Extravasation Injuries

REC Rose[1], R Felix[1], A Crawford-Sykes[2], R Venugopal[3], G Wharfe[4], G Arscott[3]

ABSTRACT

Objectives: *To evaluate the time and type of treatment following extravasation from intravenous infusion and the sequelae of the injuries.*

Method: *The charts of 12 patients who were referred to the Plastic and Orthopaedic Services at the University Hospital of the West Indies were reviewed. The study period was between May 2003 and January 2007. Data were collected on age, gender, site of extravasation, extravasated agent, treatment of the extravasation, necrosis interval, duration of hospital stay for treatment of injury and whether the intravenous line was resited and at what site in relation to the injury.*

Results: *The age of patients ranged from three days to 67 years. The female-to-male ratio was 2 : 1. In five patients, the intravenous infusion was discontinued immediately after the swelling was noticed. In two patients, the intravenous infusion was stopped after seven hours and in five patients it was discontinued within 12 to 22 hours. The necrosis interval ranged from 12 hours to three weeks. Immediate treatment following extravasation and discontinuation of the infusion included limb elevation in three patients and application of cold compresses in one patient. Eleven patients developed skin necrosis of varying severities. There was no skin necrosis in one patient. Ten patients spent an average of 31 extra days in hospital for treatment of the extravasation injury. Two patients were treated in an out-patient clinic.*

Conclusions: *Extravenous leaks can cause severe tissue injuries. Morbidity is increased by delay in recognition and treatment of the extravasation. A protocol for the treatment of extravasation is recommended.*

Lesiones por Extravasación

REC Rose[1], R Felix[1], A Crawford-Sykes[2], R Venugopal[3], G Wharfe[4], G Arscott[3]

RESUMEN

Objetivos: *Evaluar el tiempo y tipo de tratamiento tras la extravasación de una perfusión intravenosa y las secuelas de las lesiones.*

Método: *Se revisaron las historias clínicas de 12 pacientes que fueron remitidos a los Servicios de Ortopedia y Cirugía Plástica del Hospital Universitario de West Indies. El periodo del estudio tuvo lugar entre mayo de 2003 y enero de 2007. Los datos fueron recopilados en relación con edad, género, lugar de la extravasación, agente extravasado, tratamiento de la extravasación, duración del intervalo de necrosis, duración de la permanencia en el hospital para el tratamiento de la lesión, y reubicación o no de la línea intravenosa, así como la especificación de su lugar en relación con la lesión.*

Resultados: *La edad de los pacientes fluctuó de tres días a 67 años. La proporción hembra/varón fue de 2:1. En cada uno de los casos, una sustancia capaz de causar la necrosis se había infiltrado por goteo en el tejido subcutáneo a partir de una perfusión intravenosa. En cinco pacientes, la perfusión intravenosa fue discontinuada inmediatamente después de que se observó la inflamación. En dos pacientes, la perfusión intravenosa fue detenida después de siete horas y en cinco pacientes fue discontinuada dentro de 12 a 22 horas. El rango de intervalo de la necrosis fue de 12 horas a tres semanas. El tratamiento inmediato tras la extravasación y el cese de la perfusión incluyeron la*

From: [1]Divisions of Orthopaedics, [2]Anaesthesia and Intensive Care, [3]Department of Surgery, Radiology, Anaesthesia and Intensive Care, [4]Division of Haematology, Department of Pathology, The University of the West Indies, Kingston 7, Jamaca, West Indies.

Correspondence: Dr REC Rose, Division of Orthopaedics, Department of Surgery, Radiology, Anaesthesia and Intensive Care, The University of the West Indies, Kingston 7, Jamaica. West Indies. E-mail: recrose@hotmail.com.

elevación de miembros en tres pacientes y la aplicación de compresas frías en un paciente. Once pacientes desarrollaron necrosis cutánea de diversos grados de severidad. No hubo necrosis cutánea alguna en un paciente. Diez pacientes pasaron un promedio de 31 días extras en el hospital para el tratamiento de la lesión de la extravasación. Dos pacientes fueron tratados en una clínica ambulatoria.

Conclusiones: *El goteo extravenoso puede causar lesiones severas del tejido. La morbosidad aumenta con la demora en el reconocimiento y tratamiento de la extravasación. Se recomienda un protocolo para el tratamiento de la extravasación.*

West Indian Med J 2008; 57 (1): 41

INTRODUCTION

Extravasation or infiltration occurs when fluids or medications administered by the intravenous route penetrate the perivascular or subcutaneous space. All intravenous fluids can cause tissue injury following extravasation. However, certain substances such as cytotoxic drugs, hyperosmolar agents and vasoactive drugs are associated with a greater risk of tissue injury (1–6).

The reported incidence of extravasations varies in the literature but is believed to range from 10% to 30% (7, 8). Patients undergoing chemotherapy have a 4.7% risk of developing extravasation (9). In children, the incidence is between 11% and 58% (10). Most extravenous leaks have relatively minor sequelae but severe injuries requiring surgical debridement, skin grafting or amputation have been reported (11–14). Treatment of these complications lengthens the patients' hospital stay.

This paper reports a series of twelve patients affected by infiltration of fluid into the soft tissue. The authors evaluated the time and type of treatment following extravasation and the sequelae of the injuries. A treatment protocol is recommended.

SUBJECTS AND METHODS

The time period of this study was between May 2003 and January 2007. The charts of 12 patients who were referred to the Plastic and Orthopaedic Services at the University Hospital of the West Indies were reviewed. Five patients were referred as inpatients from the Medical Wards, four patients were referred as inpatients from the Paediatric Wards, one patient was an inpatient on the Otolaryngeal Ward and two patients were referred from outpatient clinics. The age ranged from three days to 67 years. The female-to male ratio was 2:1.

RESULTS

In each case, a substance capable of causing necrosis had leaked into the subcutaneous tissue. The causative agents were osmotically active chemicals in seven cases, a cytotoxic drug in one case, antibiotics in two cases, a diuretic in one case and an anaesthetic agent in one case. In six cases, the dorsum of the hand was affected; in three cases, the dorsum of the foot; in two cases, the scalp and in one case, the forearm.

In all cases, clinical assessment revealed one or more of the following signs: swelling, discoloration, induration, blisters and skin necrosis. In five patients, the intravenous infusion was discontinued immediately after the swelling was noticed. In two patients, the intravenous infusion was stopped after seven hours and in five patients, it was discontinued within 12 to 22 hours. The intravenous access was resited in seven of the 12 patients. Two of those seven patients had it resited in the same limb (Table 1).

Table 1: Patient data

Case	Age Gender	Site	Agents	Time intravenous (IV) was discontinued (hours)	IV resited
1	2 months/male	Forearm	5% Dextrose in 0.2% Normal saline	11 hours after swelling was noticed	Yes – same limb
2	2 years/female	Scalp	Crystalline penicillin Gentamicin	Immediately	No
3	6 months/male	Scalp	10% Calcium chloride Potassium chloride	Immediately	Yes – limb
4	47 years/female	Dorsum of hand	10% Calcium gluconate 50% Dextrose/water	22 hours after onset of swelling and pain	Yes – opposite limb
5	67 years/female	Dorsum of hand	Furosemide	12 hours after onset of symptoms	Yes – opposite limb

Table 1: Patient data (Cont'd)

Case	Age Gender	Site	Agents	Time intravenous (IV) was discontinued (hours)	IV resited
6	66 years/female	Dorsum of hand	10% Calcium chloride 50% Dextrose water	15 hours after onset of symptoms	Yes – opposite limb
7	60 years/male	Dorsum of hand	10% Calcium gluconate 50% Dextrose solution	Immediately	Yes – opposite limb
8	22 years/female	Dorsum of foot	Ciprofloxacin	17 hours after onset of symptoms	No
9	3 days/female	Foot and leg	10% Dextrose solution, Potassium chloride, Calcium chloride	2 hours after onset of swelling	No
10	41 years/female	Foot and leg	10% Calcium chloride	Immediately	No
11	42 years/male	Dorsum of hand	Doxorubicin	6 hours after onset of symptoms	Yes – same limb
12	32 years/female	Dorsum of hand	Midazolam	Immediately	No

Immediate treatment following extravasation and discontinuation of the intravenous infusion included limb elevation in three patients and application of cold compresses in one. Eleven patients developed skin necrosis. Two patients needed split skin grafting; five healed by secondary intention and one case (Case 6) had a groin flap. One patient (Case 12) had excision of the small area of contracture on the dorsum of the hand, tenolysis of the extensor tendons along with dorsal capsulotomies of the metacarpophalangeal joints of the index and middle fingers. One patient (Case 11) required a groin flap but declined surgery since an above-elbow amputation had been performed on the other limb for osteogenic sarcoma of the distal radius. There was no skin necrosis in one patient (Case 5). This patient developed a 1x1cm hypopigmented area around the intravenous access site and was treated with parenteral antibiotics. One patient (Case 3) died from congestive cardiac failure while awaiting a skin graft procedure (Figs. 1–3).

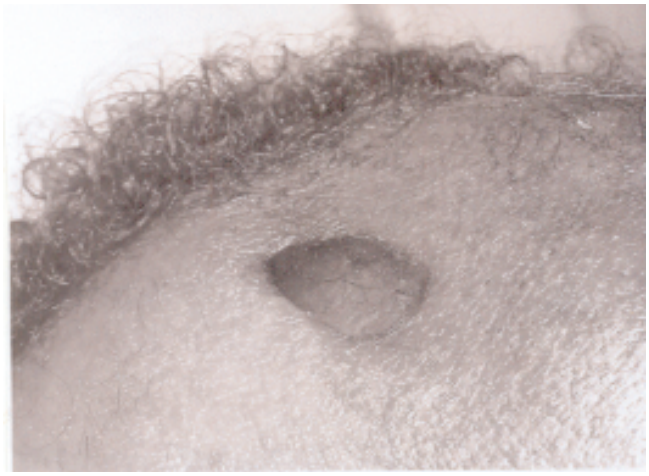

Fig. 1-a: Scalp of six month old child following extravasation of calcium and potassium chloride. Early extravasation injury.

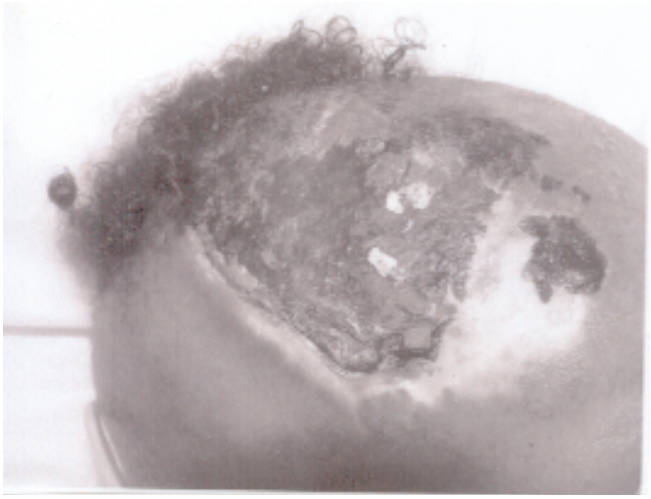

Fig. 1-b: Full thickness skin loss to the scalp

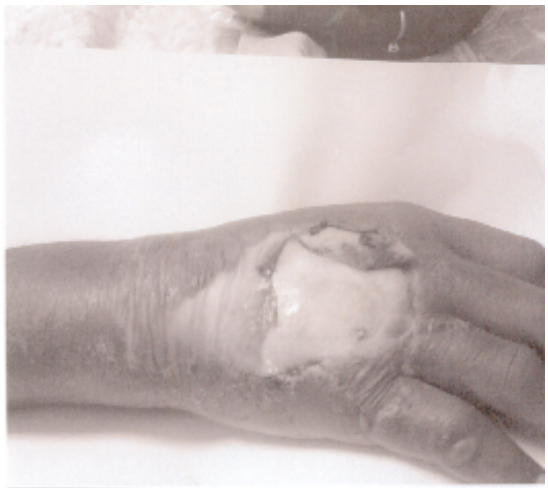

Fig. 2-a: Dorsum of hand showing blisters and skin loss. Causative agents were calcium chloride and 50% dextrose water.

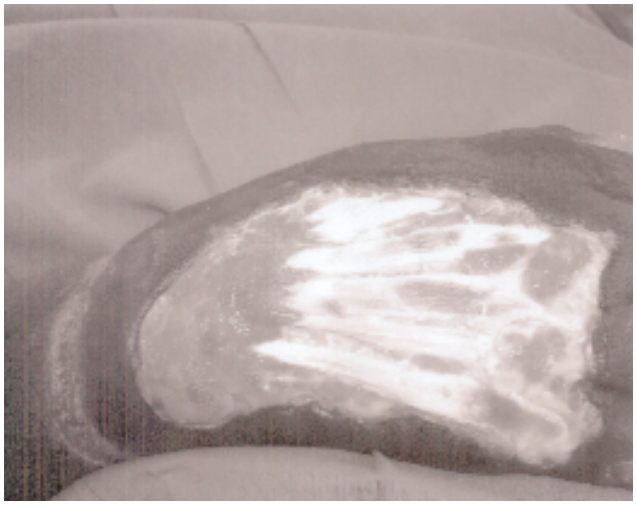

Fig. 2-b: Dorsum of hand showing extensor tendons

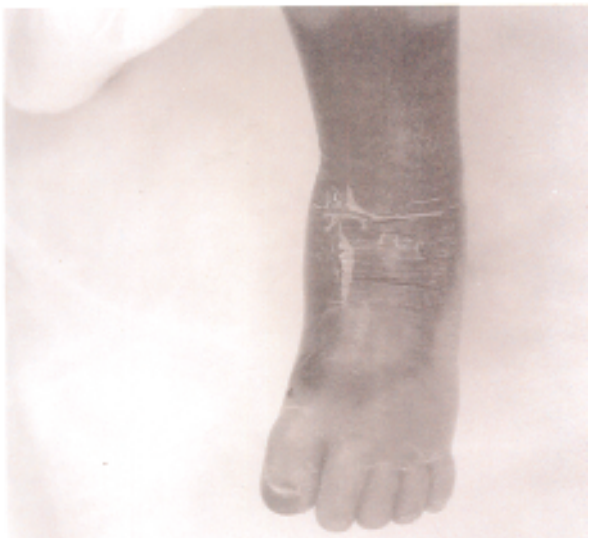

Fig. 3: Extravasation necrosis to dorsum of foot, anterior leg and tip of great toe. Causative agents were potassium and calcium chloride.

The necrosis interval, which is the time from which extravasation was noticed to irreversible tissue damage,

Table 2: Patient data and results

Case	Treatment for the extravasation	Necrosis interval (hours)	Extravasation injury	Treatment of injury	Days in hospital for treatment
1	None	48	Swelling 1 x 0.7 cm partial thickness skin loss	Elevation antibiotics healed by secondary intension	34
2	None	24	4 cm x 2 cm partial thickness skin loss	Bactroban ointment healed by secondary intension	Managed as an out-patient
3	None	24	6 cm x 7 cm full thickness skin loss	Died while awaiting skin graft procedure	70
4	Limb elevated	34	6 cm x 4 cm partial thickness skin loss	Skin grafting	44
5	Limb elevated	No skin necrosis	1 cm x 1cm hypopigmented area around the intravenous site	Parenteral antibiotics	6
6	None	Not recorded	5 cm x 4 cm full thickness skin loss	Groin flap	55
7	Limb elevated	48	3 cm x 1.5 cm partial thickness skin loss	Skin graft	21
8	None	34	2.5 cm x 1.5 cm ulcer	Debridement healed by secondary intension	12
9	None	12	Purple discolouration of the foot, ankle and leg	Elevation Bactroban ointment separation of eschar re-epithelization of wound	37
10	None	Not recorded	Ulcers	Debridement antibiotics healed by secondary intension	14
11	None	24 hours	3 x 3 cm full thickness skin loss	No treatment scar formation Tenolysis excision of scar with Z-lengthening	Out-patient
12	Cold compresses	3 months	Scarring around the tendons 1 x 1 cm scar dorsum of hand	Dorsal capsulotomies of metacarpophalangeal joints of the index, middle and ring fingers	21

ranged from 12 hours to three weeks. Ten patients spent an average of 31 extra days in hospital for treatment of the extravasation injury (range 6–70 days). Two patients were treated in an out-patient clinic. The data of the 12 patients are listed in Table 2.

DISCUSSION

Tissue damage after fluid extravasation may be slight, involving a local or limited inflammatory response or may be large, causing necrosis of the skin and underlying soft tissue (15, 16). The degree of damage is in relation to the speed with which extravasation is recognized and treated, the age and nutritional state of the patient, as well as the amount, type and toxicity of the extravasated agent (13). However, it is difficult to compare series from different authors as the amount of the drug infiltrated in individual cases is rarely precisely known (17). In our series, the amount of drug which had extravasated in each case was not known.

Vesicants are fluids and medications that are inherently more likely to produce necrosis. Irritants frequently produce inflammatory reactions at the site of infiltration but rarely lead to necrosis. Finally, there is a large group of agents that are fairly innocuous and are rapidly resorbed without any apparent tissue damage (18). Table 3 lists the more common agents encountered clinically (18).

Table 3: Classification of intravenous agents based on local toxicity: Cytotoxic drugs

Vesicants	Irritants	Non-vesicants
Actinomycin D		
Carmustine	Busulphan	Melphalan
Decarbazine	Carboplatin	Cyclophosphamide
Daunorubicin	Etoposide	Cisplatin
Doxorubicin	Methotrexate	Bleomycin
Epirubicin	Taxol	Asparaginase
Mitomycin C		5-Fluorouracil
Mustine		
Vinblastine		
Vincristine		
Vindesine		

Non-Cytotoxic agents with vesicant potential

Hyperosmolar agents	Vasopressor agents	Alkaline and acid agents
Calcium Chloride	Adrenaline	Erythromycin
Calcium gluconate 10%	Dopamine	Diazepam injection
Hypertonic glucose (10% or >)	Dobutamine	Vancomycin
Parenteral nutrition	Noradrenaline	Phenytoin
Sodium bicarbonate	Vasopressin	Aminophylline
Mannitol (10% and 20%)	Prostaglandins	Acyclovir
X-ray contrast media		Amphotericin B

Cytotoxic drugs have a direct toxic effect on the vessel walls and may also bind to tissue DNA. The drug is then released continually from dying to healthy cells resulting in gradual tissue destruction causing late ulcerations (13). Osmotically active substances can cause tissue damage by producing an osmotic imbalance across the cell membrane when in the subcutaneous tissue. This results in disruption of cellular transport mechanisms, leading to cell death from fluid overload (13). Vasoactive substances can cause tissue injury by inducing ischaemia through severe vasoconstriction (13). Calcium and potassium are important because they cause a prolonged depolarization and therefore a contraction of the precapillary and postcapillary smooth muscle sphincters (13).

Age is also considered to be a significant risk factor in the development of tissue necrosis. Infants and young children are known to have more extravasations, possibly due to their inability to communicate pain at the intravenous site as an early warning sign, as well as the immature skin and frequent need for antibiotics and nutritional support in babies in Special Care Units (13).

Cancer patients are at risk for extravasation because of limited venous access due to repeated use of their veins (13). The general fragility of the skin and veins of the elderly may also lead to an increased susceptibility to injury (17). In addition, patients with peripheral neuropathy and decreased level of consciousness are prone to unnoticed extravasation injuries (13). In our series, only four patients were between three days and two years of age and they all developed skin necrosis. The other eight patients were adults, seven of whom developed skin necrosis.

A review of the literature indicates a diversity of views for the treatment of the acute stage of this adverse event. Elevation of the involved extremity and application of cold compresses to minimize the inflammatory reactions have been recommended (20, 21). Hyaluronidase, phentolamine injections and glyceryl trinitrate patches have been used to promote drug absorption (13, 21, 22–25). Saline flush-out has been used to dilute the drug (17, 21). Some authors advocate specific antidotes as the mainstay of treatment (26). Early surgical debridement and skin grafting have also been recommended (18, 27).

However, once extravasation has been detected, a prompt and systematic approach should be taken to prevent or minimize the extent of tissue injury. The infusion must be stopped immediately and any product that remains in the veins should be aspirated via the catheter. Most authors recommend aspiration of any visible fluid collection in the subcutaneous tissue (14, 17, 21, 23). The intravenous access should be resited in another limb should further fluid administration be required.

The site of extravasation should then be evaluated and staged according to Millam's Classification [Table 4] (11). Millam proposed conservative treatment for Stages I and II, and intervention for Stages III and IV. Conservative measures include elevation of the involved extremity and application of warm or cold compresses. Larson, in 1985, treated 119 patients who had mild chemotherapeutic agent extravasations with elevation of the involved extremity and application of cold compresses for 15 minutes four times

Table 4: Staging of intravenous (IV) infiltrates

Stage	Features
I	Painful IV site No erythema No swelling
II	Painful IV site Slight swelling (0%–20%) No blanching Good pulse below infiltration site Brisk capillary refill below infiltration site
III	Painful IV site Marked swelling (30%-50%) Blanching Skin cool to touch Good pulse below infiltration site Brisk capillary refill below infiltration site
IV	Painful IV site Very marked swelling (75%) Blanching Skin cool to touch Decreased or absent pulse* Capillary refill > four seconds* Skin breakdown or necrosis*

* The presence of any one of these characteristics constitutes a Stage IV infiltrate.

daily for three days. Eighty-nine per cent of the patients required no further treatment (19, 20). Researchers, however, have shown that the application of warm or cold compresses do not have any significant benefit in reducing the ultimate size and duration of skin ulceration (28, 29). Despite these studies, elevation and the use of compresses may still be good adjuncts to the management of extravasation. While they may not reduce the amount of drug penetration, these therapies may significantly improve patient comfort (30).

Stages III and IV infiltrates require prompt and aggressive intervention. Gault found that saline flush-out was an easy and practical procedure (17). Four small exit stab incisions under local or general anaesthesia were made around the periphery of the area of extravasation and saline was injected in 20 mls or 50 mls aliquots, and even in infants 500 mls were flushed through the zone of infiltration. Gault reported that it was important to ensure that fluid did not collect in the surrounding tissues. He found that saline flush-out alone, or a combination of saline flush-out and liposuction was equally effective. On the basis of Gault's results, other authors have used saline flush-out alone with good results (14, 21). The authors stressed the importance of performing these measures within 24 hours of the extravasation injury (17, 21).

Hyaluronidase is a highly purified enzyme derived from bovine protein sources. It acts by hydrolysing hyaluronic acid which is a polysaccharide found in the intracellular ground substance of connective tissue. Hyaluronidase temporarily decreases the viscosity of the ground substance and promotes diffusion and rapid absorption of the toxic fluid (31). Restoration of normal tissue structures occurs within 24 to 48 hours after administration. Hyaluronidase is available as a lyophilized powder requiring reconstitution (23). The 150 unit vial of hyaluronidase is reconstituted with 1 ml of normal saline. A tuberculin syringe is used to withdraw 0.1cc of the hyaluronidase solution. This is diluted with normal saline to 1cc to provide a concentration of 15 units per ml. Fifteen units of hyaluronidase is then injected through the catheter. In the event that the intravenous catheter is inadvertently removed, hyaluronidase should be injected into the infiltrated area using a 25 gauge needle with up to five 0.2 ml injections in a circular pattern around the infiltrated area. A sterile needle is to be used for each injection. Hyaluronidase is most effective if administered within the first two hours after an extravasation, however, it may still be beneficial when given up to twelve hours after the event. It is effective for non-vasopressor infiltrates. There have been rare reports of allergic reactions, ranging from urticaria to anaphylaxis following its use (32). Hyaluronidase should not be injected into an infected or cancerous site (33).

Phentolamine is a nonspecific alpha-adrenergic blocking agent which serves as a competitive antagonist of alpha-adrenergic agents. It acts at both arterial and venous sites inhibiting vasoconstriction and allowing improved blood circulation through the affected area (7). This drug has proven effective in treating infiltrates that are vasoconstrictors. A maximum of 10 mg should be injected through the catheter or subcutaneously around the site. Phentolamine is most effective if given within the first 12 hours after the extravasation. The use of the drug in children has not been well documented and some sources recommend that it should not be given to premature infants due to the potential for excessive vasodilation (7). Phentolamine's adverse effects include acute hypotension, tachycardia and dysrrhythmias. The possibility of these serious side-effects should limit its use.

Glyceryl trinitrate acts as a vasodilator in the ischaemic area (24, 25). Transdermal patches containing 2.5 ml of glyceryl trinitrate delivers 0.2 mg of the drug in the first hour while producing a local concentration for venodilation. The final dose of glyceryl trinitrate used for this purpose should be no more than 2 mg per kilogram per day. These patches are applied to ischaemic areas following extravasation of fluids such as total parenteral nutrition with high dextrose and calcium concentrations. Glyceryl trinitrate patches are not indicated in neonates under 21 days or in the presence of skin breakdown because of the potentially variable absorption rate.

Specific antidotes exist for anthracyclines, mitomycin C and mustine (27, 34). For mitomycin C and anthracyclines, 50% topical dimethyl-sulphoxide is applied to the

affected area four times per day for 14 days. For mustine, 5-10 cc of 3% sodium thiosulphate is injected at several points around the circumference of the extravasation site.

Loth *et al* recommended early surgical intervention during the necrosis interval which is the period between extravasation and irreversible tissue damage (18). Surgery done early in the necrosis interval prevented skin necrosis. The necrosis interval for many of the vesicant chemotherapeutic agents is 72 hours and four to six hours for vasopressor agents (35, 36). Radiographic contrast agents have a necrosis interval of six hours (37). In our study, 11 patients developed skin necrosis but the necrosis interval was recorded in nine patients. In eight of these patients, the necrosis intervals ranged from 12 hours to 48 hours (average 31 hours). In the patient where the necrosis interval was recorded as three weeks, the time recorded was between the extravasation and when the patient returned to the clinic. Although the full extent of the damage from the infiltrates are not initially apparent and may not be evident until 24 hours after the event, most authors recommend immediate treatment as opposed to a "wait and see policy" (13, 14, 17, 20, 21).

In none of the 12 patients in the present series was any attempt made to aspirate the remaining fluid in the subcutaneous tissue. In addition, neither saline flush-out alone nor in combination with medications to relieve tissue damage was performed. Ten of the 12 patients reported herein remained in hospital 31 extra days (range six to 70 days) for treatment of the extravasation injury. Most protocols recommend hyaluronidase for non-vasopressor infiltrates and phentolamine for vasopressor infiltrates (13, 14, 19, 23).

Despite prompt recognition of the infiltration and early, appropriate treatment, tissue necrosis can still occur. This is related mainly to the toxicity of the solution as that determines the extent of the pre-operative skin damage (22). Awareness of methods to minimize extravasation will also reduce the incidence of skin necrosis. The following points are guidelines for good practice which may minimize extravasation injury (Table 5).

A protocol for treatment of extravasation is also recommended (Appendix).

Extravasation may be unavoidable, but if the appropriate measures are implemented promptly, morbidity can be greatly reduced. All medical and nursing personnel must be familiar with the protocols for treating the extravasation of drugs which have the potential for tissue damage.

Table 5: Guidelines for minimizing the risk of extravasation

1.	Do not site cannulae over joint spaces, as this can cause irreparable damage to nerves and tendons should extravasation of vesicant occur
2.	Ask patients to report any change in sensation, stinging or burning. Always listen to the patient
3.	Never cover cannula site with a bandage
4.	Dilute irritant drugs as much as possible and give at appropriate rate
5.	Whenever possible, administer vesicant drugs as a bolus
6.	Check for swelling, inflammation and pain around cannula site during administration of intravenous drugs
7.	Special vigilance is needed in patients who may not experience the pain of extravasation or are unable to localize the pain – babies, diabetics with peripheral neuropathy and patients with decreased level of consciousness
8.	A central line should be used to administer cytotoxic medication.

REFERENCES

1. Upton J, Mulliken JB, Murray JE. Major intravenous extravasation injuries. Am J Surg 1979; **137:** 497–506.
2. Robijins BJL, de Wit WM, Bosma NJ. Localized bullous eruptions caused by extravasation of commonly used intravenous infusion fluids. Dermatologica 1991; **182:** 39–42.
3. Ignoffo RJ, Friedman MA. Therapy of local toxicities caused by extravasation of cancer chemotherapeutic drugs. Cancer treat Rev 1980; **7:** 17–27.
4. Montrose PA. Extravasation management. Semin Oncol Nurs 1987; **3:** 128–32.
5. Gaze NR. Tissue necrosis caused by commonly used intravenous infusions. Lancet 1978; **2:** 417–9.
6. Denkler KA, Cohen BE. Reversal of dopamine extravasation injury with topical nitoglycerin ointment. Plas Reconstr Surg 1989; **84:** 811–3.
7. Montgomery LA, Budreau GK. Implementing a clinical practice guideline to improve pediatric intravenous infiltration outcomes. AACN Clin issues 1996; **7:** 411–24.
8. MacCara ME. Extravasation: A hazard of intravenous therapy. Drug Intell Clin Pharm 1983; **17:** 713–7.
9. Wang J, Cortes E, Sinks LF. Therapeutic effect and toxicity of adriamycin in patients with neoplastic disease. Cancer 1971; **28:** 837–43.
10. Yosowitz P, Ekland DA, Shaw RC. Peripheral intravenous infiltration necrosis. Ann Surg 1975; **182**: 553–6.
11. Millam DA. Managing complications of iv therapy (continuing education credit). Nursing 1988; **18:** 34–43.
12. Brown AS, Hoelzer J, Piercy SA. Skin necrosis from extravasation of intravenous fluids in children. Plas Reconstr Surg 1979; **64:** 145–50.
13. Khan MS, Holmes JD. Reducing the morbidity from extravasation injuries. Ann Plast Surg 2002; **48:** 628–32.
14. Schummer W, Schummer C, Bayer O, Mûller A, Bredle D, Karzai W. Extravasation injury in the perioperative setting. Anesth Analg 2005; **100:** 722–7.
15. Boyle DM, Engelking C. Vesicant extravasation: myth and realities. Oncol Nurs Forum 1995; **22:** 57–67.
16. Heckler FR. Current thoughts on extravasation injuries. Clin Plast Surg 1989; **16:** 557–63.
17. Gault DT. Extravasation injuries. Br J Plast Surg 1993; **46:** 91–6.
18. Loth TS, Eversmann WW, Jr: Extravasation injuries in the upper extremitiy. Clin Orthop 1991; **272:** 248–54.
19. Larson DL. Treatment of tissue extravasation by antitumor agents. Cancer 1982; **49:** 1796–9.
20. Larson DL. What is the appropriate management of tissue extravasation by antitumor agents? Plast Reconstr Surg 1985; **75:** 397–405.
21. Casanova D, Bardot J, Magalon G. Emergency treatment of accidental infusion leakage in the newborn: report of 14 cases. Br J Plast Surg 2001; **54:** 396–9.
22. Dufresne RG. Skin necrosis from intravenously infused materials. Cutis 1987; **39:** 197–8
23. Flemmer L, Chan JSL. A pediatric protocol for management of extravasation injuries. Pediatr Nrusing 1993; **19:** 355–8, 424.

24. O'Reilly C, McKay FMA, Duffy P, Lloyd DJ. Glyceryl trinitrate in skin necrosis caused by extravasation of parenteral nutrition. Lancet 1988; **2:** 565–6.
25. Vaksmann G, Rey C, Breviere GM, Smadja D, Dupuis C. Nitroglycerin ointment as aid to venous cannulation in children. J Pediatr 1987; **3**: 89–91.
26. Olver IN, Schwartz MA. The use of dimethylsulphoxide in limiting tissue damage caused by extravasation of doxorubicin. Cancer treat Rep 1983; **67:** 407–8.
27. Linder RM, Upton J, Osteen R. Management of extensive doxorubicin hydrochloride extravasation injuries. J Hand Surg 1983; **8:** 32–8.
28. Hastings-Tolsma MT, Yucha CB, Tompkins J. Effect of warm and cold applications on the resolution of IV infiltrations. Red Nurs Health 1993; **16:** 171–8.
29. Yucha CB, Hastings-Tolsma MT, Szeverenyi NM. Effect of elevation on intravenous extravasation. J Intravenous Nurs 1994; **17:** 231–4.
30. Buck ML. Treatment of intravenous extravasations. Pediatr Pharm 1998; **4:** 1–4.
31. Laurie SW, Wilson KL, Kernahan DA. Bauer BS Vistnes LM Intravenous extravasation injuries: the effectiveness of hyaluronidase in their treatment. Ann Plast Surg 1984; **13:** 191–4.
32. Zenk KE, Dungy CI, Greene GR. Nafcillin extravasation injury. Am J Dis Child 1981; **135:** 1113–4.
33. Banta C. Hyaluronidase. Neonatal Netw 1992; **11:** 103–5.
34. Bertelli G. Prevention, management of extravasation of cytotoxic drugs. Drug Saf 1995; **12:** 245–55.
35. Loth TS, Eversmann WW, Jr. Treatment methods for extravasation of chemotherapeutic agents. A comparative study. J Hand Surg 1986 **11A:** 388–96.
36. Close AS. Phentolamine hydrochloride in prevention of cutaneous necrosis due to levarterenol J Am Med Assoc 1959; **126:** 1916–7.
37. Loth TS, Jones DEC. Extravasations of radiographic contrast material in the upper extremity. J Hand Surg 1988; **13A:** 395–8.

Appendix: Protocol for the management of extravasation

As soon as extravasation is noticed, the following should be instituted