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Clinical paper

Comparison of right and left ventricular enhancement times using a microbubble contrast agent between proximal humeral intraosseous access and brachial intravenous access during cardiopulmonary resuscitation in adults☆

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ABSTRACT

Aim: The present study aimed to compare the ventricular enhancement time between humeral intraosseous access (HIO) and brachial intravenous access (BIV) during cardiopulmonary resuscitation (CPR) in adult humans. To our knowledge, this is the first such study during CPR in adult humans.

Methods: This prospective single-centre observational cohort study assessed the medical records of patients who underwent CPR between January 2018 and March 2018. The primary endpoints were the left and right ventricular enhancement (LVE and RVE, respectively) times after administration of a microbubble contrast agent via HIO or BIV. Continuous variables are reported as means and standard deviations depending on normal distribution, while categorical variables are reported as frequencies and percentages. The paired *t*-test and analysis of variance were used to compare HIO and BIV. Differences were considered significant at a P-value < 0.05.

Results: The study included 10 patients. The HIO time (15.60 ± 6.45 s) was significantly lower than the BIV time (20.80 ± 7.05 s; P = 0.009). The RVE time was significantly lower with HIO (5.60 ± 1.71 s) than with BIV (15.40 ± 3.24 s; P < 0.001). Additionally, the LVE time was significantly lower with HIO (120.20 ± 4.18 s) than with BIV (132.00 ± 3.09 s; P < 0.001).

Conclusion: Our results indicated that the arrival times of a drug at the right and left ventricles are significantly lower with HIO than with BIV in an adult cardiac arrest model.

Introduction

Many medications are being administered during cardiopulmonary resuscitation (CPR) for adult cardiac arrest [1]. The American Heart Association recommends the administration of drugs via the intraosseous route if intravenous access cannot be obtained in a cardiac arrest situation [2]. However, clinical studies have shown that the peripheral intravenous access time can range from 2 to 49 min. The rate of successful establishment of peripheral intravenous access after cardiac arrest ranges broadly from 30% to 75% in adult patients. On the other hand, intraosseous access is an established rapid, safe, and effective alternative for peripheral intravenous drug delivery [3–5]. A previous study compared the flow rate of intraosseous access placed in the sternum, humeral head, and proximal tibia in a fresh human cadaver model and found that the mean flow rate in the sternum was 1.6 times greater than that in the humerus and 3.1 times greater than that in the tibia [6]. However, it is difficult to access the sternal site during CPR. Additionally, no human study has compared the flow rate between humeral intraosseous access (HIO) and brachial intravenous access (BIV) during CPR.

Abbreviations: HIO, humeral intraosseous access; BIV, brachial intravenous access; CPR, cardiopulmonary resuscitation; SD, standard deviation; EMT, emergency medical technician; ACLS, advanced cardiac life support; RVE, right ventricular enhancement; LVE, left ventricular enhancement; ROSC, return of spontaneous circulation; RA, right atrium; RV, right ventricle; LA, left atrium; LV, left ventricle; RVE–LVE, time interval from right ventricular enhancement to left ventricular enhancement; EMS, emergency medical system

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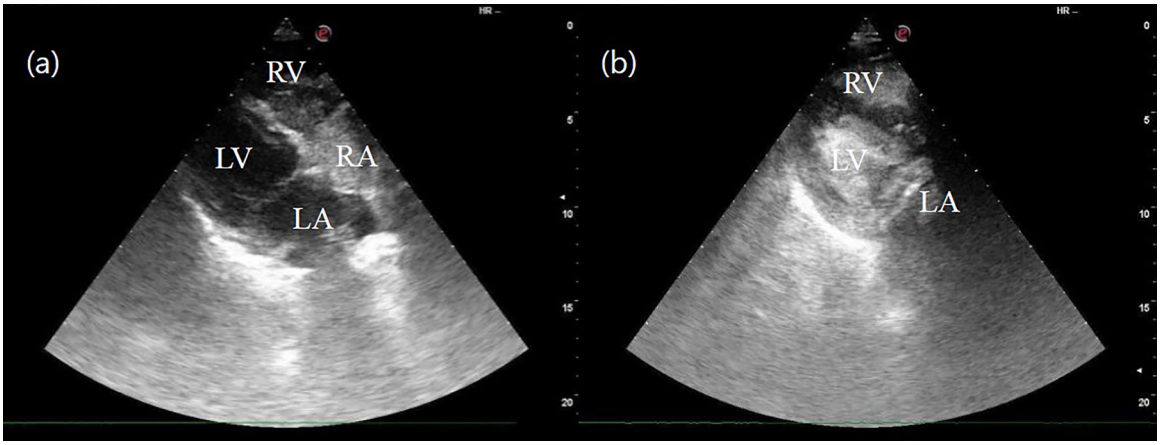

Fig. 1. Echocardiography shows enhancement of the right (a) and left ventricles (b) after microbubble contrast agent administration.
RA, right atrium; RV, right ventricle; LA, left atrium; LV, left ventricle.

Therefore, we compared the ventricular enhancement time between HIO and BIV during CPR in adult humans. To our knowledge, this is the first such study during CPR in adult humans.

Methods

This study was approved by the Institutional Review Board of Chungnam National University Medical Centre (CNUH IRB 2018-04-055), and the requirement for consent was waived because it was not possible to obtain consent during CPR.

Study design and patients

This prospective single-centre observational cohort study assessed the medical records of patients during CPR between January 2018 and March 2018. The primary endpoints were the left and right ventricular enhancement (LVE and RVE, respectively) times after administration of a microbubble contrast agent via HIO or BIV. The secondary endpoint was the successful first attempt rate of HIO or BIV. The exclusion criteria were bony malignancy, fracture of the target bone, previous orthopaedic procedures near the insertion site, recent intraosseous placement, a prosthetic limb or joint, infection at the insertion site, inability to locate landmarks because of excessive tissue, evidence of surgical procedures involving the site accessed with an intraosseous or intravenous needle, completion of intravenous or intraosseous access before reaching the hospital, and failure to achieve good flow of fluid, even after 3 BIV or HIO attempts.

Study protocol

All protocols were performed during CPR in this study. To compare speed and utility between HIO and BIV, only patients who required venous access and arrived at the resuscitation bay without adequate pre-existing venous access were included. Chest compression was performed by emergency medical technicians (EMTs) who had advanced cardiac life support (ACLS) certificates from the American Heart Association. To decide the order of HIO and BIV, randomised note cards were used. HIO and BIV were performed immediately after patient arrival at the emergency centre. A microbubble contrast agent was injected according to the access selected through the card 10 min after arrival, and the agent was injected again via the alternate access 10 min after the first injection. Both approaches did not use the pressure line. HIO and BIV were attempted by resident physicians involved in the study, who underwent educational training in services and standardised testing for intraosseous catheter placement, management, and removal. The HIO site was identified using anatomical landmarks as follows: for the humeral head, it was the most prominent aspect of the greater tubercle of the humerus with the arm positioned in internal rotation. Before infusion, correct HIO needle placement was confirmed by visualizing aspiration of bone marrow and firm placement of the needle in the bone and assessing the ability to smoothly flush 10 mL of fluid. For HIO, a 15-gauge × 45-mm EZ-intraosseous device (TeleflexMedical, San Antonio, TX) was inserted into the right humerus. For BIV, an 18-gauge × 48-mm peripheral intravenous catheter was placed in the right brachial vein to deliver fluids. The measurement of the catheter insertion time (BIV time and HIO time) was started when the skin was sterilised before catheter insertion and ended when the flow of fluid was subjectively considered adequate for resuscitation. The approach was considered to have failed when good flow of fluid was not achieved, even after 3 BIV or HIO attempts. After BIV, we infused 5 mL of SonoVue® (Bracco, Inc., Milan, Italy), followed by a 20-ml bolus of normal saline, and then, the patient's arm was elevated at about 30° for 30 s. After HIO, we infused 5 ml of SonoVue® (Bracco, Inc.), followed by a 20-ml bolus of normal saline. The resuscitation medication was administered every 3 min (0, 3, 9, 12, 15, 18, 21, and 24 min), and the microbubble contrast agent was administered at 10 (HIO or BIV) and 20 min (alternate approach). We measured the RVE and LVE times after administration of the microbubble contrast agent through BIV or HIO, using the subxiphoid view of MyLab™ Seven (Esaote, Inc., Genoa, Italy) (Fig. 1). RVE and LVE times were based on the first identification of a microbubble. All procedures were recorded with a camera, and all time values were rounded up to the nearest second.

Data collection

The BIV, HIO, RVE, and LVE times via HIO or BIV were measured during CPR. The following data were collected from the database: time from emergency medical system (EMS) activation to RVE (HIO and BIV), age, sex, body mass index, and the time and total number of HIO and BIV attempts.

Sample size

In our pilot study, the RVE time with BIV was 31.67 ± 23.37 s and the RVE time with HIO was 5.89 ± 1.83 s. Based on the findings, 10 patients were needed in each group to achieve a power of 0.90 at a significance level of 0.05 (two-sided test).

Statistical analysis

Continuous variables are reported as means and standard deviations