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Original Study

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Evaluation of ultrasound-guided vascular access in dogs

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Abstract

Objective – To describe the technique and determine the feasibility, success rate, perceived difficulty, and time to vascular access using ultrasound guidance for jugular vein catheterization in a cardiac arrest dog model.
Design – Prospective descriptive study.
Setting – University teaching hospital.
Animals – Nine Walker hounds.
Measurements and Main Results – A total of 27 jugular catheterizations were performed postcardiac arrest using ultrasound guidance. Catheterizations were recorded based on the order in which they were performed and presence/absence of a hematoma around the vein. Time (minutes) until successful vascular access and perceived difficulty in achieving vascular access (scale of 1 = easy to 10 = difficult) were recorded for each catheterization. Mean time to vascular access was 1.9 minutes (95% confidence interval, 1.1–3.4 min) for catheterizations without hematoma, versus 4.3 minutes (1.8–10.1 min) for catheterizations with hematoma ($P = 0.1$). Median perceived difficulty was 2 of 10 (range 1–7) for catheterizations without hematoma, versus 2 of 10 (range 1–8) for catheterizations with hematoma ($P = 0.3$). A learning curve was evaluated by comparing mean time to vascular access and perceived difficulty in initial versus subsequent catheterizations. Mean time to vascular access was 2.5 minutes (1.0–6.4 min) in the initial 13 catheterizations versus 3.3 minutes (1.5–7.5 min) in the subsequent 14 catheterizations ($P = 0.6$). Median perceived difficulty in the first 13 catheterizations (3, range 1–8) was significantly greater ($P = 0.049$) than median perceived difficulty in the subsequent 14 catheterizations (2, range 1–6).
Conclusions – Ultrasound-guided jugular catheterization is associated with a learning curve but is successful in obtaining rapid vascular access in dogs. Further prospective studies are warranted to confirm the utility of this technique in a clinical setting.

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Introduction

Rapid vascular access can be lifesaving in emergency situations, yet is often a challenge in hypotensive or hypovolemic patients. Unsuccessful attempts at obtaining vascular access often result in hematoma formation, further increasing technical difficulty of the procedure. Peripheral venous catheterization is often preferred in the veterinary setting due to familiarity, decreased risk of iatrogenic damage to nearby structures, and proximity to the skin surface. Catheters in larger central vessels such as jugular veins have closer and more direct access to key structures like the heart, thereby providing a therapeutic advantage compared to peripheral catheterization.[1–3]

Studies in people evaluating ultrasound-guided vascular access methods have documented greater success rates with fewer complications when compared to traditional vascular access techniques in emergency, critical care, and anesthesia settings.[4–11] A large clinical trial in 900 human critical care patients noted vascular access with ultrasound guidance resulted in success in less than half the time and half the number of attempts compared to approaches using conventional landmark techniques.[6] Additionally, some studies proved that the benefits observed when utilizing ultrasound guidance are still present even when minimally trained

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or less-experienced operators are attempting vascular access.[5,7]

Ultrasound-guided vascular access techniques have not been described in veterinary medicine, despite their recognition as standard of care in human medicine[8,11] and the growing availability of ultrasound machines in veterinary practices. The present study characterized the time needed to gain vascular access and perceived difficulty of an ultrasound-guided technique when used for jugular catheterization in a cardiac arrest dog model. The null hypothesis was that perceived difficulty and time to access would not differ by operator inexperience or the presence of a perivascular hematoma.

Materials and Methods

Cardiac arrest model

This study was approved by the Institutional Animal Care and Use Committee (IACUC). Dogs were first anesthetized for a 3-hour laboratory demonstrating laparoscopic surgical procedures. For anesthesia, the dogs were premedicated with atropine[a] 0.02 mg/kg, morphine[b] 1 mg/kg, and acepromazine[c] 0.02 mg/kg, subcutaneously. A cephalic IV catheter[d] was placed. Anesthesia induction was performed using ketamine[e] 5 mg/kg plus diazepam[f] 0.25 mg/kg IV. Dogs were intubated and maintained under general anesthesia with 100% inspired oxygen and isoflurane.[g] Anesthesia monitoring included ECG, end-tidal carbon dioxide, direct arterial blood pressure, and pulse oximetry using a multiparameter monitor.[h] Lactated Ringer's solution[i] was administered IV at 10 mL/kg/h. Additional fluids and dopamine[j] 1–5 μg/kg/min were administered as needed to maintain a mean arterial pressure >60 mm Hg. Dogs were maintained on a morphine (0.1 mg/kg/h) –lidocaine[k] (20 μg/kg/min) –ketamine (10 μg/kg/min) continuous rate infusion for analgesia. Following the laboratory, euthanasia solution[l] (sodium pentobarbital and sodium phenytoin) per labeled dose at 1.5 mL per 5 kg body weight was administered to induce cardiac arrest while the dogs were still anesthetized.

Vascular access

Hair was clipped over both jugular veins and dogs were placed in lateral recumbency. Immediately following euthanasia, 1 of 3 operators was randomly assigned to perform immediate jugular catheterization. Alcohol was applied to improve anatomic structure visualization and maintain a sterile field.

A SonoSite M Turbo ultrasound machine[m] with either a 13–6 MHz linear or 8–5 MHz convex probe was used to locate the jugular vein (Figure 1). The ultrasound probe was placed in the jugular groove in either transverse or sagittal alignment just caudal to the desired catheter entry point on the skin. Structures (particularly artery versus vein) were identified by anatomic location and by using gentle probe pressure to collapse the more compliant jugular vein (Figure 2). Type of probe and orientation in this study was based on operator comfort and which probe yielded best visualization of the jugular vein. Following identification of the jugular vein using ultrasound (Figure 2), the operator percutaneously placed an 18-Ga catheter[d] in the jugular vein while monitoring for correct placement on the ultrasound screen (Figures 3 and 4). The IV catheter was placed with the dominant hand through the skin directly over the jugular vein and approximately 2–3 cm rostral to the ultrasound probe. Correct placement was first confirmed when the catheter could be visualized within the vessel (Figures 3 and 4), then by aspirating ≥3 mL of blood into a 10 mL syringe[n] connected to the catheter (Figure 1).

For each catheterization, information recorded included name of operator performing catheterization,

Figure 1: Ultrasound probe depicting aspiration of blood via 18-Ga catheter, confirming vascular access. Dog's head is to the right, and ultrasound probe is caudal to catheter hub and syringe.

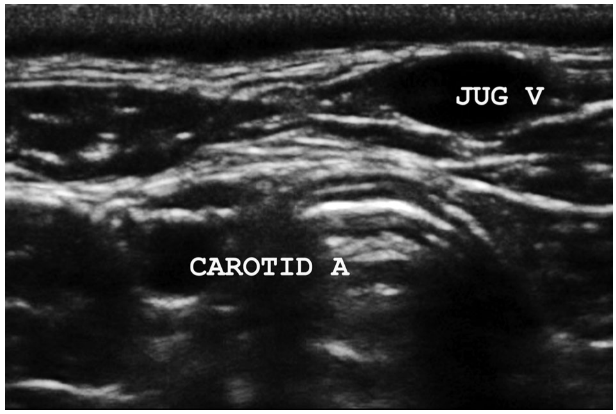

Figure 2: Transverse view of carotid artery and jugular vein.

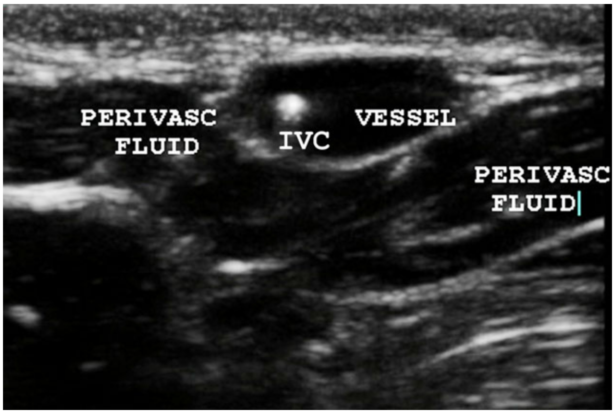

Figure 3: Transverse view showing IV catheter in the jugular vein. Perivascular fluid is after formation of hematoma as described in the text.

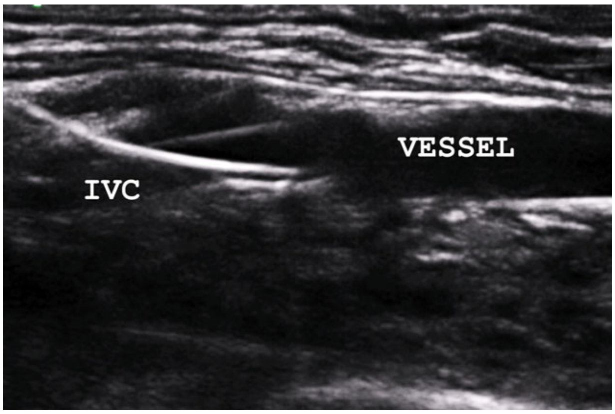

Figure 4: Sagittal view of IV catheter in the jugular vein.

time (minutes) elapsed from cardiac arrest until start of catheterization (placement of probe on skin), time (minutes) elapsed from start of catheterization until successful completion of catheterization, and operator's assessment regarding level of difficulty in achieving successful catheterization. Level of difficulty was subjectively assessed by each operator using a scale of 1 (easy)–10 (difficult). Operators were given no specific guidance in assessing perceived difficulty, since each were very competent in catheter placement but varied considerably in general experience using ultrasound.

Following confirmation of initial venous access in 18 jugular veins, the catheter was removed and 5–15 mL of blood injected into the subcutaneous tissue immediately surrounding 9 jugular veins, simulating hematoma formation (Figures 3 and 5). Catheterization was reattempted with the added difficulty of the hematoma, and all variables were rerecorded. Hematomas were added to either or both left or right jugular veins through arbitrary selection. Operator position relative to the jugular vein and ultrasound machine, as well as specific jugular

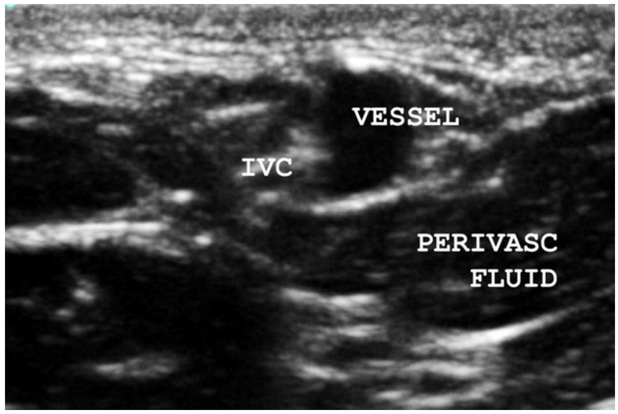

Figure 5: Transverse view showing perivascular hematoma. IV catheter is beside the jugular vein, indenting but not penetrating the vessel.

vein (right versus left), were adjusted based on operator comfort to optimize successful catheterization.

Statistical analysis

Observations were entered into a computer spreadsheet, entries were validated, and then data were summarized graphically and using descriptive statistics. Normality of outcome variables (time to vascular access [minutes] and difficulty score) was evaluated by visual assessment of a Q–Q plot. These variables were not normally distributed and were therefore transformed to meet assumptions for regression analysis. Time until vascular access was log-transformed and perceived difficulty scores were rank-transformed. Geometric means and associated 95% confidence intervals were reported from back transformation of vascular access time data; medians and ranges were reported for difficulty scores. Repeated measures linear regression was used to analyze the primary outcome variables. Independent variables investigated in regression analysis included the presence of a perivascular hematoma (yes versus no) and order of placement (first half of procedures versus second half). The operator being evaluated was included as a fixed effect in all models. Lack of independence associated with making multiple observations on dogs was controlled using generalized estimating equations. Statistical analyses were performed using commercial statistical analyses programs.[o,p] A value of $P < 0.05$ was considered significant for all comparisons.

Results

Twenty-seven jugular catheters were placed via ultrasound guidance by 3 different operators in 9 adult Walker hounds (27–35 kg). Ultrasound-guided jugular

Table 1: Time to vascular access and perceived difficulty

Parameter	No hematoma	Hematoma	*P*-value
Time to vascular access†	1.9 min (1.1–3.4 min)	4.3 min (1.8–10.1 min)	0.1
Perceived difficulty score‡	2 of 10 (1–7)	2 of 10 (1–8)	0.3
	First Half ($n = 13$)	Second Half ($n = 14$)	
Time to vascular access†	2.5 min (1.0–6.4 min)	3.3 mins (1.5–7.5 min)	0.6
Perceived difficulty score‡	3 of 10 (1–8)	2 of 10 (1–6)	0.049*

†Mean (95% confidence interval).
‡Median (range), scale of 1 (easy)–10 (extremely difficult).

catheterization was successful 27/27 times, 18 without a hematoma and 9 posthematoma formation. Both linear and curved probes were successfully used to guide jugular catheter placement, but too few attempts were made using the curved probe to examine significant differences in any clinical parameter. Geometric mean time to vascular access was 1.9 minutes (95% confidence interval 1.1–3.4 min) for catheterizations without hematoma, versus 4.3 minutes (1.8–10.1 min) for catheterizations with hematoma (Table 1). There was no difference ($P = 0.1$) in mean time to vascular access when comparing hematoma versus nonhematoma catheterizations. Median perceived difficulty was 2 of 10 (range 1–7) for catheterizations without hematoma, versus 2 of 10 (range 1–8) for catheterizations with hematoma. There was also no difference ($P = 0.3$) observed regarding perceived difficulty between these 2 groups.

Time to vascular access and perceived difficulty were also compared between the first-half ($n = 13$) and second-half ($n = 14$) of catheterizations, in an effort to identify the presence of a learning curve as operators became more proficient. Mean time to vascular access, irrespective of hematoma presence, was 2.5 minutes (95% confidence interval 1.0–6.4 min) in the initial 13 catheterizations versus 3.3 minutes (1.5–7.5 min) in the subsequent 14 catheterizations. Perivascular hematoma was present in 2/13 of the initial catheterizations, and 7/14 of the subsequent catheterizations. There was no difference ($P = 0.6$) in time to vascular access between the first 13 attempts and the second 14 attempts, even though almost all catheterizations with perivascular hematoma were performed in the later group. However, median-perceived difficulty in the first half of all catheterizations was significantly greater than median-perceived difficulty in the subsequent second half catheterizations (3 out of 10 versus 2 out of 10; $P = 0.049$).

Discussion

Ultrasound-guided jugular catheterization has been documented to improve time to vascular access and decrease the number of attempts and complications per catheterization over traditional landmark techniques in people[4–11] and is now regarded as standard-of-care in most human emergency, critical care, and anesthesia settings.[8,11] In this study, all 27 attempts of ultrasound-guided jugular catheterization in dogs were successful. Mean times to vascular access were 1.9 and 4.3 minutes (in the absence and in the presence of perivascular hematomas, respectively). These values are similar to reported times from human studies evaluating ultrasound-guided vascular access.[5–7] These results demonstrate that this technique may be applicable to veterinary medicine.

Extent of clipping and aseptic preparation (not performed in these dogs postarrest) should be considered in the context of patient stability when performing this technique in clinical cases. Alcohol was the only contact agent applied to improve anatomic structure visualization and maintain a sterile field; when applied liberally, alcohol generally provides a satisfactory ultrasound image without requiring the addition of ultrasound gel. However, hypothermia can become a complication in smaller patients, and probes should be cleaned off after contact with alcohol to preserve their covering and function. Sterile ultrasound gel can also be used to improve contact and image quality.[4,6–9,11]

The ultrasound probe was placed in the jugular groove in either transverse (shown to be easier for beginners[12]) or sagittal alignment just distal to the desired catheter entry point on the skin (Figures 1–4). Structures (particularly artery versus vein) are most easily identified by anatomic location and by using gentle probe pressure to collapse the more compliant jugular vein (Figure 2). Vessels may also be differentiated in a live patient using Doppler imaging to detect pulsatile flow in the artery. Compressing or "holding off" the jugular vein caudal to the catheterization site did not improve visualization of the vein or distend it from its original diameter to help IV access in the arrested dogs in this study, although this technique could aid placement in live patients. A "static" technique of identifying the vessels as above, then blindly placing the catheter without ultrasound guidance has been described in the human literature as an acceptable though less successful[8] method than the "dynamic" or real-time technique described here.

When holding the probe in transverse orientation relative to the vessel, place the probe near the tip of the catheter under the skin when entering the vein for best visualization and control. If the beam is placed too far rostrally (close to the catheter midpoint or hub) in transverse view then the part of the catheter on the screen may be outside the vessel while the sharp tip of the stylette could have already penetrated the near or far wall of the vessel or caused damage to other structures.[13] The concept is the same in the sagittal view—the vessel and catheter tip should be in the same plane for best efficiency and safety.

A facilitative maneuver[14] (nicking the skin, ie, making a 1–2 mm shallow incision with a No. 11 scalpel blade or the edge of the bevel of an 18-Ga needle) may be considered in select cases where excessive tissue drag is anticipated during percutaneous catheter placement (neither required nor performed in this study). Once vascular access is confirmed via ultrasound or aspiration, the catheter can be secured depending on the circumstances and condition of the patient requiring venous access. A short 1.5 inch catheter could also be replaced with a longer indwelling line using the Seldinger technique.[14,15]

There was no statistical difference when comparing time to vascular access with a hematoma versus no hematoma, or when comparing the time to vascular access in initial versus subsequent attempts at catheterization. The limited sample size and large variation in time to vascular access in each of these groups may have impacted the detection of statistical significance in this study (type-II error). However, the main study objective was to describe this technique in veterinary medicine and document that rapid central venous catheterization that can be achieved in cardiovascularly unstable dogs with moderate operator experience and minimal technical difficulty. Larger studies may further determine if a clinically relevant difference exists in time to vascular access in the presence of complications such as a hematoma, or as operators gain more experience.

A learning curve was observed by comparing perceived difficulty in gaining vascular access in the first half versus the second half of all attempts. Operators reported that perceived difficulty declined in the second half of catheterizations, despite the fact that almost all of the perivascular hematoma catheterizations in the study were undertaken in the later group (7 outof the 14 later catheterizations comprised the 9 total hematoma attempts). This demonstrates a detectable learning curve that is fairly shallow, and an ultrasound-guided technique can be easily learned and applied by individuals of varying experience levels. Much of this learning curve related to operator comfort, specifically maintaining the vessel and catheter tip in the same plane as the ultrasound probe to produce a clear image for directing the catheter. Safely and accurately guiding the catheter tip via ultrasound guidance helps overcome, but does not eliminate, the vessel's ability to "roll" away from the stylette (Figure 5). Interestingly, mean time to vascular access was not statistically different between the first and second halves. This suggests that, although a difference regarding level of comfort was perceived by the operators, it did not result in additional time to successful catheterization. Again, the practical application of this investigation highlights the accessibility of ultrasound guidance for a wide range of practitioners treating critical patients presenting considerable complications for vascular access.

This study did not directly follow the protocols of the human studies describing ultrasound-guided vascular access by comparing landmark versus ultrasound-guided techniques, which is a significant limitation of this analysis. A future randomized study, including a group of control dogs in which traditional landmarks are utilized for percutaneous jugular catheterization, is important to fully validate this technique. Additionally, this study employed uniformly sized dogs with the same cause of cardiac arrest. A prospective clinical study evaluating this technique in veterinary patients of different sizes, with various underlying diseases and other complicating factors, will also be important in validating the benefits of an ultrasound-guided technique.

Several studies in human medicine have documented improvements in success rate and time to vascular access using ultrasound guidance versus traditional landmark techniques across varying levels of operator experience.[4–11] In this study, each operator had some understanding of ultrasound principles but ranged widely in experience, from using ultrasound guidance to place IV catheters in a few clinical cases, to moderate experience performing abdominal ultrasound exams with organ assessment, to only experience with FAST (focused assessment with sonography for trauma) exams on an emergency basis.[16] Due to the relatively small number of operators and catheterizations, in-depth analysis of inter- and intraoperator variability was impracticable. Comparison of time to vascular access and perceived difficulty between the first half (initial, $n = 13$) and second half (subsequent, $n = 14$) of all attempts was used to more objectively assess intraoperator variability, as an apparent learning curve. None of the operators placed more catheters at the beginning or end of the study; all operators' efforts were evenly distributed throughout the total study period/attempts (including with/without hematomas). Differences among operators were controlled in the statistical analysis, which also minimized variable interoperator experience as a factor affecting other conclusions from the study. Future similar

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studies in veterinary medicine are warranted to examine if a similar benefit exists across operator experience for veterinary patients, especially in light of the interoperator variability in comfort and experience with ultrasound machines across veterinary medicine. The shallow learning curve shown here makes the idea very promising.

Although further studies are warranted, the current study is the first description of an ultrasound-guided technique for jugular catheterization in dogs, which resulted in a 100% success rate. The technique was found to be technically easy and rapid, with a relatively shallow learning curve amongst various operators. In future clinical cases, when traditional percutaneous access is unsuccessful or not feasible, an ultrasound-guided technique should be considered. Advantages include rapid identification of the vessel, confirmation of catheter placement within the vessel, and increased operator comfort with accessing larger vessels, permitting more rapid fluid and drug delivery to the central circulation.[1–3]

Footnotes

[a] Atropine Sulfate, Baxter, Deerfield, IL.
[b] Morphine, Baxter.
[c] Acepromazine, Vedco Inc, St. Joseph, MO.
[d] Catheter, Beckton Dickinson Infusion Therapy Systems, Inc, Sandy, UT.
[e] Ketamine, Fort Dodge Animal Health, Fort Dodge, IA.
[f] Diazepam, Hospira, Lake Forest, IL.
[g] Isoflurane, Piramal Critical Care, Inc, Bethlehem, PA.
[h] Multiparameter Monitor, Medical Data Electric, Arleta, CA.
[i] Lactated Ringer's Solution, Hospira.
[j] Dopamine, Hospira.
[k] Lidocaine, Hospira.
[l] Euthasol, Shering-Plough, Union, NJ.
[m] SonoSite, Inc, Bothell, WA.
[n] Syringes, Tyco Healthcare, Mansfield, MA.
[o] SAS version 9.2, SAS Institute, Cary, NC.
[p] StatCrunch, Integrated Analysis LLC, Westwood, NY.

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