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Double-barrelled resuscitation: A feasibility and simulation study of dual-intraosseous needles into a single humerus

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ABSTRACT

Introduction: Resuscitation can be delayed, or impaired, by insufficient vascular access. This study examines whether dual-intraosseous needles, inserted into a single porcine humerus, can facilitate rapid and concomitant fluid and medication delivery.

Methods: After inserting one- and then two-intraosseous needles into the same porcine humerus, we determined the rate of fluid administration using (i) an infusion pump set to 999 mL/h, and (ii) a standard pressure-bag set to 300 mmHg. Next, we concomitantly infused blood, crystalloid and medications into the same medullary canal, using the two-needle set-up. Humeri were inspected for fluid-leakage, needle-displacement, and bone damage.

Results: Using an infusion pump, the mean normal-saline infusion-rate was significantly higher with dual-intraosseous needles compared to a single-intraosseous needle: the infusion-rate was 16 mL/min using dual-needles versus 8 mL/min for a single needle set-up ($p < 0.001$). In contrast, using the pneumatic pressure-bag, the infusion rate was not statistically different when comparing dual-intraosseous needles versus single-intraosseous: the infusion-rate was 22 mL/min versus 21 ml/min ($p = 0.4$) for 500 mL, and 22 ml/min versus 21 ml/min ($p = 0.64$) for one-litre, respectively. Blood product could be infused at a mean rate of 20 mL/min through one needle while tranexamic acid was simultaneously infused through a second. There were no complications with a dual-intraosseous set-up (no fluid leakage; no needle-displacement; no high-pressure alarms, and no external bone-fractures or internal macrohistological damage) during any of our simulated resuscitation scenarios.

Conclusions: This is the first published study evaluating dual-intraosseous needles in a single bone. Despite limitations, this preliminary study (using a porcine humerus) suggests that dual-intraosseous needles are feasible. For critically-ill patients with limited insertion sites, dual-intraosseous (a.k.a. 'double-barrelled resuscitation') may facilitate rapid and concurrent resuscitation.

Introduction

Use of intraosseous (IO) vascular access is becoming more common [1–5]. Moreover, when compared to direct IV access, IO needles may have higher first-attempt success, shorter time-to-insertion, and the need for less prior experience [1,6–8]. IOs can also deliver most drugs and fluids that can be infused through either peripheral-or central-IV cannulae, and result in comparable systemic-concentration and deliver-time [1–4,9,10]. Accordingly, the American College of Surgeon's Advanced Trauma Life Support Course, the Eastern Association for the Surgery of Trauma, the American Heart Association and the European Resuscitation Council recommend that they be considered for a range of resuscitation scenarios where direct intravenous (IV) access cannot be established in a timely manner [2,3,11,12].

Despite their potential, there are putative limitations to IOs. For example, EZ-IO (Arrow EZ-IO Inc., Shivano Park, TX, USA) product

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[1] All four authors (MD, GB, DO, PB) have made substantial contributions to the conception, design, and analysis of our study and manuscript preparation. None of us have related papers already published or under consideration for publication.

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directions indicate that only one IO needle should be inserted per-bone, and if an IO was previously inserted, that site should not be reused within 48 hours [4]. Multiple same-site IOs may also be associated with excessive bone-damage and fluid extravasation (Personal Communication, Medical Director of Clinical Affairs, Teleflex Incorporated, Vidacare Business Unit). However, no published studies have validated these concerns. This is relevant in scenarios where insertion sites may be limited by factors such as poly-trauma, extremity-trauma or obesity preventing needles from reaching the medullary canal. Accordingly, this study explores whether dual-IO needles, inserted into the same pig humerus, are feasible or associated with complications. We also study whether dual-IOs can facilitate more rapid fluid resuscitation and concomitant administration of fluids and bolus medications in a variety of simulated resuscitation scenarios. Our hope is that acutely ill trauma and surgery patients may ultimately benefit from increased resuscitation options.

Methods

We used whole adult-male porcine forelegs (Yorkshire swine; *Sus scrofa*) obtained locally (Edmonton, Canada). Prior to commencement, each foreleg was inspected in a systematic fashion for (i) absence of fractures and (ii) presence of joint integrity. This study consists of four parts (see below). A dedicated timekeeper used a digital stopwatch (TAGHeuer, Microsplit MS 200, La Chaux de Fonds, Switzerland) to record all trials. Mean results and descriptive statistics were calculated using independent sample two-tailed Student's *t*-tests. We deemed statistical significance as $p \leq 0.05$ (Microsoft Excel, Microsoft Corporation, Redmond, WA). The Alberta Community Research Ethics Board provided study approval.

Protocol part one: establishing dual IO access and infusion times of normal saline by infusion pump. An IO was inserted in the porcine foreleg/humerus using recommended technique [13]. This consisted of the EZ-IO drill and 25 mm 15-ga IO-needle(s), (Arrow EZ-IO Inc., Shivano Park, TX) connected to the EZ-Connect Extension Set, and followed by a brisk 10 mL saline-flush by syringe. Next, a one-litre bag of normal saline (NS) was primed through an infusion-pump administration set (CareFusion Corporation, SmartSite Infusion Set, San Diego, CA), inserted into an infusion-pump module (CareFusion Alaris SmartPumps; San Diego, CA) and attached to the IO extension set. The pump was set to its maximum rate of 999 mL/h, and the infusion occlusion-alarm set at 525 mmHg. Then the time to infuse 500 mL and then one litres NS through the single IO was measured. After completion of the single needle trial, a second IO needle was drilled 1.5 cm distally (see Fig. 1) and an identical infusion set-up was used to firstly measure the time to infuse two 250 mL bags through the double IO set up (i.e. the same total volume of 500 mL but 250 mL per needle) and then, secondly, the time to infuse one-litre NS via dual-IO setup (500 mL per needle) compared to two IOs (2000 mL total; 1000 mL per needle). The study was repeated five-times, each time with a new foreleg.

Protocol part two: infusion times of normal saline by pneumatic-pressure assistance. The infusion-pump tubing (used in part-one) was replaced with standard infusion tubing (Baxter International Inc., CONTINU-FLO Solution Set, Deerfield, IL) and the infusion pump was replaced with pneumatic pressure-bags set at 300 mmHg (Infu-Surg Pressure Infusion Bag, Ethox Medical, Buffalo NY). The above trial was repeated.

Protocol part three: simulation scenarios with concomitant administration of fluids and drugs via dual IO. Three separate resuscitation simulations were undertaken on each humerus with dual access. In order to simulate trauma, 10 day out-dated human packed red blood cells was infused using a 300 mmHg pneumatic pressure-bag through one needle, and tranexamic acid (1 g/10 min; 1 g/100 mL; 600 mL/h) was infused through the second. In order to simulate sepsis-resuscitation, NS was infused using a 300 mmHg pressure-bag through the first needle, and noradrenaline (10 mcg/min; 16 mg/250 mL; 9.4 mL/h) through the second. To simulate emergency anaesthesia, a ketamine bolus (200 mg of 10 mg/mL solution) and infusion (70 mg/h of 250 mg/250 mL at 70 mL/h) was administered through needle-one, with simultaneous syringe boluses of fentanyl (150 mcg of 50 mcg/mL) and rocuronium (70 mg of 10 mg/mL) through the second needle.

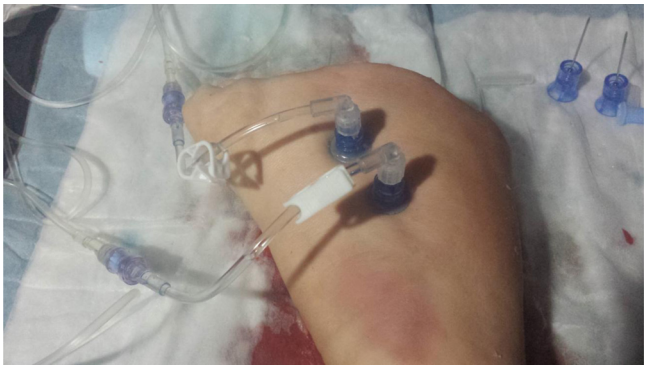

Fig. 1. Dual 25 mm 15 ga intraosseous needles simultaneously infusing crystalloid and norepinephrine.

Protocol part four: complications of dual IO. Two examiners continuously monitored all trials, whether the single or dual-IO set-up, was associated with complications: visible leak from the infusion site; needle displacement infusion-pump pressure alarms or interruptions in medication administration. The humeri were re-examined at the study's completion (with the naked-eye) (i) exteriorly for fracture and (ii) interiorly for damage to the medullary canal.

Results

Part one: establishing dual IO access and infusion times of normal saline by infusion pump. As shown in Table 1, infusing NS by infusion pump (set to 999 mL/h) required approximately half-the-time through dual-IOs compared to one-IO. Expressed another way, dual-IOs were associated with approximately double the fluid infusion-rate compared to single IO ($p < 0.001$). For 500 mL saline it took 1825 s (95% Confidence Interval [CI] 1810–1840) via dual-IOs (a rate of 16 mL/min) vs 3650 s (95% CI 3620 to 3680 s) via single-IO (a rate of 8 mL/min). Similarly, for one litre it required 3666 s (95% CI 3636 to 3694) via dual-IOs (a rate of 16 mL/min) versus 7300 s (95% CI 7246) via single-IO (a rate of 8 mL/min). Because actual infusion-rate approximates expected infusion-rate (i.e. 999 mL per-hour per-needle) there was no apparent increased flow-resistance in the medullary-canal with a dual-IO and dual-pump infusion set-up.

Part two: infusion times of normal saline by pneumatic-pressure assistance. As shown in Table 2, NS infusion using pneumatic-pressure assistance (Table 2) was not statistically different when comparing single and dual-IOs. The mean speed of

Table 1
Mean time (s) to infuse one vs two litres normal saline.

Infusion pump set at 999 mL/h		
	Single IO needle	Dual IO needles
1 L	1825 (95% CI 1810–1840)	912.5 (95% CI 905–920)
2 L	3650 (95% CI 3623–3677)	1833 (95% CI 1818–1847)

Abbreviations: mL = millilitres; IO = intraosseous; h = hour; CI = confidence interval.