Slipping up on the sliding scale: fluid and electrolyte management in variable rate intravenous insulin infusions

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Abstract
This study aimed to analyse variations in intravenous fluid therapy and electrolyte management with variable rate intravenous insulin infusions (VRIIs); and to quantify serum electrolyte changes pre- versus post-VRII and variations therein depending on supplemented fluid electrolyte compositions.

A retrospective study was undertaken involving 174 VRIIs prescribed over a 10-week period at a tertiary teaching hospital. Each VRII had their associated fluid prescription and serum electrolytes analysed.

The results showed that 5% dextrose (46%) and 0.9% NaCl (34%) were the most commonly prescribed fluids; 64% of fluids did not have the recommended potassium supplementation. Administration of a VRII resulted in a significant drop in serum potassium levels (p<0.0001) for those who did not receive supplementation. There was no drop in serum potassium for those patients who did receive supplemental potassium. Eleven patients (6.4%) developed new-onset hypokalaemia (K ≤3.5mmol/L) after implementation of a VRII.

Our study supports the hypothesis that VRIIs cause hypokalaemia and that this can be averted by supplemental potassium, thus preventing potentially avoidable hypokalaemic complications. A large variation exists in prescribing fluids with VRIIs. Introduction of the national surgical and medical VRII guidelines, together with improved availability to recommended fluids, and a quality improvement project, are our next steps to improve patient outcomes. Copyright © 2016 John Wiley & Sons.

Key words
variable rate intravenous insulin infusion; electrolyte; hypokalaemia; intravenous fluids

Introduction
Diabetes affects around 5% of people in the UK. The prevalence of diabetes in patients in hospital is as high as 10–28%.1 Hyperglycaemia has shown to be associated with increased morbidity and mortality in a number of inpatient situations, including critically ill patients,2–9 patients who have had a myocardial infarction,10–13 postoperative patients,14–17 and septic patients.18

One way of accurately and tightly controlling blood glucose levels is with the use of a variable rate intravenous insulin infusion (VRII). Simply put, this is a method of infusing IV insulin into a patient, at a rate determined by regularly measured capillary blood glucose levels. VRII has now replaced the term ‘sliding scale’ as it provides a less ambiguous and clearer indication of what is involved.19,20 This insulin infusion is almost always accompanied by an IV fluid which contains glucose to prevent hypoglycaemia.20

The advantage of VRIIs are that they provide a tightly controlled target blood glucose so improving the clinical outcome, as highlighted above.19

The choice of IV fluid to accompany the VRII is a controversial topic.20 In surgical patients, the mismanagement of patients’ fluid and electrolyte balances is linked with an increased risk of mortality and morbidity. Iatrogenic complication rates of fluid and electrolyte mismanagement may be as high as 50% in surgical patients.21 Complications can include: hypokalaemia (25%), hyponatraemia (16%), cardiac dysrhythmias (12.2%), fluid overload (17.9%), hyperkalaemia (2.8%) and hypernatraemia (3.7%). The complications of fluid and electrolyte mismanagement in the use of a VRII are less well studied, and there is limited evidence on which the guidance is created.19,20 Bhadresha et al. recorded a hyponatraemia incidence of 30% when a VRII with a 5% glucose solute was initiated in postoperative patients.22

It is therefore vital that the correct fluid, administered at the correct rate
is chosen. One reason that is often cited for these high iatrogenic complication rates is that fluid and electrolyte prescribing is often left to junior doctors. These are doctors who may be unaware of the daily fluid and electrolyte requirements and, in addition, the constituents of commonly-used fluids. The authors’ NHS trust now requires all new foundation doctors to complete mandatory diabetes training modules within the first few months of work.

The aims of ideal fluid management in a VR III are to: (1) provide a source of substrate (glucose) to avoid hypoglycaemia and hence proteolysis, lipolysis and ketogenesis; (2) maintain serum glucose levels between 6–10mmol/L; (3) achieve a euvolemic state; and (4) maintain electrolyte homeostasis.

To this end it is recommended that urea and electrolyte levels (U&Es) be monitored daily in patients receiving a VR III.

The Joint British Diabetes Societies (JBDS) have published guidelines for both surgical and medical patients on the use of a VR III. The fluid of choice in both medical and surgical cases is 0.45% saline with 5% glucose and either 0.15% or 0.3% potassium chloride (KCl). The issue with this fluid is that it is not readily available in hospitals and is around three times the cost of regular 5% dextrose. The guidance published in 2011 predicted that increased use of this fluid should result in reduced costs and improved availability. The guidelines for medical patients published later in 2014 re-highlighted the continuing minimal access to this fluid of choice. Acceptable fluid alternatives, therefore, of 5% glucose with 20–40mmol/L KCl or 0.18% sodium chloride (NaCl) with 4% glucose and 20–40mmol/L KCl are described. The addition of KCl is advised for all patients with serum potassium levels <3.5mmol/L.

This retrospective review analysed variations in IV fluid and electrolyte management choices in medical and surgical VR III patients. In addition, this study attempted to analyse what happens to serum electrolyte values after implementation of a VR III. Minimal data exist in this field, as highlighted by the JBDS guidelines.

Methods

Retrospective data were collected from 1 July to 8 September 2015 on all VR IIIIs prescribed at a tertiary teaching hospital in Birmingham. The results were collated by the hospital informatics department who performed a database search on the hospital’s electronic prescribing system (PICS). Any patient, during the allocated time period, who was prescribed a VR III outside ITU (critical care) was included in the dataset. This included both medical and surgical patients.

Patients who were prescribed fixed-rate insulin infusions or other variations of insulin infusions were not included in the dataset. Those patients not receiving supplemental IV fluids were excluded from further fluid analysis (n=10). Patients who did not receive full bloodwork were excluded from further serum electrolyte analysis (n=33).

A VR III was specifically defined for the purpose of the database search as 49.5ml of 0.9% NaCl with 50 units (0.5ml) of Actrapid insulin. Serum electrolyte values were recorded as the closest temporal values available pre- and post-VR III.

A schematic table showing what information was being collated and summarised can be seen in Table 1. All the information about the fluid prescription and the blood results were retrieved from the PICS database.

In cases where there were multiple fluids prescribed for the same VR III, we chose the fluid most commonly used as the named prescribed fluid. In the same way, if there was a change in rate of fluid administered, the most common rate was recorded as the main rate.

The data were analysed using Microsoft Excel 2010. The data are displayed as raw numbers and as percentages. Statistical analysis using paired t-tests was performed to assess for differences in serum electrolyte values before and after implementation of the VR III.

Results

A total of 174 individual VR IIIIs were analysed from a total of 172 patients. All received the trust’s standard VR III insulin regimen. Ten patients were excluded from further fluid analysis on the basis that no accompanying fluids were prescribed. There were a total of 33 patients who did not have full bloodwork taken. These patients were therefore excluded from any serum electrolyte analysis.

Table 2 demonstrates the prescribed fluid chosen to accompany the VR III. Overall, 5% dextrose was the most common choice with 46% of all fluid prescriptions; 0% of prescriptions were for the JBDS guideline fluid of 0.45% NaCl with 5% glucose. In total, only 51% of prescriptions were recommended or acceptable alternative fluids as per JBDS guidelines.
The rate of fluid administration varied. The most commonly administered fluid rate was 125ml/hr or 8-hourly bags (64% of prescriptions) which is also the JBDS recommended initial fluid rate. This is shown in Table 3. JBDS guidelines highlight that alternative fluid rates may, however, be appropriate for elderly patients and those at risk of fluid overload. This study made no attempt to further sub-analyse the appropriateness of said chosen rate. Nineteen percent (n=31) of prescribed fluids had a change in the rate of administration, contrary to the literature which advocates the use of a steady rate of solute being given.19,20,25 Furthermore, around 44% (n=72) of prescriptions changed the choice of fluid to be given during the VRIII. Serum electrolyte levels before and after implementation of a VRIII were compared. As shown in Table 4, only 36% of patients received the correct potassium supplementation to their fluid prescriptions.

Analysing the entire dataset, we showed a statistically significant drop in serum potassium levels pre versus post-VRIII (4.5±0.60 vs 4.30±0.58; p<0.0001). The subgroup of patients who had no supplementary potassium added to their fluids, had a statistically significantly lower serum potassium post-VRIII (4.66±0.54 vs 4.28±0.50; p=0.0001). In the 36% of patients who had supplemental potassium prescribed there was no significant drop in serum potassium pre versus post-VRIII (4.35±0.62 vs 4.33±0.58; p=0.4). Eleven (6.4%) patients developed new onset hypokalaemia (K<3.5) post-VRIII.

Subgroup analysis of the patients who developed new-onset hypokalaemia showed that they had a lower pre-VRIII serum potassium level compared to those who did not become hypokalaemic (4.25±0.81 vs 4.57±0.57; p=0.03). This subgroup had potassium supplemented to their fluid 27% of the time (3/11) which was similar to the whole cohort.

Serum sodium levels, using the entire dataset, did not differ pre versus post-VRIII (137±5.0 vs 136±4.04; p=0.99). Subgroup analysis of patients who were only administered hypotonic solutions also showed no change in serum sodium levels (137±4.86 vs 136±4.13; p=0.051).

Discussion

This retrospective review assessed fluid and electrolyte management in VRIIs and analysed associated serum electrolyte discrepancies.

This study has shown in a moderately-sized dataset that there is a statistically significant drop in serum potassium after use of a VRIII. While this is not surprising, there is a paucity of quantifiable data on which the JBDS VRIII electrolyte supplementation guidelines are based.18,20,25

Those patients who had supplemental potassium did not show a significant drop in serum levels. Taken together, these results infer that supplementing crystalloid fluids with potassium, as the JBDS national guidelines suggest, does indeed stop serum potassium levels from falling when prescribing a VRIII.

Hypokalaemia can cause significant cardiovascular morbidity and mortality with acute-onset ventricular tachycardia/fibrillation among the most serious.26 Eleven patients (6.4%) developed new-onset hypokalaemia after implementation of a VRIII, adding a potential clinical significance to the data. These patients had lower starting serum potassium levels on average, highlighting a logically at-risk subgroup of patients for whom supplemental potassium is of extra importance.

Previous data have suggested there may be a 30% incidence of hyponatraemia in postoperative patients given fluids and a VRIII.22 This was not the case in our study, even when hypotonic solutions were used to accompany the VRIII. However, our data were not limited to surgical postoperative patients and did not follow up serum electrolyte values after discontinuation of the VRIII.

This study also analysed prescription variations in the fluid of choice accompanying VRIIs. We have reviewed current practice before implementation of new guidelines and explored the cost and availability of the JBDS recommended fluids. Expense and subsequent availability remain the biggest issues with these fluids.19,20,25 The hypothesis that with increased use will come economic viability and increased prevalence19,20 is not holding true, and in our trust the relative procurement costs when compared to other crystalloids have actually increased.

As this was before implementation of JBDS guidelines, 51% of prescriptions were found to be using an acceptable alternative fluid. The most commonly prescribed wrong fluid was 0.9% NaCl (34%). The reason this is not recommended as a suitable fluid by the current JBDS guidelines is that it does not provide a source of substrate (glucose) to avoid hypoglycaemia and hence proteinolysis, lipolysis and ketogenesis.19,20 Forty-six percent of all fluids prescribed had no glucose content, thus running the risk of hypoglycaemic episodes.
While analysing the data, we noticed a common theme that 0.9% NaCl and 5% glucose were commonly co-prescribed with instructions to vary fluid choice based on capillary blood glucose. Again, this is not recommended as it does not provide a steady supply of substrate and therefore makes achieving glucose homeostasis via the use of the VRIII difficult.

Of note, 10 VRIIs had no fluid prescribed at all so were unable to meet any of the fluid therapy goals described. Furthermore, despite the risk of electrolyte derangement demonstrated above and described in the literature, 19% of the VRIIs did not have daily serum U&Es taken. Therefore the issue of hypokalaemia and other electrolyte disturbances may be well be under-reported and under-diagnosed.

Taken as a whole, these results suggest that the persons prescribing VRIIs and their associated fluids have a limited understanding of the fluid regimens that should be co-prescribed with VRIIs. These prescriptions are largely carried out by junior doctors and, in order to improve patient care, further education and training are necessary.

The lack of a consistent fluid regimen to accompany VRIIs, coupled with the evidence of potential significant serum electrolyte derangement, further highlights the utility of a singular IV fluid as recommended by JBDS, to safely address all fluid therapy goals, especially electrolyte balance. These results highlight the importance of adhering to a well-developed VRIII protocol and some of the risks associated with non-compliance including hypokalaemia.

In summary, this study adds a significant quantifiable credence to the hypothesis that VRIIs without appropriate potassium supplementation can cause hypokalaemia. It provides evidence that supplemented IV potassium can avert this effect.

There is widespread variation in the IV fluid therapy accompanying VRIIs. This may be compounded by factors including limited theoretical knowledge among medical staff prescribing the fluids with VRIIs. The importance of adhering to developed protocols to avert mismanagement is highlighted.

Going forward, our trust is keen on implementing the JBDS perioperative and medical VRIII guidelines. We aim to undertake a quality improvement project after implementation of guidelines, and further contribute to the body of evidence on the effectiveness of recommended IV fluids accompanying VRIIIs. We further suggest that widespread dissemination of current guideline adherence nationally will help local champions implement best practice and source the fluids which are not widely available, thus improving patient care.

References