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Original Contribution

A simple diagnostic test to confirm correct intravascular placement of peripheral catheters in order to avoid extravasation☆

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Abstract
Background: Intravenous catheters are ubiquitous among modern medical management of patients, yet misplaced or tissued cannulas can result in serious iatrogenic injury due to infiltration or extravasation of injectate. Prevention is difficult, and currently few reliable tests exist to confirm intravascular placement of catheters in awake spontaneously breathing patients.
Methods: Twenty conscious spontaneously breathing healthy volunteers were injected with 50 mL normal saline and 50 mL 4.2%, or 50 mL 2.1%, or 20 mL 4.2% sodium bicarbonate in a random order. A blinded anesthetist observed continuous sampling of exhaled carbon dioxide and was asked to differentiate between the sodium bicarbonate and saline injections. Peak increase in measured exhaled carbon dioxide was also calculated.
Results: Exhaled carbon dioxide increased significantly in participants injected with intravenous sodium bicarbonate. Mean peak increase was 7.4 mm Hg (±2.1 mm Hg) for 50 mL 4.2% sodium bicarbonate, 4.7 mm Hg (±2.5 mm Hg) for 20 mL 4.2% sodium bicarbonate, and 3.5 mm Hg (±1. 8 mm Hg) for 50 mL 2.1% sodium bicarbonate. The blinded observer correctly identified the injection as sodium bicarbonate or normal saline in every instance.
Discussion: Intravenous injection of dilute sodium bicarbonate with exhaled carbon dioxide monitoring reliably confirms correct intravascular placement of a catheter. A transient increase of exhaled carbon dioxide by 10% or more is an objective and reliable confirmation of intravascular location of the catheter. We recommend using 20 mL of 4.2% sodium bicarbonate to minimize the mEq dose of sodium bicarbonate required.

1. Introduction

Is the intravenous (IV) catheter in fact in the vein? This common clinical dilemma is encountered daily. The primary concern is inadvertent infiltration of IV fluids and non-vesicant solutions into surrounding tissues, and is especially relevant for the inadvertent extravasation of a vesicant, such as chemotherapy and contrast dye [1,2]. Both complications are a major patient safety concern as they not only cause

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patient discomfort, but may also result in tissue sloughing, skin necrosis, and compartment syndromes and can require surgical debridement, fasciotomy, and rarely amputation [1]. Most extravasation can be prevented with the systematic implementation of careful administration techniques [2]. However, infiltration rates were reported to be high, with as many as 20% to 30% of IV catheters in adults resulting in infiltration [3,4], with higher rates seen in children. Analysis of the American Society of Anesthesiologists Closed Claims database revealed that 2% of all claims were related to peripheral IV catheterization and more than half of these were due to extravasation [5], and higher rates could be expected with other health care providers given the presumed expertise of anesthesiologist in IV cannulation. Currently, confirmation of correct placement of an IV catheter relies on clinical assessment, with low resistance to infusion and free back-flow of blood being indicators of correct positioning. However, these indicators are unreliable in clinical practice. Injection of cardioactive drugs, such as atropine or glycopyrralate, with observation for a cardiovascular response has been used as an alternative, although anxiety and pain on injection may mimic the desired response and cloud interpretation. Ultrasound visualization is gaining popularity, but its primary benefit lies in safe insertion of central venous access and location of difficult to access peripheral veins. It is often unable to confirm that the tip of the catheter is within the lumen of the vein, it requires user expertise and training, and ultrasound devices remain expensive. Thus, a robust and safe test to confirm that a catheter remains within the vein remains elusive.

Given the frequent uncertainty regarding IV placement and the potential morbidity associated with infiltration and extravasation, we describe an alternative objective test using infusion of dilute sodium bicarbonate and observation of exhaled carbon dioxide as a robust method for confirmation of correct IV placement.

This technique has undergone a safety study in an animal model [6] and subsequently been piloted in the controlled setting of anesthetized, ventilated adults and children [6,7]. In addition, a further safety study conducted in ex vivo human skin samples has recently been conducted [8]. The technique has potentially wide applicability, as it might be used in conscious patients throughout the hospital or outpatient setting and only requires basic monitoring and access to continuous capnography. With this in mind, the current study was conceived and implemented and we now report the expanded application and diagnostic utility of this technique in the nonanesthetized, conscious, spontaneously breathing adults.

2. Methods

Following ethics committee approval and both written and oral personal informed consent, a 20-gauge peripheral IV catheter (BD Venflon, Becton Dickinson, Franklin Lakes, NJ) was inserted in the upper extremity (hand or forearm) of 20 healthy adult volunteers. Dilute sodium bicarbonate was made by mixing 8.4% sodium bicarbonate with sterile water in a 1:1 or 1:3 ratios to create 4.2% and 2.1% sodium bicarbonate respectively. In 10 participants, a 50-mL bolus of sodium bicarbonate 4.2%, sodium bicarbonate 2.1%, or normal saline was injected (as a rapid bolus, 10-20 seconds) in a random order at 10-minute intervals. In another 10 participants, 50 mL of sodium bicarbonate 4.2%, 20 mL of sodium bicarbonate 4.2%, or normal saline was injected (as a rapid bolus) in a random order, in 10-minute intervals. The data collected included patient demographics, exhaled CO_2 values measured using a CO_2 nasal-cannula breath sampling line (Oridion, Jerusalem, Israel) for 5 consecutive breaths prior and 11 consecutive breaths after each injection, heart rate continuously for 1 minute before and 5 minutes post injection, and noninvasive arterial blood pressure measured 1 minute before and 2.5 and 5 minutes after the injection. All parameters were measured using an S/5 anesthesia monitor (GE Healthcare, Waukesha, WI). Samples of venous blood gases were taken prior to commencing injections as a baseline and again after completion of all injections and were analyzed for pH and electrolytes. In addition, both a blinded observer and the participants were asked to determine whether sodium bicarbonate or normal saline was injected.

Exhaled CO_2 values at baseline and the peak level postinjection were compared using a paired *t* test, and a 95% confidence interval of the mean difference and a 95% prediction interval were calculated. Analysis of variance and Scheffe multiple comparisons were used to evaluate the increase of exhaled CO_2 among the study groups. Statistical analysis was performed using IBM SPSS software, version 19 (IBM, Armonk, NY).

3. Results

The mean ± SD age of the participants was 36.8 ± 10.5 years, weight was 82 ± 10.2 kg, and body mass index was 25.8 ± 3.1. Exhaled CO_2 (mm Hg) increased significantly from baseline in participants injected with IV sodium bicarbonate. Mean increase was higher for 50 mL sodium bicarbonate 4.2% (7.4 ± 2.1 mm Hg, 20.6% ± 6%) than for 20 mL sodium bicarbonate 4.2% and 50 mL sodium bicarbonate 2.1% (4.7 ± 2.5 mm Hg, 12.7% ± 5%, and 3.5 ± 1.8 mm Hg, 10% ± 4%, respectively; multiple comparisons Scheffe P = .006 and P = 3.09E−5). No significant difference in exhaled CO_2 (mm Hg) was found in the saline group from baseline to peak (Table). The exhaled CO_2 peaked at the fourth breath and was correctly identified by the blinded observer as bicarbonate or normal saline in every injection. Figure presents the increase (and 95% prediction interval) in exhaled CO_2 (mm Hg) from baseline to peak for the 4 study groups.