

# Implementation of standard concentration medication infusions for preterm infants

Medication safety remains a challenge in the neonatal intensive care unit (NICU). The use of standard concentration medication solutions aims to reduce the risk associated with delivering 24-hour continuous IV infusions to this vulnerable population. This paper describes a quality improvement project to implement and measure the reliability of using standard concentration 24-hour medication protocols for dopamine and dobutamine undertaken in an Australian NICU.

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## Key points

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1. Standard concentration 24-hour medication infusions allow a fixed number of concentrations for each medication, making the checking process easier, reducing the risk of error and providing the potential for pre-mixed solutions.
2. Three standard concentration solutions for each medication provide for the diverse weight range, medication dose and fluid requirements of infants, improving the compliance with medication protocols.
3. Multidisciplinary collaboration and feedback enhanced acceptance of change to standard concentration solutions.

In the NICU, many high-risk medications – those that have a heightened risk of causing significant harm when used in error<sup>1</sup>, such as dopamine and dobutamine – are delivered by 24-hour continuous IV infusions. The process of prescribing, preparing and administering medications to infants offers many opportunities for error<sup>2</sup>. Mistakes in the delivery of medications are potentially life-threatening to the infant, costly to the health system and take a personal toll on all staff<sup>3</sup>. Errors relating to 24-hour medication infusions are three times more likely in the paediatric and neonatal populations than in adults, as both prescribing and administering are more complex<sup>6,7</sup>.

Existing practice in the authors' NICU used an infant's weight to determine the amount of medication to be added to each medication syringe, when preparing 24-hour medication infusions. Preparing each infant's medication syringe as a unique concentration resulted in the initial infusion rate being equal for all infants, regardless of their weight. This method is known as the rule-of-six<sup>8,9</sup> and is calculated as follows:

*6 x patient weight (kg) equals the amount of medication that should be diluted in 100mL of compatible fluid. The infusion volume in millilitres per hour (mL/hour) will then equal the dose (µg/kg/minute) ordered.*

Designed for the emergency setting, the rule-of-six enables staff to quickly prepare 24-hour medication infusions. When prepared according to the protocol, the starting infusion rate is linked with a specific dose (µg/kg/min), regardless of the infant's weight.

A number of safety measures were

included within each medication protocol to supplement the mandatory double check procedure required by staff. This included a table within each protocol that described the corresponding volume of medication to be added to the syringe for a selection of infant weights within a range for the corresponding starting dose. This guided staff through the process of prescribing, preparing and administering medications by acting as a reference point when checking their own calculations.

## Background

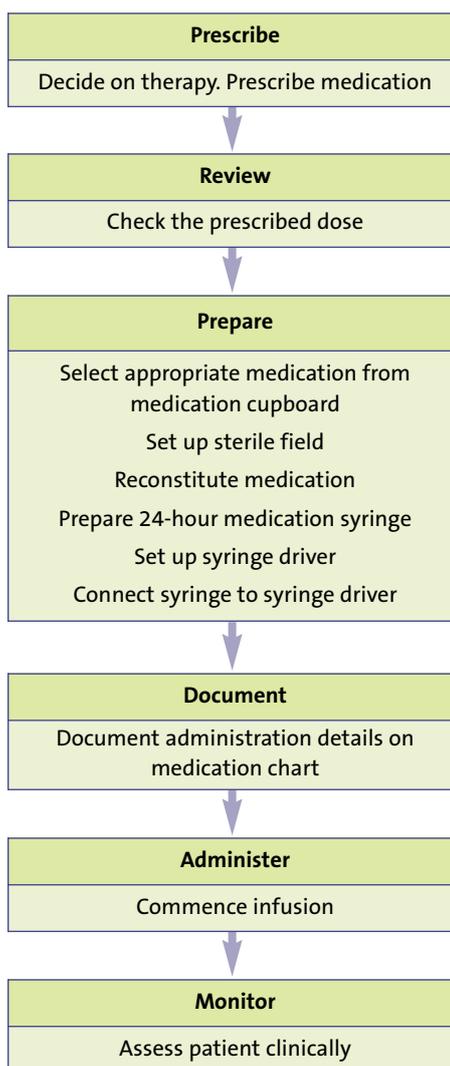
A significant incident involving the delivery of a 24-hour medication infusion in the NICU triggered a review of the infusion process. A retrospective audit of 24-hour medication infusions delivered to 40 infants (weight range 0.41-4.11kg) was conducted. It demonstrated that while all infants received the correct dose, only 4.2% (five out of 117) of the syringe concentrations prescribed matched the concentration recommended within the ward protocol. This poor compliance between the prescriptions and the protocol clearly showed that the existing protocol (using the rule-of-six method) was not meeting the needs of the infants.

Discussions with the nursing staff revealed that they were not comfortable with the extra level of calculation required to ensure that the dose they were preparing and administering was correct. A number of the nurses in the NICU grappled with the checking process as the tables within each protocol, designed to support the checking procedure, were no longer relevant for the infant within their care, due to the departure from the ward prescribing protocol.

## Identifying the need for change

A multidisciplinary team (MDT) of nurses, midwives, neonatologists and a pharmacist was formed to review this multifaceted process. The team initially mapped out each step in the delivery of a 24-hour medication infusion as a flow diagram (FIGURE 1). From here, the team listed the factors contributing to variability in practice for each step when using the rule-of-six method. These contributing factors were then prioritised to 10 key issues (TABLE 1). Half (five out of 10) of these contributing factors were related to the existing neonatal medication protocol. It was clear that, while many of the initial medication orders complied with the protocol, commonly encountered issues such as fluid restriction and the need for dose escalation meant that the concentration of medication within each syringe was often different to that recommended.

The MDT acknowledged that while



**FIGURE 1** Flow diagram: steps to deliver 24-hour medication infusions.

some variation from protocol should be expected, this should be the exception rather than the rule. A review was undertaken to investigate the method by which 24-hour medication solutions were prepared.

In reviewing the literature on safety and quality, the use of standard concentration medication infusions was flagged as an alternate model in the delivery of these high-risk medications in the paediatric population. The Australian Medication Safety Self Assessment (MSSA) recommends the use of standard concentration medication solutions where possible<sup>10</sup>. In addition, the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) in the USA has mandated the elimination of the rule-of-six method and promoted the use of standardised medication concentrations for all paediatric patients<sup>11-13</sup>.

While it was clear that the use of the rule-of-six method was not meeting the needs of this patient population, there was uncertainty from both medical and nursing groups in changing from such a firmly entrenched process.

The MDT agreed to review the process of delivering two commonly used 24-hour medication infusions (dopamine and dobutamine) as a direct observation quality improvement project. These medications were chosen for the project, as they were the most commonly prescribed 24-hour infusions within the unit. This also meant that results of the change in practice would be immediately evident. The intention was to incorporate standard concentration protocols for each of these medications and measure the compliance. Any problems could then be dealt with prior to the implementation of standard concentrations for all 24-hour medication infusions prescribed for infants in the NICU. This stepwise approach would also give all staff confidence in the process before it was rolled out to the range of protocols used within the NICU.

Taking into account the diverse weight range of this population (0.4-4kg) and the restricted rates of infusion (between 0.2mL/hr and 1mL/hr), two standard concentrations were selected by the MDT for each medication. The two concentrations selected for dopamine were 0.8mg/mL and 3.2mg/mL. This involved adding 0.5mL and 2mL respectively from a 40mg/mL dopamine solution, to make a total volume of 25mL, using the

1. Each patient has an individualised concentration medication syringe.\*
2. Difficulty in finding a second person with the appropriate skill level to check calculations.
3. Necessity to search through multiple areas for the appropriate equipment.
4. Medication ordered in different styles and with different levels of legibility.
5. Many distractions in a busy ward environment.
6. Double dilutions are required for some medications.\*
7. Final syringe volume varies with different medicines.\*
8. Need to change medication order regularly due to both fluid restrictions and the delivery of high doses.\*
9. Adjustment of infusion rates to keep within daily fluid allowance.\*
10. Varying experience in checking medication doses.

**TABLE 1** Top 10 factors contributing to variability in practice for the prescribing, preparing and administration of 24-hour medication infusions. \*Factors associated with medication protocol.

appropriate compatible fluid.

The two standard concentrations selected for dobutamine were 1mg/mL and 3mg/mL. This involved adding 2mL and 6mL respectively from the 12.5mg/mL dobutamine solution, to make a total volume of 25mL, using the appropriate compatible fluid.

The total infusion volume of 25mL was selected to ensure that, even at maximum infusion rate, the syringe did not require changing within 24 hours. Ideally identical concentrations for each medication would have been used but this would have required drawing impractical volumes of medication from the ampoule to prepare each of the standard concentration solutions.

Once two standard concentrations were selected, the pharmacist, in collaboration with medical and nursing staff, developed new protocols. The new protocols incorporated:

- A visual matrix for each concentration to assist medical and nursing staff determine the appropriate concentration for various weight ranges.
- Specific instructions to medical staff on how to write each prescription in a

standardised format.

- Specific instructions for nurses on how to prepare each concentration from the original ampoule.
- Formulae to support staff in calculating both the rate of fluid to be administered to deliver a desired dose, and the dose administered when the infusion is run at a known rate.
- Internationally recognised Tall Man lettering (see below).

### Aim of the project

The aim was to safely implement standard concentration medication solutions within the NICU and support staff through the change process.

### Methods

#### Design

This was a quality improvement project using the Plan-Do-Study-Act (PDSA) methodology<sup>14</sup>. It involved undertaking small rapid cycles of quality improvement using the PDSA model, utilising data to measure change and effect and responding in real time to any problems that the MDT team observed.

#### Setting

All observations were made in the NICU of a large 308-bed teaching hospital. The NICU is a level 3 unit, providing 24-hour care to approximately 260 patients a year with a maximum capacity of 14 intensive care cots.

#### Data collection

Details of all prescriptions were recorded daily including: the infant's weight, medication name, infusion concentration and rate of infusion delivery. Data collection for the first four weeks was based on using the rule-of-six protocols for both medications (pre-implementation). Data collection from weeks 5 to 12 weeks was based on the standard concentration 24-hour medication protocols (post-implementation). These data were used to demonstrate change in compliance rates with the change in protocol to all ward staff from week 5 (see below).

#### Medication protocols

From week 5, the new standard concentration protocols for each medication were published on the hospital intranet. Copies of the protocol were printed for all infants currently receiving either medication. All infants on either

medication had new prescriptions written to match the updated protocol and a reference sheet was provided for each cot space. This reference sheet (**FIGURE 2**) described the two standard concentrations available, instructions on how to prepare them and formulae to calculate the dose they were providing.

#### Education campaign

The education campaign for medical, nursing, midwifery and pharmacy staff also involved regular in-services and update posters. This continued throughout the study period and provided opportunities for all staff to see the progress, as well as opportunities to offer feedback on the new process.

#### Data analysis

Each observation was transcribed and entered into a spread sheet. The number of syringes prepared for both medications was recorded. Each medication infusion was assessed against the current protocol. Compliance with the protocol was calculated using the number of times one of the two standard concentrations, as advised by the protocol, was used over the

number of prescribed orders for each medication. The data were graphed on a weekly basis for each medication and displayed on the ward for all staff to see, as part of the ongoing education campaign. The compliance results for the pre-implementation and post-implementation periods were compared using the chi-square test.

#### Adjustments to protocol

As part of the PDSA methodology, at the end of each week, a nurse, neonatologist and pharmacist would review the compliance against each medication protocol and adjust the relevant protocol as necessary. Data continued to be recorded and reported for 12 consecutive weeks. This information was regularly fed back to the staff through the ongoing education programme.

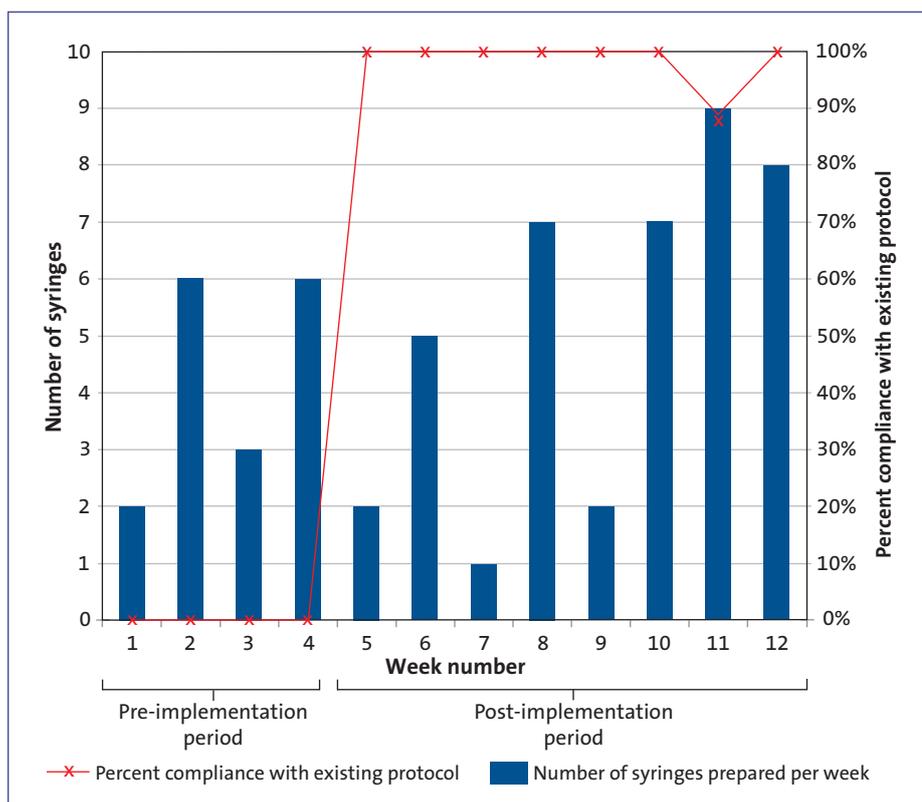
### Results

A total of 58, 24-hour infusions were prepared for both medications throughout the study period: an average of 4.8 ( $\pm 2.7$ ) medication infusions prepared per week.

Seventeen infusions were made during the pre-implementation period (using the

|  |  |
|--|--|
| DOBUtamine   | 1mg/mL strength (1000µg/mL)<br>Suits neonates ≤2kg   |
| Add 2mL of DOBUtamine 12.5mg/mL to 23mL of compatible fluid = Total 25 mL  |  |
| Start at 5µg/kg/min  |  |
| DOBUtamine   | 3mg/mL strength (3000µg/mL)<br>Suits neonates >2kg   |
| Add 6mL of DOBUtamine 12.5mg/mL to 19mL of compatible fluid = Total 25 mL  |  |
| Start at 5µg/kg/min  |  |
| DOPamine   | 0.8mg/mL strength (800µg/mL)<br>Suits neonates ≤2kg  |
| Add 0.5mL of DOPamine 40mg/mL to 24.5mL of compatible fluid = Total 25mL   |  |
| Start at 5µg/kg/min  |  |
| DOPamine   | 3.2mg/mL strength (3200µg/mL)<br>Suits neonates >2kg |
| Add 2mL of DOPamine 40mg/mL to 23mL of compatible fluid = Total 25mL   |  |
| Start at 5µg/kg/min  |  |
| To calculate infusion rate (mL/hr):<br>$\text{Rate (mL/hr)} = \frac{60 \times \text{dose } (\mu\text{g/kg/min}) \times \text{weight (kg)}}{\text{Strength } (\mu\text{g/mL})}$ |  |
| To calculate the dose (µg/kg/min):<br>$\text{Dose } (\mu\text{g/kg/min}) = \frac{\text{Rate (mL/hr)} \times \text{strength } (\mu\text{g/mL})}{60 \times \text{weight (kg)}}$  |  |

**FIGURE 2** Reference sheet used in the first iteration of PDSA cycle.



**FIGURE 3** Percent compliance with existing protocol.

rule-of-six method). None of these infusions was compliant for both medications (**FIGURE 3**).

Forty-one 24-hour infusions were prepared during the post-implementation period using the standard concentration protocols for both medications. During the post-implementation period, all dopamine and dobutamine 24-hour medication infusions were compliant with the standard concentration protocol from weeks 5-10. At week 11, a dopamine syringe was prepared at a non-standard strength. This was for a term infant with gross fluid restriction. The MDT reviewing the standard concentration solution protocols concluded that a third solution was required for each medication. This was to accommodate for critically ill term infants. This was in accordance with the PDSA model that was used.

New concentrations were selected for each medication. The three concentrations selected for dopamine were 0.8mg/mL, 1.6mg/mL and 3.2mg/mL and the new standard concentrations for dobutamine were 1mg/mL, 2mg/mL and 4mg/mL. The on-line protocols were updated (including the reference sheet) and implemented immediately, while communicating the changes to all ward staff.

At week 12, the compliance with the standard strength protocol returned to 100%.

Comparing the compliance results between the pre-implementation (zero out of 17) and post-implementation (40 out of 41) periods, there was a statistically significant improvement with the introduction of standard concentration 24-hour solutions from week 5 ( $p < 0.05$ ).

## Discussion

The change process was based on Clinical Practice Improvement (CPI) methodology<sup>15</sup>, which provides a framework with which to put published evidence into clinical practice. It recognises that research does not translate identically across different healthcare institutions. Through CPI methodology, evidence of a problem was gathered, the individual steps that contributed to the medication use process were identified and factors contributing to variability in practice were discussed and prioritised. In focussing on the contributing factors, the team concentrated on the system rather than apportioning blame to any individual or professional group. The PDSA cycle<sup>10</sup> ensured that all changes to the system were carefully and safely monitored and reported throughout the process, to further enhance the intervention and ensure that all staff could observe the reasons for change.

The success of this change in practice relied on a multidisciplinary approach.

Through teamwork, a range of risks inherent in the existing process was identified from a number of points of view. Using a quantitative approach to prioritise these risks, interdisciplinary engagement was promoted in the change process.

Some resistance to change had to be overcome. The existing practice had been in place for many years. The reported rate of incidents with the existing process was low, which resulted in, what has been described as, an illusion of safety<sup>16</sup>. Ongoing education, incorporating discussion and feedback, encouraged a sense of ownership, enabling the improvements in practice; it was paramount to the success of this practice change.

Mapping out the process of delivering 24-hour medication infusions to infants, highlighted the number of steps required as well as the dependencies each had on the previous step.

It is suggested that a complex system (such as the delivery of 24-hour medication infusions) is protected from error by a series of safety nets<sup>17</sup>. These safety nets may be physical, functional, symbolic or incorporeal<sup>18</sup>. The medication protocols are an example of a safety net in place to support staff through a process. It was clear from this review that the existing protocol did not meet the needs of this vulnerable population.

In measuring the compliance with the protocol, the MDT learnt that in all cases where the rule-of-six was used, the prescriber departed from the clinical protocol at the *prescribe* step (**FIGURE 1**). In order to deliver the appropriate dose in less fluid, the medication syringes were prescribed in greater concentrations than recommended by the protocol. This left the steps that followed prescribing, including review, prepare, document and administer, to be carried out independently from the protocol, thus removing an important safety net. While there were many options to how this problem could be addressed, the use of standard concentration solutions has improved compliance with the protocol. This has resulted in all staff being able to reliably check directly against the medication protocol at all steps of the process (from prescribe to administer).

The significant difference between the old and the new method is that, when the dose of medication is increased, the prescriber may either increase the infusion rate or make a decision to use an alternate infusion concentration using one of the

three options available, thus providing all staff performing the steps that follow with standard written guidance.

The development of the new medication protocols provided an opportunity to incorporate Tall Man lettering to distinguish medications with similar names. Integrated within the medication name, Tall Man lettering uses uppercase letters to highlight the differences between two similarly spelt medications, for example DOBUTamine and DOPamine. Studies have shown that fewer mistakes are made, in both medication dispensing and administration, when Tall Man lettering is used<sup>19</sup>. The Australian Commission on Safety and Quality in Health Care<sup>20</sup> as well as the Institute for Safe Medication Practices<sup>21</sup> have published a list of recommendations for the use of Tall Man lettering.

The success of this project has supported expansion of standard concentration solutions to other medication protocols including fentanyl, insulin and alprostadil. It has also encouraged dialogue with other neonatal units across the state (including neonatal retrieval services) to develop regional medication protocols, in the support of safer medication management for infants retrieved from regional centres.

When using the rule-of-six method, multiple concentrations of each medication were required to meet the needs of all infants within the nursery. Therefore nurses had to prepare all syringes for 24-hour medication infusions in the ward environment, immediately before use. The development of three standard concentrations for each medication has opened the opportunity for the pharmacy department to prepare standard concentration syringes in batch quantities, in advance, for storage on the NICU. This will facilitate more timely administration of medications to an infant.

## Conclusion

The literature on safety and quality, has flagged the use of standard concentration medication infusions as one model for the safe delivery of medications in paediatrics. This project has demonstrated that, with sensible selection of standard concentration medication solutions, this model can be integrated within the NICU. In doing so, the protocol is more reliably used at all points of the process, improving the safety net to support staff in the safe delivery of high-risk medications within the NICU.

Standard concentration solutions have streamlined the whole process of delivering high-risk medications, making it easier for medical, nursing and pharmacy staff in the NICU, thus contributing to a safer system.

This experience in changing to standard concentration solutions can be used in any area that uses medication infusions for the stabilisation or treatment of critically ill infants or children, including other paediatric intensive care units and retrieval services.

## Acknowledgements

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