

2012

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Recommended Citation

Nehme, Z., & Cudini, D. (2009). A review of the efficacy of 10% dextrose as an alternative to high concentration glucose in the treatment of out-of-hospital hypoglycaemia. *Australasian Journal of Paramedicine*, 7(3).

Retrieved from <http://ro.ecu.edu.au/jephc/vol7/iss3/2>

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EVIDENCE-BASED RESEARCH

Article 990341

A review of the efficacy of 10% dextrose as an alternative to high concentration glucose in the treatment of out-of-hospital hypoglycaemia

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Abstract

Objectives

Dextrose 50% is commonly accepted as the primary management of severe hypoglycaemia, however its position seems to be by default rather than clinical or research significance. The use of 10% dextrose by some prehospital care providers has demonstrated greater practical and physiological advantages, with less clinical implications than higher concentrations. The objective of this study was to review the literature into the efficacy of intravenous 10% dextrose in the management of out-of-hospital hypoglycaemia.

Methods

A review of select electronic databases was conducted from their commencement to the end of March 2008. Inclusion criteria was any article which evaluated the administration of intravenous glucose within any setting/discipline, or when compared to any alternative intervention. Exclusion criteria were articles pertaining to the administration of glucose other than in the emergency management of hypoglycaemia.

Results

The search yielded 3,651 potential articles, with 24 meeting the inclusion/exclusion criteria. Dextrose 10% has demonstrated equal time to restoration of conscious state at smaller doses, with reductions in post-treatment blood sugar levels than the higher 50% concentration. The risk of extravasation injuries and potential clinical ramifications in paediatrics are compelling reasons to consider a shift away from higher concentrations of glucose. The titration of 10% dextrose to patient conscious state has been utilised by other prehospital care providers in replacement of bolus doses of 50% preparations.

Conclusion

There is evidence to suggest that the titration of 10% dextrose to conscious state in severe hypoglycaemia is as efficacious as the administration of 50% dextrose, while reducing associated risks and producing better post-treatment outcomes.

Keywords: *blood glucose; diabetes mellitus; emergency medical services; hyperglycaemia; hypoglycaemia.*

Introduction

The prehospital administration of intravenous dextrose in the management of hypoglycaemia is standard practice within Australia. Dextrose has demonstrated to be effective in the management of hypoglycaemia, with less clinical limitations than glucagon preparations. Dextrose 50% is currently the drug of choice in hospital and prehospital settings for the management of hypoglycaemia, however there has been little research into the efficacy and safety of either 50% dextrose or less concentrated forms of glucose. This review article explores the efficacy of 10% dextrose in the management of hypoglycaemia, and provides an appraisal of its potential role within the prehospital environment.

Methods

A review of the literature was conducted incorporating a variety of electronic medical literature databases. This literature search encompassed both peer and non-peer reviewed journals for information consistent with subject headings and search terms. The search was not limited to prehospital literature, rather subject headings and search terms were ‘exploded’ to include all related disciplines. Electronic databases were searched from commencement to the end of March 2008.

- Electronic Databases
AMED; Cumulative Index of Nursing and Allied Health Literature (CINAHL); Cochrane Database of Systematic Reviews (CochraneDSR); Central Register of Controlled Trials (CENTRAL); EMBASE; Meditext; and Medline.
- Subject Headings
Hyperglycemia; Hypoglycemia; Blood Glucose; Diabetes Mellitus; Glucose; Emergency Medical Services; Allied Health Personnel; Emergency Treatment;
- Search Terms
hyperglyc\$; hypoglyc\$; glyc\$; blood sugar level; dextrose; 10%; 50%;

Search terms were cross-referenced with related topics and subject headings, and further limited to articles or abstracts written in English and human studies. News, editorials and letters were also excluded. Inclusion/exclusion criteria were adopted to assist in extracting articles that were considered relevant to the research question. Inclusion criteria was any article which evaluated the administration of intravenous glucose (dextrose) within any setting, amongst any discipline, or when compared to any alternative intervention. Exclusion criteria were articles pertaining to the administration of glucose (dextrose) other than in the emergency management of hypoglycaemia.

Results

Results from the combined electronic database sources yielded 3,651 potential articles, of which the title and abstract were reviewed for appropriate inclusion/exclusion criteria. Of the initial articles, 24 articles were considered relevant to the research methodology. Referenced publications from the articles reviewed were also identified and examined for appropriate inclusion/exclusion criteria. A further 7 articles were located from reference lists.

Discussion

The search strategy revealed a limited number of articles that pertained to the administration of prehospital intravenous dextrose. The majority of the literature compared the

administration of glucagon with intravenous 50% dextrose. While no high level of evidence was found within this area of medicine, it has been established that intravenous dextrose is more reliable and has a faster time to restoration of normoglycaemia when compared to glucagon.⁽¹⁻⁶⁾ It is therefore the drug of choice in the management of severe hypoglycaemia.⁽¹⁾ No articles were found that focused solely on the use of 10% dextrose administration in hypoglycaemia, however one randomised control trial was located that directly compared 50% with 10% dextrose within the prehospital environment.

International Consensus on Practice

While the administration of 50% dextrose for hypoglycaemia is common place in almost all Australian and American prehospital care providers, several national and international ambulance services have undergone a shift to less concentrated preparations.

In Victoria, Australia the use of intravenous 50% dextrose for hypoglycaemia by prehospital care providers is considered to be best practice. The current clinical practice guideline operating within Ambulance Victoria states that a full bolus dose of 25g 50% dextrose is administered to all hypoglycaemic patients who are unable to administer oral glucose paste.⁽⁷⁾ A bolus dose of 50% dextrose was also recommended for correction of hypoglycaemia in paediatrics. In November 2008, the Ambulance Victoria Medical Standards Committee reviewed the current use of 50% dextrose by paramedics. The committee approved a change in the clinical management of hypoglycaemia to incorporate the titration of intravenous 10% dextrose to conscious state, and replacing the current use of bolus dosing of high concentration glucose.

The *Queensland Ambulance Service Clinical Practice Guidelines*⁽⁸⁾ advocate the use of 10% dextrose for intravenous administration as the first line management of patients with a Blood Sugar Level (BSL) less than 4.0mmol/L and unable to self-administer oral glucose. An initial dose of 15g is given intravenously, with a further dose 10g administered if the BSL remains <4.0mmol/L.

The prehospital administration of 10% dextrose has also been utilised internationally by St. John Ambulance in New Zealand, as well as prehospital care providers across the United Kingdom and Europe. Published by the Joint Royal Colleges Ambulance Liaison Committee (JRCALC) in 2006, the United Kingdom Clinical Practice Guidelines⁽⁹⁾ support the prehospital administration of 10% dextrose for patients with a BSL less than 4.0mmol/L and unable to self-administer oral glucose. An initial dose of 10g is administered intravenously with subsequent doses of 10g administered every 5 mins until a Glasgow Coma Score (GCS) of 15 is achieved.⁽⁹⁾ This practice is continued across all hypoglycaemic presentations, including paediatrics and pregnant women.

Evidence-based Practice – Drivers for Change

Evidence-based practice in relation to the administration of dextrose in hypoglycaemic presentations is limited, and relies on few scientific papers carried by expert opinion. The search strategy revealed only one randomised control trial comparing the administration of 10% and 50% dextrose concentrations in adults. While the majority of the literature pertains to the administration of 50% dextrose in comparison with glucagon, there is very little evidence to suggest that high concentration dextrose is superior to less concentrated preparations in the emergency management of hypoglycaemia.

The argument against the administration of high concentration dextrose begins with a case study presented by Efron and colleagues,⁽¹⁰⁾ and the poorly documented risk of hypertonic solutions in the paediatric population. The authors presented a case of a 4-week-old male child who was admitted to the hospital after a 24 hour history of vomiting. After initial studies, a diagnosis of pyloric stenosis was made clinically and supported by ultrasound examination. The child was assessed clinically to be mildly dehydrated. In an error made by hospital staff the child received an intravenous fluid infusion of 50% dextrose in 0.45% saline commenced at 24 ml/hour (150 ml/kg/day). Within 11 hours of receiving the infusion the child became apnoeic with unrecordable blood pressure and exhibited generalised seizures. The child was resuscitated and improved haemodynamically. Initial studies confirmed severe hyperglycaemia with a blood glucose measure of 105mmol/l. As a result, the child sustained significant cerebral ischaemia, severe visual impairment and developed both cognitive and physical dysfunction consistent with cerebral palsy.⁽¹⁰⁾ Other extreme examples of death and seizure activity have been provided by other authors in two separate case studies involving children and use of 50% dextrose.⁽¹¹⁾ After review of these papers it was concluded that low concentration glucose, such as 10% and 20% dextrose solutions, are the drugs of choice in the management of neonatal and paediatric hypoglycaemia.

Further support for low concentration dextrose has been seen by professional organisations within Australia. On behalf of the Australian Government, the Australasian Paediatric Endocrine Group (APEG) prepared national clinical practice guidelines for the management and treatment of type 1 diabetes in children and adolescents.⁽¹²⁾ APEG explicitly advocate the use of 10% - 25% dextrose solutions and state 50% dextrose should not be administered by physicians or paramedics to the paediatric population. The current national recommendation for the emergency treatment of paediatric hypoglycaemia is a dose of 0.2 - 0.5g/kg (2 - 5 ml/kg) of 10% dextrose. APEG further state that care must be taken to ensure doses of 25% dextrose are not exceed for its potential to precipitate rapidly causing severe hyperglycaemia.⁽¹²⁾ The Victorian Royal Children's Hospital (Australia) reaffirm APEG recommendations with clinical practice guidelines that outline the use of 10% and 25% dextrose for the emergency treatment of hypoglycaemia in paediatrics.⁽¹³⁾

The evidence for 10% dextrose as a treatment option for adult hypoglycaemia is less clear due to the scarcity of research in the area. Moore and Woollard⁽¹⁴⁾ presented the only randomised controlled trial that compared the efficacy and safety of intravenous 10% and 50% dextrose in the out-of-hospital management of adult hypoglycaemia. While not supported by other high level of evidence studies, this randomised control trial contributes knowledge to an area of evidence-based medicine where a significant scientific knowledge gap exists. Fifty-one adult patients who were unresponsive with a BSL \leq 4mmol/l were allocated 5g aliquots of either 10% or 50% dextrose at one minute intervals by paramedics until GCS 15.⁽¹⁴⁾ The authors found that following treatment there was no statistically significant difference in median time to recovery/GCS 15 (8 minutes), median post-treatment GCS, or the number of recurrent hypoglycaemic episodes within 24 hours between each intervention. Only 12% of patients required the full 25g dose when treated with 10% dextrose, while 65% of patients treated with 50% dextrose received the entire 25g bolus ($p < 0.0001$). The median post-treatment blood sugar levels were also significantly lower in the 10% dextrose group (10% = 6.2mmol/L and 50% = 9.4mmol/L, $p=0.003$).⁽¹⁴⁾ The authors concluded that dextrose 10% administered in 5g/50ml aliquots results in lower post-treatment BSLs and therefore is the treatment of choice in the prehospital management of adult hypoglycaemia.⁽¹⁴⁾

Mattila and colleagues⁽¹⁵⁾ investigated whether patients who were treated with dextrose by paramedics could be left at home without follow-up at the emergency department. The

authors found that paramedics (Helsinki, Finland) could safely and cost effectively treat 58 moderate to severe hypoglycaemic patients, who were unable to self administer oral carbohydrates, using intravenous 10% dextrose.⁽¹⁵⁾ In 91.3% of patients, the initial dose of dextrose 10% 200ml caused an increase in the BSL above 4.0mmol/L and patients were conscious and orientated. Approximately 45% of patients were unconscious on presentation. A follow-up study questionnaire completed by 58% of its participants revealed that on a scale from one to five the mean patient satisfaction with the EMS treatment was 4.6±0.8. Furthermore, the cost savings associated with not transporting the patient to the emergency department was found to be significant. This data should be interpreted with caution due to the high rate of loss to follow up.

Clinical Implications

One of the most common problems with the treatment of hypoglycaemia involves the imprudent use of intravenous glucose replacement.⁽¹⁶⁾ Nolan⁽¹⁶⁾ highlights that the use of 50% glucose as a bolus injection in the management of serious cases of hypoglycaemia does not match the shape and rate of the whole body glucose uptake curve. The consequence often leads to recurrent hypoglycaemic episodes and a more prolonged and unstable phase of treatment before restoration of normal physiology.⁽¹⁶⁾ Equally important when administering intravenous glucose is the avoidance of hyperglycaemia and regulation of normal serum glucose levels. Normoglycaemia has been shown to have a neuroprotective effect and reduces mortality and morbidity in the critically ill and those at risk of cerebral ischaemia.⁽¹⁷⁻²⁰⁾ Moore and Woollard⁽¹⁴⁾ highlighted that 10% dextrose given in small incremental doses and titrated to conscious state delivered ideal post treatment BSLs and significantly better results when compared to its alternative intervention.

One study found that the relative risk of death in stroke patients with a BSL of > 7mmol/L was 3.28 (95% CI, 2.32-4.64).⁽²¹⁾ Hyperglycemia has been attributed as the cause of a pro-coagulant state that can further compromise blood supply to the penumbral areas in acute ischemic stroke,⁽²²⁾ and has been associated with poorer outcomes for patients with severe traumatic brain injury.⁽²³⁾ Similarly, the detrimental effects of hyperglycaemia have also been associated to an increased risk of cardiovascular mortality. A study by Ainla and colleagues⁽²⁴⁾ showed that AMI patients with hyperglycaemia on admission (independent of a history of diabetes) represent a high-risk population for 180-day mortality. Poorer outcomes occurred in all hyperglycaemic patients and completely independent of diabetic status.⁽²⁴⁾ Fujimoto et al⁽²⁵⁾ evaluated the effect of acute hyperglycemia on coronary microcirculation by noninvasive measurement of coronary flow velocity reserve (which reflects the physiological status of coronary microcirculation). Their results indicate that acute hyperglycaemia may have significant adverse effects on coronary microcirculation. The authors found that coronary flow velocity reserve was significantly decreased 1 hour after acute oral glucose loading.⁽²⁵⁾

Hyperglycaemia has also demonstrated a viable risk for patients with an acute medical illness. Andersen and colleagues⁽²⁶⁾ undertook a review of the roles of insulin and hyperglycaemia in sepsis pathogenesis. Experimental studies suggest that increased levels of glucose and free fatty acids have distinct effects on inflammatory signalling, leading to additional release of pro-inflammatory mediators and endothelial/neutrophil dysfunction.⁽²⁶⁾

Czarny et al⁽²⁷⁾ documented a case report highlighting two patients with extrinsic asthma and coexistent insulin dependent diabetes mellitus. Both patients experienced an anaphylactoid reaction after the intravenous administration of 50% dextrose. Further studies revealed that

higher concentrations of dextrose induce increased histamine release from blood cells, and that this phenomenon is more marked in diabetic, and particularly diabetic allergic individuals. The authors concluded that the treatment of hypoglycaemia with 50% dextrose is associated with significant risk in diabetic individuals who are either allergic or are receiving beta-adrenoreceptor blocking medications.⁽²⁷⁾

As with all hypertonic solutions, the risk of extravasation injury is possible. The use of dextrose 10% may prove a safer option than the higher 50% preparation, particularly when detecting extravasation injuries early, and reducing secondary complications such as thrombophlebitis.⁽²⁸⁾ Dextrose 10% preparations are considerably less hypertonic than the 50% preparation and is therefore less irritable/destructive to the venous endothelium.^(16, 29) Kuwahara and colleagues⁽²⁹⁾ undertook a study that aimed to determine the tolerance osmolarity of peripheral veins. The study found that for peripheral veins the maximal tolerance osmolarity was approximately 900mOsm/L and for pH was 6.5. Unlike 10% dextrose whose osmolarity of 506mOsm/L is well within the range for safe peripheral administration, 50% dextrose exceeds the maximal tolerance osmolarity of peripheral veins by almost 3 times (2,525mOsm/L).⁽²⁹⁾ Glucose preparations greater than 20% concentration should be administered via large central vein (i.e. subclavian vein) to avoid the risk of thrombophlebitis and extravasation injury.⁽³⁰⁾

The greatest clinical risk, and equally the strongest driver for change, lies within the use of high concentration glucose in paediatric populations. This paper raises key questions over why national clinical recommendations over the use of dextrose in the paediatric population have taken so long to be translated into the adult population and incorporated into prehospital clinical practice guidelines. While the authors acknowledge that there is a lack of valuable evidence highlighting a significant benefit of less concentrated glucose preparations over current practice, clinical change does not always require it. Clinical change management involves a number of critical components; the process of synthesis of evidence-based practice moves beyond the assessment of quantitative research data: *“In the absence of strong evidence, practitioners need to weigh benefit to risk factors [and] also need to consider the feasibility of implementing the findings in their own practice setting.”*⁽³¹⁾ The role of evidence-based practice therefore highlights not only research significance, however also investigates the benefits, risks and feasibility of a chosen intervention. This process must be explored in the current clinical dilemma of glucose administration in hypoglycaemic emergencies.

Study Limitations

This research study is limited due to the low number of high level of evidence studies evaluating 10% dextrose in the management of hypoglycaemia. Some potential articles may have been missed by limiting the literature search to human and English studies only. Furthermore, there was no hand-searching of grey literature. Analysis of available literature needs to be interpreted with caution due to the limited value of case studies in evidence-based practice.

Conclusion

While there no doubt exists strong evidence to suggest that 50% dextrose achieves better recovery times with less clinical limitations than glucagon, its superiority when compared to less concentrated solutions such as 10% dextrose remains questionable. What can be said is that while both 50% and 10% dextrose concentrations are equally effective at reversing

hypoglycaemic episodes, there is some evidence that the 10% preparation excels in its efficiency in doing so. Dextrose 10% has been shown to require significantly reduced doses to reverse moderate-severe hypoglycaemic episodes, and subsequently produces more ideal post-treatment BSLs. In addition, it should be noted that the current method of dextrose administration in the prehospital setting is never without risk. Extravasation injuries and thrombophlebitis are a genuine concern with peripheral administration of hypertonic solutions. If there remains any doubt over the clinical benefit of 10% solutions compared to the status quo, then at the very least, 10% dextrose positions itself as the safer of the two interventions in the management of out-of-hospital hypoglycaemia.

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This Article was peer reviewed for the Journal of Emergency Primary Health Care Vol.7, Issue 3, 2009