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**Article** *Anaesthesia and intensive care* · July 2014

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Retrieved on: 10 August 2016
Syringe Drivers: incorrect selection of syringe type from the syringe menu may result in significant errors in drug delivery

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SUMMARY

There have been many reported adverse incidents due to syringe driver use, most of which have been attributable to human error. In this paper we present a previously unreported, but potentially widespread practice which may result in significant over or under-delivery of medication. Even with the naked eye it is evident that syringes of equal volume have different dimensions and to quantify this we sectioned a range of syringes and measured the inner and outer dimensions. Extensive menus for syringe brand and volumes are available on syringe drivers, offering users greater flexibility. However, this feature also allows users to select an incorrect syringe brand with potential consequences for drug delivery. We measured outputs under all selectable permutations, to determine the degree of fluid delivery variation and discovered inaccuracies in volumes ranging from 10% under-delivery to 24% over-delivery. There is a wide variation in syringe metrics and complex syringe menus may increase errors, resulting in significant under or over-delivery of medication. Availability of more than one brand of syringe in a clinical area increases the risk of adverse drug delivery events. Systems need to be implemented to minimise the risk of adverse events.

Key Words: syringe driver, medication errors, adverse events, infusion pump

SYRINGE DRIVERS

Syringe driver devices were first developed in the 1950s and have, over time, become essential tools in critical care environments. There have been many adverse incidents related to these devices, most of which are due to human error. Raising or lowering the syringe driver relative to the patient (vertical displacement of the device) during use, air in the syringe and incorrect mounting of the syringe have all been shown to influence infusion rates. When a syringe is manufactured the interrelated dimensions of barrel diameter and length determine internal volume capacity, however different manufacturers achieve the desired capacity by using differing diameter and length combinations (Figure 1). As a result of the lack of industry standardisation, many equal capacity syringes manufactured by different companies vary in their physical dimensions.

Syringe drivers are validated for a limited number of syringe sizes and brands. When a syringe is inserted, the outer diameter of the syringe is measured by the syringe change lever and a menu containing the choice of validated syringes matching that size is displayed. Errors can occur at this stage, non-validated syringes may be accepted if their external diameter is similar to a validated syringe and even if a validated syringe is used, the incorrect syringe can be selected from the menu. During use, the syringe driver monitors linear forward motion and translates this into delivered volume, which, depending on the syringe barrel and length dimensions, will be more or less than the target volumes set on the device. The potential for over or under-dosage to patients is very real.

Groote Schuur Hospital Neonatal Unit is a tertiary centre with eight neonatal intensive care unit beds. Electronic syringe drivers are routinely relied upon to deliver accurate dosages of continuous medications.

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Accepted for publication on April 7, 2014

Anaesthesia and Intensive Care, Vol. 42, No. 4, July 2014
A recent investigation into an adverse incident, which resulted in an overdose of medication, sparked this study into the use of different syringe types in our syringe drivers.

We could find no literature describing the consequences of selecting the incorrect syringe brand from the syringe driver menu. The purpose of the study was to investigate if using non-validated syringes or choosing the incorrect syringe from the menu would have an impact on drug delivery.

As our institution purchases disposable syringes via a tender process, the supplier may change from time to time. Many users are under the impression that any syringe that may be accommodated by the syringe driver is perfectly safe to use as long as the stated capacity or volume of the syringe is the same.

**Table 1**

<table>
<thead>
<tr>
<th>Type</th>
<th>Outer Diameter (mm)</th>
<th>Inner Diameter (mm)</th>
<th>Cross Flange Diameter (mm)</th>
<th>Web Thickness (mm)</th>
<th>Graduated Barrel Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BD Plastipak 50 ml</td>
<td>29.5</td>
<td>26.4</td>
<td>33.2</td>
<td>2.4</td>
<td>91.0</td>
</tr>
<tr>
<td>B.Braun Omniflex 60 ml</td>
<td>30.8</td>
<td>28.1</td>
<td>34.7</td>
<td>3.1</td>
<td>81.5</td>
</tr>
<tr>
<td>B.Braun OPS 50 ml</td>
<td>30.8</td>
<td>28.1</td>
<td>34.7</td>
<td>3.1</td>
<td>81.5</td>
</tr>
<tr>
<td>Surgiplus 50 ml</td>
<td>31.0</td>
<td>29.4</td>
<td>33.8</td>
<td>2.0</td>
<td>76.0</td>
</tr>
<tr>
<td>Ivac 50 ml</td>
<td>29.6</td>
<td>26.3</td>
<td>39.4</td>
<td>2.5</td>
<td>90.0</td>
</tr>
<tr>
<td>B.Braun Omniflex 20 ml</td>
<td>21.5</td>
<td>20.0</td>
<td>24.7</td>
<td>2.0</td>
<td>62.6</td>
</tr>
<tr>
<td>TARA 20 ml</td>
<td>21.2</td>
<td>19.0</td>
<td>23.8</td>
<td>2.1</td>
<td>71.4</td>
</tr>
<tr>
<td>B.Braun Omniflex 10 ml</td>
<td>17.4</td>
<td>16.0</td>
<td>20.3</td>
<td>2.0</td>
<td>51.4</td>
</tr>
<tr>
<td>Surgiplus 10 ml</td>
<td>16.4</td>
<td>14.8</td>
<td>19.5</td>
<td>1.5</td>
<td>59.0</td>
</tr>
<tr>
<td>B.Braun Omniflex 5 ml</td>
<td>13.6</td>
<td>12.5</td>
<td>12.2</td>
<td>2.0</td>
<td>41.0</td>
</tr>
<tr>
<td>Surgiplus 5 ml</td>
<td>13.9</td>
<td>12.4</td>
<td>12.3</td>
<td>1.4</td>
<td>42.0</td>
</tr>
<tr>
<td>B.Braun 3 ml</td>
<td>10.9</td>
<td>9.6</td>
<td>13.2</td>
<td>2.2</td>
<td>41.0</td>
</tr>
<tr>
<td>TARA 3 ml</td>
<td>10.5</td>
<td>9.0</td>
<td>12.8</td>
<td>1.5</td>
<td>48.4</td>
</tr>
</tbody>
</table>
MATERIALS AND METHODS.

**Syringes**

A sample of each syringe type available in our department was obtained. A Vernier calliper (0.02 mm accuracy) was used to determine external dimensions of all syringes. After sectioning each syringe barrel the internal diameters were also measured.

**Syringe Driver**

The three different syringe drivers that are available in our hospital were tested: B.Braun Perfusor Space (B.Braun, Melsungen, Germany), Alaris GH (Carefusion, Switzerland) and Injectomat Agilia (Fresenius Kabi, Bad Homburg, Germany). As the B.Braun Perfusor is the syringe driver exclusively used in our neonatal unit we extensively tested this driver with multiple syringe sizes (60 ml, 50 ml, 20 ml, 10 ml, 5 ml, 3 ml and 2 ml syringes), while due to time constraints, a more limited sample (50 ml syringes only) was used with the other two. All syringes are Luer-Slip configured. In order to simulate clinical conditions we used the standard extension set that is available in the neonatal unit (Techno Med...
TE 120090 90 cm interval volume of 1.1 ml). A laboratory measuring cylinder (Measuring cylinder Pyrex 10 ml in 20 °C “B” BS604 and Superior 1 ml 0.01 at 20 °C) were used to collect the delivered volume of each test syringe. A rate of 10 ml/hour was selected for uniformity of tests and a time period of an hour per syringe run was selected to allow pump delivery to be averaged uniformly. The syringes with volumes less than 10 ml were run at 5 ml/hour or 2 ml/hour depending on their size. All syringes were filled to past their maximum graduated volume to allow for over-delivery to be observed. Test fluid used was half-normal saline (SABAX Sodium Chloride 0.45%). The syringe and extension set were carefully checked to ensure all air had been purged. Once a syringe was inserted and accepted by the syringe driver, the syringe menu that was offered by the device was noted. The same syringe was then run under each of the syringe types that were generated by the detection algorithm, thus checking each possible permutation that a clinical user may be faced with. The occlusion setting alarm limit was set at level three (equivalent to 281 mmHg). All syringes were run at least twice under identical conditions to see if the observations were reproducible.

Dynamic performance
A laboratory bench-test was set up to check the output performance of the various syringes in the syringe driver under uniform conditions which simulated clinical conditions. Upon insertion of a syringe the number of syringe brands and types that were offered on the menu for selection was tabulated. The same syringe was then run under each of the syringe types that were generated by the detection algorithm, thus checking each possible permutation that a clinical user may be faced with. Fluid was run over a one-hour period and collected in a laboratory measuring cylinder. All tests were run twice to ensure reproducibility. The percentage of under or over-delivery was calculated. The same extension set was used for all tests thus ensuring uniform afterload conditions. No intravenous cannulae were connected to the extension set.

RESULTS

Syringe Metrics
The syringe metrics table (Table 1) highlights the variation in dimensions selected by different manufacturers in the design of their syringes. Of note is the critical external diameter of the syringe barrel, which is the initial parameter measured by the syringe change lever to detect not only the size, but subsequently brand, of the syringe inserted by reference to programmed data in the device. The data in Table 1 illustrates the variation in physical dimensions that are adopted by manufacturers to produce syringes of equal volume displacements (see Figure 2).

Dynamic volume output measurement
The results displayed in Table 2 show the type and size of syringe inserted, the options displayed on the syringe driver menu for that syringe and the volume of fluid delivered after one hour for each of these selections. All results were reproducible with the greatest variation between identical runs being 0.2 ml over one hour for all tests (Table 3 and 4).

DISCUSSION
The study provides clear evidence that there are substantial variations in delivered volumes when the incorrect syringe is selected from the menu offered by three brands of syringe drivers. Although we did not test all makes of syringe drivers, the three we tested are widely used and there is a high probability that

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Table 3

<table>
<thead>
<tr>
<th>50 ml Syringe and size selected on syringe driver menu</th>
<th>BD Perfusion</th>
<th>50cc Braun Perfusor</th>
<th>B.Braun Omnifix 50 ml</th>
<th>BD Plastipak 50 ml</th>
<th>Fresenius Injectomat</th>
<th>Monoject 50 ml</th>
<th>Terumo 50 ml</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SURGIPLUS Actual Volume Delivered (ml)</strong></td>
<td>10.9</td>
<td>10.5</td>
<td>11.4</td>
<td>10.1</td>
<td>12.4</td>
<td>10.2</td>
<td></td>
</tr>
<tr>
<td>Volume Variation in %</td>
<td>9</td>
<td>5</td>
<td>14</td>
<td>10</td>
<td>24</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td><strong>BD Plastipak Actual Volume Delivered (ml)</strong></td>
<td>9.1</td>
<td>9</td>
<td>9.2</td>
<td>10</td>
<td>10.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume Variation in %</td>
<td>-9</td>
<td>-10</td>
<td>-8</td>
<td>0</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>B.Braun OPS 50 Actual Volume Delivered (ml)</strong></td>
<td>10.5</td>
<td>10.1</td>
<td>10.2</td>
<td>11.4</td>
<td>11.3</td>
<td>9.4</td>
<td></td>
</tr>
<tr>
<td>Volume Variation in %</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>14</td>
<td>13</td>
<td>-6</td>
<td></td>
</tr>
<tr>
<td><strong>IVAC 50 Actual Volume Delivered (ml)</strong></td>
<td>9.1</td>
<td>9.1</td>
<td>9.2</td>
<td>10</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume Variation in %</td>
<td>-9</td>
<td>-9</td>
<td>-8</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
other brands would have similar problems. Reassuringly, the volumes delivered were exact when the syringes were correctly chosen, illustrating that the device is highly accurate and precise when used correctly. Filling the syringes past their maximum graduated volume to allow for over-delivery to be observed was unlikely to have influenced the results due to the fact that when the correct syringes were selected the exact program was consistently delivered.

Using non-validated syringes produced errors of between 10% under-delivery and 24% over-delivery. However, the largest differences in flow rates occurred when validated syringes were used but the incorrect choice was made from the syringe driver menu (up to 22% over-delivery). Thus, using only validated syringes is not a safeguard against the incorrect delivery of medications and even confusing two different types of validated Braun syringes (for example when B.Braun Omnifix 20 ml was incorrectly selected as B.Braun OPS 20 ml) could result in over-delivery of fluid by 14%.

Several test runs demonstrated some poor physical characteristics of some of the non-validated syringes under dynamic conditions in the syringe driver. The occlusion pressure alarms were triggered several times during our testing. Resistive forces due to friction in the bore of the syringes as well as excessive flexing of the plunger were observed at the time of the occlusion alarms which halted the fluid delivery. This finding is significant as it illustrates that sufficient resistive forces generated by the interaction of the syringe plunger and barrel walls, combined with external flexion of the plunger in the syringe driver are able to provide enough resistance to trigger the occlusion alarm and halt the fluid delivery, even when no intravenous cannula or vascular system afterload is present.

Although there have been no reported adverse events from under or over-delivery due to incorrect syringe use, there is definite potential for complications. Excessive inotropic agents could result in hypertension or cardiac arrhythmias whilst overdosing of sedation or analgesia can result in hypotension and a diminished respiratory drive. Neonates are extremely sensitive to insulin and giving too much to a hyperglycaemic infant could result in iatrogenic hypoglycaemia. Finally, inappropriate occlusion alarms result in under delivery of medication and may lead to the unnecessary flushing or changing of lines or drips.

The standards of reliability in current syringe drivers are excellent, thus almost eliminating device failures as a reason for error. However, considering the number of syringe changes taking place in a busy unit per year (potentially over 10,000 per year in our eight bed intensive care area), the potential for error is definitely present, even if not always clinically apparent. Rather than blame human error when an incident occurs, it is essential that systems be implemented that would minimise the risks of an adverse incident occurring. These systems should be routinely assessed and updated rather than reacted upon only when a near-miss or adverse incident occurs.

We have identified five ways to help minimise the risk of further adverse incidents:

- Use only validated syringes.
- As far as possible only stock one brand of syringe, thereby minimising the chances that people will choose the incorrect one from the menu.
- Syringe recognition technology should be improved which would minimise choice from the menu.
- Staff should be made aware of the potential hazards on a regular basis and as part of their induction program.
- Systems should be reviewed on an annual basis to help identify possible pitfalls.

We feel that this study brings to light some of the unexpected potential problems with menu-driven syringe drivers. Lessons learned can be expanded to a wide range of clinical situations where systems need to be in place to minimise potential adverse events.

REFERENCES


