Intravenous therapy: Practice issues

This is the final article in a series of three concerned with the delivery of effective intravenous (IV) therapy to neonates and children. There are many clinical issues that influence the administration of IV therapy and this article will focus upon those most likely to be encountered by practitioners. The common complications that can occur and the strategies that can be employed to minimise them will be identified.

Claire Evans

BSc (Hons), RM RGN, Cert HE, ADM, Dip Med Soc Anth, ENB 405, N96,
Lecturer/Practitioner, Neonatal Unit, Warrington Hospital, North Cheshire Hospitals NHS Trust and
Neonatal Team, Department of Midwifery Studies, University of Central Lancashire

Annie Dixon

MSc, RGN/RSCN, PG Cert HE and NHS Mgt, Cert Counselling, R23, ENB 405
Senior Lecturer, Neonatal Team
Department of Midwifery Studies
University of Central Lancashire

Keywords

clinical considerations; IV equipment; IV disposables; incompatibilities; precipitation; in-line filters; IV complications; training

Key points

Evans, C., Dixon, A. (2006) Intravenous therapy: Practice issues. *Infant* 2(4): 133-36, 38, 39.

1. Professional accountability, calculation and safe administration are the three key elements involved in the competent and confident administration of IV therapy.
2. Nurses must have access to resources to minimise potential incompatibilities between infusions and/or drugs.
3. Using standardised equipment helps to reduce the incidence of adverse events as nurses become competent and confident in its use.
4. Appropriate selection of IV single-use items avoiding ill fitting or ineffective disposables, alleviates risk.
5. Cost benefit analyses and audit of new systems, equipment and disposables is important if a quality service is to be provided.

The aim of this article is to review current clinical perspectives with regard to IV therapy and how they affect infants and children. Issues to be explored include aspects of infusing solutions and drugs; concerns regarding equipment used for IV therapy; in-line filtration technology; documentation; and common complications of IV therapy. Strategies for reducing potential problems in these areas will be discussed to facilitate neonatal and paediatric nurses in the provision of best practice.

Parenteral fluids and medications

Both internal and external environmental factors affect the efficacy of prescribed IV therapy, whether administering fluid or medication. Whilst the factors involved in the delivery of one drug or infusion are manageable, compromised infants and children often receive multiple infusions or drugs[1,2]. The risk of chemical, physical or mechanical problems arising in these patients is much greater.

Nurses routinely commence IV therapy, therefore an awareness of the chemical composition of any fluid being infused is important as these may affect body systems depending on whether they are isotonic, hypotonic or hypertonic – these are defined in **FIGURE 1**.

Isotonic infusions have no net effect on the cells of the body, whereas hyper and hypotonic solutions can influence cell function. The tonicity of a solution will affect whether it can safely be administered via a peripheral line[3] as non-isotonic solutions can cause local irritation and pain along with electrolyte shifts in the body[4]. Therefore, when infusing *hypertonic* solutions such as total parenteral nutrition (TPN) or solutions with a dextrose concentration greater than 10%, it is important that central lines are used, whenever possible. This will minimise the risk of extravasation injury and prevent excessive amounts of fluid leaving cells due to the higher concentration of solutes in the extracellular fluid. Conversely, *hypotonic* solutions can lead to anaemia as the red blood cells may swell and rupture due to the osmotic absorption of the hypotonic solution infused[5].

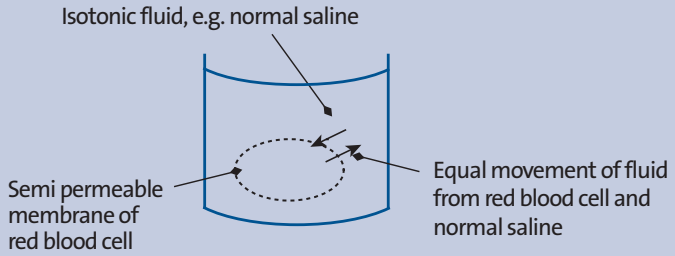
Similar principles apply when administering IV medications which is why some drugs, such as teicoplanin, require further dilution; and certain drugs can only be diluted in particular diluents[6]. When administering IV drugs it is important to remain within the manufacturer's recommended pH range to maintain drug stability, eg amphotericin B[7]. Failure to adhere to manufacturer's instructions may lead to unwanted side effects or a reduction in drug efficacy.

Incompatibilities/reactions between agents

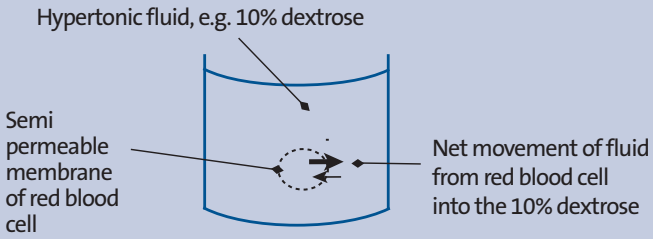
An incompatibility occurs when two agents that are not suitable to be mixed are combined. In IV therapy the agents involved are drugs, infusion fluids and infusion systems. Incompatibilities arise from interactions between these agents, e.g. drug ↔ drug, drug ↔ infusion fluid, drug ↔ infusion system and infusion fluid ↔ infusion system. There is a risk of incompatibility occurring with a single drug administration; however, this risk increases with regimes involving multiple drugs[8]. Therefore, potential incompatibilities should be identified through the use of available resources such as pharmacy, drug information units/help lines, the data sheet and other pharmacological texts.

A common form of incompatibility is precipitation. This is where agents interact to form particulate matter, for example,

Isotonic solution – has the same concentration as another solution. For example, in the body 0.9% saline is seen as isotonic as the amount of sodium in 0.9% NaCl is similar to the amount of sodium in the bloodstream. This means that there is no net movement of fluid from the cells of the body into the bloodstream.



Hypertonic solution – has a higher concentration than another solution. For example, in the body 10% dextrose in water is hypertonic. This means that there will be a net movement of water from the cells of the body into the bloodstream to try and maintain equilibrium.



Hypotonic solution – has a lower concentration than another solution. For example, in the body 0.45% saline is hypotonic as there is a smaller amount of sodium in the half strength saline solution than there is in the bloodstream. This leads to a net movement of fluid from the saline solution into the cells of the body.

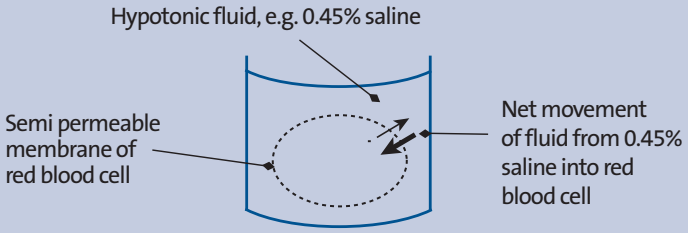


FIGURE 1 Types of intravenous solution.

calcium which is often used as a fluid additive[9]. Not all incompatibilities are visible with the naked eye, reinforcing the importance of knowledge regarding mixing of drugs and/or fluids together[10].

One strategy to reduce this risk is to have a dedicated access point for the administration of IV medication. In neonates this is usually an additional peripheral catheter and in children it is preferable to have central access, for example, peripheral intravenous central catheter (PICC), Port-a-Cath, Hickman or Broviac catheter[11], depending on the needs or treatment therapy required.

When interactions between agents occur, it is important to be aware of how a drug is affected. For example, a desired drug effect may be lost when drugs react together. Other drugs act synergistically where the combination of the drugs working together has an enhanced effect which can be positive, or conversely, may lead to adverse effects such as toxicity[12]. To reduce the risk of unwanted reactions occurring, appropriate and adequate flushing agents should be used before, between, and following medication administration. Local Trust guidelines will inform the type and amount of flush solution to be used in clinical practice. Many drugs are compatible with 0.9% normal saline, however, there are certain drugs that require alternative flushing agents, eg, amphotericin B[6] is only compatible with 5% dextrose, hence the importance of checking available literature to eliminate the risk of incompatibility for this reason.

Syringe size – does it matter?

Evidence would suggest that the size of syringe used when flushing and administering drugs is important. There are two main reasons for this – the pressure and velocity of the fluid.

Pressure

When a force is applied to the plunger of a syringe, the pressure generated is proportional to the surface area of the plunger. For example, when the width of the plunger is decreased by half the pressure is increased by a factor of 4, i.e. the ratio of the diameters squared. This means that if the same force is applied to the plungers of two syringes of different diameter, the syringe with the smaller radius (or diameter) will generate the larger pressure (in pounds per square inch – psi)[13-15]. In practice this would suggest that the narrower the bore of the syringe the greater the pressure exerted on the catheter and vein, which may lead to rupture if the pressure is too high[13], i.e. a 2mL syringe will exert a greater pressure than a 10mL syringe when the same force is applied to the plunger regardless of how much fluid is contained within the syringe.

Whilst the physics of this theory are reliable the mechanics in practice are variable. There is a danger that larger volumes of flush will be given when larger syringes are used, which is of particular importance in children on a strict fluid balance regime and in extremely low birthweight infants. Additionally, different operators may apply variable amounts of force to the plunger leading to disparity in practice.

Velocity

The velocity of the fluid leaving the syringe is directly proportional to the external force applied by the operator[14]. Thus, when the force applied to the plunger is doubled so is the velocity. The velocity will increase further as the fluid leaves the catheter within the vein. This is because the diameter of the catheter is smaller than the

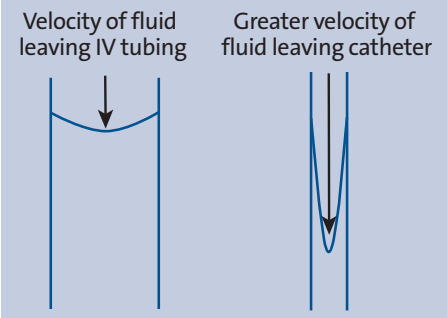


FIGURE 2 Velocity in relation to the diameter of the lumen.

diameter of the IV system tubing connecting the pump to the catheter, thus increasing the velocity further. For example, the velocity will be increased by a factor of 4 if the diameter of the catheter is half that of the IV tubing. This combined increase in velocity exerts a force which, if it impacts on the vein wall, may lead to puncture (**FIGURE 2**).

Until further empirical evidence suggests otherwise, healthcare professionals should refer to the RCN 'Standards for Infusion Therapy'[15] which advocates adherence to the catheter manufacturer's recommendations in relation to syringe size. In essence, syringe size continues to generate controversy within clinical practice. All staff administering IV therapy must continue to use their clinical skills and judgment when deciding if a catheter is offering resistance during the flush procedure or drug administration.

Maintenance of catheter patency and vein integrity

Many factors influence the length of time a catheter remains *in situ*. The material the catheter is made of, its gauge and length in relation to the size of vein, all directly affect the duration of the catheter life and efficacy.

There are some materials particularly suitable for the fragile and small veins of the neonate and child, for example, those that expand and soften to fit the contours of the vessel upon insertion[16]. Choice is often limited in the workplace due to a variety of reasons, including; a large selection of catheters exceeding the expiry dates; cost considerations of different makes; and personal preferences determining which catheters to stock. However, ensuring short term cost effectiveness does not always equate to long term benefits as higher failure rates lead to more disposables being used. The risk of complications is multiplied by the number of cannulation attempts undertaken; especially insertion site associated scarring in the neonate. Nurses should use the evidence base to challenge and promote the use of the most appropriate products for such vulnerable populations.

The location of the catheter can affect the functioning of the system eg, bony prominences and veins which bifurcate close to the point of insertion shoud be avoided. It is also important to choose the non dominant hand or arm when cannulating children to minimise loss of independence.

Fixation and splinting of catheters must comply with Trust guidelines to maximise observation of the site and minimise trauma to the skin. Appropriate use of these adjuncts also reduces bacterial contamination and maintains full functionality of the limb and catheter.

Common complications

Complications of IV therapy remain a significant hazard of its use[17,18]. The most common complications fall into three main categories – pathological, mechanical and chemical (**TABLE 1**). Pathological complications range from local occlusion of the cannula or infiltration of a non vesicant fluid into the surrounding tissues[19], to systemic involvement which can contribute to the risk of significant morbidity and mortality. Mechanical complications involve equipment and operator factors. Chemical complications refer to those that arise from the solution composition.

Other mechanical factors that can influence the development of injurious complications include duration of the infusion, incorrect infusion rate, site of the infusion and a poorly secured cannula.

A less common complication is extravasation which can be defined as the infiltration of a vesicant fluid (capable of causing necrosis) into the surrounding tissues[19]. All Trusts should have a policy in place in case such an adverse injury arises. In the event of this type of injury occurring Trust policy should be followed to minimise any long term sequalae[20,21]. However, a survey conducted by Wilkins and Emmerson[22], suggested that very few neonatal units actually have a policy for the management of extravasation injuries and indeed there is no clear evidence to suggest what optimal management may be. Further research is therefore required to establish the effectiveness of short term management strategies currently available to prevent the long term scarring from skin necrosis.

In order to reduce the incidence of the complications highlighted in this section nurses must combine available evidence with vigilant nursing care to have a positive impact upon the longevity of the catheter and vein. One approach to facilitate this would be to use an assessment tool to evaluate the catheter site regularly enabling early detection of problems.

IV filtration technology

The nature of intravenous access predisposes the system to iatrogenic and pathogenic events. For decades the adverse effects of particulate matter arising from intravenous therapy have been documented[23,24]. Despite all the quality measures in place when IV infusions and medications are being manufactured, there is still the possibility that some particulate matter will be present within the fluid. Therefore, the multidisciplinary team must always inspect the intravenous fluid, ampoule of medication and the infusion system for visible particles. Whilst it is unusual for any particulate matter to be seen visibly, its presence cannot be disregarded. The average human eye can usually see particles that are 0.5mm in

	Local	Systemic	Central access
Pathological	Infiltration Phlebitis Thrombophlebitis Haematoma from blood transfusion Localised infection Tissue necrosis from irritant solutions Extravasation	Thrombosis Air embolus Electrolyte imbalance Anaphylaxis Fluid overload Dehydration	Catheter thrombosis Catheter debris embolus Air embolus Pericardial effusion Endocarditis Bleeding from insertion site Catheter related blood-stream infection (CR-BSI)
Mechanical	Infiltration Phlebitis Extravasation Thrombophlebitis Haematoma from blood transfusion	Thrombosis Air embolus Electrolyte imbalance Fluid overload Dehydration Speed shock	Catheter malposition Catheter snapping Catheter thrombosis
Chemical	Phlebitis Thrombophlebitis Localised infection Extravasation	Drug toxicity Agent interactions	Catheter thrombosis Catheter debris embolus

TABLE 1 Common complications of IV therapy.

diameter[25], anything smaller is likely to require microscopic examination. Particulate contaminants can take the form of in-line chemical or microparticulate matter, entrapped air (with the potential for embolus formation) or microbacterial contamination[26].

Despite pathogenic-related pulmonary disease being confirmed by postmortem evidence[23] controversy still surrounds the use of filters. Adverse histology at post-mortem has been attributed to pulmonary microvascular deposits forming granulomata[27]. A range of particulate material has been identified in both neonatal and paediatric patient groups, in particular, cotton fibres, glass particles, rubber and crystalloid particles[28]. More extreme descriptions include crustacean claw particles reported in an Australian study by Garvan and Gunner (1964), cited in[29]. In another instance plastic syringe material was the identifiable cause in a fatal case of neonatal bowel necrosis[30]. These examples serve to highlight the spectrum of the problem.

The pathogenic consequences of such systemic contamination has been hypothesised to increase the severity of respiratory distress syndrome and multiple organ failure as a result of thrombosis, capillary endothelial damage, granuloma formation and initiation of neoplastic activity[29,32].

In clinical practice, filter needles are often utilised in place of in-line filters due to perceived cost effectiveness. There are several reasons why this may not be true. Firstly, accepted practice suggests that filter needles are primarily used when drawing up from glass ampoules[15,32] and due to their cost they are rarely used in other situations. Secondly, filter needles allow components less than 5 microns[33,34] to pass through and do not aid removal of particulate matter from IV solutions being infused. Thirdly, filter needles will not necessarily prevent or minimise the potential problem of air which has already accumulated in the IV system. These issues require consideration when debating the use of an in-line filtration system.

Ideally a 0.2 micron in-line filter should be employed when delivering IV therapy or medication to neonates or children who are less able to tolerate the complications of contaminated infusates[29]. Even a filter of this size will allow particulate matter into the body, but it will minimise the risk associated with the issues previously discussed.

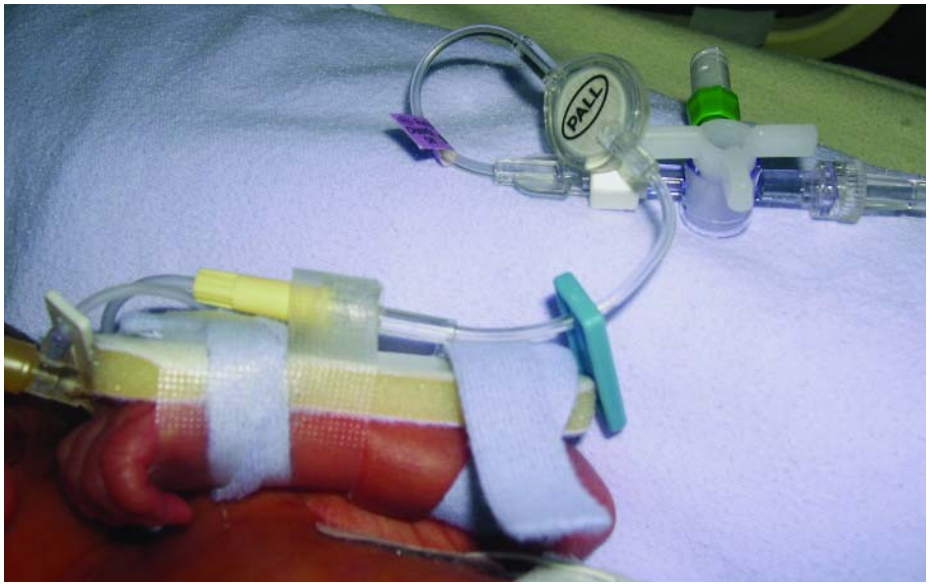


FIGURE 3 Baby receiving IV therapy with an in-line filter *in situ*, utilising the 3 'P' principle. *Reproduced with permission from Pall Medical.*

One neonatal audit evaluating the cost implications and practical aspects of using in-line filters, illustrated a significant reduction in equipment costs and IV fluid replacement over the 6 month study period when Pall 0.2 or 1.2 micron filters were used[35]. Supporting these findings, a prospective controlled trial by Van Lingen et al[26] suggested a significant reduction in complications such as thrombi and clinical sepsis in their filter use group, including a substantial reduction in the cost of disposables.

Catheter related bacteraemia remains a challenge for healthcare professionals. Many manufacturers produce filters that are able to trap bacterial as well as any particulate contamination, which forms within the IV system. There are filters available which offer a 96 hour endotoxin-retentive facility for non lipid solutions. This reduces microbacterial contamination and minimises the potential risks associated with system manipulations[28]. For the infusion of lipid emulsions a 1.2 micron filter is required[36].

Whilst research evidence supports the use of in-line filtration in regard to particulate matter, the efficacy of in-line filtration in preventing extrinsically induced bacteraemia[37] continues to be debated. In-line filters will only protect against intrinsic microbial contamination distal to the filter, therefore, the insertion site and cannula must be kept clean and dry with a fixation system that allows for regular visual assessment.

In order to combat extrinsic routes of contamination, many areas are now using needle free access devices[38] to minimise line manipulations and risk of catheter related bacteraemia. Despite the implementation of such preventative strategies, catheter related bacteraemia still occurs. Controversy surrounds the debate of whether to remove vital central access on the strength of probable contamination. Ideally, cases should be considered on their individual merits until further prospective randomised trials are conducted to provide empirical evidence as to the best course of clinical management[39,40].

The evidence presented provides a compelling argument for the use of in-line filtration for all neonates and children receiving intravenous drugs and fluids irrespective of access site. When considering placement of an in-line filter the health professional should follow the 'Three P' principle – Proximal Position Point, that is, the filter should be placed as near to the cannula as is possible to ensure maximum functionality (**FIGURE 3**).

However, as with all technology, the use of in-line filters must not preclude multidisciplinary team members from adhering to strict aseptic and clean techniques during the preparation and administration of intravenous therapy.

Equipment and disposables

Infusion systems often require a device to maintain the continuous administration of fluids, TPN, fluid bolus and slow infusion medication (**FIGURE 4**). There are a variety of devices available on the market and thus compatibility between catheters, infusion systems and infusion pump devices must be established based on clinical need.

All medical devices within Trusts must

be operated safely in compliance with the local Trust Medical Devices Policy. Such a policy will reduce any potential risk to patients, whilst maximising the function and clinical effectiveness of the devices. Therefore all staff should be conversant with the possible causes of malfunction. Problems related to infusion systems and pump devices are reported centrally through the Medicines and Health Care Products Regulatory Agency (MHRA). One of the many functions of the MHRA is to release safety information (Medical Device Alerts) on infusion equipment and provide information on the purchase, management and use of infusion systems to promote best practice[41]. The MHRA have stated that many of the problems reported about devices are associated with user error[41] which reinforces the need for ongoing mandatory competency-based training. To minimise the risk of adverse incidents standardised equipment should be used.

Given the constraints within which most neonatal and paediatric areas work this is not always achievable. As more technologically-advanced, safer, equipment becomes available, clinical areas will purchase what they can afford in order to replace out of date or broken equipment. This leads to a situation where several different makes of equipment that have the same function are available for use. In addition, infusion devices require the use of appropriate disposables to minimise the risk of system or operator error. Thus, the more infusion devices there are available, the greater the range of disposables that are in use. This may lead to a higher incidence of adverse events.

Existing infusion pump devices have the ability to measure in-line intravenous pressure and yet this does not facilitate the early detection of infiltration when used in isolation. There is no current consensus on appropriate pressure limits for use in neonates and paediatrics[42]. This is in part due to the fact that individual circumstances may require different pressure limits to be set[43]. Therefore in practice, pressure limits are set in an *ad hoc* manner, which may lead to inappropriate alarm limits being used. In addition, the pressure needed for an occlusion alarm to be triggered is usually higher than the pressure at which infiltration first begins to occur[44]. Therefore, nurses have to be competent and confident to use all available strategies including appropriate equipment, assessment tools and observation in order to minimise the risk of infiltration occuring.

FIGURE 4 Commonly used infusion device. *Reproduced with permission from Alaris Medical Products.*

The specific problems that can arise from the use of infusion devices can be reduced by ongoing mandatory equipment training, which will identify management strategies for troubleshooting such problems.

Documentation in relation to IV therapy

Accurate and contemporaneous documentation is an inherent part of professional accountability and excellence in nursing care[45]. When a catheter is inserted all relevant information should be recorded (**FIGURE 5**).

With regard to **FIGURE 5** the importance of documenting the time of insertion as well as the time of commencement of fluid therapy becomes apparent when considering central lines. Invariably there is a delay from insertion of the line to functional time, while awaiting X-ray confirmation of tip position. The longer this delay, the greater the risk that line function may be adversely affected.

Since the Guidelines for Records and Record Keeping[45] and Standards for Infusion Therapy[15], both state that complete information should be included in nursing and medical notes, then formal document labels, incorporating the information in **FIGURE 5** could be deemed to be best practice. Ideally, such measures should be employed for the whole infusion system including, for example, batch numbers of infusion set, long lines and expiry dates. By documenting the consumables used it would be possible to highlight and reduce the problems associated with any manufacturing faults. This information would also provide audit trails for clinical as well as cost effectiveness purposes.

Conclusion

The publication Standards for Infusion Therapy[15] provides a collection of evidence-based best practice statements which support the principles of IV therapy

The following should be documented upon completion of procedure:

- Evidence that informed consent was gained
- Name of practitioner inserting catheter
- Make, product type and gauge of catheter used
- Location of catheter placement
- Number and locations of unsuccessful attempts
- Time of insertion
- Length of time taken for procedure to be completed
- Type of dressing applied to catheter site
- Pain assessment and management strategies employed
- Condition of infant/child pre, during and post procedure
- Batch number of infusion system being used
- Equipment number and type of device being used
- Appropriate pressure and alarm limit settings
- Any other safety checks performed
- Patient fluid requirements
- Infusion batch number, expiry date, type and amount of fluid being infused
- Type and amount of fluid being infused
- Hourly infusion rate
- Time of commencement of fluid therapy
- Date when infusion system requires changing
- Date when in-line filter requires changing
- Date when needleless system requires changing

} can be facilitated by a tag system

FIGURE 5 Elements of documentation required for IV catheter insertion and/or fluid therapy.

irrespective of client group. This article has reviewed a number of the issues raised in the RCN document in relation to neonatal and paediatric IV therapy. It should be read in conjunction with the previous articles in this series to facilitate a tripartite approach encompassing professional accountability, accurate calculation and safe administration to minimise the potential iatrogenic complications associated with administration of IV therapy.

This series can only provide a superficial synopsis of IV therapy due to the extensive range of factors that must be considered. Hopefully the information included will stimulate further exploration of the topic and thus the continued implementation of an evidence base to evaluate and improve practice.

Acknowledgement

The authors would like to thank Dr Richard W McCabe, Department of Forensic and Investigative Sciences, UCLan for his input into syringe size and pressure. Thanks also go to Dr. Nick Wild, Consultant Paediatrician, North Cheshire Hospitals NHS Trust, Warrington Hospital for his comments on this article and others in the series.

Note

The authors are not endorsing any one product, but have provided examples of the type of equipment available to healthcare professionals.

References

1. **Ariffin H., Arasu A., Mahfuzah M., Ariffin W., Chan L., Lin H.** Single-daily ceftriaxone plus amikacin versus thrice-daily ceftazidime plus amikacin as empirical treatment of febrile neutropenia in children with cancer. *J Paediatrics Child Health* 2001; **37**(1): 38-43.
2. **Kolb E.A., Steinhertz P.G.** A new multidrug reinduction protocol with topotecan, vinorelbine, thiotepa, dexamethasone, and gemcitabine for relapsed or refractory acute leukaemia. *Leukemia* 2003; **17**(10): 1967-72.
3. **Moureau N.** Intravenous Catheter Selection and Tip Termination – A Guide to Making the Best Choice. Business Briefing: Long-Term Healthcare Strategies July Touch Group PLC. http://www.touchbriefings.com/pdf/14/lth031_r_moureau.PDF 2003 (20/04/2006)
4. **Springhouse Company.** Fluids and Electrolytes made Incredibly Easy. 2nd Edition. 2002.
5. **Vander A., Sherman J., Luciano D.** Human Physiology: The Mechanisms of Body Function. 8th International Edition. Mc Graw Hill International. 2001.
6. **Hey E.** (ed) Neonatal Formulary 4th Edition. BMJ Books, Blackwell Publishing http://www.blackwellpublishing.com/medicine/bmj/nnf4/default.asp 2003. (03/02/06)
7. **Paediatric Formulary Committee** (eds) British National Formulary for Children. British Medical Journal Publishing, London. 2005.
8. **Gikic M., Di Paolo E.R., Pannatier A., Cotting J.** Evaluation of physicochemical incompatibilities during parenteral drug administration in a paediatric intensive care unit. *Pharmacy World Science* 2000; **22**(3): 88-91.
9. **Royal College of Nursing.** Administering intravenous therapy to children in the community setting. RCN, London. 2001.
10. **Royal College of Nursing.** Competencies: An education and training competency framework of administering medicines intravenously to children and young people. RCN, London. 2005.
11. **McInally W.** Whose line is it anyway? Management of central venous catheters in children. *Paediatric Nursing* 2005; **17**(5): 14-18.
12. **Hardman J.G., Limbird L.E., Molinoff P.B., Ruddon R.W., Goodman Gilman A.** (eds) The Pharmocological Basis of Therapeutics 9th Edn (International) McGraw Hill, New York. 1996.
13. **Medicines and Healthcare Products Regulatory Agency**. One Liners "Blow Out" Issue 31 December. http://www.mhra.gov.uk/home/idcplg?IdcService=SS_GET_PAGE&useSecondary=true&ssDocName=CON007376&ssTargetNodeId=574 2004. (29/04/2006).
14. **Primhak R.H., Gathercole N., Reiter H.** Pressures used to flush central venous catheters. *Arch Dis Child FetalNeonatal Ed* 1998; **78**: F234.
15. **Royal College of Nursing.** Standards for Infusion Therapy. RCN, London. 2005.
16. **Beckton, Dickinson and Company.** The material difference in vascular access. BD, United States. http://www.bd.com/infusion/technologies/vialon/index.asp 2006. (20/04/2006).
17. **Workman B.** Peripheral intravenous therapy management. *Emergency Nurse* 2000; **7**(9): 31-37.
18. **Pettit J.** Assessment of infants with peripherally inserted central catheters: Part 1. Detecting the most frequently occurring complications. *Adv Neonatal Care* 2002; **2**(6): 304-15.
19. **Perdue M.B.** "Intravenous Complications" In: Infusion Therapy in Clinical Practice. 2nd Edn Pennsylvania: WB Saunders, 2001: 418-45.
20. **Hadaway L.C.** Preventing and managing peripheral extravasation. *Nursing* 2004; **34**(5): 66-68.
21. **Sawatzky-Dickson D., Bodnaryk K.** Neonatal intravenous extravasation injuries: Evaluation of a wound care protocol. *Neonatal Network* 2006; **25**(1): 13-19.
22. **Wilkins C.E., Emmerson A.J.B.** Extravasation injuries on regional neonatal units. *Arch Dis Child Fetal Neonatal Ed* 2004; **89**: F274-75.
23. **Granger C.A., Danial P.P., Roe J.A.** The Clinical Consequences and Management of Particulate Contamination in Paediatric IV Therapy. National Conference Proceedings: British Association of Critical Care Nurses, September. 1994.
24. **Parikh M.J., Dumas G., Silvestri A., Bistrian B.R., Driscoll D.F.** Physical compatibility of neonatal total parenteral nutrient admixtures containing organic calcium and inorganic phosphate salts. *Am J Health-System Pharmacy* 2005; **62**(11):1177-83.
25. **Wikipedia Encyclopedia**. Naked eye. http://en.wikipedia.org/wiki/Naked_eye 2006.(26/04/2006).
26. **Van Lingen R.A., Baerts W., Marquering A.C.M., Ruijs G.J.H.M.** The use of in-line intravenous filters in sick newborn infants. *Acta Paediatr* 2004; **93**: 658-62.
27. **Puntis J.W.C., Wilkins K.M., Ball P.A., Ruthton D.I., Booth I.W.** Hazards of parenteral treatment: Do particles count? *Arch Dis Child* 1992; **67**: 75-77.
28. **Pall Biomedical Clinical Update:** Filtration in IV Therapy for Neonates. 1999.
29. **Granger C. A, Danial P.P., Roe J.A.** The Clinical Consequences and Management of Particulate Contamination in Paediatric IV Therapy. National Conference proceedings: British Association of Critical Care Nurses, September. 1994.
30. **Cant A.J., Lenney W., Kirkam N.** Plastic material from a syringe causing fatal bowel necrosis in a neonate. *British Medical Journal* 1988; 296-99.
31. **Walpot H., Francke R.P., Burchard W.G., Agterncamp C., Mueller F.G., Mittermayer C.H.** Particulate contamination of intravenous solutions and drug additives during long- term intensive care. *Anaesthetist* 1989; **38**: 544-48.
32. **Lye S.T., Hwang N.C.** Glass particle contamination: Is it here to stay? *Anaesthesia* 2003; **58**(1): 93-94.
33. **Braun B.** Sharing Expertise: Product Catalog content B Braun Medical Inc. Bethlehem PA http://www.bbraunusa.com/images/bbraun_usa/bbrauncatalog.pdf 2005 (14/04/2006).
34. **Helapet.** Disposables for Hospital Pharmacies Online Catalogue ClinMed Group Company, Bedfordshire, UK. http://www.helapet.com/downloads/FilterNeedles.pdf 2006 (14/04/2006).
35. **Kunac D.L., Ball P.A., Braodbent R.S.** In-line intravenous filtration in neonates. Help not hindrance. *Aus J Hosp Pharmacy* 1999; **29**(6): 321-27.
36. **Bethune K., Allwood M.C., Granger C., Wormleighton C.** Use of filters during the preparation and administration of parenteral nutrition: Position paper and guidelines prepared by a British Pharmaceutical Nutrition Group Working Party. *Nutrition* 2001; **17**: 403-08.
37. **Ball P.A.** Intravenous in-line filters: Filtering the evidence. *Curr Opin Clin Nutr Metabol Care* 2003; **6**: 319-25.
38. **Rosenthal K.** Do needleless connectors increase bloodstream infection risk? *Nursing Management* 2006; **37**(4): 78.
39. **Nistalla K., Nicoll R.** Should preterm neonates with a central venous catheter and coagulase negative Staphylococcal bacteraemia be treated without removal of the catheter? *Arch Dis Child* 2003; **88**: 458-59.
40. **Benjamin D.K. Jr, Miller W., Garges H. et al.** Bacteremia, central catheters, and neonates: When to pull the line. *Pediatrics* 2001; **107**: 1272-76.
41. **Medicines and Healthcare Products Regulatory Agency.** How we regulate. http://www.mhra.gov.uk/home/idcplg?IdcService=SS_GET_PAGE&nodeId=26 2006. (29/04/2006).
42. **Gnanalingham M.G., Irving V., Shaw M.J.** Consensus on neonatal infusion pumps and pressure monitoring. *Arch Dis Child Fetal and Neonatal Ed* 2005; **90**: F93.
43. **Medical Devices Agency.** Infusion systems. http://www.show.scot.nhs.uk/gghbpharmacy/publications/national/MDA%20BULLETIN%202003%20(0).pdf 2003. (29/04/2006).
44. **Medical Device Safety Reports**. Infiltration during infusion therapy. http://www.mdsr.ecri.org/summary/detail.aspx?doc_id=8072 1998. (29/04/2006).
45. **Nursing and Midwifery Council.** Guidelines for Records and Record Keeping. NMC, London. 2005.