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ORIGINAL ARTICLE

Practical considerations in the administration of intravenous vasoactive drugs in the critical care setting: the double pumping or piggyback technique—part one

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Summary Part I of this review aims to identify the factors associated with safe administration of continuous intravenous vasoactive drug therapy, specifically epinephrine and norepinephrine. Intravenous vasoactive drugs are administered in the critical care setting to maintain patients' cardiovascular function by continuous intravenous infusion. To ensure uninterrupted administration, one infusion is commenced when the other is almost empty. A technique often employed to achieve this is known as 'double pumping' or 'piggybacking'. Due to the absence of a standardised protocol for administering continuous intravenous vasoactive medication and technological developments in infusion pumps, a review of current literature was undertaken. Despite a paucity of evidence regarding safe administration of these drugs, recommendations from the available literature included ensuring that critical care nurses are competent and formally trained in the use of equipment and the administration of continuous intravenous vasoactive medication. Furthermore, the infusion pump should feature minimal start up delay, a sensitive occlusion alarm system and the absence of a bolus in the event of infusion occlusion. This may reduce patients experiencing adverse haemodynamic responses due to alterations to the infusion. Indeed, a review of the 'double pumping' or 'piggybacking' technique in the clinical setting is required to establish current practice and develop evidence based guidelines.

Introduction

Patients admitted to critical care units may require intravenous vasoactive medication to optimise or support their cardiovascular function. Vasoactive medications are substances that affect the

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blood vessels, vascular tone and cardiac output. Inotropes (e.g., epinephrine, norepinephrine and dopexamine) alter the contractility of the heart's myocardium and therefore influence how effectively the heart can pump (Davies, 2001; Sheppard, 2001). Other groups of vasoactive medication include vasopressors (e.g., vasopressin and phenylephrine), phosphodiesterase inhibitors (e.g., milrinone) and nitrates (e.g., nitroprusside) (Opie and Gersh, 2001).

Continuous intravenous vasoactive medication infusions are administered utilising the double pump or piggyback technique via central venous access. This is where one infusion is substituted for another without interrupting the flow of drug to the patient. However, there are a number of techniques by which this may be achieved, many of which are not evidence based.

The aim of this review was to identify risk factors and other variables associated with the administration of intravenous vasoactive medication; establish best practice for the administration of concentrated vasoactive medication in the critical care setting and ascertain the evidence base to support current practice to minimise the risks associated with continuous administration of vasoactive medication. Part II will evaluate the safest infusion exchange method for critically ill patients utilising a clinical practice audit of a standardised protocol and training programme based on factors highlighted in this review.

Search strategy

A literature search was undertaken utilising Medline (1993—present), Cumulative Index to Nursing, Allied Health Literature (CINAHL) (1984—present) and manual searches of critical care journals. Keywords included infusion pumps, intravenous infusions, inotropes, vasoactive drugs, double pumping, piggybacking and medical devices. Terms were exploded to ensure identification of all potentially relevant material.

Vasoactive medication

Vasoactive medications have a very short half life (Sheppard, 2001). Consequently, if administration is not consistent, fluctuations in cardiac function with a consequent potential risk to patients' haemodynamic status may occur (Table 1).

Vasoactive medication infusions are administered in either a concentrated or more dilute form with a sole aim to maintain and support stable cardiovascular function (Davies, 2001). Table 2 illustrates that vasoactive drug dilutions which deliver the same drug dose in different fluid volumes, consequently varying the infusion rate and infusion device required for administration.

A concentrated continuous infusion of vasoactive medication, rather than a dilute concentration is frequently utilised due to fluid restrictions for critically ill patients. Furthermore, these medications are administered via central venous access to en-

Table 1 Examples of vasoactive medications and their cardiovascular effect (Davies, 2001; Opie and Gersh, 2001).

Vasoactive medication	Terminal half life	Cardiovascular effect
Norepinephrine (noreadrenaline)	2—3 min	Peripheral vasoconstriction, increased afterload, heart rate and improved coronary blood flow resulting in increased blood pressure.
Epinephrine (adrenaline)	2 min	Increased myocardial contractility and heart rate resulting in increased blood pressure, cardiac output and cerebral perfusion.
Dobutamine	2—3 min	Increased cardiac output and reduced afterload.
Dopexamine	7 min (11 min in patients with low cardiac output)	Increased cardiac output, reduced afterload due to vasodilation resulting in increased blood supply to the kidneys and splanchnic vessels.
Vasopressin	10—20 min	Potent vasoconstrictor with increased sodium reabsorption resulting in increased blood pressure.
Milrinone	45 min	Increased myocardial contractility and vasodilation.
Hydralazine	2—8 h	Arteriolar dilator given as a bolus not continuous infusion. Increased cardiac output and reduced afterload.

Table 2 Two dilutions methods for administering intravenous vasoactive medication in the critical care setting.

Infusion	Example	Dose per millilitre	Infusion device
Dilute	Norepinephrine: 4 mg in 500 ml of 0.9% (w/v) sodium chloride or 5% (w/v) dextrose	Low concentration per millilitre of solution: 8 μg/ml	Volumetric infusion pump
Concentrated	Norepinephrine: 4 mg in 50 ml of 0.9% (w/v) sodium chloride or 5% (w/v) dextrose	High concentration per millilitre of solution: 80 μg/ml	Syringe pump

able rapid delivery to the systemic vascular system and prevent local effect on peripheral veins, e.g., extravasation and tissue necrosis (Sheppard, 2001).

Continuous intravenous vasoactive medication

A continuous infusion of intravenous vasoactive medication, using a medical device, is utilised to maintain cardiovascular stability and achieve a constant plasma concentration. When commencing intravenous vasoactive medication, the dose should be increased until the desired effect is achieved (Sheppard, 2001). If the infusion is interrupted, e.g., when replacing the infusion, cardiovascular instability may occur. To reduce alterations in plasma concentration it is often necessary to have the same drug running simultaneously in two infusions. One of these infusions will be near completion while the second replacement infusion is introduced by means of a multiway stopcock, e.g., a three-way tap. This technique is colloquially known as 'double pumping' or 'piggybacking' (Crisp, 2002). Skill and experience are required with this technique, both to prevent over or under infusion of the intravenous vasoactive medication and to manage any alterations in blood pressure and heart rate during the procedure.

Anecdotal evidence and an article by Crisp (2002) suggested various methods were utilised to achieve this infusion exchange. Crisp (2002) found the most frequent method documented by nursing staff involved running both infusions together. The new infusion was titrated to maintain the patient's cardiovascular function within appropriate parameters whilst the near ending infusion was reduced until the patient's cardiovascular function was once again maintained using a single infusion or the infusion ended. This may, however, have been problematic, with patient's experiencing periods of hypotension, hypertension and consequent cardiovascular instability. Reasons for this may have been due to the mechanics of the infusion device, the double pumping or piggybacking technique or the nurses' level of experience. Furthermore, although this study provided the first published clinical guidance for infusion exchange, the technique was that most frequently utilised by nursing staff.

With improvements in infusion device technology and until recently, the absence of a published standardised protocol for the administration of intravenous vasoactive medication, a review of the available literature associated with medical devices was undertaken.

Medical devices

The Department of Health utilises a universal system of classifying both infusion devices and the properties that infusion devices should feature to safely deliver medications (Table 3; Fox, 2000b).

Table 3 Classification of infusion devices and associated intravenous medications.

Infusion classification	Intravenous medication	Main features	Model example
High risk infusions	Epinephrine, norepinephrine, nimodopine, cytotoxic medication	Accurate and consistent flow; good occlusion alarm response; comprehensive alarm displays. At a rate of 1 ml/h, the occlusion alarm pressure must be less than 500 mmHg. Bolus following release of occlusion at all flow rates less than 0.6 ml/h.	Alaris, Asena

Table 4 Desirable and essential features of a high risk syringe pump for the administration of intravenous vasoactive medication in the critical care setting.

Essential	Desirable
Mechanisms to:	Easy to use
Reduce start up delay	Affordable
Prevent medication bolus	Clinical support package on implementation of the device into the critical care unit
Prevent free flow	Feature to change the infusion rate without stopping the infusion
Confirm rate changes	
Purge a new administration set using the device	
Sensitive occlusion alarm systems	

Continuous intravenous vasoactive medication must be administered via a high risk infusion device because of its ability to infuse at low flow rates but maintain highly accurate delivery (Auty, 1995; Jenson, 1995). However, with no universal guidance on drugs for intravenous infusion, syringe pumps may be inappropriately selected with resultant loss of accuracy (Pickstone, 1994). A syringe pump categorised as high risk by the Medical Devices Agency should demonstrate a number of features, either desirable or essential (Table 4). These features may assist critical care staff to maintain patients' cardiovascular function during infusion exchange.

Start up delay

When a syringe pump is started, there is a time delay before the medication is delivered to the patient irrespective of the set flow rate (Amoore and Adamson, 2003; Amoore et al., 2001; Medical Devices Agency, 1998; Morling, 1998; Quinn, 2000). The syringe pump engaging with the syringe plunger and subsequent medication delivery at the pre-set rate is not immediate. This is due to mechanical slack in the pump-syringe system, both in the driving mechanism and placement of the syringe in the infusion pump (Amoore et al., 2001; Quinn, 2000). The lower the pre-set flow rate, the longer the time required to take up the mechanical slack, resulting in an increase in start up delay. Indeed, this delay may be as long as forty minutes to one hour (Amoore et al., 2001; Medical Devices Agency, 1998). Consequently, patients may not receive the required intravenous vasoactive medication dose or the administration line and the central venous catheter may occlude (Medical Devices Agency, 1998).

Methods to reduce this include fitting the syringe tightly into the driver (Fox, 2000b) and priming the infusion system (administration line) utilising either the bolus or purge feature prior to connection to the central venous catheter (Amoore et al., 2001; Medical Devices Agency, 1998; Quinn, 2000). However, administration lines are frequently primed manually resulting in no increase in pressure in the infusion system. Priming the administration line using the pump may not, however, eradicate the start up delay due to compliance within the system, which must be overcome (Medical Devices Agency, 1998).

Patency

Maintaining patency of an infusion administration line is important when administering any medication, however is essential for patients dependant on vasoactive medication. If blood flows back into the administration line or central venous catheter lumen, patency will be compromised and affect the start up delay time (Amoore et al., 2001). Subsequently the flow of medication may be interrupted causing cardiovascular instability, in addition to central venous catheter occlusion.

Occlusion

Occlusion may result from a kinked administration line, a blocked central venous catheter lumen or when the pressure in the vein is higher than at the tip of the central venous catheter (Mallett and Dougherty, 2001). The patient's supported cardiovascular function may be compromised if the intravenous vasoactive medication is interrupted (Davies, 2001; Quinn, 2000). If the administration line or central venous catheter lumen requires flushing due to occlusion, this may result in a bolus of vasoactive medication being administered to the patient with an adverse effect on cardiovascular stability.

The pressure required to deliver medication via a syringe pump is influenced by:

- bore size of the infusion set,
- flow rate,
- resistance to flow,
- length of the administration line,
- viscosity of the solution (Quinn, 2000).

The occlusion pressure alarm limits determine when the user is alerted to the occlusion and the subsequent volume of bolus the patient receives following occlusion resolution (Quinn, 2000). When administering intravenous vasoactive medication, the infusion pump should have a feature preventing medication bolus (Medical Devices Agency, 1998).

Free flow or syphonage

A solution may flow freely through the administration set to the patient due to gravity or a leak of air caused by a cracked syringe barrel (Fox, 2000b). Wallace (1996) reported the fatality of a patient due to syphonage from a syringe pump opoid infusion. The risk of free flow may be reduced by ensuring the syringe is securely loaded into the syringe driver and the equipment is placed at a safe height above the patient (Morling, 1998; Pickstone, 1995). The optimum height varies within the literature. Some authors suggested that the safe distance was 80 cm (Pickstone, 1995; Wallace, 1996), however more recently, placing the infusion device no more than one metre above the patient's heart was recommended (Pickstone, 1999; Springhouse Corporation, 1999). This created seventy millimetres of mercury of pressure, preventing back flow of blood by overcoming venous return.

User knowledge

To reduce user error, knowledge of the equipment and operating instructions is essential (Crisp, 2002; Glenister, 2000; Pickstone, 1995; Quinn, 2000; Whyte, 2001). In a review of critical incidents associated with infusion devices, Fox (2000a) and the Scottish Home Office (1995) reported the majority of incidents related to the over infusion of medications, potentially related to inappropriate use of the medical device. The Medical Devices Agency (1995) monitored adverse events associated with medical devices. Between 1989 and 1994 in England and Wales, five hundred and five reports were received including 12 fatalities (Fox, 2000b). Nearly half of these incidents were due to over infusion and 80% due to user error, rather than a fault with the medical device (Fox, 2000b; Wallace, 1996). Infusion device technology is continually improving and it is therefore essential for all healthcare professionals to be trained in and maintain their knowledge and skills required for safe use of devices, including regular updates.

Healthcare professionals should also be aware of the therapeutics associated with the medication they administer, including dose, side effects, precautions and contra-indications (Nursing and Midwifery Council, 2002a). The professional group most frequently associated with medication preparation is nurses. As such, this group must be aware of medication administration policy and guidelines including that medication should not be reconstituted and prepared in advance of their immediate use or administer medication prepared by another practitioner when not in their presence, unless it is an already established infusion instigated by another practitioner (Nursing and Midwifery Council, 2002a).

Crisp (2002) surveyed current double pumping or piggybacking methods in several intensive care units across the United Kingdom and reported deficits in nurses' knowledge of infusion devices. In particular, nurses were confused by the term mechanical slack and the implications associated with the administration of medication. This information deficit may impact on the delivery of intravenous vasoactive medication, resulting in under infusion, cardiac instability and the potential for over infusion with bolus dosing.

Education may however be problematic, inadequate and variable in nature and quality (McConnell, 1995). It was suggested that in-service practical training was efficacious to assist nurses with their competence to solve problems and be aware of their limitations (Morling and Ford, 1997). Although equipment is an important element to caring for a critically ill patient it does not replace the healthcare professional and the skill of observation (Williams and Lefever, 2000).

Infection control

Administering medication via a central venous cathether presents an increased risk of infection. Patients requiring critical care support are more susceptible to infection due to their immunocompromised condition and critical ill status (Polderman and Girbes, 2001). Patients may

develop a central venous catheter related infection due to inadequate device decontamination prior to manipulation (Department of Health, 2001, 2003). During the double pumping or piggybacking procedure, syringes are frequently disconnected from the administration line, therefore increasing the risk of infection, particularly if decontamination is omitted. To reduce the risk of microbial contamination and potential infection, stringent hand washing with 4% (w/v) chlorhexidine in 4% (v/v) isopropyl alcohol or the use of alcoholic handrubs should be adhered to prior to and following central venous catheter manipulation. Furthermore, clean gloves and an apron should be worn when caring for the patient (Department of Health, 2003).

Prior to manipulating the central venous catheter, the stopcock entry ports should be disinfected with an alcoholic solution and allowed to air dry to reduce the risk of contamination (Department of Health, 2003). Indeed, needleless connectors may be used to maintain positive pressure in the catheter lumen and prevent exposure to air as well as reducing central venous catheter associated infection rates (Gabriel, 2002).

Following the recent publication of the Department of Health (2003) guidelines for prevention of infection and management of central venous catheters, healthcare providers should review any local documentation to adhere to evidence based guidelines.

Record keeping

Healthcare professionals should make clear, accurate and immediate records of all administered medication, ensuring that entries are signed and legible (Nursing and Midwifery Council, 2002b). Nurses should be aware that accurate record keeping is integral to their professional practice.

There are various methods used to document intravenous vasoactive medication administration in addition to the prescription chart. In the authors' clinical practice, nurses often document the rate per hour, the volume left in the syringe every hour, the dose infused per hour or a combination of these methods. Documenting the actual volume of drug delivered to the patient minimises potential inaccuracies from start up time delay and enable recording of bolus administrations. In clinical practice there is usually no facility to record any extra volume infused during periods of infusion exchange, unless each new infusion is recorded on a separate line of the observation chart. In addition, infusion exchange can result in over infusing, which may exceed prescribed dose ranges (Crisp, 2002).

Standardised protocols or clinical guidelines

Crisp (2002) reported three methods of infusion exchange:

(i) a new syringe at a low rate and increasingly titrated as the near ending syringe was reduced;
(ii) a new syringe at the same rate as the near ending syringe and reducing the near ending infusion rate;
(iii) a new syringe at the same rate as the near ending syringe and stopping the near ending syringe.

Seventy-five percent used the second method compared with 50% from the author's critical care unit. This study presents limitations with regard to the evidence base of the infusion exchange methods. Crisp (2002) suggested that the most frequently used method should be implemented as the standard, however its efficacy was not evaluated against patient variables including cardiovascular stability during infusion exchange. Furthermore, Crisp (2002) reported that only 21% of critical care units had a protocol or guidance supporting their method of infusion exchange, reflecting the paucity of evidence.

Conclusion

The aim of this review was to identify risk factors and other variables associated with administration of intravenous vasoactive drugs; establish best practice for the administration of concentrated vasoactive medication in the critical care setting and ascertain the evidence base to support current practice.

Currently there is a paucity of evidence on administration of intravenous vasoactive medication for critically ill patients. When administering these medications in a concentrated form, the frequently used technique to exchange a near empty infusion without interrupting its continuous flow is described as 'double pumping' or 'piggybacking'. Although there are at least three methods for infusion exchange used in current practice (Crisp, 2002), there is little evidence on which method causes least fluctuation in patients' cardiovascular stability. The efficacy of infusion exchange

appears to be dependent upon the experience and knowledge of the critical care nurse, as well as the medical device. Device choice, start up delay, free flow, line patency and user knowledge all influence the efficacy of intravenous vasoactive medication administration and patients' cardiovascular stability. Furthermore, infection control issues should be considered to ensure minimal risk of infection due to the central venous catheter.

Recommendations from the literature which may minimise the risks associated with intravenous vasoactive medication infusions include using a written protocol or clinical guideline; an infusion device classified for ''high risk'' infusions; prime or purge the infusion system before connecting to the patient and carefully monitor changes in cardiac function during infusion exchange.

Furthermore, a review of medical devices and the development of guidelines is necessary to establish national standardised clinical practice within critical care settings. Guidelines and an evidence based standardised protocol are required to ensure that patients receive care regardless of the critical care unit. Moreover, adherence to Clinical Governance necessitates critical care units and individual staff to embrace the shared goal of minimising hazards related to infusion pumps by improving service quality (Williams and Lefever, 2000). Indeed, by implementing evidence based guidelines and training with consequent staff competence, these factors should improve standards, procedures and clinical risk management awareness with a subsequent impact on Clinical Negligence Schemes for Trusts (CNST) management standards.

Part II of this series will aim to establish the safest infusion exchange method for critically ill patients. Results of a clinical practice audit using a standardised protocol, training programme and equipment measuring patients' haemodynamic parameters will be reported.

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