Case Report

Pediatric Reconstructive Surgery in Extravasation Injuries: Experience with Dermal Matrix

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Abstract

Introduction: Extravasation injury is defined as the damage caused by the accidental leakage of intravenous solution from a vessel into surrounding tissues. Extravasation damage ranges from painful intravenous sites to soft tissue necrosis and even nerve damage and tendon rupture. The incidence in hospitalized adults has been reported up to 39%; while up to 70% of newborns in neonatal intensive care units suffer an extravasation incident. Because of their location—the hand and foot—and because most extravasations occur at night (and therefore often go unnoticed for many hours), the consequences of such events can be both functionally and aesthetically devastating, in particular in pediatric patients. Despite their grave consequences, no surgical treatment guidelines have been published to date.

Material: In this article, we aim to address the surgical challenges posed by this problem and present our treatment algorithm for patients who present with full thickness tissue necrosis following extravasation. Here we also describe our own experience using early aggressive debridement followed by tissue coverage with a dermal skin substitute (Integra®) and a thin skin graft in an infant who suffered an extravasation injury of the dorsum of the hand. We were able to obtain adequate soft tissue coverage while preserving complete hand function. No complication was observed except for skin hyperpigmentation.

Conclusion: It is our opinion that these patients should be treated as burn patients and undergo early aggressive surgical excision of involved areas to limit untoward sequelae.

INTRODUCTION

Extravasation injury is defined as the damage caused by the accidental leakage of intravenous solution from a vessel (most commonly through the walls of a vein) into surrounding tissue [1,2]. Extravasation damage ranges from painful intravenous sites to tissue inflammation and edema, and can even lead to nerve damage, tendon rupture, and soft tissue necrosis [1]. The incidence of extravasation is hard to calculate since many injuries go unreported. In the literature, an estimated incidence of 0.1% to 6% of adult patients receiving chemotherapy has been described [2]. We believe that it is highly underestimated and an investigation by the National Extravasation Information Service in one UK National Health Service hospital estimated the incidence at 39% (http://www.extravasation.org.uk) [2]. In the pediatric population the incidence is even higher [3]. Indeed, up to 70% of newborns treated in neonatal units suffer an extravasation injury, although tissue damage is reported to be uncommon [4]. Because of their location (most commonly involved extravasation sites are the hand and foot) and because most extravasations occur at night (and therefore often go unnoticed for many hours) [5]; the consequences of such events can be both functionally and aesthetically devastating [2]. Indeed, there is little soft tissue protection for the underlying essential structures (tendons, nerves) that allow hand and foot function. Moreover, the pediatric population will be less able to communicate pain and discomfort; which can further delay diagnosis and early treatment [3].

Other identified risks factors include obesity, small and/or fragile veins (children for example), mobile or hard sclerosed veins, multiple previous attempts/venipunctures, untrained personnel, IV location (flexion crease for example), any medical condition that impairs a patient’s ability to detect a change in sensation at the IV site (eg, non verbal patient, paralysis, impaired cognition, sedated patient...), diseases associated with impaired circulation, agitated patients and prolonged infusion time [6,7].

Most available literature on the subject details the cytotoxic mechanisms of soft tissue destruction based on extravasated solution type, the majority of which involve chemotherapy solutions [1,2,4,8]. Other articles describe injury patterns from specific solutions relative to concentration and volume, duration of infiltration, insertion site, and patient comorbidities. Regardless of the chemical extravasated, the end result is the same if it is not diagnosed early: extensive soft tissue damage and necrosis. Unfortunately the sequelae of injury are not limited...
to the immediate post-extravasation period; patients may suffer lifelong consequences, requiring multiple interventions to correct the soft tissue defects and functional deficits imposed on the extremity. A case of squamous cell carcinoma of the skin after doxorubicin extravasation 10 years earlier has even been described [9].

Little is known about the best surgical approach to use once extensive injuries occur. Because of the extent of the damage, we believe that these wounds should be treated as third degree burn wounds (which has been stressed out by other plastic surgery teams[10]). Indeed, extravasation injury can involve all skin layers due to delayed diagnosis, leading to complete necrosis of the entire skin and soft tissue envelope. Early intervention is essential for the patient’s prognosis and recovery. Based on our experience, timely aggressive surgical debridement followed by soft tissue coverage with a dermal substitute (Integra® Dermal Regeneration Template) and skin graft can salvage hand function and provide a good aesthetic solution while limiting donor site morbidity.

Surgical treatment

The stage of extravasation, the nature of the infiltrating solution and the availability of specific antidotes determine treatment. We will only address the treatment of severe extravasation injuries leading to full thickness skin and soft tissue necrosis (Stages III and IV according to Kostogloudis and Heckler classifications) [1,11].

Up to one third of extravasations lead to tissue necrosis in some reported series [9]. Small areas of full thickness skin necrosis may heal with conservative wound care, leaving minimal risk of long-term sequelae; however based on our experience, edema from the lack of limb elevation often progresses to significantly larger eschar formation and tissue ulceration. This can ultimately lead to a compartment syndrome requiring urgent surgical treatment in order to avoid a Vollmann Ischemia Deformation. More importantly, it was found that repeated infusion of the offending agent, even in another limb, may induce a recall reaction at the site of extravasation [12].

Many authors favor conservative and attentive treatment until lesions evolve for at least 1 week [13-16]. However it is our opinion that the surgical team should be contacted immediately (as soon as the extravasation has been diagnosed), especially in newborns where late diagnosis has even more devastating complications. Early adequate wound care can change the course of the injury. Moreover, in some cases early aspiration using liposuction cannulas can evacuate most of the extravasated fluids and salvage the skin [17]. Additionally, if paresthesias and limb mobility restriction is present in the acute phase, we believe that immediate care is required. In these circumstances, previously described surgical treatments range from simple excision followed by a skin graft, to reconstruction with a local flap, delayed flaps, or free tissue transfer reconstruction for extensive wounds [14,15].

While these options are valid ways to replace soft tissues in general, they are not always appropriate with respect to the hand and wrist. Skin grafting alone may lead to retraction and hypertrophic scarring, resulting in devastating movement restriction. The use of local flaps to cover the dorsum of the hand is limited by the availability of an adequate donor site. Moreover, donor site morbidity is unavoidable and can bring its own sets of complications. This option is also not applicable in neonates (tissue shortage due to their size), where the majority of these injuries are found. Likewise, free tissue transfer to the hand while technically feasible, is limited by donor tissue bulk and donor site morbidity and is also not an option in neonates either.

Integra® Dermal Regeneration Template is an acellular dermal matrix composed of an outer layer of thin silicone film and an inner layer of cross-linked fibers. The silicone sheet mimics the skin’s epidermis and protects the wound from infection, heat and moisture loss. The cross-linked matrix acts as a scaffold that enables dermal skin cell regeneration. The dermal matrix acts as a sliding layer over the subcutaneous fascia to allow mobility without adhering to underlying tissues; thereby only requiring a very thin skin graft. This alleviates the concern for skin retraction while also limiting donor site morbidity. Since its commercialization, it has been extensively used in many clinical situations and perhaps most successfully in severely burned patients. Moreover, current data from a systematic review of the Cochrane and MEDLINE databases appear to support the use of acellular dermal matrices in chronic and acute injuries where bone, tendon, and/or muscle are exposed [18]. Restoring the dermis is essential for restoring cosmesis as well as skin elasticity and underlying function.

As previously mentioned, we are often contacted when the wound has already reached a Stage III or IV. In these cases, our protocol is as follows: first, all necrotic tissues are debrided down to healthy and viable tissue. Next Integra®Double Layer is transferred to the wound bed in the operating room. The Integra® itself is then covered with Jelonet®, paraffin gauze dressing. Postoperative wound care includes twice weekly dressing changes in the office, where we clean the edges of the dermal matrix with non alcoholic Isobetadine® and reapply the paraffin gauze. This takes place until the neodermis has formed and vascularization is adequate (at 21 days). After three weeks, the silicone layer is removed and a thin (0.006 inch) epidermal autologous non-meshed skin graft is applied to the Integra®. Because the skin graft is extra thin, we favor donor sites such as the scalp in infants (therefore no additional visible scar created by the graft harvest) or the upper thigh. With appropriate wound care and sun avoidance for a whole year, donor site scarring is minimal. After another ten days, the graft take is certain and no bandage is required.

We have currently treated 4 patients using this technique and are nearing completion of long-term data collection. The results thus far are excellent and we present here one case using our technique to illustrate its efficacy.

CASE

An 11-month-old baby girl was sent to our outpatient clinic five days following the extravasation of an Hartmann solution (isotonic crystalloid solution containing 131 mmol/L of Sodium, 111 mmol/L of Chloride, 29 mmol/L of Lactate, 5 mmol/L of Potassium and 2 mmol/L of Calcium) extravasation injury in her right hand. She had been hospitalized for bronchitis when the
extravasation occurred. The perfusion catheter was placed in the dorsum of the hand and the extravasation was diagnosed after 24 hours. The entire volume (500cc in 24h) of the Hartmann solution had infiltrated the surrounding tissues.

Physical exam on presentation included extensive edema of the entire upper limb, blanching of the skin of the dorsum of the right hand as well as blisters on the forearm and arm (Figure 1A). Three clear zones of injury could be appreciated: the blanching ischemic skin at the injection site, a surrounding ring of hyperemic skin, and most peripheral to the extravasation site, a zone of epidermolysis and blistering. Her digits were also swollen with limited range of motion. Her presentation was similar to that of a severely burned patient.

Early treatment consisted of Flamazine, a silver sulfadiazine-based cream followed by a gauze bandage of the entire arm changed three times a week, as well as complete elevation of the arm 24 hours a day. We felt this would limit burn deepening and progression. After 7 days, the burned zone was delimited to the dorsum of the skin and the entire arm was salvaged (Figure 1B). An initial conservative debridement was performed, which did not initially expose tendon structures. However, after one week an additional extensive debridement of necrotic tissue had to be performed. This led to complete exposure of the extensor tendons of the hand (Figure 2A). Integra® was immediately grafted to the wound bed (Figure 2B-C). Because this was a full thickness defect and we wanted to avoid having a contour defect (and single layer Integra® wasn’t available at the time); two sheets of double layer Integra® were used. In the same operation, we first applied only the dermal layer of the double layer Integra® (Figure 2B). On top of that layer was secured a complete double layer Integra® (Figure 2C). A Jelonet® bandage and gauze with a loosely secured compression band was then placed. Wound care for the following three weeks consisted of biweekly bandage change after Isobetadine® disinfection (in the office). After 3 weeks, the patient was taken back to the operating room to remove the silicone sheet and apply a thin (0.006 inch) skin graft from the thigh. The skin graft was secured with a Jelonet® sheet and gauze. The bandage was kept closed for a whole week with a splint to limit movement. Complete grafts take three weeks. After about 12 days, no bandage was required and the skin graft was moisturized by the parents three times a day using a commercial hydrating body cream. Two years later, the patient has no limitations in active or passive range of motion, with complete flexion and extension of the wrist and all digits maintained (Figure 3). Hyperpigmentation of the skin graft likely due inadequate protection from sun exposure in the first year of treatment is seen.

DISCUSSION

Prevention of extravasation injuries remains the best approach to avoid injury and long-term morbidity. The following measures have been recommended in the literature to help reduce extravasation: if possible, always select a large an intact vein, with good blood return established prior to starting the infusion. Indeed, the patency of the IV line should always be verified by flushing 10ml of saline solution before any infusion is started. The IV site should be secured with a clear dressing to allow for monitoring. Infusion sites should be picked carefully;
try to avoid creases (wrist or antecubital fossa for example) and favor the forearm or dorsum of the hand. Avoidance of limbs with impaired circulation or severe scarring/sclerosis or even prior radiation has been also stressed out as well. Central lines should be preferred for high risk drugs with a slow infusion rate. Regular inspection of the IV site (every hour is recommended) and regulated delivery of IV fluids from continuous infusion pumps may prevent high volume extravasations. Lastly, adequate education of patients about extravasation symptoms will help detect extravasation as early as possible [2,6]. Implementation of prevention measures and extravasation management programs has been found to reduce incidence significantly [19].

All these measures help reduce severe extravasation injuries. However, major extravasations leading to significant soft tissue damage still occur. We believe that severe extravasation injuries should be treated as burns as they can lead to full thickness tissue loss.

The use of a dermal matrix to cover full thickness wounds caused by extravasation injuries offers multiple advantages over other surgical options: there is almost no donor site morbidity, it can be used in the acute setting, complete treatment can be achieved in less than 6 weeks with limited hospital stay, and it has been developed specifically for situations where donor site is limited. In addition, its use limits the need for further major interventions thereby requiring little additional medical resources. Most importantly it offers skin elasticity and flexibility that cannot be achieved with other techniques. Skin elasticity and pliability is essential to preserve function when reconstructing mobile areas such as the hand, the wrist or the dorsum of the foot.

Donor site morbidity is limited even more by harvesting the skin graft from the scalp. Indeed it is our preferred donor site for children because the resulting scar will be hidden under the hair and the graft is so thin that there is virtually no risk of resulting alopecia.

Potential downsides to this method include increased infection risk and cost. Infection associated with dermal substitutes in a variety of settings has been described in the literature but remains controversial [20-24]; we believe that with careful wound care and use of a single dose of prophylactic antibiotic prior to each surgery it can be minimized. The cost associated with dermal substitutes is not negligible; however when compared to the cost of free flap reconstruction or other techniques that often require multiple revisions, the total cumulative cost of the entire treatment is likely to be more cost effective relative to other techniques.

CONCLUSIONS

Extravasation injuries have devastating consequences that could be avoided with early detection and adequate care. We recommend early involvement of the surgical team in the acute care of extravasation injuries, early aggressive surgical debridement, and the use of a dermal matrix substitute in combination with a thin skin graft for the treatment of full thickness skin defects.

REFERENCES

