regular and predictable cycle reduces this risk, results in less catabolism, more mobility and less pain and psychological distress.

In summary (Figure 13), an immediate scrub and escharotomy is performed as required, Nexobrid for the face, early total burn debridement with grafting of tracheostomy and line sites only and early functional vertical movement. Oxandrolone is considered from day 5, as is grafting for the hands with MatriDerm in case of deeper injuries. Delamination and grafting commence at week 2 with tracheostomy considered and theatre planned for delamination and SSG of 10–15% every 10 days, rotating ultra-thin donor sites. This protocol emphasises donor site preservation, early mobilisation and staged reconstruction. BTM proved to be more robust than Integra, with far fewer infection-related losses but success requires close collaboration with microbiology for infection management and careful timing of interventions in addition to standard MDT involvement of dietetics, nursing, physiotherapy, occupational therapy and clinical psychology.

Conclusions

As a burns team, we need to be united in our vision and common goals and our treatment pathway and the outcomes will follow. Having an agreed protocol-driven surgical approach is an effective way of converting the surgical plans from 'my patient' to 'our patients' with the added support of the rest of

the Multi-Disciplinary Team and your surgical colleagues behind you. As for the outcomes of massive burns, Professor Wood says, 'The quality of the outcome must be worth the pain of survival'. Continuing to examine what we do and how we can improve outcomes is a good start and we are proud that we can share what our team has built together so far.

Ethical approval

Not required.

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None.

Declaration of Competing Interest

Fiona Wood is the inventor of ReCell® and assigned all Intellectual Property for ReCell® to a charitable foundation (Fiona Wood Foundation). All ReCell® kits in WA health are used on a not-for-profit basis.

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