NURSING STAFF HAVE a range of sophisticated electronic devices at their disposal for delivering essential drugs, fluids and nutritional therapy to patients in the healthcare setting. Accurate, low-flow-rate, small-volume infusions can be controlled by means of a syringe pump, medium-to-high flow rates can be controlled by a volumetric infusion pump and basic fluid replacement can be delivered by the age old method of gravity infusion – more commonly known as the ‘drip’.

Gravity infusion relies solely on the user setting up the infusion using a safe and sturdy drip stand, then manually adjusting a plastic roller clamp, fitted to a disposable administration set, to achieve the desired drip rate. Many factors can influence this drip rate once it has been calculated and set. These include positional problems, temperature and other external factors.

A study carried out on mathematical skills for nurses in a large NHS hospital highlighted areas of concern and identified a lack of confidence in undertaking basic infusion rate calculations (Lee 2008). In particular, the study showed that 41% (n=78) of qualified nurses who have been trained to use medical infusion devices lacked confidence in tackling basic drip rate calculations. Recommendations made included the design and development of tools to assist nursing staff to carry out basic calculations.

This article describes how an easy-to-use computer software tool, a poster and a pocket-size help card were developed to assist staff in calculating common infusion regimens.

**Summary**

Nurses often lack confidence in carrying out basic infusion rate calculations, particularly those needed to work out drip rates for medical infusion devices. This article describes the design and development of a computer software tool, poster and a pocket card in one trust to help reduce accidental errors when using infusion pumps and gravity infusions.

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Information technology; Infusion therapy; Mathematics; Numeracy

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**Background**

A trust-wide study was carried out in an acute NHS trust using a simple questionnaire to gauge individuals’ confidence levels in tackling mathematical calculations used in intravenous therapy (Lee 2008). In total, 480 questionnaires were sent to staff who had already attended infusion pump training courses. These anonymous questionnaires asked for a graded response, using a Likert-type scoring scale, for individuals’ confidence levels in undertaking mathematical drug-related calculations. A total of 190 completed questionnaires were processed for detailed analysis. Two areas identified in the study were a perceived lack of confidence in carrying out basic drug calculations and drip rate calculations. Forty one per cent (n=78) of staff indicated a lack of confidence in tackling drip rate calculations and 22% (n=42) when working out basic rates for infusion pumps. Maths skills and drug calculation errors are often cited as common contributing factors in clinical incidents (Hutton 1998, Sabin 2001, Hughes 2002, Department of Health (DH) 2004, Wright 2006), and support mechanisms are recommended rather than punitive measures.

The Nursing and Midwifery Council states explicitly that calculators ‘should not act as a substitute for mathematical knowledge and skill’ and recommends they are only used ‘to support calculations’ (NMC 2007). However, others recommend and support the use of calculators.
for more complex calculations (Hutton and Gardner 2005). All qualified nursing staff should be able to estimate a sensible answer for these calculations as nurses should already know the first principles of mathematics. Any calculators or tools developed would need to be bespoke and designed to assist in this process. They would need to be perceived as supportive rather than as aiming to replace any conceptual maths skills that may have been lost.

Calculating drip rates

The practice of using gravity or drip infusions is commonplace in many care centres and benefits include a simple method of set up and low cost. In 2003 an audit in the author’s trust (1,000 beds) revealed that more than 40,000 giving sets were used every year for gravity infusions. However, this method has no means of alerting staff to impending errors, or any other infusion-related problems. Furthermore, it is reliant on using the force of gravity to deliver the fluid accurately to the patient. Apart from fluid viscosity, type of cannula and clinical complications after set up, other factors can affect the initial rate of infusion. These include static pressure, temperature, fluid level, patient position and drip factor (Medical Devices Agency 2003, Dougherty and Lister 2004).

Static pressure

The pressure (in mmHg) exerted on the fluid varies according to the height difference between the patient access site and the fluid bag. An optimum height of one metre above the patient should be sufficient to overcome initial venous pressure. Should the bag be repositioned after set up, this height difference and subsequent pressure difference will affect the drip rate.

Temperature

Increases in temperature can cause the plastic components in the roller clamp to lose tension and hence grip on the tubing as it tries to revert to its original shape and this can adversely affect the drip rate.

Fluid level

As the fluid level falls in the bag, the static pressure decreases and results in a slowdown of the established infusion.

Patient position

The set infusion rate (drip rate) is relative to the position of the patient and the fluid bag. Should the patient change position then the drip rate can also be affected.

Drip factor

This is usually indicated on each manufacturer’s giving set package and is approximately the number of drops equivalent to 1ml water ($H_2O$) (Figure 1). Any change in the type of giving set can affect the drip rate, and staff need to be aware of the drip factor for each giving set used in their area of work.

Each patient’s prescription is delivered from a fluid bag that can vary in size from 50ml to 2 litres. An administration set, or giving set, is attached to the clean, sterile port of the fluid bag and primed ready for the infusion. Once safely connected to the patient’s cannula, the roller clamp is slowly opened to establish a flow rate (in drops per minute). This drip rate is calculated before each infusion and set accordingly. Patients are then monitored throughout the infusion to ensure that the delivery is as expected.

The drip rate is calculated by dividing the total volume (in millilitres) prescribed for the patient by the number of hours required for the delivery. This gives the infusion rate in millilitres per hour (ml/hr). The infusion rate (ml/hr) is then multiplied by the drip factor for the giving set (nominal number of drops per ml) to calculate the total number of drops required per hour (Dougherty and Lister 2004):

\[
\text{Drops per hour} = \frac{\text{Total volume (ml) \times Drip factor}}{\text{Total time (hours)}}
\]

To obtain the number of drops required per minute divide the number of drops per hour by 60 (number of minutes in 1 hour):

\[
\text{Drops per minute} = \frac{\text{Drops per hour}}{60}
\]

### FIGURE 1

<table>
<thead>
<tr>
<th>Drip factor (typical symbol used)</th>
<th>Number of drops = 1ml ($H_2O$) (nominal value)</th>
<th>Type of giving set</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_2O$</td>
<td>20 drops = 1ml ($H_2O$)</td>
<td>Most basic adult giving sets</td>
</tr>
<tr>
<td>$H_2O$</td>
<td>60 drops = 1ml ($H_2O$)</td>
<td>Some paediatric giving sets</td>
</tr>
<tr>
<td>Blood</td>
<td>15 drops = 1ml (usually blood) (Note: some blood sets quote the drip factor for $H_2O$ rather than blood)</td>
<td>Blood giving sets</td>
</tr>
</tbody>
</table>
Combining the preceding two equations also gives the drip rate formula in drops per minute:

\[
\text{Drops per minute} = \frac{\text{Total volume (ml) x Drip factor}}{\text{Total time (hours) x 60}}
\]

However, for ease of use and set up, the calculated drip rate is sometimes easier to set initially in drops per second or drops per 15 seconds (some ward-based medical equipment already has an in-built 15 second timer) and so further division may be necessary:

- Drops per 15 seconds = \(\frac{\text{Drops per minute}}{4}\)
- Drops per second = \(\frac{\text{Drops per minute}}{60}\)

Once the desired drip rate has initially been set, it should then be measured over a minute to ensure accuracy for the rest of the infusion.

As can be seen, many steps are required in the process before the final answer can be obtained, and it is easy to see why some staff may lose this skill if drip rate calculations are not practiced frequently.

**Developing the poster, pocket card and computer software tool**

Small wooden tongue depressors, commonly used by nursing staff to write down calculations, have been in use for many years. However, their use cannot be endorsed as they carry no formal approval, have no quality control methods to ensure their accuracy and can pose a risk of contamination as they cannot be cleaned easily.

Wall charts and posters which are common in hospital wards can act as useful reminders to users of medical devices and help in treatment regimens. Online assist tools are also becoming more common and can help those who have access to local intranet services.

A memorandum was sent to all senior ward staff asking for common infusion rates and volumes for basic fluid replacement using intravenous infusions and the answers were tabulated (Table 1). In addition, common infusion times were also tabulated to help design cards with appropriate cross-reference charts and easy-to-find calculations (Table 2).

An internet search using Google™ revealed that a few drip rate calculator tools are available. However, most lack detailed information and require manual entries of values, and this can lead to error if the number of decimal places for the calculations is not known.

The variety of calculations and infusion parameters proved to be too large to be developed into meaningful pocket-sized help cards, therefore only common regimens were included. A comparison table was developed to compare drip rates (rounded up or down) against calculations to one decimal place.

The design of a simple-to-use, interactive spreadsheet (using Microsoft Excel®) was chosen as an easy method of performing the calculations. Once the formulae had been assigned, this allowed data entry and displayed the calculated infusion rates in millilitres/hour and drops per minute. Infusion rates and drip rates were then transposed to the table and summarised for data analysis. Formulae attributed to cells in the programme were then corrected or altered to suit.

A Microsoft Excel® spreadsheet was initially designed with open cells allowing staff to enter a variety of inputs, to one decimal place. Copies of the spreadsheet were sent to infusion device experts for feedback. Formulae were applied to cells to help calculate drip rates and infusion rates (ml/hr). Minor errors with Microsoft Excel® spreadsheets are known to exist when dealing with very large numbers (McDougal 2007). However, it soon became apparent that errors were evident when users were allowed to enter the volume required and calculated drip rates were rounded up or down. To overcome this anomaly, drip rates were re-calculated to one decimal place to remove the rounding up/down errors that can occur with smaller

**TABLE 1**

<table>
<thead>
<tr>
<th>Common volumes for delivery of intravenous infusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common volumes delivered by gravity</td>
</tr>
<tr>
<td>50ml</td>
</tr>
</tbody>
</table>

**TABLE 2**

<table>
<thead>
<tr>
<th>Common times for delivery of intravenous infusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common times for gravity infusions</td>
</tr>
<tr>
<td>½ hr</td>
</tr>
</tbody>
</table>
values but not for drops per minute as rounding up/down errors at this level are not considered to be critical (Figure 2). A dropdown menu was developed that contained all common intravenous fluid bag sizes and infusion times.

A method of locking cells and limiting the choice of infusion rate was required and this was achieved using the validation tool in Microsoft Excel®. A limited dropdown menu for each data input range could then be used to select volumes and times for each infusion. The dropdown volumes cover common bag sizes but if drugs or fluids are added to fluid bags their size may be increased so staff need to be able to enter the exact bag volume into the software screen. The validation tool allowed for variations from the ‘total volume’ pick list. A variety of infusion volumes could then be entered manually, even if they did not appear on the dropdown list.

No variations were allowed in the ‘drip factor’ or ‘total time’ data input range. The spreadsheet was then password-protected to prevent reprogramming errors and a copy was sent to the medical electronics department for checking and verification. However, difficulties in running the software on an older version of Microsoft Excel® (before 2003) prompted the redesign of the spreadsheet to suit older software packages in the organisation.

Copies were then sent to the members of the trust’s infusion devices committee for comment. A feedback form was supplied asking for a graded response to the design of the spreadsheet including choice of colours used, dropdown lists, ease of use, warning messages, overall layout, instructions for use and calculations. Additional comments were encouraged. Although only a few responses have been received, feedback was positive about layout, content and usefulness of the tool. No further suggestions for improvement have been made.

The drip rates for the selected range of infusions were tabulated for the software programme, posters and pocket cards (Table 3). Because of limited space on the card and poster it was decided not to include the three-hour infusion rate which is not common. Table 3 shows a small sample of the rates calculated.

![Representation of screen display (user selectable inputs shown in boxes)](image)

<table>
<thead>
<tr>
<th>Total volume (ml)</th>
<th>Total time (hrs/mins)</th>
<th>Drip factor (drops per ml)</th>
<th>Infusion rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 (ml)</td>
<td>8 hrs 0 mins</td>
<td>20 drops per ml</td>
<td>62.5 ml/hr</td>
</tr>
<tr>
<td></td>
<td>0.3 Drops per second</td>
<td>0.7 Drops per 2 seconds</td>
<td>1.7 Drops</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.5 Drops per 10 seconds</td>
<td>5.2 Drops</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.2 Drops per 15 seconds</td>
<td>21 Drops</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 3**

Sample taken from comparison table of calculations

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total volume (ml)</td>
<td>Time (hours)</td>
<td>Rate (ml/hr)</td>
<td>Drops/min (1 decimal place)</td>
<td>Drops/min (rounded up/down)</td>
<td>Volume (rounded up/down)</td>
<td>Error</td>
<td>Drops/15 seconds (rounded up/down)</td>
<td>Volume</td>
<td>Error</td>
<td>Difference</td>
</tr>
<tr>
<td>------------------</td>
<td>--------------</td>
<td>--------------</td>
<td>----------------------------</td>
<td>----------------------------</td>
<td>--------------------------</td>
<td>-------</td>
<td>----------------------------------</td>
<td>--------</td>
<td>-------</td>
<td>------------</td>
</tr>
<tr>
<td>100</td>
<td>4</td>
<td>25</td>
<td>8.3</td>
<td>8</td>
<td>96</td>
<td>-4%</td>
<td>2</td>
<td>96</td>
<td>-4%</td>
<td>0%</td>
</tr>
<tr>
<td>100</td>
<td>6</td>
<td>16.7</td>
<td>5.6</td>
<td>6</td>
<td>108</td>
<td>8%</td>
<td>1</td>
<td>72</td>
<td>-28%</td>
<td>36%</td>
</tr>
<tr>
<td>500</td>
<td>6</td>
<td>83.3</td>
<td>278</td>
<td>28</td>
<td>504</td>
<td>0.8%</td>
<td>7</td>
<td>504</td>
<td>0.8%</td>
<td>0%</td>
</tr>
<tr>
<td>1000</td>
<td>24</td>
<td>41.7</td>
<td>139</td>
<td>14</td>
<td>1008</td>
<td>0.8%</td>
<td>3</td>
<td>864</td>
<td>-13.6%</td>
<td>14.4%</td>
</tr>
<tr>
<td>280</td>
<td>4</td>
<td>70</td>
<td>175 (blood set)</td>
<td>18</td>
<td>288</td>
<td>2.9%</td>
<td>4</td>
<td>256</td>
<td>-8.6%</td>
<td>11.5%</td>
</tr>
</tbody>
</table>
The Microsoft Excel® spreadsheet calculation was designed with one decimal place and programmed into the formulae. It soon became apparent the calculations were becoming overcrowded on the spreadsheet and the pocket card. In an effort to simplify these infusion rates, all calculations were ‘rounded up or down’ by the software and tabulated for comparison. Further comparisons were made between the initial calculated drip rates (to one decimal place): those rounded up or down in Microsoft Excel®, and those further ‘rounded up or down’ on the pocket cards (Table 3).

The software tool included 15 second drip rate divisions to help indicate rates at the lower end of the scale (Figure 2). However, the comparison table (Table 3) showed that this rounded up/down value could deliver infusion errors as great as -28%, whereas the rounded up/down value of drip rates ‘per minute’ indicated much lower errors of between -4% and +8% for all infusion regimens. Therefore, only the ‘drops per minute’ calculation was rounded up or down, and all others were reprogrammed back to one decimal place, to help reduce this error from occurring. The drip rate (per minute) values were used on the cards to help simplify calculations at ward level. Staff are reminded that drops per minute is the target infusion rate required. One side of the pocket card shows infusion rates (ml/hour) for use with infusion pumps and the other side shows drip rates in drops per minute for gravity infusions (Figure 3).

Blood transfusions (red blood cells, leucocyte-depleted blood) are often delivered in the organisation using gravity giving drip sets. Blood infusion rates were calculated taking a mean value of 280ml, the nominal size of blood transfusion bags (McClelland 2007) and average rates were calculated for the computer software tool and pocket card. Drip factors for blood giving sets (nominally 15 drops per ml) were written into formulae on the spreadsheet and included on the pocket card. This section of the help card was coloured red to help distinguish blood transfusions from other basic solutions.

Discussion

Evidence on nursing staff’s lack of confidence in undertaking mathematical calculations is emerging (Hutton 1998, DH 2004, Wright 2006, Lee 2008). Even though universities are trying to tackle the problem by introducing training programmes at a local level, this will not address the shortfall that may already exist in the nursing profession. Training tools, such as help cards, calculators, pocket guides and posters, can help deliver important reminders to staff, but may not be able to address fundamental issues surrounding maths anxiety or lack of ability in mathematical calculations. Organisations therefore need to have in place robust systems to identify training needs and address any shortfalls where they exist.

The use of simple, bespoke tools can help staff overcome their anxieties by providing a second method of checking results and calculations. However, allowing users to type in free characters (with no limitations) when using Microsoft Excel® can cause calculation errors. Developers need to be aware of leading zeros and decimal places attributed to each cell. For example, if “0.7” is displayed without the leading zero, the zero before the decimal point, it may be mistaken for “7”. Designers of calculation software programmes need to be aware of how numbers are displayed and select the function accordingly because some programmes will drop the zero, while others may place two zeros in front of the number. The programme validation tool can overcome these errors and allow selection of a pre-determined pick list. This will help limit the range of data inputs and target calculation tools to each domain (drip rates, drug regimens and so on). Rounding up or down mathematical values for simple calculations can introduce errors (as shown in Table 3) and users need to be aware of the significance of these errors as patients may receive an under-infusion or overdose. Microsoft Excel® spreadsheets and simple
formulae may help, however, staff need to be aware that checking all calculations using another method is always recommended.

Incompatibilities can occur between different software versions (Microsoft Excel® '97, 2007) and it is not clear whether this simple programme will transfer easily. An infusion rate (ml/hr) calculator is already available within existing infusion devices in the trust and is beginning to be used by staff in some clinical areas. The use of a trust-wide drip rate calculator tool, that can be easily read and used, has long been awaited. The trust has an established intranet service with all staff having access at the ward level. However, current workloads mean that access to computers may be limited and converting the calculator tool to work on portable devices such as the personal digital assistant is being investigated.

The author is planning to conduct an audit to provide feedback on the impact of these training tools and help cards.

The posters, containing the same information as the cards, as well as extra guides, have been available for approximately one year, the software tool has been in use since summer 2008, and the pocket cards are issued to all staff attending training days. Funding has been provided to produce the pocket cards professionally in credit card shape, size and quality, and 8,000 cards are due to be distributed in May 2009.

Conclusions

Pocket-sized help cards, although useful, need to be manageable and need to carry the relevant information required in all care areas. The vast range of drip rate calculations used in the healthcare setting may not be easily transferred to such a small pocket-sized card. Larger posters are being considered which will carry the full range of infusions used in the organisation as well as helpful information and contact numbers for assistance.

Access to, and reliance on computers at ward level is an issue, but simple, bespoke software tools can help when carrying out basic calculations and such tools are already proving useful in the clinical setting. Users are reminded that they must not rely solely on the calculations within the programme, but use them as a second method of checking already calculated answers.

Free copies of the calculation tool described in the article will soon be available on the ABM University NHS Trust website (www.abm.university-trust.wales.nhs.uk).

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References


