Comparison of success rate and time to obtain venous cannulation by cutdown technique at 3 locations using canine cadavers

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Abstract

Objective – To compare the success rates and time taken to cannulate the jugular, cephalic and lateral saphenous veins using a cutdown technique by personnel with four different levels of experience.

Design – Prospective study.

Setting – Veterinary university teaching hospital.

Animals – Eighteen canine cadavers.

Interventions – Recently euthanized canine patients that were donated to the hospital for research purposes between October 2019 and March 2020 were enrolled. Four groups of personnel participated in the study to give four varying levels of experience; eight final year veterinary students, two registered veterinary nurses, one emergency and critical care intern and one ACVECC diplomate. Each cannula placer had 5 minutes to attempt cannulation by venous cutdown at each site. Time to venous cannulation was compared for each site and group and complications encountered during each attempt recorded.

Measurements and Main Results – The overall success rate for cannulation of the jugular, cephalic and lateral saphenous veins were 81%, 84% and 87%, respectively. The median venous cutdown times for all personnel were: jugular vein 119 seconds (range 51-280 s), cephalic vein 82 seconds (range 39-291 s) and lateral saphenous vein 110 seconds (range 41-294 s). There was no difference in time to venous cannulation between veins. When comparing personnel at the three cannulation sites, the ACVECC diplomate was faster than the registered veterinary nurses and students (P=0.042 and 0.048 respectively). No differences were found between any other groups. Complications encountered often related to cadaver factors such as hematoma from ante-mortem venipuncture.

Conclusions - All groups were able to perform venous cutdown at each site with good overall success even without prior experience of the technique. Venous cannulation by cutdown technique of the jugular, cephalic or lateral saphenous veins may be considered in an emergency setting by personnel of various skill levels.

Keywords: dog, emergency vascular access, resuscitation

Abbreviations

CPA – cardiopulmonary arrest

CPR – cardiopulmonary resuscitation

DACVECC – Diplomate of the American College of Veterinary Emergency and Critical Care

IO - intraosseous

IV – intravenous

RVN – registered veterinary nurse

VC – venous cannulation

Introduction

Vascular access is crucial in the emergent and critical patient to enable institution of appropriate stabilization measures such as intravenous fluid therapy and drug administration. Percutaneous venous cannulation (VC) can be challenging in patients with poor cardiac output, low circulating intravascular volume culminating in cardiovascular collapse or in patients which have undergone cardiopulmonary arrest (CPA) requiring cardiopulmonary resuscitation (CPR) measures. Repeated attempts of percutaneous VC in these patients can be time consuming and may not prove successful, thereby negatively affecting patient outcomes.

If percutaneous peripheral cannulation attempts are unsuccessful and patient stability hinges on gaining vascular access, VC by cutdown technique may be considered.[1] This emergency technique involves creation of an incision slightly lateral or medial to the anatomical location of the vein to allow for vessel visualization and ensure cannulation on the first attempt.[2] This technique may be used for peripheral (e.g. cephalic, lateral saphenous) or central (e.g. jugular) veins and is similar for both.[2] Venous cannulation by performing a venous cutdown may be a more rapid technique to obtain venous access than the more familiar percutaneous method in these difficult circumstances.

Cannulation of the jugular vein by cutdown technique has previously been documented to be achieved with an overall success rate of 87.5% in canine cadavers by individuals with varying experience levels.[3] The median time to cannulation by all individuals in this study was 217.3 seconds.[3] To the authors' knowledge, to date no studies have investigated either the success rate or time to VC by use of a cutdown technique at other sites in canine patients. If VC by cutdown technique is required in an emergency, it is crucial for the clinician to know which vein can be most readily cannulated. The primary aims of this study were to compare the success rates of VC and time taken to obtain venous access by cutdown technique of the jugular, cephalic and lateral saphenous veins in canine cadavers. The secondary aims were to compare the success rates of VC and the time taken to complete the task by personnel with varying levels of clinical experience. We hypothesized that venous cannulation by cutdown technique of the jugular, cephalic and lateral saphenous vein

68 would be readily achieved by personnel with different clinical experience levels and that time to
69 cannulation of the lateral saphenous vein would be shorter compared to the cephalic or jugular vein.
70

Materials and methods

Full ethical approval from the institution's ethical review committee was obtained prior to study enrollment. Following euthanasia, all canine cadavers donated with full owner consent for teaching and research purposes at the small animal teaching hospital between October 2019 and March 2020 were considered for study inclusion. Exclusion criteria included chondrodystrophic breeds, obesity (assessed as having a body condition score of 9 out of 9) or trauma to the neck or legs that would hinder the ability to perform venous cannulation. Following inclusion, any previously placed intravenous cannulas were removed.

Participants

Differing levels of clinical experience were represented by including four different groups of cannula placers; one Diplomate of the American College of Veterinary Emergency and Critical Care (DACVECC), one emergency and critical care (ECC) specialty intern, two registered and experienced ECC veterinary nurses (RVN) with > 5 years of clinical experience and eight final year veterinary students. No individuals within the RVN or student group had any prior experience of performing cannulations by venous cutdown. The intern had performed venous cutdown in a cephalic vein on one occasion prior to the study and was competent placing central venous catheters. The DACVECC had ample experience of performing a venous cutdown at each site. Each category of cannula placer (DACVECC, intern, RVN, student) attempted cannulation by cutdown technique at each site 8 times. The final year veterinary student category was represented by 8 different students who each participated in the study on one occasion and the two nurses enrolled in this study performed cannulation by cutdown technique at each site a total of 8 times between them. Eight veterinary students were included to reflect an inexperienced veterinary surgeon attempting this technique for the first time. Two RVN, working different shift patterns, were included to increase the likelihood of RVN availability corresponding with cadaver availability. Participation in the study was on a voluntary basis and written consent from all participants was obtained prior to study enrollment.

Training

A 10-minute PowerPoint presentation describing the cannulation technique was devised for all study personnel (presented by the DACVECC) to view prior to study enrollment. Following study enrollment, each participant (apart from the DACVECC) also viewed a demonstration of the cutdown technique on a cadaver at each site prior to their cannulation attempts. The DACVECC initially demonstrated the technique to the intern and then either the DACVECC or intern demonstrated the procedure to the nurses and students. The time taken for cannulation for each demonstration was recorded and included in the results of this study for the relevant placer.

Venous cutdown technique

The cutdown technique has been previously described.[2] Materials required for cannula placement were readily available at the start of each attempt and included a number 11 scalpel blade, mosquito forceps, non-absorbable suture material and over-the-needle cannulas[a] with the gauge selected by the placer. A new cannula and scalpel blade was used for each cannulation attempt. All cannulation attempts were placed with the cadaver lying in lateral recumbency. To eliminate the influence of coat type on time to cannulation, the fur over the insertion sites was clipped prior to study commencement. Aseptic preparation of the site was not performed. An assistant was available to assist with stabilizing the limb or neck as needed for cannulation. For standardization, each cannula placer started with the jugular vein followed by the cephalic and then the lateral saphenous vein on the same side of the body in each cadaver. Each cannulation attempt was timed using a stopwatch by an independent observer. When the cannula placer was ready to start, the independent observer communicated that the cannula placer could begin and started the stopwatch. The stopwatch was stopped when the cannula was visualized to be within the vein and blood identified in the cannula hub and correct placement confirmed by one of the study investigators (DACVECC or intern). This time was recorded in seconds and defined as the cannulation time.

Each cannula placer was given five minutes to attempt cannulation at each site by venous cutdown. If the time taken exceeded five minutes the attempt was deemed a failed attempt and timing was stopped. Veins which had been previously cannulated by percutaneous technique prior to

127 euthanasia were included in this study but there was never repeated cannulation by cutdown technique
128 by more than one attempt into the same vein.
129
130 The breed, body weight and body condition score of each cadaver was recorded. The time
131 from euthanasia to the start of the attempt and any complications encountered during the cannula
132 placement were recorded as free text. All cutdowns were aimed to be performed within 4 hours of
133 euthanasia. The cadavers were stored at room temperature until participants and materials were ready.
134

Statistical analysis

Observations were entered into a computer spreadsheet and data analysis was performed using the R statistical software[b] and Tidyverse suite of packages.[c] The overall success rates for each group of cannula placer (DACVECC, intern, RVN, student) were compared using a binary logistic regression model. Cannulation times were also compared between the four groups of cannula placer (DACVECC, intern, RVN, student) and also between cannulation sites (jugular, cephalic and lateral saphenous veins) with linear regression models. The distribution of cannulation times was visually assessed using histograms and was right skewed so they were log transformed prior to statistical modelling. Cannulation times were censored at 5 minutes so time comparisons are conditional on successful cannulation within this time limit. Each subject performed three or more cannulations (at least one per site) so both regression models included random effects to explicitly include the potential similarities of success rates and times within each subject's attempts. Models were estimated using the lme4 R package.[4] After the models were fitted post-hoc paired comparisons were made between each the three possible pairs of sites and the six possible pairs of subject groups. To control the risk of falsely identifying a difference between groups that may arise with multiple grouped comparisons the p-values were adjusted using Tukey's method (using the emmeans[5] and multcomp[d] R packages). Results tables were generated with the R sjPlots package.[e] A p-value of less than 0.05 was considered statistically significant.

Results

Study population

A total of 19 cadavers were considered for study inclusion during the study period and a total of 18 cadavers were included. One cadaver was excluded due to pathology affecting the limbs which would have precluded obtaining a full set of cannulation times. Cadaver demographics are shown in Table 1. Body weight ranged from 5.5 to 43.3kg, with a mean of 25.4kg. The median body condition score was 5 out of 9 (range 2-8). There was no difference in cadaver weight between the four cannula placer groups (P=0.84).

The average time from euthanasia to first cannulation attempt by a placer was 107 minutes (range 25-405 minutes). A total of 16 out of 18 cadavers enrolled in the study had cannulation attempts within 4 hours of euthanasia. A total of 8 sets of times were obtained for the DACVECC, intern and student group. Only 7 sets of times were obtained for the RVN group due to study enrollment ceasing with the COVID-19 pandemic. One RVN completed 5 sets of times and the other RVN 2 sets of times.

One intravenous cannula was present in each cadaver at time of enrollment. The location of these cannulae were recorded for 9 cadavers. Eight cadavers had a cannula placed into the cephalic vein and 1 cadaver had a cannula placed into the lateral saphenous vein.

Success rate

The combined rates for successful cannulation of each vein and the rate of successful cannulation of each vein subcategorized by study group are shown in Table 2 and the results of the logistic regression model of cannulation success are shown in Table 3. No differences in success of cannulation by venous cutdown were identified based on cannula placer group or vein used for cutdown.

Cannulation time

The individual times taken (up to the 5-minute cut-off) for successful cannulation of each vein by all personnel are shown in Figure 1. The median time taken for all personnel to successfully cannulate the cephalic, jugular and lateral saphenous veins were 82 seconds, 119 seconds and 110 seconds, respectively (Table 2).

The individual times taken for successful cannulation of each vein categorized by group are depicted in Figure 2. The mean and median times for each group by vein location are shown in Table 2. Table 4 shows the results of the linear regression model of cannulation time versus group and site. No significant differences were identified when comparing the time to cannulation of each site. Post-hoc analysis with correction for multiple grouped comparisons identified that the DACVECC was significantly faster than the RVN group ($p = 0.042$ after Tukey's adjustment) and the student group ($p = 0.048$ after Tukey's adjustment). No other groups were found to be different.

Complications

Twenty-six comments relating to complications or difficulties encountered were recorded from a total of 93 placement attempts (Tables 5 and 6). Ante-mortem factors were encountered most commonly, namely if the vein was cannulated previously and/or the presence of a hematoma from prior venipuncture (N = 14/26; 53.8%) and associated with a 35.7% (N = 5/14) failed attempt rate. The cephalic vein had the highest incidence of ante-mortem tissue damage (Tables 5 and 6). Difficulty locating the vein commonly resulted in a failure to achieve cannulation (N = 8/10, 80%) (Table 6). Iatrogenic damage to the vein during the cutdown technique occurred on two occasions, both instances by two final-year veterinary students and resulted in a failed attempt on one occasion. Of the 15 failed attempts for venous cannulation by cutdown technique, a complication or difficultly was identified in 13 of these attempts.

Discussion

The results of our study conclude that the jugular, cephalic and lateral saphenous veins in canine cadavers can be readily cannulated using a venous cutdown technique by personnel of varying experience levels. No significant differences were identified for time to cannulation at each of the three venous cutdown locations, suggesting that venous cutdown of the jugular, cephalic or lateral saphenous vein may be considered in emergency situations. However, the intergroup differences suggest proficiency may improve with increased experience of the venous cutdown procedure.

Cannulation by venous cutdown technique had high overall success rates for each of the three sites, with no significant differences in cannulation success rates between groups. All students and nurses enrolled in this study had limited surgical tissue handling experience and no prior clinical experience of performing a venous cutdown. The absence of significant differences for successful cannulation attempts between groups suggests that the venous cutdown technique can be rapidly learnt with minimal training and performed by all members of the clinical team.

Unsuccessful cannulation rates of 19.4%, 16.1% and 13% were recorded for the jugular, cephalic and lateral saphenous veins respectively. We specifically chose to define an unsuccessful or failed attempt as a cannulation attempt exceeding 5 minutes and not simply failure of VC regardless of time required. As this technique is usually being performed in patients with cardiovascular collapse, to include patients having undergone CPA, rapid vascular access is crucial. Therefore, assessing whether this procedure could be performed within 5 minutes was thought to be clinically appropriate as opposed to whether a venous cutdown could be performed regardless of time taken.

To the authors' knowledge, this is the first study to document both the success rate and time to VC of the cephalic and lateral saphenous vein by cutdown technique in dogs. We documented an overall success rate of 80.6% for cannulation of the jugular vein by all cannula placers by cutdown technique, which is lower than the success rate of 87.5% documented in a previously published study.[3] Although individuals with various clinical experience were also included in the study by

Allukian et al, their success rates may not be directly comparable. The time limit of 5 minutes per attempt in our study, along with ready access to the required instruments highlights major differences in methodology and is reflected by our shorter median jugular cannulation time (119 seconds versus 217 seconds).

We hypothesized that the lateral saphenous vein would have the shortest cannulation time given it is less likely to be surrounded by subcutaneous fat, is often readily visible in canine patients and due to the positioning of the cadaver in lateral recumbency. However, we did not identify a significant difference in cannulation times between the jugular, cephalic or lateral saphenous veins. This suggests that any of these veins could be considered for a venous cutdown. The lateral saphenous vein may still be advantageous in a CPR scenario given the pelvic limbs are at a distance from where a member of the team may be intubating the patient, which could hinder placement of a jugular or cephalic cannula. However, we did not simulate a CPR scenario in this study so we cannot be certain of these potential clinical implications.

In human medicine the venous cutdown technique is typically used to cannulate either the greater saphenous vein either near the groin or at the ankle or the basilic vein above the elbow.[5] In recent years this technique has largely been superseded in favor of less invasive techniques such as the modified Seldinger technique to access the femoral vein, use of ultrasound-guidance for percutaneous cannulation or IO catheterization.[5-7] Although peripheral venous cutdown is part of Advanced Pediatric Life Support training this technique is now considered to be a last resort.[6] Nonetheless, peripheral venous cutdown is still considered a valuable skill for emergency physicians.[5]

Obtaining vascular access is empirical in the treatment of critically ill patients and is part of advanced life support to facilitate administration of vasopressor drugs and intravenous fluids.[8] Cannulation of the jugular vein provides an advantage over the peripheral veins due to the jugular vein's proximity to the central circulation, providing higher peak concentrations of drugs and shorter lag times compared to peripherally administered drugs during CPR.[9] Therefore, in people if a central

venous cannula is in situ at the time of CPA then this route is recommended for the administration of emergency drugs.[10] The European Resuscitation Council guidelines report that peripheral venous cannulation is faster, easier to perform and safer than attempting central venous cannulation during CPR.[10] However, during CPA or shock states peripheral veins are more likely to be vasoconstricted and difficult to identify.[1] Furthermore, trauma to the limbs may preclude using the cephalic or lateral saphenous veins. Currently, there are no veterinary guidelines advising on the preferred location of intravenous cannula placement during CPA.

A survey conducted in 2010 investigated various aspects of veterinary CPR performed in practice, to include site and method of cannulation, by board-certified specialists, general practitioners working in emergency practice and general practice practitioners.[11] The majority of respondents chose peripheral over central venous cannulation during CPR with at least 90% of all respondents using the percutaneous approach. Respondents cited the cephalic vein as the preferred location followed by the lateral saphenous and jugular veins. The estimated mean time taken to obtain vascular access during a CPA event was reported as 3.17 minutes across all respondents which is similar to the time to cannulation obtained using the cutdown technique in our study. Therefore, although percutaneous peripheral venous cannulation is a more familiar technique to veterinary surgeons, RVNs and veterinary students, cannulation of the jugular, cephalic and lateral saphenous vein can be learnt and performed in at least a similar time period.

Should intravenous cannulation prove difficult, a valid alternative in human medicine is IO catheterization.[10] Intraosseous administration of drugs has been shown to achieve similar plasma concentrations to central venous catheter.[12] A study comparing the cutdown technique to secure the saphenous vein with IO catheterization in adult human cadavers found that IO catheterization was faster and associated with fewer complications than venous cutdown.[13] However, one retrospective study evaluating IV versus IO catheterization in cardiac arrest patients found return of spontaneous circulation was achieved more frequently with vascular as opposed to IO access,[14] suggesting there may be benefit despite the additional time required.

The use of an automatic rotary insertion device to secure IO access has been investigated in comparison to jugular cannulation using a cutdown technique in canine cadavers.[3] In this study IO catheter placement was found to be significantly faster than jugular cannulation regardless of the level of clinical experience of the person placing the catheter. However, as not all institutions or general practices will have access to an insertion device, we chose not to include IO assessment in our study. In comparison, the materials required for the venous cutdown technique are readily available in all practices and we suggest that all veterinary professionals should be aware of this technique, should they require emergency vascular access.

Complications were encountered by all groups in this study. Difficulty identifying the vein often led to failure for all cannula placers. Ante-mortem factors such as the tissue damage or hematomas resulting from previous cannulation or venipuncture were also frequent and could not be avoided given the nature of this study. The cephalic and saphenous veins were most often affected and likely reflects the increased use of these veins for cannulation and venipuncture during hospitalization. As these ante-mortem factors were often associated with failure to complete the task, it would be advisable to use the cutdown technique for an untouched vein if possible. As the intern and DACVECC encountered hematomas or previously cannulated veins more frequently than the student and RVN groups it is possible that there was an element of bias with allowing the less experienced cannula placer to use the side of the cadaver's body with fewer potential complications. This could have been avoided by randomizing the side of the body to be used by the first cannula placer, which was not performed in this study. There were also two instances where students caused significant iatrogenic damage to the vein whilst carrying out the task, one case resulting in bleeding from the jugular vein and failure to cannulate. In a live patient, this would contribute to morbidity and potentially mortality, therefore familiarization and practice of this technique prior to use in patients is advisable.

There are several limitations with this study. The sample size for this study was small and a sample size calculation was not performed. For this study we obtained ethics approval to include up to 24 cadavers. This number was based on a previous similar study[3] and our aim was to enroll an equal number into each group during the study period. Pre-hoc power analysis was considered however it was felt that it would be difficult given the limited literature available in both veterinary and human medicine relating to time to cannulation at each site. It is hoped this study will help provide information on cannulation times for individuals with varying levels of experience and so should assist future studies investigating venous cutdown, to include ability of study investigators to calculate meaningful power analyses. Recently deceased canine patients were used as a model of cardiovascular collapse, however ante-mortem and post-mortem factors such as hematomas at the site of previous intravenous cannulas may have affected the time taken to visualize the vein and place the cannula. The location of the previously placed intravenous cannula was not recorded for every patient and it is unknown how this affected the results. The time taken to start the cannulation attempts varied between cadavers and in two instances cannulation times were obtained from two cadavers euthanized more than four hours prior to study commencement. One chondrodystrophic breed, a Shih Tzu, was also included despite the study exclusion criteria. However, these were all included for analysis due to the limited availability of cadavers donated for research. Other cadaver factors such as body condition score or cause of death may have impacted cannulation times. For example, if the patient had a disease process which resulted in reduced intravascular volume prior to euthanasia this may have made cannulation more difficult. For standardization, each cannula placer started with the jugular vein followed by the cephalic and then the lateral saphenous vein on the same side of the body. Consequently, there may have been increased confidence and proficiency from cannulation of the jugular vein to the lateral saphenous vein by each individual per cadaver used. There were different numbers of participants in each cannula placer group. Increasing the number of individuals in each group, along with the number of attempts each individual performed, may have given us a wider range of experience levels and skills to compare between groups. Assessment of increased proficiency with subsequent placement attempts was not performed for the RVN, intern or DACVECC group due to the variable time periods between cadaver availability and small sample size and so evaluation of a

345 learning effect with the cutdown technique should be explored in future studies. It is also unknown
346 how having an individual watch the DACVECC or intern perform the VC as part of the demonstration
347 may have affected their times to cannulation. Despite having two individuals (DACVECC and intern)
348 demonstrating the cutdown technique, both used the same technique previously described[2], therefore
349 it is not thought this would contribute to bias. Finally, the cannulation attempts not being performed
350 as part of a clinical scenario, e.g. with movement of the cadaver as a result of chest compressions
351 during CPR; and having all materials readily available prior to study commencement, are additional
352 study limitations.
353
354 In conclusion, venous cannulation by cutdown technique of the jugular, cephalic and lateral
355 saphenous vein can be performed with high success rates by personnel of varying experience levels in
356 canine cadavers within a clinically relevant time frame. No significant differences in time to
357 cannulation were identified, suggesting that the jugular, cephalic or lateral saphenous vein may be
358 considered, but a jugular venous cutdown may be associated with increased risk of a clinically
359 significant adverse event, especially in novice operators. Cannulation failure was common when
360 using a vein which had previously been cannulated, suggesting a 'new vein' should be used when
361 possible. Further studies are required to assess the venous cutdown technique in canine patients in
362 clinical situations, such as CPR.
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365
366 Footnotes
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368
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421 **Table 1**. Demographic information of the cadavers included in the study.

422 BCS, body condition score; CKCS, Cavalier King Charles Spaniel; GSD, German Shepherd dog;

423 GSP, German Shorthaired Pointer

Breed	Age (years, months)	Weight (kg)	BCS (n/9)
Bearded Collie	11y 7m	30.6	4
Border Collie	4y 10m	20.3	3
Boxer	8y 11m	37.1	6
CKCS	7y 2m	15.4	8
Cocker Spaniel	10y 2m	15	4
Cocker Spaniel	8yr 4m	22	7
Crossbreed	9y 9m	27	5
GSD	6y 11m	40.9	4
GSD	8y	38	6
Labrador	2y	24.5	4
Miniature Schnauzer	0y 6m	5.5	2
Otterhound	8y 4m	30	3
GSP	8y	26.5	6
Rhodesian Ridgeback	8y	43.3	5
Shar Pei	3y 2m	16.5	5
Shih Tzu	16y	8.6	5
Springer Spaniel	6y	16	3
Springer Spaniel	8y 8m	20.65	4

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425

426

427 **Table 2.** Cannulation success rates and cannulation times of the jugular, cephalic and lateral
428 saphenous veins for individuals in each of the 4 cannula placer groups (student, RVN, intern,
429 DACVECC). Time to cannulation is expressed in seconds as both the mean time and median time
430 with range. The number of cannulation attempts at each site is stated along with the median cadaver
431 weight.
432
433 DACVECC, Diplomate of American College Veterinary Emergency and Critical Care; RVN,
434 registered veterinary nurse
435

Group	Cannulation attempts at each site (N)	Median cadaver weight (kg) (range)	Vein	Success rate N (%)	Mean (seconds)	Median (seconds) (range)
Student	8	24.3 (15.0-43.3)	Cephalic	6 (75)	153	149 (82-256)
			Jugular	5 (62.5)	161	153 (51-280)
			Lateral Saphenous	7 (87.5)	120	110 (74-227)
RVN	7	16.5 (16.0-37.1)	Cephalic	5 (71.4)	126	69 (67-283)
			Jugular	5 (71.4)	177	174 (105-250)
			Lateral Saphenous	6 (85.7)	160	132 (95-263)
Intern	8	24.3 (15.0-37.1)	Cephalic	8 (100)	118	82 (50-291)
			Jugular	7 (87.5)	141	119 (51-246)
			Lateral Saphenous	7 (87.5)	168	161 (56-294)
DACVECC	8	31.3 (5.5-43.3)	Cephalic	7 (87.5)	82	72 (39-170)

			Jugular	8 (100)	80	68 (51-139)
			Lateral Saphenous	7 (87.5)	61	55 (41-84)
Overall	31	24.5 (5.5-43.3)	Cephalic	26 (83.9)	118	82 (39-291)
			Jugular	25 (80.6)	127	119 (51-280)
			Lateral Saphenous	27 (87.1)	126	110 (41-294)

436

437 **Table 3**. Results from logistic regression model of cannulation success. Estimates are odds ratios i.e.
438 the odds of success for a group or vein divided by the odds of success in the reference group. Odds
439 ratios lower than 1.0 imply a lower relative success rate and odds ratios greater than 1.0 a higher
440 success rate than the reference group. P-values are for the test if the odds ratio is significantly
441 different from 1.0.
442

Predictors	Odds Ratios	CI	p
vein [cephalic]	Reference level		
vein [jugular]	0.77	0.19 – 3.17	0.721
vein [saphenous]	1.35	0.29 – 6.16	0.701
group [DACVECC]	Reference level		
group [Intern]	1.00	0.04 – 23.48	1.000
group [RVN]	0.23	0.01 – 3.63	0.296
group [Student]	0.29	0.02 – 3.70	0.339

443
444

445 **Table 4.** Results of linear regression model estimating log transformed cannulation time. Estimates
446 from the model are exponentiated as time was log transformed. These values for each variable level
447 can be interpreted as multiplicative e.g. RVN's took, on average, 2.06 times longer than DACVECC's
448 (the reference level for personnel group).

Predictors	Exponentiated estimates	CI	p
vein [cephalic]	Reference level		
vein [jugular]	1.18	0.91 – 1.54	0.208
vein [saphenous]	1.05	0.81 – 1.36	0.710
group [DACVECC]	Reference level		
group [Intern]	1.77	1.01 – 3.12	0.048
group [RVN]	2.06	1.20 – 3.53	0.008
group [Student]	1.87	1.16 – 3.02	0.010

449

450

451 **Table 5.** The complications and difficulties encountered by all personnel during cannulation attempts
452 according to vein.
453
454 IVC, intravenous cannula.
455

Vein	Total number of cancellation attempts (N)	Difficulty locating vein (N)	Iatrogenic damage during cannulation attempt (N)	Previous IVC and/or hematoma at site (N)
Cephalic	31	3	0	8
Jugular	31	5	1	1
Lateral saphenous	31	2	1	5

456

457 **Table 6**. The complications recorded during cannulation attempts are shown in the table according to
458 group. The frequency of each complication is reported and the frequency the complication resulted in
459 a failed attempt by individuals in each cannula placer group is also shown.
460
461 DACVECC, Diplomate of American College of Veterinary Emergency and Critical Care; IVC,
462 intravenous cannula; RVN, registered veterinary nurses.
463

Complication	**Vein**	**Study group**							
		Student		**RVN**		**Intern**		**DACVECC**	
		Frequency reported (N)	Frequency resulted in failed attempt (N)	Frequency reported (N)	Frequency resulted in failed attempt (N)	Frequency reported (N)	Frequency resulted in failed attempt (N)	Frequency reported (N)	Frequency resulted in failed attempt (N)
Difficulty locating vein	Cephalic	2	1	-	-	-	-	1	1
	Jugular	2	1	2	2	1	1	-	-
	Lateral Saphenous	1	1	1	1	-	-	-	-
Previous IVC and/or hematoma at site	Cephalic	1	1	3	2	2	-	2	-
	Jugular	-	-	-	-	1	-	-	-
	Lateral Saphenous	-	-	-	-	3	1	2	1
Iatrogenic damage to vein	Cephalic	-	-	-	-	-	-	-	-
	Jugular	1	1	-	-	-	-	-	-
	Lateral Saphenous	1	-	-	-	-	-	-	-

464
465

Figure legends

Figure 1. Scatter plot showing each successful cannulation time by all personnel by vein. Cross indicates median cannulation time.

Figure 2. Scatter plot showing each successful cannulation time by cannula placer group and by vein. Cross indicates median cannulation time.

DACVECC = Diplomate of American College of Veterinary Emergency and Critical Care, RVN = registered veterinary nurse.