Journal of Veterinary Internal Medicine

Journal of Veterinary Internal Medicine Open Access ACVIM American College of Veterinary Internal Medicine

PILOT STUDY OPEN ACCESS

Small Animal Internal Medicine Cardiology

Feasibility of Near-Infrared Image Guided Vascular Identification and Access in Dogs

Seth Bowden | Jake Johnson | Kursten V. Pierce

North Carolina State University College of Veterinary Medicine, Raleigh, North Carolina, USA

Correspondence: Kursten V. Pierce (kvpierce@ncsu.edu)

Received: 13 November 2024 | **Revised:** 13 February 2025 | **Accepted:** 21 February 2025

Funding: The authors received no specific funding for this work.

Keywords: canine | phlebotomy | vein finder | venipuncture

ABSTRACT

Background: Use of real-time imaging with near-infrared (NIR) light technology to assist with gaining vascular access in humans is increasingly common. There is a lack of research on the NIR imaging modality in animals.

Hypothesis/Objectives: To assess the feasibility of NIR vessel finding technology at vascular sites in a cohort of dogs, between shaved and unshaved fur, and under conditions of vasoconstriction.

Animals: 6 healthy, adult dogs (three beagles, three hounds) in a university teaching colony.

Methods: 5 peripheral vascular sites were imaged before and after shaving. Images were scored based on the following criteria: *not feasible* (0), *feasible* (1), *helpful but not feasible as sole guidance* (2). Each vascular site was re-imaged after intravenous administration of dexmedetomidine.

Results: The left medial saphenous, right cephalic, and right lateral saphenous veins were the most feasibly identified vessels (18/18, 17/18, and 15/18, respectively). The effects of dexmedetomidine administration ($p = 0.5$ at 20 cm; $p = 0.78$ at 26 cm) and fur color ($p = 0.25$ at 20 cm; $p = 0.50$ at 26 cm) on the feasibility of vessel imaging were not statistically significant. However, a significant difference between shaved and unshaved areas was identified when directly compared at 20 cm ($p = 0.04$). The external jugular vein was less reliably identified (6/18 and 5/18 in sternal and lateral recumbency, respectively), and the left femoral artery was not identified (0/18).

Conclusions and Clinical Importance: Use of NIR imaging for identification of superficial, peripheral veins is feasible in healthy beagles and hounds, regardless of shaving and administration of dexmedetomidine. This technology could be useful in other clinical scenarios.

1 | Introduction

Near-infrared (NIR) light is defined as electromagnetic radiation with a wavelength (700–3000 nm) longer than visible light (350–700 nm). Chromophores, such as hemoglobin, absorb NIR light. The extent of hemoglobin's light absorption defines the NIR window, which allows for the visualization at a specific wavelength of blood vessels. Recently, advancements in light-emitting diodes and highly sensitive cameras for NIR light have facilitated real-time imaging [1]. This technology is more commonplace to aid in obtaining vascular access in human medicine [2–17]. Near-infrared imaging is limited somewhat by depth of penetration; thus, use in vascular access is primarily employed for accessing superficial vasculature [7].

Abbreviations: BCS, body condition score; LF, left femoral artery; LMS, left medial saphenous vein; MCS, muscle condition score; NIR, near-infrared; RC, right cephalic vein; RJ, right external jugular vein; RLS, right lateral saphenous vein.

In veterinary medicine, there is a lack of research regarding this modality and its utility in achieving vascular access. A meta-analysis of 5298 children and adolescents found using NIR light devices in peripheral intravenous cannulation significantly reduced both procedure time and the number of attempts [15]. Furthermore, a retrospective and observational study in human medicine used NIR imaging for the transradial approach for arterial access. This resulted in a reduced procedure time and an increased success rate, which would be beneficial for animals as well [4]. Insight into the use of NIR imaging for vascular access in animals could provide an array of beneficial clinical applications, including teaching, guidance in intravenous catheter placement in critically ill animals, efficient drug administration, and decreased complications associated with venipuncture (hematoma, thrombosis, pain).

The study aims to assess the feasibility of NIR vessel finding technology in visualizing peripheral vasculature at various access sites under conditions including shaved or unshaved fur and drug-induced vasoconstriction, and utility to aid in obtaining peripheral vascular access in dogs. Data will be applied to larger prospective studies to further evaluate the clinical utility and application of NIR technology in veterinary medicine. We hypothesized that using NIR imaging would reliably identify superficial vasculature in this cohort of dogs, supporting its use in guiding vascular access. Furthermore, we hypothesized that NIR vessel finding technology would perform better after the dog's fur was shaved and that the identification of blood vessels would remain unaffected by the administration of vasoconstrictive agents.

2 | Materials and Methods

2.1 | Ethics Statement

Study was approved by North Carolina State University's Institutional Animal Care and Use Committee. Animals were cared for according to principles outlined in the NIH guide for the Care and Use of Laboratory Animals.

2.2 | Study Group

Study group consisted of six healthy, adult dogs (three beagles and three hounds) from a university teaching colony. Each dog had complete blood counts performed within the past year, revealing no evidence of anemia. All dogs received multiple examinations throughout the year and were deemed free of clinically apparent disease.

2.3 | Dog and Vascular Site Preparation

All dogs were premedicated with 1 mg/kg of ondansetron before sedation per laboratory animal research protocol, orally. After at least 30 min, the same five pre-determined vascular sites were imaged after topical application of isopropyl alcohol to mimic venipuncture preparation in a clinical setting. Each vessel was held off proximal to the imaging window during the imaging process, except for the left femoral artery (LF). Chosen vascular sites included the right external jugular vein (RJ) at the mid-cervical region, right cephalic vein (RC) proximal to the carpal joint, right lateral saphenous vein (RLS) proximal to the tarsal joint, left medial saphenous vein (LMS) proximal to the level of the stifle, and LF at the inguinal region. All imaging was performed in the following recumbency: sternal or standing (RC and RJ) and left lateral (RJ, RLS, LMS, and LF). Fur coat color over the vessel of interest, muscle condition scores (MCS) and body condition scores (BCS) were recorded using WSAVA Global Nutrition Committee Guidelines [18].

Each site was imaged in the same manner before shaving (Phase 1) and after shaving fur using a #40 electric blade (Phase 2) with the application of isopropyl alcohol to mimic preparation before intravenous catheter placement. Once Phases 1 and 2 were completed, each dog received 1 mcg/kg of dexmedetomidine, intravenously, via the direct stick method utilizing the NIR device on a vein distinct from the five pre-determined vascular sites. At 15–30 min after dexmedetomidine administration, each shaven vascular site was re-imaged (Phase 3) with the same protocol as described for previous phases to mimic venipuncture or catheter placement in critically ill dogs or dogs sedated with α-2 agonists. After imaging acquisition, an equal volume of atipamezole was administered intramuscularly at the discretion of the supervising clinician.

2.4 | Imaging

Each vascular site was palpated, visualized, or a combination of both techniques was used to confirm the location of the target vessel and imaged with AIMVEIN PRO 3.0 (YDX Innovation Company Limited Hennessy Road, Wan Chai, Hong Kong) NIR device using Yellow-Red filter on high brightness, held in place with an AIMVEIN GO Mobile Trolly (Figure S1). The two-color (yellow–red) mode was chosen as it provides additional information regarding venous depth (yellow 0–3 mm; red > 3 mm). The device guidelines recommended imaging distances of 24–26 cm for humans; 26 cm was initially chosen. After Phase 1 for the first dog, this technique was adjusted to include both 20 and 26 cm, after which 58/108 vessels were imaged at both 20 and 26 cm distances. Vascular sites were imaged above and perpendicular to the vessel. Imaging was performed by veterinarians (S.B., J.J.) under the direct supervision of ACVIM board-certified cardiologist (K.P.).

2.5 | Feasibility

Each imaged site was categorized into one of three categories: not feasible, feasible, and helpful but not feasible as sole guidance (Figures 1 and 2). Feasibility was defined as the ability of the NIR device to correctly overlay the anatomic location of the target vessel, which was assessed based on knowledge of anatomic vessel location and confirmation by palpation (Figure 1). Those not feasible were unable to identify nor appropriately outline or track near/alongside the vessel. Those in the "not feasible but helpful category" occurred when the NIR device could only detect the vessel when positioned at different angles or when it identified the appropriate anatomic path alongside the vessel but did not completely overlay or outline the vessel (Figure 2). The NIR device was utilized during intravenous administration of dexmedetomidine and feedback regarding whether the

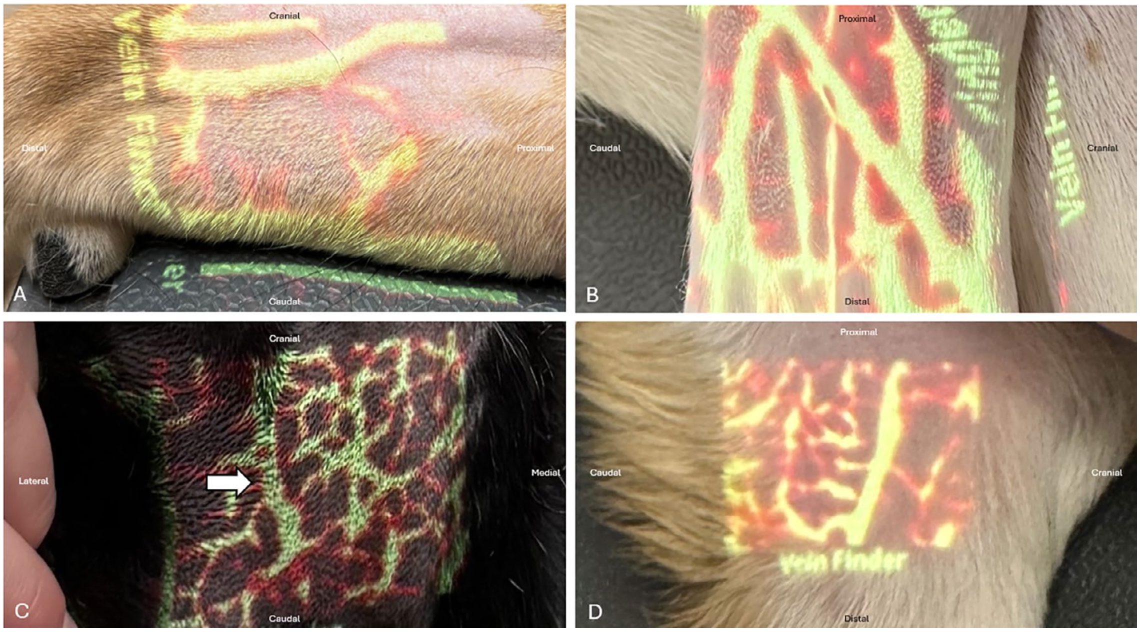

FIGURE 1 | Feasible imaging of each peripheral vessel location. Left femoral artery imaging was excluded due to lack of feasible imaging. (A) Right cephalic vein. (B) Right lateral saphenous vein. (C) Right external jugular vein. White arrow is pointing to the right external jugular vein, which was confirmed to appropriately overlay the vein via palpation. (D) Left medial saphenous vein.

FIGURE 2 | Feasibility was assessed based on the ability to accurately identify the location and course of peripheral vessels. Feasibility was scored as (A) feasible (image: right lateral saphenous vein), (B) not feasible, but helpful (image: right external jugular vein in left lateral recumbency), or (C) not feasible (image: right external jugular vein in sternal recumbency).

device could be helpful for trainees learning venipuncture was recorded. Feedback was from a registered veterinary technician involved in teaching venipuncture in hands-on teaching laboratories for first year veterinary students.

2.6 | Statistical Analysis

Data were analyzed using R (version 4.4.1, released 2024-06-14). To explore the association between the categorical variable feasibility (0 = *not feasible*, 1 = *feasible*, 2 = *not feasible but helpful*) and other categorical variables, including shaven status (unshaved vs. shaved), height (20 vs. 26 cm), jugular vein between different recumbencies (sternal vs. left lateral), dexmedetomidine (no administration versus administration), fur color (black, brown, white), breed (beagle versus hound), and location (RC, RJ, RLS, LMS, LF), Fisher's exact test was performed. *p*-Values were calculated using the Monte Carlo method due to the small sample size and more than two levels in each categorical variable. Statistical significance was reported if p-value < 0.05.

3 | Results

The study group (Table S1) included 6 healthy, hemodynamically stable adult neutered dogs from North Carolina State University, laboratory animal research teaching colony (3 beagles, 3 hounds), of which four were female and two were male. All dogs were between 1 and 2 years of age. All dogs had MCS of 3/3 ($n = 6$) and BCS varied between 4/9 ($n = 3$) and 5/9 ($n = 3$). Weight ranged between 9 and–29.7 kg (mean 18.5 kg, median 17.45 kg). Fur coat color over the intended vascular access site for each site on each dog was black (2/34), brown (9/34), and white (23/34). Administration of dexmedetomidine via venipuncture was performed at: LC ($n = 2$), RMS ($n = 2$), and left lateral saphenous vein ($n = 1$). Hound 2 was administered dexmedetomidine into RLS ($n = 1$).

The LMS, RC, and RLS veins were the most reliably and accurately identified vessels using the NIR device regardless of shaven status (Figure 3; 18/18, 17/18, and 15/18, respectively). However, a statistically significant difference was observed when comparing unshaved (Phase 1) and shaved (Phase 2) areas directly ($p = 0.04$). Shaved areas were more reliably and accurately identified than unshaved areas at an imaging height of 20 cm ($p = 0.04$). The effects of dexmedetomidine administration (Phase 3; $p = 0.5$ at 20 cm; $p = 0.78$ at 26 cm) and fur color ($p = 0.25$ at 20 cm; $p = 0.50$ at 26 cm) on the feasibility of vessel imaging were not statistically significant. Feasibility between breeds (Hound vs. Beagle) was assessed for Phase 2 (shaven) to allow for assessment based on body size while excluding the variable of the presence of fur, which had already been shown to affect feasibility. No statistically significant differences were found between breed and feasibility at either distance ($p = 0.29$ at 20 cm; $p = 0.48$ at 26 cm). No significant difference in feasibility was appreciated between recumbency (sternal, left lateral) during RJ imaging ($p = 0.74$ at 20 cm; $p = 0.57$ at 26 cm), although left lateral recumbency was noted to be more helpful.

When imaging heights of 20 versus 26 cm were compared, there was no statistically significant difference detected ($p = 1.0$). When paired with data comparing Phase 1 (unshaved) and Phase 2 (shaved), a statistically significant difference between Phases 1 and 2 was only detected at an imaging height of 20 cm ($p = 0.039$ at 20 cm; $p = 0.355$ at 26 cm). The LF was unable to be identified for any dog at either height (20 cm, 26 cm), regardless of vessel site preparation (unshaved or shaved) or dexmedetomidine administration (0/18).

4 | Discussion

The use of the NIR imaging device in this study was feasible to detect superficial peripheral limb veins in healthy, adult dogs independent of site preparation or administration of a commonly used vasoconstrictive sedative (Figure 3). Similar feasibility was not appreciated with imaging of deeper vessels such as LF or RJ (Figure 3). These findings are not unexpected as NIR imaging devices reportedly identify superficial vessels with greater accuracy than deeper vascular structures. Variable penetrating depths between NIR devices could allow for some devices to have deeper penetrating capabilities. This is comparable to human medicine, where imaging of deep subcutaneous blood vessels is limited and is considered a drawback of this method of vascular imaging. The primary factor regarding the depth of NIR penetration is the wavelength of light, although other factors such as luminosity and light source angle play an important role. Variations in these properties among NIR imaging devices are responsible for the subsequent variation in product efficacy and feasibility regarding the imaging of deeper blood vessels [19, 20].

Vascular access is an important aspect of veterinary medicine as it determines the ability to obtain blood samples, administer medications, and establish access points for minimally invasive catheter-based procedures [17, 21]. For most clinical cases, vessel palpation alone is sufficient to provide an estimation of vessel location for experienced professionals. However, clinical factors including poor peripheral circulation/volume depletion, older age, or increased body habitus [17, 21, 22] could add challenges. Thus, prompting investigation into the utility of vascular imaging aids when palpation alone is insufficient [1–3, 6, 9, 14]. Vascular ultrasound has been used as this aid; however, this requires expensive equipment and advanced training for efficient use [7]. Recently, NIR devices have become more commonplace in human medicine for routine venipuncture and additional investigation evaluating arterial access for minimally invasive procedures [4]. An ultrasound machine and linear probe for vascular imaging could be cost prohibitive for some veterinary clinics whereas NIR imaging devices offer a hands-free, lower-cost option, not requiring training [16, 17].

4.1 | Dog Positioning and Imaging Technique

This study aimed at mimicking real-life clinical scenarios in which NIR imaging devices could be applied. As such, the four veins imaged were chosen based on common veterinary venipuncture or catheter placement sites (RJ, RC, RLS, LMS). Furthermore, imaging was performed in the recumbency in which venipuncture is commonly performed for each respective vessel. Since the external jugular vein is a common venous access site in both sternal recumbency and lateral recumbency (ex.

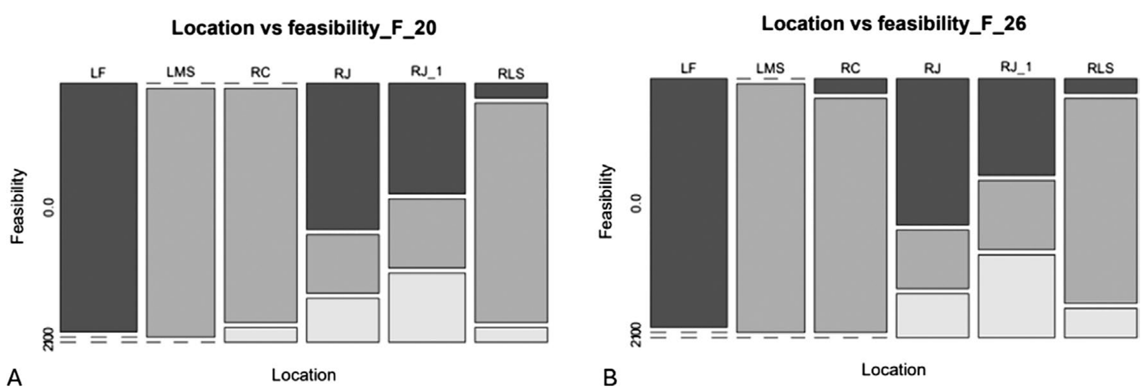

FIGURE 3 | Mosaic Plots showing the feasibility of NIR imaging at each vessel location for 20 cm (A) and 26 cm (B) imaging heights regardless of site preparation or dexmedetomidine administration. Feasibility is indicated numerically as follows: 0 = Not feasible (dark gray); 1 = feasible (gray); 2 = not feasible but helpful (light gray). Vessel location is indicated by the following abbreviations: RC = right cephalic vein, RJ = right external jugular vein in sternal recumbency, RJ_1 = right external jugular vein in left lateral recumbency, RLS = right lateral saphenous vein, LMS = left medial saphenous vein, LF = left femoral artery. All $p = 0.0004$. The dashed line indicates that there are no cases presented for the combination cell in the plot. For example, in (A) there are zero cases in which the LF was in the feasible (gray) or helpful (light gray) category as it was unable to be imaged with this NIR device.

central line placement and minimally invasive catheter-based cardiac procedures), this is the only vessel that was imaged in two positions. When comparing sternal and lateral recumbency, a statistical difference was not present. However, the ability to keep the skin more taught in lateral recumbency likely aided in vascular imaging of the vessel.

Imaging distance played a role in vessel identification. The device guidelines recommended imaging distances of 24–26 cm for humans; 26 cm was initially chosen. After Phase 1 for the first dog, this technique was adjusted to include both 20 and 26 cm. Our data indicate that NIR imaging of a shaved leg at a height of 20 cm might be more beneficial for clinical use.

4.2 | Overall Feasibility

Feasibility is a subjective assessment often requiring situational understanding of circumstances. Therefore, as previously mentioned, the use of NIR imaging devices might not be feasible or readily identify vessels in all scenarios. This study demonstrates that using a NIR imaging device in a small cohort of healthy dogs for peripheral venous imaging is feasible at the LMS, RC, and RLS veins ($p = 0.0004$). Imaging of the RJ in left lateral recumbency was found to be at least helpful ($p = 0.0004$). Therefore, another imaging device with greater penetrating ability could be useful for deeper venous structures.

4.3 | Limitations

The present study has several limitations. First, the number of dogs is small, and all were of similar MCS and BCS. This was purposeful to eliminate other factors affecting imaging variability. Consequently, we can only speculate on the feasibility of using NIR imaging to identify superficial vessels in two body conformations (Beagle and Hound dogs). Considering the wide spectrum of phenotypes, including skin pigment, fur color, BCS, MCS, body conformation, and weight, further investigation into the utility of NIR imaging in a larger cohort is necessary. These six dogs represent the initial reported experiences in NIR real-time imaging in dogs. As such, imaging techniques were modified throughout the study to improve efficacy and will likely continue to evolve with more experience, understanding, and advancement in NIR technology. This study evaluated NIR imaging in healthy dogs, whereas the clinical utility could be more directed toward unhealthy animals and does not mimic real-life clinical scenarios. Lastly, different manufacturers of NIR imaging devices might not be equivalent in quality, portability, depth of imaging capabilities, or ease of use. Alternative approaches to NIR imaging for vascular access are ultrasonography and manual palpation of the target vessel.

4.4 | Conclusion

The NIR vessel finding device used in this study was able to correctly identify the LMS, RC, and RLS veins regardless of site preparation status or dexmedetomidine administration in 6 healthy adult dogs. Similar feasibility was not appreciated for RJ or LF vascular sites.

Acknowledgments

The authors thank Vanessa Roman, RVT, for aiding in study design and drug administration and biostatistician Yang Qu, PhD, for performing the statistical analysis and writing of the statistical analysis section.

Disclosure

Authors declare no off-label use of antimicrobials.

Ethics Statement

Approved by North Carolina State University Institutional Animal Care and Use Committee, protocol 24-206-02. Authors declare that human ethics approval was not needed.

Conflicts of Interest

The authors declare no conflicts of interest.

References

1. N. J. Cuper, "Chapter 1. IntroductionNear-Infrared Vascular Imaging in Peripheral Venous and Arterial Access" (Dissertation, Utrecht University 2012).

2. F. B. Chiao, F. Resta-Flarer, J. Lesser, et al., "Vein Visualization: Patient Characteristic Factors and Efficacy of a New Infrared Vein Finder Technology," *British Journal of Anaesthesia* 110, no. 6 (2013): 966–971, https://doi.org/10.1093/bja/aet003.

3. M. D. Francisco, W.-F. Chen, C.-T. Pan, et al., "Competitive Real-Time Near Infrared (NIR) Vein Finder Imaging Device to Improve Peripheral Subcutaneous Vein Selection in Venipuncture for Clinical Laboratory Testing," *Micromachines* 12, no. 4 (2021): 373, https://doi.org/10.3390/mi12040373.

4. N. Murotani, F. Yoshimachi, H. Nagamatsu, et al., "First Reported Use of a Visualization Device for the Radial Artery With Near-Infrared Rays Through the Transradial Approach," *Journal of Invasive Cardiology* 33, no. 10 (2021): E817–E822.

5. E. Goldschmidt, A. H. Faraji, B. T. Jankowitz, P. Gardner, and R. M. Friedlander, "Use of a Near-Infrared Vein Finder to Define Cortical Veins and Dural Sinuses Prior to Dural Opening," *Journal of Neurosurgery* 133, no. 4 (2020): 1–8, https://doi.org/10.3171/2019.5.JNS19297.

6. C. T. Pan, M. D. Francisco, C. K. Yen, S. Y. Wang, and Y. L. Shiue, "Vein Pattern Locating Technology for Cannulation: A Review of the Low-Cost Vein Finder Prototypes Utilizing Near Infrared (NIR) Light to Improve Peripheral Subcutaneous Vein Selection for Phlebotomy," *Sensors* 19, no. 16 (2019): 3573, https://doi.org/10.3390/s19163573.

7. S. Sekiguchi, K. Moriyama, J. Tokumine, et al., "Near-Infrared Venous Imaging May Be More Useful Than Ultrasound Guidance for Novices to Obtain Difficult Peripheral Venous Access: A Crossover Simulation Study," *Medicine* 102, no. 12 (2023): e33320, https://doi.org/10.1097/MD.0000000000033320.

8. Z. Alizadeh, "Effect of Vein Finder and Common Venipuncture Method in Anxiety and Psychological Indicators Among 3-6-year-old children: A Comparative Study," *NAVIDNO* 24, no. 78 (2021): 113–124, https://doi.org/10.22038/nnj.2021.57659.1286.

9. S. J. Curtis, W. R. Craig, E. Logue, B. Vandermeer, A. Hanson, and T. Klassen, "Ultrasound or Near-Infrared Vascular Imaging to Guide Peripheral Intravenous Catheterization in Children: A Pragmatic Randomized Controlled Trial," *Canadian Medical Association Journal* 187, no. 8 (2015): 563–570, https://doi.org/10.1503/cmaj.141012.

10. S. Seddone, L. Ermini, P. Policastro, L. Mesin, and S. Roatta, "Evidence That Large Vessels Do Affect Near Infrared Spectroscopy,"

Scientific Reports 12, no. 1 (2022): 2155, https://doi.org/10.1038/s41598-022-05863-y.

11. A. B. Abd Rahman, F. Juhim, F. P. Chee, A. Bade, and F. Kadir, "Near Infrared Illumination Optimization for Vein Detection: Hardware and Software Approaches," *Applied Sciences* 12, no. 21 (2022): 11173, https://doi.org/10.3390/app122111173.

12. Y.-J. Jung, J. Gonzalez, and A. Godavarty, "Near-Field Microwave Resonating Sensor for Chronic Bone Assessment Through Novel Electromagnetic Band Gap Structures," *ACS Omega* 10, no. 5 (2025): D82, https://doi.org/10.1364/AO.54.000D82.

13. Y. Chen, Z. Shen, Z. Shao, P. Yu, and J. Wu, "Free Flap Monitoring Using Near-Infrared Spectroscopy: A Systemic Review," *Annals of Plastic Surgery* 76, no. 5 (2016): 590–597, https://doi.org/10.1097/SAP.0000000000000430.

14. A. I. Chen, M. L. Balter, T. J. Maguire, and M. L. Yarmush, "3D Near Infrared and Ultrasound Imaging of Peripheral Blood Vessels for Real-Time Localization and Needle Guidance," *Medical Image Computing and Computer Assisted Intervention* 9902 (2016): 388–396, https://doi.org/10.1007/978-3-319-46726-9_45.

15. S. L. A. Ng, X. R. G. Leow, W. W. Ang, and Y. Lau, "Effectiveness of Near-Infrared Light Devices for Peripheral Intravenous Cannulation in Children and Adolescents: A Meta-Analysis of Randomized Controlled Trials," *Journal of Pediatric Nursing* 75 (2024): e81–e92, https://doi.org/10.1016/j.pedn.2023.12.034.

16. J. A. Lee, L.-V. S. Guieu, G. Bussières, and C. K. Smith, "Advanced Vascular Access in Small Animal Emergency and Critical Care," *Frontiers in Veterinary Science* 8 (2021): 703595.

17. M. W. Beal and D. Hughes, "Vascular Access: Theory and Techniques in the Small Animal Emergency Patient," *Clinical Techniques in Small Animal Practice* 15, no. 2 (2000): 101–109.

18. L. Freeman, I. Becvarova, N. Cave, et al., "WSAVA Nutritional Assessment Guidelines," *Journal of Feline Medicine and Surgery* 13, no. 7 (2011): 516–525.

19. A. Madrid García and R. Horche P, "Light Source Optimizing in a Biphotonic Vein Finder Device: Experimental and Theoretical Analysis," *Results in Physics* 11 (2018): 975–983, https://doi.org/10.1016/j.rinp.2018.10.033.

20. B. Shin and D. Lee, "Deep Blood Vessel Visualization Over 10-mm Depth Using NIR Light," in *15th International Conference on Ubiquitous Robots (UR)* (IEEE, 2018), 714–718, https://doi.org/10.1109/URAI.2018.8441817.

21. N. J. Cuper, J. H. G. Klaessens, J. E. N. Jaspers, et al., "The Use of Near-Infrared Light for Safe and Effective Visualization of Subsurface Blood Vessels to Facilitate Blood Withdrawal in Children," *Medical Engineering and Physics* 35, no. 4 (2013): 433–440, https://doi.org/10.1016/j.medengphy.2012.06.007.

22. S. Juric, V. Flis, M. Debevc, A. Holzinger, and B. Zalik, "Towards a Low-Cost Mobile Subcutaneous Vein Detection Solution Using Near-Infrared Spectroscopy," *Scientific World Journal* 2014 (2014): 365902, https://doi.org/10.1155/2014/365902.

Supporting Information

Additional supporting information can be found online in the Supporting Information section.