Exploring the clinical effects of height elevation and depression on syringe pumps

The position of syringe pumps in relation to patients affects the delivery of drugs. This article discusses the risks of raising and lowering these devices.

**INTRODUCTION**

Changing the elevation of syringe pumps in relation to the entry site has clinical implications. These are generally associated with volume changes in the flexible components of the system, such as connection lines and syringes, and are caused by pressure changes as these components are raised or lowered.

It is crucial for nurses to understand the effects of changing the elevation of a device in relation to the patient, as it can alter the rate at which the drug is delivered. If the device is raised, this can result in the patient receiving a bolus dose; if it is lowered, it may interrupt the infusion.

For a given level change, the effects are greater where the flexible component can be more easily deformed by a change in pressure. This characteristic is known as compliance; the higher a system’s compliance, the greater the effect of a change in pressure.

For a given syringe pump and flow rate there is also a direct link between the time to occlude and the compliance of the infusion line. These effects are more pronounced at low flow rates, where a system of high compliance may take significantly longer to occlude than one of low compliance. This means care should be taken when evaluating infusion devices for occlusion characteristics. Such evaluations need to be identified with the compliance value of the delivery systems (lines and syringes) being used.

Most infusions via a syringe pump in the UK use 50ml syringes, which allow for long periods between syringe changes but also lead to greater system compliance, largely due to the more easily deformable rubber plunger head.

**BACKGROUND**

A number of researchers, including Donald et al (2007) and Neff et al (2001), have studied the performance of syringe pumps when their height elevation in relation to the entry site is changed. They suggested that caution should be taken when drugs such as inotropes and vasodilators are being administered at low flow rates in situations where the syringe pump may have to be moved. For example, increasing the height of a device delivering a positive inotrope such as noradrenaline where patients receiving drug infusions are to be moved, a risk assessment should be undertaken on the possible effects of changes in the relative heights of the entry site and the syringe pump.

Protocols should be developed for safely transferring patients who are receiving infusions. Nurses need to understand the dynamics of drugs administered by infusion.

The use of more dilute infusates delivered at higher flow rates should be considered as a way of reducing the risks associated with height changes.

**TABLE 1. OBSERVED EFFECTS ASSOCIATED WITH HEIGHT ELEVATION CHANGES OF SYRINGE PUMPS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value of ZDDT</th>
<th>Value of retrograde aspiration volume</th>
<th>Bolus volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height change</td>
<td>Increases with extent of level depression</td>
<td>Increases with extent of level depression</td>
<td>Increases with extent of level elevation</td>
</tr>
<tr>
<td>System compliance</td>
<td>Increases with increasing compliance</td>
<td>Increases with increasing compliance</td>
<td>Increases with increasing compliance</td>
</tr>
<tr>
<td>Flow rate</td>
<td>Increases with decreased flow rate</td>
<td>No dependence on flow rate</td>
<td>No dependence on flow rate</td>
</tr>
</tbody>
</table>
could deliver a bolus dose that would increase the patient's blood pressure, while lowering the device could interrupt drug delivery and reduce blood pressure.

These studies use specific terms related to changes in the height of syringe pumps in relation to the entry site:

- **Zero drug delivery time (ZDDT)** is where drug delivery is stopped when the infusion device is lowered;
- **Retrograde aspiration volume** is the volume of fluid aspirated from the patient when the device is lowered;
- **Infusion bolus** is the volume of fluid infused when the device is raised.

Researchers have described characteristics of infusions when subject to changes in elevation. Neff et al. (2001) observed values of ZDDT, retrograde aspiration bolus and infusion bolus for three models of syringe pump. Volume or flow changes were measured using an electronic weighing balance.

Igarashi et al. (2005) described how raising and lowering syringe pumps during the administration of noradrenaline could lead to haemodynamic instability in animals. A particular concern is where the ZDDT caused by lowering a device is equivalent to the activity time of the drug being delivered. In the example of noradrenaline, the body responds rapidly to inadequate drug levels, so this could result in a dangerous lowering of the patient's blood pressure.

The effect of infusion line compliance, including the syringe, has also been linked to start up times of syringe pumps. Lines incorporating smaller syringes demonstrate faster start up flow characteristics (Schmidt, 2010).

**MECHANISM OF EFFECTS**

Most of the effects of height change can be explained by pressure changes within components of the infusion system and their compliance properties. These components have specific values of compliance, often expressed as microlitres per mmHg pressure.

A change in pressure can, in turn, change the volume of components such as the infusion line and syringe. Components with low compliance tend to be more rigid and deform less as a result of changes in line pressure.

Despite the significance of compliance values in infusion lines and syringes and their response to changes in height elevation, manufacturers do not make information on these values available. Without this, health professionals have no way of knowing how to manage overall system compliance.

However, researchers have established some information on the effects of compliance. Weiss (2000) found that the compliance of delivery lines that incorporate syringes is dominated by the component associated with the syringe, and that the component of syringe compliance was in direct proportion to the cross sectional area of the plunger. This effect can be demonstrated in a 50cc syringe, where positive pressure will easily deform the rubber plunger head.

Table 1 summarises the observed effects associated with height elevation changes of syringe pumps.

Various researchers have suggested ways to minimise the effects of height change. These include taking steps to minimise height change itself, particularly when transferring patients who are receiving infusions of drugs such as inotropes and vasodilators.

In addition, the use of higher flow rates with lower levels of drug concentration will reduce both the effect of ZDDT if a syringe pump is lowered and the effect of bolus if it is raised.

Weiss (2000) observed that a doubling of flow rate typically resulted in a halving of the value of ZDDT when devices were lowered.

The delivery of low flow rates is important in neonatal or paediatric anaesthesia, where high flow rates would result in excessive fluid loading.

**DEMONSTRATION OF THE EFFECTS OF HEIGHT CHANGE**

A local project set out to confirm the influence of height change effects on syringe pumps between theatres and cardiac critical care.
Measurements of infused volume were derived using a high precision analytical weighing balance, with a measurement resolution of 0.00001g to allow us to detect small changes in delivered fluid from the infusion devices being tested.

Using an infusion of distilled water, measurements were taken at one second intervals using the configuration outlined in Fig 1, and captured on a computer.

Measurements were taken using a range of syringes and giving sets, and for a range of height levels and positional manoeuvres. These confirmed that changing the height could lead to a bolus of fluid or a period of reduced rate of infusion. A typical bolus value of around 0.1ml was observed for a height change of 89cm using a 50cc Plastipak syringe.

Fig 2 illustrates the effects of raising and lowering a syringe pump. When the pump is lowered, fluid is sucked back along the delivery line; when it is raised, a fluid bolus is infused into the delivery line.

**Clinical Practice**

The effects of elevation on syringe pumps are primarily related to pressure compliance of syringes and connecting lines. The phenomenon is therefore common to all pumps.

A particularly high risk infusate is noradrenaline, which is commonly used to increase blood pressure. Typical levels of active drug used are 4mg or 8mg in 40ml saline, although higher concentrations are sometimes used. There are considerable variations in the response of individual patients to administered levels of noradrenaline, and response to changes in levels of this drug are usually quite rapid, both for over infusion and under infusion.

**Discussion**

Adequate training is crucial for healthcare professionals who operate infusion devices or care for patients receiving infusions, to ensure safe practice (Scales, 2008; Scroggs, 2008).

While this training is generally available, it often focuses primarily on setting up and operating specific models of device, and on the drugs they are used to deliver. However, it should also cover the effects of changing the height of syringe pumps, which can occur in a range of situations, including:

- Patient transfers between wards or departments;
- When patients undergo CT scans, as normal practice is to move syringe pumps from mobile supports onto the scanning gantry with the patient.

**References**


