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Original Study

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Comparison of time to obtain intraosseous versus jugular venous catheterization on canine cadavers

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Abstract

Objective – To compare the time required and the success rate of personnel with 4 different levels of experience to place a humeral intraosseous (IO) catheter versus a jugular venous catheter (IV) in cadaver dogs.
Design – Prospective study.
Setting – Veterinary university teaching hospital.
Interventions – Canine cadavers from recently euthanized dogs were obtained from the cadaver donation program between May and December 2014. Catheter placers (CPs) with varying clinical experience, including a first year emergency and critical care resident, a senior emergency veterinary technician (VTS certified), a final year veterinary student, and an ACVECC diplomate, participated in the study. Each CP catheterized a total of 6 dogs so that there was a total of 6 IO and 6 IV catheters placed, by automatic rotary insertion device (with an EZ-IO gun) and vascular cut-down technique, respectively, for each CP. Time for IO catheterization and IV catheterization was recorded and compared. The success of IO catheterization and IV catheterization was verified by visualization of an injection of iodinated contrast material under fluoroscopy within the medullary cavity or vessel.
Animals – Twenty-four canine cadavers.
Measurements and Main Results – Outcomes were analyzed using the Wilcoxon rank-sum test and the Kruskal–Wallis one-way analysis of variance. The median time for all IO catheterization operators was faster at 55.4 seconds (range 15.0–153.0 s) compared to the median time for all IV catherization operators at 217.3 seconds (range 55.6–614 s). The success rate for IO and IV was equal at 87.5%.
Conclusion – IO catheterization using an automatic rotary insertion device was performed more rapidly and successfully than jugular venous catheterization using a cut-down technique in canine cadaver. These findings suggest IO catheterization may be more efficient for gaining vascular access in the appropriate emergency clinical situations when preexisting IV access does not exist.

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Keywords: dogs, emergency vascular access, IO, resuscitation

Abbreviations

CP	catheter placer
IO	intraosseous
IV	intravenous
CP1	Veterinary Technician Specialist in Emergency and Critical Care; VTS (ECC)
CP2	DACVECC
CP3	first year ECC resident
CP4	final year veterinary student

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Introduction

The ability to obtain rapid vascular access in an emergency setting is of paramount importance to allow for the administration of resuscitative drugs and fluids. Obtaining prompt IV access can be difficult, especially in patients that present with cardiovascular collapse. Other challenges such as small patient size, trauma to commonly used vascular sites, obesity, or peripheral edema can also hinder gaining rapid IV access. Multiple attempts at gaining IV access lead to delays in treatment, and subsequently, can increase morbidity and mortality.

When IV access is not possible, intraosseous (IO) catheterization is a viable alternative to obtain vascular access.[1-3,6-11] In fact, due to IV access limitations in small patients, the IO catheter in avian, exotic mammals, and some reptile patients is well utilized.[12] The reason that IO catheterization provides rapid accessible vascular access is due to the rigid nature of bone that prevents bone marrow vessels from collapsing.[1,2,5] Administration of drugs and fluids into bone marrow is effective because bone marrow has a well-defined venous system that empties quickly into the systemic circulation.[3] Human medicine now widely accepts IO catheterization when IV access is not obtainable and several IO insertion devices (ie, automated bone injection guns) have been developed to allow for rapid IO catherization.[2,4,6,8,9] It has been demonstrated that when using an automated bone injection gun in pediatric patients, it takes between 10 seconds to 1 minute to place an IO catheter with 70–80% success rate.[7] In adults requiring resuscitation from trauma, 1 study showed that the IO catheterization success rate was 85% on first attempt with a mean of 2.0 minutes, compared to 60% success rate and a mean of 8.0 minutes for central line placement.[8] In another study of adults requiring resuscitation, there was a 90% success rate for IO insertion versus 60% for central line placement with a mean procedure time being significantly lower for IO cannulation (2.3 min $\pm$ 0.8) compared to central line placement (9.9 min $\pm$ 3.7).[9] Due to the speed at which an IO catheter can be placed, the American Heart Association finds the use of an IO catheter a reasonable alternative once venous access cannot be obtained peripherally.[4,6]

To date, there is limited information on the use of IO catheters in veterinary patients. Olsen et al demonstrated that the placement of an IO catheter in dogs using an automated bone injection gun provided reliable vascular access,[14] and another study using feline cadavers identified that the use of a bone injection gun to facilitate IO catheter placement allowed for rapid placement.[15] Both studies suggest that the use of an IO catheter in animals suffering from cardiac arrest may be a viable alternative to an IV catheter; however, to our knowledge, no veterinary studies have yet investigated the use of an IO catheter in this setting. The purpose of this study was to compare the time required to place an IO catheter with the time to place an IV catheter in recently deceased dog cadavers.

We hypothesized that the placement of an IO catheter would take less time than placement of a jugular venous catheter and placement would be more successful with the IO catheter.

Materials and Methods

The study occurred between May and December 2014. Cadaveric material (dogs) was obtained from the hospital donation program, which permits the utilization of animals euthanized for reasons unrelated to the study. To be considered for inclusion in the study, dogs needed to weigh between 5 and 50 kilograms and a catheter placer (CP) had to be available to complete the study within 1 hour of euthanasia, which avoided rigor mortis in all cadavers. Exclusion criteria included morbid obesity as assessed by the primary clinician as a body condition score of 9 out of 9, trauma to the legs or neck region that would hinder placement of an IO or IV catheter, and being an English Bulldog breed to prevent bias toward IO catheter placement. Immediately prior to euthanasia, all dogs received a dose of heparin[a] (1,000 U/kg IV) as part of the hospital standard protocol for all donated cadavers and unrelated to the study. In an attempt to include a variety of skill levels, 4 categories of a CP were recruited: a certified veterinary technician (VTS in emergency and critical care), an experienced diplomate of the American College of Veterinary Emergency and Critical Care (DACVECC), a first year emergency and critical care resident, and a final year veterinary student on the emergency service. The VTS, ACVECC diplomate, and resident were each represented by 1 person that participated in the study 6 times, while the final year veterinary student category was represented by 6 different students that each participated in the study one time.

The final year veterinary student CPs received verbal instructions on how to perform a jugular venous cutdown and IO catheterization prior to participating in the study. CPs were told to insert an IV catheter in the left or right jugular vein and an IO catheter in the right or left humerus. To mimic an emergency as closely as possible, the cadaver was placed on a table in lateral recumbency in the emergency room where CPR is commonly performed and the CP designated one assistant to either hold off a vein for IV catheterization, or stabilize the leg for IO catheterization. Additionally, all materials used for IV catheter or IO catheter were in their normal emergency room locations and were not prepared beforehand. An automatic rotary insertion device[b] (using a 15-Ga needle with a length of 15 or 25 mm selected by the CP) and Jelco IV catheters[c] (over the needle catheters with gauge selected by the CP) were used to gain vascular access. A coin was flipped to determine which catheterization would be performed first. When the CP designated that they were ready to start, an

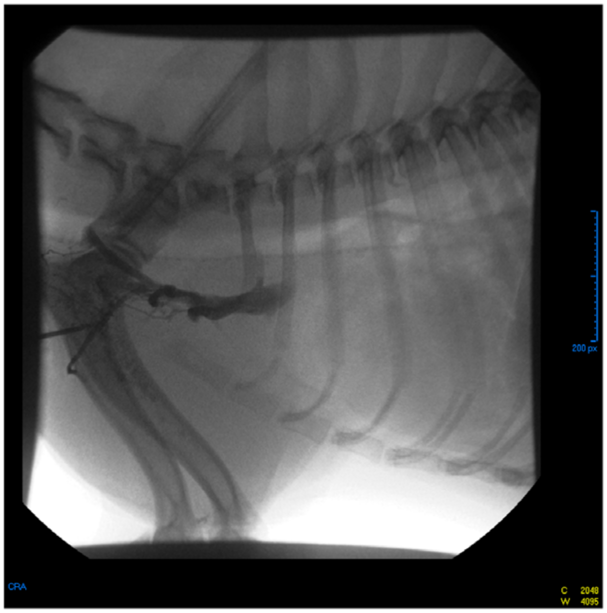

Figure 1: Fluoroscopic image of cadaver with intraosseous catheter in place and contrast enhancement of cranial vena cava.

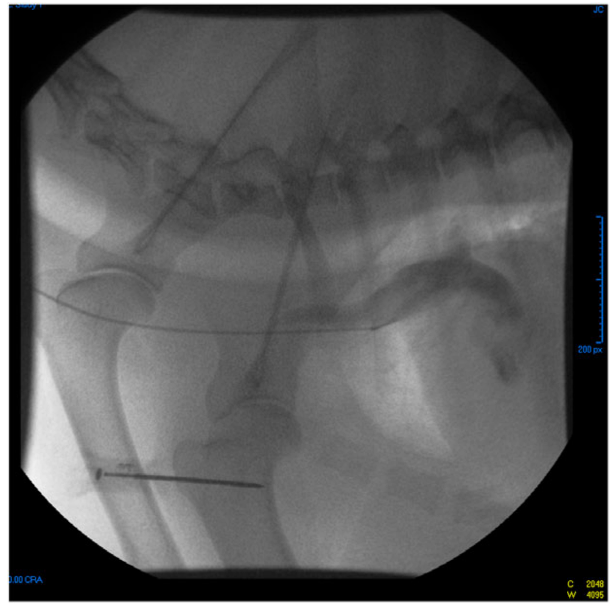

Figure 2: Fluoroscopic image of cadaver with IV in place and contrast enhancement of cranial vena cava.

independent observer started a stopwatch and the CP placed the catheter. When the CP believed that they had successfully placed the catheter, time was stopped and the placement time was recorded. After the timer stopped, jugular venous catheters were secured using suture until placement could be verified, while IO catheters required little reinforcement if well seated in the bone. The total time to placement was recorded in seconds, as well as the anatomic location of the catheter, the name of the CP, cadaver body weight, and the breed. The stopwatch was reset and supplies used for placement of the catheter were returned to their normal locations. When the same CP was ready, the second catheter placement commenced following the same guidelines as previously described. At the completion of the placement of both catheters, cadavers were immediately moved into the fluoroscopy suite. In fluoroscopy, iohexol contrast[d] (5–10 mL) was injected into each catheter and images were saved to the university's digital imaging database. Successful placement was defined as visualization of contrast enhancement within the medullary cavity or vessel (Figures 1 and 2, respectively).

Statistical Methods

A priori sample size calculation was performed. Using data from people and assuming that results may be similar in dogs, the independent 2 sample *t*-test suggested a sample size of 6 cadavers and it was calculated using an IO catheter placement time of 2.3 minutes (SD 0.8 min) and a IV catheter placement time of 9.9 minutes (SD 3.7 min) assuming an alpha of 0.001 and a desired power of 90%.[8,9] The Wilcoxon rank-sum test was used to investigate unpaired continuous non-normal data. For the purposes of this analysis, the two methods of catheterization were considered independent since the anatomical location of the placement and the methods for placement were substantially different from each other. The median IO catheter placement time was compared to the median IV catheter placement time using pooled (all operators) and individual operator data. A nonparametric analysis of variance was performed (Kruskall–Wallis analysis of variance) on IO catheter and IV catheter placement times with operator as the categorical predictor variable. Statistically significant results from the analysis of variance were followed by pairwise comparisons by operator using the Wilcoxon rank-sum test. No correction was made for multiple comparisons. Continuous variables (weight, body condition score, IO, catheter, and IV catheter placement times) were assessed for normality by visual inspection of a histogram. A P-value < 0.05 was considered statistically significant. Data analysis was performed using statistical software.[e]

Results

Study population

Twenty-four canine cadavers were utilized in the study. There were 22 breeds represented, with mixed breed (6), Shih Tzu (2), and Boxers (2) being the most represented. Other breeds included 1 each of a Rat Terrier, Maltese, Pit Bull, Rottweiler, Shiba Inu, Golden Retriever,

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Table 1: Baseline characteristics for each operator's cadavers

Operator	CP1	CP2	CP3	CP4
Weight in kilograms (range, median)	6.7 – 35 (25.95)	10 – 40 (22.13)	8.0 – 30 (16.7)	6.2 – 31.8 (16.7)

CP, catheter placer; CP1, Veterinary Technician Specialist in Emergency and Critical Care; VTS (ECC); CP2, DACVECC; CP3, first year ECC resident; CP4, final year veterinary student.

Standard Poodle, Saint Bernard, Jack Russell Terrier, Miniature Schnauzer, Boston Terrier, Bichon Frise, Pyrenees, and a Labrador Retriever. Body weight ranged from 6.2 to 40 kilograms and the mean was 20.2 kilograms (Table 1). Median body condition score was 5 out of 9 (range 2–6).

Catheter time and successful placement

The median time for all IO catheter operators was 55.4 seconds (range 15–153 s) and the median time for all IV catheter operators was 217.3 seconds (range 55–614 s), with IO catheterization being faster than IV catherization ($P < 0.0001$). When comparing IO versus IV catheterization times for each individual CP, an IO catheter was statistically faster to place than IV catheter for all CPs except for CP2 who was equally as fast (see Table 2).

In comparing median IV catheterization time to placement and CP, there was a significant time difference between operators ($P = 0.0012$). There was a significant time difference between CP1 with CP3 and CP4, operator CP2 with CP3 and CP4, and operator CP3 with CP4. Alternatively, there was no significant time difference between operators when placing an IO catheter ($P = 0.263$). The overall IO catheter success rate was 87.5% (21/24). The overall success rate for intravenous catheter was also 87.5% (21/24). Individual operator success rates for both IO catheter and IV catheter are reported in Table 2.

Discussion

This study demonstrates that in a model of canine vascular collapse, venous access can be achieved faster via IO catheterization than by jugular venous cut down. This result is similar to what has been documented in people, where it has been shown that IO catheters can be placed faster than IV catheters during resuscitation events.[8,9] We did not perform CPR on the cadavers in this study; however, we did mimic a CPR setting in our hospital. Cadavers were used as their vascular collapse is similar to a dog needing resuscitation, as they do not have spontaneous venous filling. Additionally, the catheter supplies were in their proper location (not previously prepared), we used the same table where we regularly perform CPR, and used the same personnel (VTS, students, residents, and faculty) who would normally participate in a code; however, in this mock scenario, there were no actual chest compressions performed. Despite this, we believe that our results suggest that, similar to its use in CPR in people, IOC is a good alternative for vascular access when performing CPR in the dog, but further studies would need to be performed to assess its use in the clinical ER and CPR setting.

The researchers chose to compare times for IO to jugular venous catheterization over jugular to peripheral catheterization for several reasons. The American Heart Association guidelines indicate central line use is ideal for resuscitation[4] because peak drug concentrations are higher and circulation times are shorter compared to peripheral infusions,[16] but due to the time-consuming nature, peripheral access is recommended if central access cannot be obtained rapidly. Unfortunately, peripheral IV catheterization is most often not possible due to vascular collapse when resuscitation is required, and a jugular venous catheterization via cut down is

Table 2: Main results for success rate and insertion times for intraosseous catheter and intravenous catheter for the 4 operators

	IOC				IVC			
Operator	CP1	CP2	CP3	CP4	CP1	CP2	CP3	CP4
Success rate (%)	83 (5/6)	83 (5/6)	100 (6/6)	83 (5/6)	100 (6/6)	100 (6/6)	66 (4/6)	83 (5/6)
Mean insertion times (s)	49.0[a]	43.68	47.97[a]	89.83[a]	99.41	88.10	263.7	418.2
Range (median)(s)	22 – 81 (30.0)	19.6 – 98 (26.72)	25 – 87 (38.70)	15 – 153 (87.0)	67.0 – 143.0 (96.24)	55.60 – 150.0 (80.0)	123 – 512 (196.5)	175.0 – 614.0 (431.5)

[a]Indicates significantly faster times between each CP's corresponding IVC value.
IOC, intraosseous catheter; IVC, intravenous catheter; CP, catheter placer; CP1, Veterinary Technician Specialist in Emergency and Critical Care; VTS (ECC); CP2, DACVECC; CP3, first year ECC resident; CP4, final year veterinary student.

a common vascular access alternative. As a result, we chose to compare IO and IV jugular catheterization because peripheral access is often not available in veterinary emergency hospital patients requiring resuscitation due to vascular collapse, obesity, and previously utilized veins.

We found that more experienced CPs were able to place jugular venous catheters faster than less-experienced CPs. This is likely a reflection of the fact that performing a jugular venous cut down requires practice. As evidence of this, with each IV catheter attempt for CP3, there was an improvement in placement time. This is in contrast to IO catheterization, where experience level did not impact the time to placement, as all operators were equally inexperienced. In fact, the fastest successful placement time of 15 seconds was performed by a student who had never performed the procedure before. Likely reasons that IO catheterization can be performed faster is that it does not require an incision, the automated bone gun is designed to work quickly, and the IO catheter is inserted into bone where vascular collapse does not occur, making it an easier target to catheterize.

Success rate of catheter placement was investigated and there were a total of 3 unsuccessful placements in both the IO and IV category. We found that experience level impacted successful placement of the intravenous catheter, with the more experienced CPs (CP1 and CP2) successful on all attempts, and the less experienced CPs (CP3 and CP4) accounting for all 3 failed attempts. This finding is not unexpected, as performing a jugular venous cut down is a complicated skill that requires practice to master. As evidence of this, both failed IV catheterization attempts made by CP3 took place at the beginning of the study.

We did not find that experience in the emergency room played a role in successful placement of the IO catheter as the 3 failed attempts were made by 3 different operators, 2 by the more experienced CPs (CP1 and CP2), and 1 by a less experienced CP (CP4). IO insertion devices are designed to make placement of an IO catheter simple. The insertion device essentially operates like a drill that drives the IO needle into the bone. In order to achieve successful placement using one of these devices, one must be certain to drill the needle all the way into the medullary cavity. In all instances of failure in this study, the needle length selected was too short to reach the medullary cavity. This could be a reflection on the way in which CPs were instructed on how to use the IO insertion device. The instruction focused on how to load the needle and the location to place the IO catheter rather than how to select an appropriate size. It may be that with better initial training on how to select an appropriate needle size, there would be greater success with the IO catheterization. Perhaps with better training guidelines in place, the use of an IO catheter may be a better option to gain vascular access in an emergency room where the staff is of varied experience levels.

The results of this study propose that IO catheterization with an automatic rotary insertion device is a viable alternative to IV catheterization with cut down for gaining vascular access rapidly and successfully. IO catheterization provides vascular access in these patients for which intravenous catheterization is difficult or impractical and would prove useful in a CPR event. Given that the sample size of this study is small, a prospective study to evaluate the clinical use of IO catheterization with an automatic rotary insertion device in small animal CPR is needed.

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Footnotes

[a] Heparin sodium injection, USP 1000 units/mL, SAGENT Pharmaceuticals, Schaumberg, IL.
[b] EZ-IO gun (15-Ga Pediatric Needle Set) Vidacare Corporation, San Antonio, TX.
[c] Jelco catheters, McKesson Medical, Northborough, MA.
[d] Omnipaque (iohexol) injection 300 mgI/mL, GE Healthcare Inc, Princeton, NJ.
[e] R v.3.1.1 (The R Foundation for Statistical Computing – copyright 2014).

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