Syringe pumps and start-up time: ensuring safe practice


Summary
The start-up time is the delay between starting an infusion pump and the delivery of fluid at the set flow rate. Mechanical slack in syringe pumps can lead to start-up delays of an hour or more at low-flow rates. During this period no medication is delivered to the patient. The causes of the start-up time delay, its implications and methods of minimising the delay are explained.

Introduction
Infusion devices are in widespread general use in health care, however, concerns are commonly expressed about the lack of users' knowledge about the detail of their operation (Quinn 2000, Williams and Lefever 2000). One functional aspect that is often not well understood is the delay between pressing the start button on syringe pumps and the infusion commencing — referred to as the start-up time. This might be evident in a discrepancy between the record of the volume infused from the movement of the syringe plunger and the volume counter on the pump. Fault reports such as 'pump not infusing but registering delivery', where examination of the pump shows a set flow rate of 0.5ml/hr and a totaliser volume of 2.4ml, typically arise because of a lack of understanding of start-up time. Alternatively, if blood enters the extension set when the Venflon is inserted into the vein, a failure to manage start-up time delays can cause the blood to remain in the line for an hour or more until fluid delivery commences. However, in many cases, staff might be unaware that fluid delivery has not commenced. In this article, start-up time, its causes and prevention are explained.

What is the start-up time?
When a syringe pump is started there is typically a delay before fluid delivery to the patient commences. This is caused by the time required to take up the mechanical slack in the pump-syringe system, both in the pump's driving mechanism and in the fitting of the syringe into the pump. When a syringe is loaded into many models of syringe pumps before clamping the plunger, but with the syringe flange in the pump groove, the syringe can be moved back and forth by about one to two millimetres. If the plunger clamp is then loosely dropped over/applied to the plunger, it will often still be possible to move the syringe back and forth. The pump takes up the slack by moving the whole syringe — plunger and barrel — forward. During this period there is little, if any, movement of the plunger in relation to the barrel, and hence little or no fluid flow. The slower the set flow rate, the longer the time required to take up the slack and the longer the start-up time. At a flow rate of 1ml/hr, the plunger — for example, of a BP Plastipak 50/60ml syringe — will be driven at 1.8mm per hour. With 1.8mm of slack, the first hour of what is taken as infusion time will simply take up the slack — no fluid will be delivered. The time required to take up the slack is flow-rate dependent: at a flow rate of 0.5ml/hr, two hours will be required, but only six minutes will be required at a flow rate of 10ml/hr.

Implications of start-up time
Start-up time has two main implications for infusion device therapy. First, it delays the delivery of medication to the patient. Second, there will be a difference between the volume delivered recorded by the pump's totaliser and that read from the barrel of the syringe — the volume actually delivered. Most infusion devices do not measure fluid delivery, they measure the movement of the pumping mechanism (Amoore et al 1998). The syringe pump's totaliser volume counter is based on measuring the movement of the driving mechanism which is then converted to a volume delivery rate based on the cross-sectional area of the syringe. During the start-up delay there is no movement of the syringe plunger in relation to the barrel, so no fluid is delivered. This is shown by recording the volume left in the syringe. However, the drive mechanism moves forward, taking up the slack and pushing the syringe tightly into the pump, so the pump will record a fluid delivery. This is illustrated in Table 1.

Key words
- Intravenous therapy
- Technology in health care

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Fig. 1. Start-up delays when a syringe was firmly and loosely fitted into a Graseby MS2000 syringe pump

![Graph showing flow rate (ml/hr) vs. time (minutes) with two lines labeled Firmly and Lazy.]

Fig. 2. A syringe fitted badly into a syringe pump

![Image of a syringe mounted in a pump with a flashing arrow indicating that the device is pumping.]

How to reduce the start-up time delay

The start-up delay can easily be reduced with most syringe pumps using one or more of three techniques:

- Fitting the syringe tightly into the pump.
- Using the prime facility, if available, on the syringe pump.
- Using a smaller syringe size, if available and applicable.

Fitting the syringe tightly into the pump

This can be done with all syringe pumps and involves taking a little care when inserting the syringe into the pump. This should be done before connecting the line to the patient.

After filling the syringe and priming the line, fit the syringe in the cradle of the pump, ensuring that the flange of the syringe barrel is pushed forward in the direction of travel. Before clamping the plunger, push the plunger clamp hard against the plunger, moving the plunger forward a few millimetres until a few drops of fluid flow out of the line. Then drop the plunger clamp over the plunger. The plunger clamp should be pushed along the axis of the syringe drive shaft.

This should ensure that the syringe is firmly fitted into the pump. Figure 1 shows how successful this technique can be at reducing the start-up delay. A Graseby MS2000 pump (which does not have a prime facility and is the most common syringe pump in use in the authors' hospital) was set to deliver fluid at 1 ml/hr. The figure shows two examples of start-up delay. When the syringe was fitted loosely into the pump (lazy), fluid delivery started only after 90 minutes. With the syringe fitted firmly, however, fluid delivery was within 10 per cent of the set rate within 15 minutes. Conversely, if the syringe is placed very lazily in the pump with the flange of the barrel not even located in the groove, a very long start-up delay may ensue. Figure 2 shows a syringe mounted in a pump in a way that led to a five-hour start-up delay.

Using the prime facility

If the pump has a prime — also referred to as a purge — facility, use it. Many syringe pumps now include a prime button that takes up the mechanical slack in the drive mechanism (not fully taken up by pushing the driver clamp hard against the plunger) as well as the looseness in the fit between syringe and pump. Purging should be carried out before connecting the line to the patient, as the purging flow rate is typically at the pump's highest flow rate. Most pumps include safeguards to prevent accidental initiation of the prime function, such as the requirement to hold the prime button down. The primed volume is not added to the pump's totaliser. Priming can reduce the start-up time to a few minutes, even at low-flow rates.

Certain pumps include the ability to take up the slack automatically when the infusion is started. The Alaris P7000, for example, includes a 'fast-start' option that, when the infusion is started, initially drives the plunger forward at a fast rate to take up the slack. The higher fast-start flow rate stops when the force on the plunger or the line pressure exceeds a preset limit or when a preset volume has been infused. Some pumps include spring-loaded plunger clamp mechanisms, which take up most of the slack.

Using a smaller syringe size

The driving rate of the plunger for a given flow rate depends on the syringe size (Table 2). At 1 ml/hr, the plunger is driven forward at 6.15 mm/hr when a 10 ml syringe is used, but at only 1.81 mm/hr when a 50/60 ml syringe is used. The start-up delay with the 10 ml syringe will be less than one-third of that with the 50/60 ml syringe. If possible, a smaller syringe should be used when infusing at low-flow rates. Many modern pumps can accom-
moderate a wide range of syringe sizes. However, users should be aware that the use of a smaller syringe size might lead to higher occlusion alarm pressures unless the pump compensates for the syringe size.

What not to do

The practice of temporarily increasing the flow rate to a higher rate, for example, 101 ml/hr if the prescribed rate is 1 ml/hr, to prime the line should be discouraged. While it is tempting to do this for devices without a prime facility, other techniques can be used. There is a risk that the high rate could inadvertently be left programmed when the line is connected to the patient, with consequent overdose. Temporarily increasing the flow rate to reduce the start-up delay ‘ignores the ever present possibility of human error’ which, as Scott (1990) indicated, can result in user error and over-infusion.

However, the introduction to a review of infusion devices advised that syringe pumps should be temporarily run at a high flow rate before connection to the patient to reduce the start-up delay if no prime control is available (MDA 1999). The article highlighted the importance of resetting the rate before connecting the line to the patient. It also noted that syringe pumps should ideally have a prime facility.

The danger of this approach is that it lends itself to user error. It is known that the most common cause of adverse incidents with infusion devices is user error (SHHD 1995). Safe practice should promote ways that minimise the possibility for user error.

The term ‘user error’ is applied loosely to a wide range of fault conditions involving human factors, including accidental or deliberate errors, but also to the design of the pump or the operational procedures. Closer examination of some user errors would suggest that the fault might be better ascribed to, and solutions found from addressing, poorly designed equipment and poor operating methodologies and guidelines. It is incumbent on those drawing up operating procedures to be mindful of the risks and benefits of particular options.

Conclusion

Start-up delays can be a real problem when syringe pumps are used at low-flow rates. However, there are various ways of reducing the delay. The techniques employed should seek to minimise the potential for user error and be simple and easy to accomplish. These include fitting the syringe firmly into the pump and using the prime facility if available. Purchase decisions should include the requirement for the pump to have a prime facility and staff should be trained in its use. Operational procedures should be developed and implemented to reduce the start-up delay, while ensuring patient safety remains paramount.

Infusions should be carefully charted (SHHD 1995) -- the volume remaining in the syringe and the volume displayed on the syringe pump’s totaliser should be noted. Staff should be trained to understand start-up time and the reasons for discrepancies between volumes.

Table 1. Fluid delivery chart showing the effect of start-up times

<table>
<thead>
<tr>
<th>Time</th>
<th>Distance travelled by plunger driver (mm)</th>
<th>Distance travelled by plunger into barrel (mm)</th>
<th>Volume left in syringe (ml)</th>
<th>Totaliser (recorded from pump) (ml)</th>
<th>Volume actually delivered in preceding hour (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9h00</td>
<td>0.0</td>
<td>0.0</td>
<td>50.0</td>
<td>0.0</td>
<td>50.0</td>
</tr>
<tr>
<td>10h00</td>
<td>0.9</td>
<td>0.0</td>
<td>50.0</td>
<td>0.5</td>
<td>50.0</td>
</tr>
<tr>
<td>11h00</td>
<td>1.8</td>
<td>0.0</td>
<td>50.0</td>
<td>1.0</td>
<td>50.0</td>
</tr>
<tr>
<td>12h00</td>
<td>2.7</td>
<td>0.7</td>
<td>49.6</td>
<td>1.5</td>
<td>49.6</td>
</tr>
<tr>
<td>13h00</td>
<td>3.6</td>
<td>1.6</td>
<td>49.1</td>
<td>2.0</td>
<td>49.1</td>
</tr>
</tbody>
</table>

The two columns showing distance travelled by the plunger indicate how the initial plunger movement is not reflected in a movement of plunger with respect to the barrel. These data would not be charted.

Table 2. Distance of plunger travel per hour to provide a flow rate of 1ml/hr

<table>
<thead>
<tr>
<th>Syringe size (ml)</th>
<th>Distance of plunger travel per hour (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>17.4</td>
</tr>
<tr>
<td>5</td>
<td>8.86</td>
</tr>
<tr>
<td>10</td>
<td>6.15</td>
</tr>
<tr>
<td>20</td>
<td>3.54</td>
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<td>30</td>
<td>2.73</td>
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<tr>
<td>50/60</td>
<td>1.81</td>
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</table>

References


