Management strategies for preventing complications in infusion therapy

Infusion therapy in critically ill infants using multiple IV lines can result in serious complications. One of the problems is the presence of particles within the infusion system. This can be eliminated and the safety of the procedure increased by the use of in-line positively charged nylon filters which remove micro- and nano-particles from the infusion system. Improvements can also be made to the standard line arrangements for the application of drugs. The background theory has been outlined in a hands-on training workshop on infusion management.

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The increasingly complex nature of infusion therapy and the growing number of patients receiving this treatment, have led to a concurrent rise in complications. However, many of these are preventable. This article presents solutions, such as the use of in-line filtration for removal of micro and nano-particles, standard line arrangements for the administration of drugs and the background theory as outlined in a hands-on training workshop on infusion management.

As ever more sophisticated hardware and a proliferation of drugs for infusion therapy become available, an increasing number of patients are benefitting from crucial life-saving IV administration of fluids, parenteral nutrition, drugs and blood products. However infusion therapy is a potentially hazardous procedure, which could lead to critically impaired organ function or death of the infant[1]. Further potentially serious risks include incorrect dosage, precipitation particles from drug incompatibilities, infection, phlebitis, thrombosis, extravasation, air embolism, hardware defects and mistakes in the rate of infusion. An evaluation of critical incident reporting systems showed that up to 50% of all documented treatment errors are related to infusion therapy[2].

PARTICLES IN INFUSION SYSTEMS

Micro- and nano-particles, which are contaminants of infusion solutions, have been shown to trigger the onset of inflammation. In *in vitro* studies particles have been shown to increase or decrease modulation of the immune response[3]. Particles may cause mechanical damage of endothelial cells and can lead to thrombosis, embolisation of small blood vessels – predominantly the pulmonary capillaries, or the formation of a nucleus for development of granulomas. Particles from a drug preparation have been found to cause loss of functional capillary density *in vivo*, which leads to an impairment of the microcirculation and may result in organ dysfunction[4]. In randomised clinical trials a reduction of thrombophlebitis by the use of in-line filtration has been shown[5]. Also a single-centre trial in 88 preterm neonates receiving in-line filtration showed a significant reduction in the occurrence of typical neonatal complications such as sepsis and systemic inflammatory response syndrome (SIRS)[6].

There is also evidence from slow motion camera footage that glass particles are produced when ampoules are broken open and may be infused into critically ill intensive care patients (*FIGURE 1*). Particle load depends on the number of solutions administered to patients, in particular short infusions and bolus injections increase the particle load[3].

Another complication of infusion therapy is the precipitation of particles resulting from a reaction between incompatible drugs administered simultaneously. Drug incompatibility reactions are preventable chemical and/or physical reactions between drugs, preservatives, buffers and stabilisers. They are generally visible as colour changes, clouding, gas formation, turbidity and/or formation of insoluble crystals or precipitates. Invisible incompatibility reactions are rare, but many may not be obvious to the naked eye, if the precipitate is contained in very small diameter tubing.

Drug incompatibility reactions account for up to 20% of all medication errors and up to 90% of administration errors and impair the efficacy of administered drugs or even increase side effects[7].

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In intensive care, the result of co-infusion of two drugs is uncertain in up to 45% of instances underlining the need for separate lines for the application of incompatible drugs to ensure therapeutic efficacy.

INFUSION MANAGEMENT SOLUTIONS

At Hanover Medical School, considerable experience of organisational problems and successful solutions for management of patients undergoing IV therapy has led to the development of an interdisciplinary educational workshop on infusion management for nurses, physicians and pharmacists. The team specialises in paediatric and neonatal therapy, but the model is equally applicable for adults. The workshop has been run successfully more than 25 times in Germany since 2009. It was run for the first time at the Wythenshawe Hospital in the UK in Manchester in May 2011 and will be available at ESPNIC in Hanover (2-5 November 2011) and at Erasmus Hospital in Rotterdam on 25 November 2011.

The workshop comprises a theory session outlining the risks involved in infusion therapy and a discussion of the solutions, followed by three simultaneous practical sessions. A session on drug incompatibility reactions teaches participants how to eliminate particles caused by incompatible medications and includes an outline of the licensing regulations for handling drugs (the 1969 Medicines Act in the UK) by a senior pharmacist. A second section involves practical training on vascular access with focus on the insertion of central venous catheters (CVCs) and intraosseous lines. The third session focuses on standard operation procedures of infusion sets and handling of infusion hardware. A fourth module is planned for the future covering calculation, handling and administration of parenteral nutrition.

MODULE 1: INCOMPATIBILITY PROBLEMS

Drug incompatibility reactions expose patients to considerable risks. For example, parenteral nutrition given with furosemide is known to destabilise pH and to cause precipitation. Also drugs added to lipid-containing parenteral nutrition may cause 'creaming' or over-sized lipid droplets.

There are currently around 1300 available drugs, presenting an overwhelming number of possible drug combinations, with a relative lack of published information about possible interactions when co-administered. Although considerably less are used in neonates, drug incompatibility is still an issue in this age group. Strategies formulated to address this problem include the 'one drug, one syringe' principle, the use of appropriate diluents,the need for standard operating procedures for the infusion setup and the use of a standard panel of drugs for which the chemical

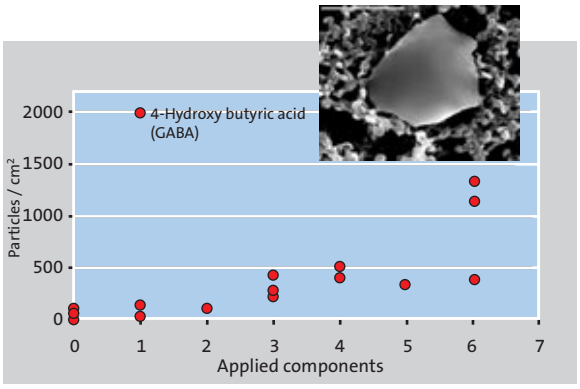

FIGURE 1 Electron microscopy of used filter membranes. The graph shows the correlation of measured particle load and the amount of applied components via the filter membrane (modified from Jack et al. Intensive Care Medicine[3]). In the right upper corner is an example of a typical particle retained by the in-line filter membrane (eg from opening of glass ampoules).

and physical properties are known. Compatibility is particularly important when two drugs are simultaneously administered via a Y-piece cannula. Information about compatibility can be found on certain internet resources and in reference books such as Trissel[8], which offers valuable information on administration sites and rates, pH, instructions for reconstitution, stability and compatibility for around 350 drugs. With so many possible interactions and incompatibilities of the different drugs, only computer programs can reliably give a prediction of possible complications.

MODULE 2: VASCULAR ACCESS

It is important staff are trained in safe and aseptic central venous, arterial and possibly intraosseous access. This includes optimal positioning of the patient, aseptic preparation of the equipment, use of ultrasound and Doppler techniques when appropriate, as well as for intraosseous access, opportunities to practise using eggs and chicken legs.

Central venous catheters (CVC)

There are several indications for insertion of a CVC sited in the jugular, femoral or subclavian veins. After adequate training ultrasound can be used to shorten the time of insertion and minimise complications. The femoral vein should be used in emergency cases and puncture can be done without sedation using only local anaesthesia. Compared to adults, insertion of the CVC is more difficult in neonatal and paediatric patients due to their small vessels. Frequently observed complications include thrombosis, embolism

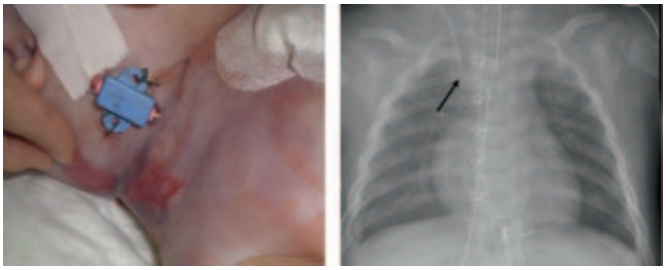

FIGURE 2 Displacement of a CVC in an infant after cardiac surgery. The original CVC became displaced (marked with arrow) because of insufficient fixation. The line tissued next to the insertion point and the extravasation caused a severe skin and tissue necrosis (infusion of glucose 10% and potassium chloride 7.45%).

and arrhythmia. Displacements, incorrect positioning, haemorrhaging and defective catheters are also common problems and can cause skin necrosis, pneumo-or haemothorax (*FIGURE 2*). In preterm and newborn infants umbilical vein cannulas can be used for drug administration, parenteral nutrition and measurement of central venous pressure, but should not be used for more than 5-7 days and sometimes can be incorrectly positioned causing complications[8].

Most crucial to avoid sepsis is an aseptic insertion, which may be carried out as a surgical procedure, with insertion, fixation and dressing under aseptic conditions. Use of a pre-assembled industry-standard CVC is advised to save time and protect against loss of sterility. The transparent and semi-permeable dressings allow easy visual control of the insertion site and prolong the interval between changes of insertion site dressing up to seven days, without an increase in catheter-related infections[9].

Intraosseous access

In an emergency in a paediatric patient if a peripheral venous access cannot be established within the first 60 seconds the European Resuscitation Council guidelines recommend the use of intraosseous access to provide fluids and medication. Placement can be in the tibia, femur or the head of the humerus, with location in the bone marrow. Once correctly located even high osmolarity solutions or vasoactive drugs can be safely applied by this technique.

MODULE 3: HARDWARE AND CVC LINE ARRANGEMENT

The standard infusion set-up taught at the workshop (*FIGURE 3*) uses a triple line CVC with the following assignment of lines:

- the distal line for monitoring and bolus injections
- the medial line for catecholamine therapy
- the proximal line for parenteral nutrition.

Sedation and heparinisation are always administered via separate peripheral venous access. In-line filters are fitted on each of the peripheral lines, on the distal line and on the parenteral line. Each catecholamine line should be fitted individually with a filter. Positively charged nylon filters with a pore size of 0.2 µm are generally used for crystalloid solutions and 1.2 µm filters for lipid-containing infusions. Crystalloid filters and IV system components are changed every 96 hours, the lipid filter every 24 hours.

The number of separate lines needed depends on the patient's condition, disease severity and the expected duration of infusion therapy. Patients, for example with septic shock, in need of inotropes, parenteral nutrition and treatment of severe acidosis, need a CVC within the first hour of treatment to guarantee safety and efficacy of therapy.

The 0.2 µm positively charged nylon infusion filters, can easily be integrated into a point-of-care infusion system and have been shown to considerably reduce complications associated with micro and nano-particles[7]. Membranes which have a positive charge across a wide pH range have been proven to significantly reduce nano-particles in particular. At Hanover, the use of in-line filters and a standard infusion set-up (*FIGURE 3*), has helped the paediatric ICU team to avoid complications and eliminated the need for daily time-consuming incompatibility checks.

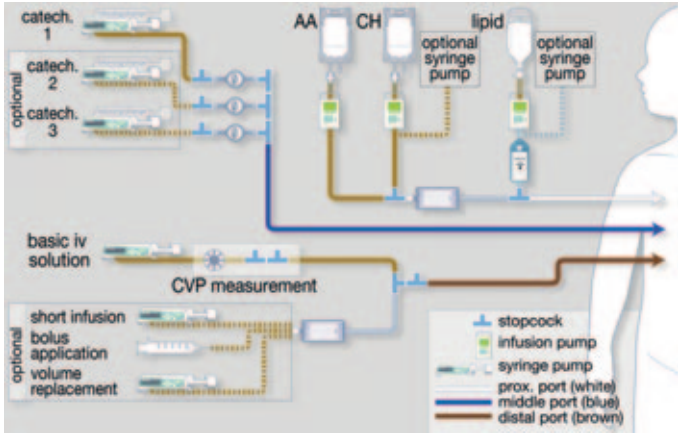

FIGURE 3 Infusion setup used at Hanover showing a triple-line CVC for parenteral nutrition, bolus applications, vasoactive drugs and central venous pressure measurement and the position of in-line filters.

CONCLUSION

The complexity of IV drug therapy has increased over the last few decades and thus, the correct administration of drugs and fluids has become a challenge for both physicians and nursing staff. Standard operating procedures and training of staff are vital to improve patients' safety on the ward.

REFERENCES

1 **Valentin A. et al.** Errors in administration of parenteral drugs in intensive care units: multinational prospective study. *BMJ* 2009; 338:b814.

2 **Hübler M. et al.** [Anonymous critical incident reporting system. Implementation in an intensive care unit]. *Anaesthesist* 2008; 57:926-32.

3 **Jack T. et al.** Analysis of particulate contaminations of infusion solutions in a pediatric intensive care unit. *Intensive Care Med* 2010;36:707-11.

4 **Schaefer S.C. et al.** 0.2µm in-line filters prevent capillary obstruction by particulate contaminants of generic antibiotic preparations in postischemic muscle. *Chemother J* 2008;17:172-78.

5 **Falchuk K.H. et al.** Microparticulate-induced phlebitis. Its prevention by in-line filtration. *N Engl J Med* 1985;10;312:78-82.

6 **van Lingen et al.** The use of in-line intravenous filters in sick newborn infants. *Acta Paeditr,* 2004;93:658-62.

7 **Trissel, Lawrence A.** Handbook on Injectable Drugs. *American Society of Health-System Pharmacists®.* 16th edition, 2011.

8 **Schlesinger A.E. et al.** Neonates and umbilical venous catheters: normal appearance, anomalous positions, complications, and potential aid to diagnosis. *AJR* 2003;180:1147-53.

9 **Timsit J.F. et al.** Chlorhexidine-impregnated sponges and less frequent dressing changes for prevention of catheter-related infections in critically ill adults: a randomized controlled trial. *JAMA* 2009;301:1231-41.