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PLACEMENT OF SYRINGE INFUSION PUMPS AND SOLUTION DENSITY CAN IMPACT INFUSION PERFORMANCE? AN EXPERIMENTAL STUDY.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

ABSTRACT

Aim

To verify how variations in the height and solution density can influence syringe infusion pumps accuracy.

Methods

Three syringe infusion pumps were studied in two infusion rates 0.5ml/h and 10.0ml/h. The solutions studied were saline solution and parenteral nutrition. The syringe infusion pumps were placed at the level of the distal exit of the infusion line, 30 cm above and 30 cm below.

Results

After two hours of infusion, loss of accuracy was verified mainly at 0.5 ml/h with a significant influence of infusion pump placement ($p<0.001$). At 10.0 ml/h there were differences between saline solution and parenteral nutrition at the same level ($p<0.004$) and 30cm above ($p<0.001$). After two hours of infusion the higher error rate identified was 20.1%.

Conclusion

The placement of the syringe infusion pump and the infusion rate influence accuracy mainly at 30 cm below and 0,5ml/h.

Keywords: Infusion pumps; Syringe; Intensive Care; Medication Error; Patient Safety; Hydrostatic pressure; Neonatal.

INTRODUCTION

Data from the United States of America (USA) show that about 100,000 patients dye per year because of medication errors that could be prevented.[1] Patient safety is a global concern and medications errors are the major sources of severe adverse events.

The associated healthcare spending related to medication errors has been estimated to be as high as 20 million dollars.[2] Therefore, studies investigating medication errors are becoming relevant to increase the quality and safety of patient care delivery.

Pediatric and neonatal patients are one of the most affected group by medical errors, especially when admitted to an intensive care unit.[3] This is due to the need of many different medications, immature body system and their inability to communicate symptoms.[4] Around 57% of adverse events are considered as preventable errors and one of the most frequent are the dosing errors.[5] Administration via infusion pumps should ensure an accurate dose deliver.[6]

Characteristics of each type of infusion pump should be known by clinicians in order to adequate its use to patients and therapeutic needs and prevent adverse events. In syringe infusion pumps the adjustment of the syringe size to the programmed volume of the infusion pump is a factor that improves the equipment performance. To achieve a steady flow rate when using a 60ml syringe in a low infusion rate as 0.2ml/h, the equipment requires almost an hour. When using a 3 or 12ml syringe the time drops for ten minutes, reducing the patient exposure to hemodynamics instability.[7-8]

Hydrostatic pressure (P) is directly proportional to the fluid density (ρ) and the vertical height (h) of the liquid column relative to a reference point and can

~~Hydrostatic pressure can~~ influence the syringe infusion pumps accuracy. [9] Changes on the placement of the syringe infusion pump, according to patient positions might have consequences on the accuracy of infusion flow due to pressure variations as it is a closed system. [9] ~~Hydrostatic pressure is the strength made by a fluid to a surface, and it depends directly on the density of the fluid, the height of the infusion device and gravity force.[9] The hydrostatic pressure in a closed infusion system is dependent on its characteristics and venous pressure.[9]~~

Studies about syringe infusion pumps have demonstrated that changes on the infusion rate were related with hydrostatic pressure influence.[10] One study documented that positioning the syringe infusion pump above the patient resulted in a drug bolus seven times higher than the rate set as 2 ml/h, and an increase in time for the equipment adaptation. When the pump was placed below the patient a temporary infusion interruption of around 180 seconds was observed. This temporary interruption was due to the fact that the pump had to overcome the pressure reduction at the exit of the infusion line caused by suddenly moving the pump to a position below the patient.[10]

Current clinical practice in pediatric and neonatal Intensive Care Units (ICUs) is that syringe infusion pumps are widely used and not all equipment are positioned on the same level of the patient's intravenous catheter, despite the type of solution infused. The search for patient safety and prevention of medication errors calls for further understanding of the accuracy of the infusion devices. Therefore, the aim of this study was to evaluate the performance of syringe infusion pumps on the variations in placement and density of the infused solution.

METHODS

Type of Study

An experimental study was deployed in a laboratory under controlled conditions of temperature and air humidity. All the equipment used were certificated and calibrated. The intravenous systems and solutions were sterile and adequate to the study requirements. Study approved by Research Ethics Committee of Federal University of São Paulo number 2091200916.

Sample

The sample was composed by results of 36 experimental infusions randomly study using three syringe infusion pumps, in two infusion rates, three equipment positioning and two solution densities.

Experimental Design

Three syringe infusion pumps from Samtronic® (model ST 6000, Brazil) were used. Two infusion rates were tested: 0.5ml/h and 10.0ml/h. The infusion pumps were positioned at three different placements: H1 the height at the same level of distal infusion system exit; H2 30cm above and H3 30cm below.

To verify if the density of the solution influences the performance of the infusion pumps, two solutions were used being denominated as D1 the solution composed by 0.9% sodium chloride (normal saline) and D2 the parenteral nutrition composed by polyaminoacids, poliminerals, glucose and electrolytes.

The solutions had their density and osmolality measured before the beginning of the infusion procedure. To verify the density, pycnometry technique was applied; 05 ml of each solution was collected and transferred to the pycnometer, glassware, and weighted through a Shimadzu® (model AUY220, Japan) analytic balance. The value found after the measure, was applied to a

mathematical formula corresponding to the density value. The density of D1 was 0.98 – 1.00 g/cm^3, and the D2 was 1.09 – 1.12 g/cm^3. The osmolality of the solutions was verified by using the osmometer from PZL® (model PZL-1000, Brazil). With a syringe the D1 solution was collected in a 2.3ml cuvette that was submitted for analysis. The same procedure was performed with the D2 solution. The results were 0.224 – 0.296mOsmol for D1 solution and 1.613 – 1.829mOsmol for D2.

Once the density and osmolality of the solution were measured, a beaker was installed inside the analytical balance, and the next step was the execution of the experiments. The experimental infusion system is composed by a 20ml syringe filled with the solution and installed in the infusion pump, according to the randomization proposed. A three way stopcock and an IV tube 24 gauge were connected at the syringe. Another three-way stopcock was attached on the distal portion of the IV tube. The infusion pump was then positioned at the studied placement and an infusion rate was programmed. The filling of the IV tube was performed via the electronic bolus of the infusion pump.

The infusion pumps remained in operation for two uninterrupted hours in order to obtain a better equipment performance.[11]Then the infusion was interrupted and the final volume was measured by Shimadzu® (model AUY220, Japan) analytic balance. The data was collected by the same professional during all the experiments.

Data analysis

The data obtained was expressed by mean and standard deviation, student's t-test and ANOVA test. Significance was set at a level of 0.05.

RESULTS

We analyzed 36 experimental procedures, lasting two hours each, totaling 72 hours of data collection.

When studying the amount of infused volume in two hours of continuous infusion, the three positions studied demonstrated a significant influence with D1 at rate 0.5 ml/h ($p<0.001$). There was no statistical difference between group D1 and D2 at rate 0.5 ml/h. Although, with a rate of 10.0 ml/h statistical differences were found between group D1 and D2 according to the three positions (Table 1). Group D1 infused less than D2 at H1 ($p=0.004$), H2 ($p=0.001$) and H3 ($p=0.018$).

Table 1. Total infused volume, in two hours, according to density, infusion rate and the syringe infusion pump placement.

Exit infusion line	0.5 ml/h			10.0ml/h		
	Density I Mean (SD)	Density II Mean (SD)	Student-t test P	Density I Mean (SD)	Density II Mean (SD)	Student-t test P
Same level as the infusion line exit (H1)	0.866ml (0.003)	0.867ml (0.091)	0.985	19.505ml (0.203)	20.796ml (0.035)	0.004
30 cm above the infusion line exit(H2)	0.927ml (0.125)	0.961ml (0.064)	0.695	19.341ml (0.132)	20.676ml (0.245)	0.001
30 cm below the infusion line exit(H3)	0.799ml (0.033)	0.881ml (0.080)	0.716	19.325ml (0.305)	20.503ml (0.437)	0.018
Anova test P value:	<0.001	0.394		0.584	0.502	

Legend: ml = milliliter; h = hour; SD = standard deviation

Calculating the infusion error according to the total infused volume, the equipment evidenced inaccuracy. With a rate of 0.5 ml/h in D1 group, the syringe infusion pump had an error of 13.4% at H1, 7.3% at H2 and 20.1% at H3. Comparing to group D2, the error rates were of 13.3% at H1, 3.9% at H2 and 11.9% at H3. At a rate of 10.0 ml/h the equipment showed a rate error of 5%.

DISCUSSION

The performance of the syringe infusion pump is an important aspect to ensure patient safety and preventing medication errors. This study demonstrated an association of performance of syringe infusion pump, type of solution infused and positioning of the equipment.

Critically ill patients are most affected by medication errors due to the vast use of drugs, such as vasoactive drugs in infusion pumps.[11] The most important risk factors associated with the clinical use of syringe pumps includes overdose or under dose through the infusion of non-accurate amounts of drug leading to adverse events such as over sedation, respiratory depression, or significant fluctuations in blood pressure. [12] The pediatric population is the one that stands out most in the incidence rate of this type of error, because they need more precise doses and low infusion volumes.[13] However, as this study found, the syringe infusion pumps lost its accuracy when a low infusion rate was settled and an extreme error rate of 20.1% was observed when the total volume infused was evaluated.

After two hours of operation, it was identified that the syringe infusion pump, with an infusion rate of 0.5 ml/h, infused a volume lower than the programmed, in the three positions studied. Besides that, in all the experiments

with low rate, the equipment had an infusion error between 7.3% at H2 and 20.1% at H3 during the infusion of normal saline solutions. These infusion errors exceeded the maximum limit acceptable by the Brazilian Agency of Technical Standards (ABNT) of 5%.[14]

The rate of errors found can be associated with the SIP mechanics. When the stepper motor turns the drive screw rotator, the equipment starts the infusion, and the fluid is delivered in a continuous way when a higher infusion rate is settled. When it is low, the infusion tends to be intermittent in regular bolus affecting the final volume delivered to the patient and its hemodynamics conditions.[15] This affects the infusion flowrate and reflects on the patient hemodynamic and medication delivery.[16] Another explanation can be given based on the intravenous sets compliance which can be affected by variations in hydrostatic pressure, such as equipment positioning and density of the infused solution.[17] By lowering the infusion system, there is an increase in the pressure exerted on the distal infusion exit, causing the system to dilate and store more fluid.[18] This results in less volume infused, explaining the higher infusion errors found when the equipment was positioned below the exit infusion line.

Other study described that with an infusion rate below 1.0 ml/h, the variations in the positioning and density will be more likely to influence negatively on syringe infusion pumps performance.[19] Evaluations regard the SIP placement also demonstrated that changing the placement of the equipment during its operation can cause an unexpected infusion interruption, explained by the equipment adjust due to changes in placement.[20]

When the infusion solution contains any catecholamine, the recommendation of not change the SIP placement during its operation is

important. Case reports has shown that moving the equipment upwards to 80-100 cm from the patient causes an unexpected infusion about 12 micrograms of epinephrine, increasing heart rate and blood pressure. Whereas if the patient is strongly dependent of catecholamine, is advised not to change the distance from the patient to the infusion device while its operation.[21]

When choosing the use of syringe infusion pump, it is important that healthcare professionals be aware of the placement of the equipment at a low rate of infusion. More studies must be carried out in order to evaluate and measure the consequences of a poor accuracy of SIP in low rates on the patient. The findings of this research need to be returned to practice and ensures correct intravenous therapy, guarantying that the patient has a safety and optimal treatment.

Implications for practice

This study suggests that nurses and other healthcare professionals using infusion pumps must pay attention on syringe infusion pump placement. Areas of attention for safe practice when using infusion pumps in the pediatric population are the positioning of the equipment and infusion rate. When the infusion pump is placed below the patient, this will deliver less drug to the patient, mainly in low infusion rates. Changes on the flow-rate can occur and if the infused solution is a catecholamine or a multiple infusions system, the patient might be exposed to an unsafe practice causing errors with possible significant consequences.

CONCLUSION

The position of the syringe infusion pump can influence the amount of volume infused. The influence was more evident in low infusion rate. These variants

should be considered in intravenous therapy with syringe infusion pumps in pediatric patients, in order to reduce medication errors triggered by changes on hydrostatic pressure and the system compliance. Further investigations should be carried out in order to evaluate the use of unbending infusion system to reduce the compliance and if temperature or others variables can influence the system to expand.

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