Intravenous catheterization of the jugular vein is performed at least weekly by veterinarians in general equine practice and more frequently in hospital settings. Seventy-five percent of clinicians consider the ability to place an intravenous catheter (IVC) in a horse a "day-one skill" for graduating veterinary students and a skill that new graduates should be highly proficient in performing. In teaching hospitals, clients, faculty, or technical staff may be reluctant to allow student involvement in catheter placement due to the impression that complications are more likely when the IVC site is prepared or the IVC placed by a veterinary student. Complications of IVCs occur in 8% to 29% of horses, and many risk factors have been identified related to the IVC type and clinical status of the patient. Specific complications attributed to IVC placement in horses are thrombophlebitis, local cellulitis, perivascular abscessation, air embolism, thromboembolism, shearing off of the IVC within the vein, and loss of guidewires into the vasculature and heart. Endotoxemia, fever, diarrhea, use of locally made fluids, salmonellosis, general anesthesia, use of polytetrafluoroethylene (PTFE; Teflon) or silicone catheters, and increased dwell times increase the odds of developing complications, mainly thrombophlebitis. Thrombophlebitis in horses can lead to severe clinical signs including induration of the

OBJECTIVE
To determine whether student involvement in intravenous catheter (IVC) placement increases the risk for complications and to report the rate and types of complications associated with IVCs in adult horses in a university teaching hospital.

ANIMALS
455 IVCs placed in 394 horses.

METHODS
Data relevant to IVC placement and removal were retrieved from an electronic medical record search including records of adult horses from January 1 to December 31, 2022. Data retrieved from records included the role of the individual who prepared the site and placed the IVC, site of IVC placement, and type of IVC. The reason for removal of the IVC and presence or absence of detectable changes within the vein at the time of removal were documented in addition to clinical data, allowing for classification of each case. Data were reviewed retrospectively, and statistical analyses were performed using mixed-effects logistic regression models. Significance was set at P ≤ .05.

RESULTS
The overall rate of complications was 15.6%, and the most common type of complication was swelling of the vein. Students were involved in 87 of 455 IVC site preparations and placements, and there were no statistically significant differences in complication rates between IVC sites prepared or placed by veterinary students versus nonstudent personnel.

CLINICAL RELEVANCE
Veterinary personnel and clients may be hesitant to allow student involvement in IVC placement in horses, but these data suggest that student involvement does not increase the risk of IVC complications.

Keywords: intravenous catheter, catheter complications, veterinary student, thrombophlebitis, veterinary teaching hospital

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affected vein or IVC site, reduced blood flow, swelling, abscessation of the subcutaneous tissues, purulent exudate from the IVC insertion site, congestion of facial veins, facial edema, pain, fever, dysphagia, and laryngeal hemiplegia. In small animals, IVCs placed by either students or inexperienced veterinarians are more likely to have complications, but the effect of student involvement on IVC complications in horses has not been investigated.

The objectives of this study were to identify the overall rate of complications of intravenous catheterization in a large group of hospitalized horses and to investigate variables associated with the catheterization procedure and clinical status of the patient that may increase the risk of catheter site complications, including the specific roles of the personnel involved. We hypothesized that student involvement in the preparation of the site or placement of the IVC in horses would not increase the risk of complications. Additionally, we hypothesized that the overall complication rate of intravenous catheterization would be consistent with previous reports.

Methods

Data collection

Templates were added to the North Carolina State University Veterinary Teaching Hospital’s electronic medical record system in December 2021, and staff, students, and clinicians were asked to record data for each catheter placed and removed in a horse. In March of 2022, the template was amended to also record the number of attempts made to place IVCs and the presence or absence of subcutaneous swelling at the time of removal. New fourth-year veterinary students began rotations in mid-May, new interns began in mid-June, and new residents began their training programs in mid-July.

An electronic medical record search was then performed to identify all equid patients over 2 years of age in which an IVC was placed between January 1, 2022, and December 31, 2022. Data collected included patient signalment, the role of the individual who prepared the site and placed the IVC, site of placement, use of sedation, disease category of the patient (assigned retrospectively), type of IVC, number of attempts at placement, number of days the IVC remained in vein, reason for removal, and presence of complications. For patients that survived and had data recorded at time of IVC removal, complications were defined as failure of the vein to distend at time of IVC removal, purulent discharge from the vein, firmness of the vein at time of removal, and subcutaneous swelling at time of removal. For patients that were euthanized or died with an IVC in place and thus did not have removal data, individual records were reviewed by the authors for the aforementioned criteria as well as the terms “thrombo-phlebitis,” “thrombosis,” and “phlebitis.” Horses that survived for which removal and complication data were missing from the record were excluded from analysis. For horses that had multiple hospital visits during the study period, only data from the first visit were included.

Intravenous catheter placement protocol

Intravenous catheters were placed in a similar fashion according to hospital protocol by a veterinary student, veterinary technician or assistant, house officer, or faculty member. All IVCs placed by veterinary students were under the direct supervision of a member of one of the other groups. Veterinary students who place IVCs are generally in their fourth year and rotating through the equine internal medicine, equine soft tissue surgery, equine orthopedic surgery and sports medicine, or equine emergency services. Students on these rotations are permitted to place IVCs regardless of their level of experience with equine practice, though whether students are permitted to place an IVC in a specific patient is at the discretion of the supervising clinician, house officer, or technician. Hospital protocol involves first clipping a rectangle of hair over the desired site, approximately 4 X 6 inches. Clean exam gloves are donned, and the site is first prepared with dish soap (Ivory; Procter & Gamble) to remove surface dirt and oil, then wiped with 70% isopropyl alcohol. This step was added to institutional protocol in concordance with the preparation protocol for ventral midline incisions that was developed after a number of severe infections occurred. The site is scrubbed once with each piece of gauze soaked in dish soap until there is no visible dirt or debris on the gauze after each scrub. Next, the site is scrubbed with individual pieces of sterile gauze soaked in 4% chlorhexidine gluconate scrub. Each gauze square is used to scrub in concentric circles increasing in size beginning from the center of the clipped area and moving outward. Once the gauze has reached the outer perimeter of the clipped site, it is disposed of and a new square of gauze is applied until the site has been scrubbed continuously for 5 minutes. After the site is scrubbed, the site is wiped until all visible scrub is removed with sterile cotton gauze soaked in 70% isopropyl alcohol. A subcutaneous bleb (0.5 to 1.0 mL) of 2% lidocaine is injected at the desired insertion site. Sterile gloves are then donned, and an additional scrub with 4% chlorhexidine gluconate is applied in the same fashion described above. After 5 minutes, it is wiped off with gauze soaked in 70% isopropyl alcohol. If the person placing the IVC is the same person who prepared the site, a new pair of sterile gloves is donned prior to placing the IVC.

Once sterile gloves are donned, the IVC is placed through the lidocaine bleb in a manner consistent with the specific type of IVC (eg, over the needle, over the wire, etc). If excessive drag is observed on the skin or if the horse is predicted to have thick skin, a stab incision (3 to 4 mm in length) may be made with a No. 15 scalpel prior to placement of the IVC. Once the IVC is successfully placed in the vein, a needle-free connector (MicroClave; Mila International Inc) is attached to the hub of the IVC, followed by an extension set prefilled with saline. An injection cap is then attached to the end of the extension set. Catheters
are secured with suture placed through the wings of the hub and knots tied with 1 surgeon’s throw followed by at least 3 throws. An additional suture is placed at the notch of the hub of the IVC, above the connection between the needle-free connector and extension set, and through a piece of tape secured around the distal portion of the extension set. Once the IVC is secure, a small drop of adhesive is placed between the hub of the IVC and needle-free connector. Intravenous catheters are not routinely wrapped. Per hospital protocol and the manufacturer’s guidelines, PTFE IVCs are left in place for a maximum of 24 hours and then removed. Polyurethane (PU) over-the-needle IVCs can remain in place for up to 14 days if the IVC is still functioning appropriately and the vein appears healthy, and PU over-the-wire, peel-away, and double-lumen IVCs can remain in place for up to 28 days before being removed. Catheters are removed routinely when an IVC has been in place for the aforementioned duration of time or when the IVC is no longer needed for patient care. The type of IVC placed in a patient is at the discretion of the attending clinician, though over-the-needle or over-the-wire PU IVCs are placed in most cases. Once IVCs are placed, they are flushed regularly every 6 hours with heparinized saline until they are removed.

Statistical analysis
Statistical analyses were performed using SPSS Statistics (version 29; IBM Corp), and significance was set at \( P < .05 \). All analyses used mixed-effects logistic regression to determine how individual predictors were related to the probability of a complication occurring. This type of model accounts for the binary outcome of whether there was a complication in each case and the lack of independence of observations due to multiple catheters per horse. The latter was adjusted for through the inclusion of random intercepts at the horse level. Denominator degrees of freedom were computed using the Satterthwaite approximation. Due to the exploratory nature of these analyses, no \( P \) value adjustments were applied across the analyses; post hoc pairwise comparisons, used following individual analyses, were adjusted using a sequential Bonferroni adjustment.

Results

Patient information
The initial medical record search yielded 877 IVCs placed in 724 horses in the 12-month period over 745 unique visits. Three hundred seventy-four IVCs were excluded due to missing removal and complication data or for placement during subsequent hospital visits after the first. An additional 48 IVCs were excluded due to incomplete or missing data regarding the personnel involved in IVC placement. The final dataset included 455 IVCs in 394 horses. Of the 394 horses, there were 159 (40.4%) mares, 220 (55.8%) geldings, and 15 (3.85%) stallions. The most common breeds were Warmblood (104/394 [26.4%]) and Quarter Horse (103/394 [26.1%]), followed by Thoroughbred (52/394 [13.2%]), pony (30/394 [7.6%]), and paint (22/394 [5.6%]). The remaining breeds included unknown or other (31/394 [7.9%]), Saddlebred (12/394 [3.0%]), Arabian (11/394 [2.8%]), Tennessee Walking Horse (10/394 [2.5%]), Friesian (7/394 [1.8%]), draft breeds (7/394 [1.8%]), and Appaloosa (5/394 [1.3%]). Horses were hospitalized for a mean of 4 ± 6.5 days, and 374 of 394 (94.9%) survived to discharge. Horses had a mean age of 12 ± 6.6 years and mean body weight of 502 ± 106.7 kg.

The most common reason for hospitalization was elective orthopedic surgery or imaging (112/394 [28.4%]), followed by colic/colitis (91/394 [23.1%]), trauma (59/394 [15.0%]), dental, sinus or noninfectious upper respiratory disease (33/394 [8.4%]), ophthalmic disease (33/394 [8.4%]), non-gastrointestinal soft tissue surgery (29/394 [7.4%]), fever of unknown origin (13/394 [3.3%]), and infectious respiratory disease (8/394 [2.0%]). Sixteen of 394 (4.1%) horses were hospitalized for reasons classified as “other.”

Catheter data
The mean dwell time was 1.6 ± 1.9 days per IVC. The most common type of IVC placed was PU over the needle (248/455 [54.5%]), followed by PTFE over the needle (170/455 [37.4%]), PU over the wire (21/455 [4.6%]), PU with peel-away introducer (13/455 [2.9%]), and PU double lumen (2/455 [0.4%]), and all IVCs were 14 gauge with the exception of the PTFE over-the-needle 10-gauge catheters used for blood collection from blood donors. Two hundred fifty-two of 455 (55.4%) IVCs were placed in the right jugular vein, 200 of 455 (44.0%) were placed in the left jugular vein, and 2 of 455 (0.4%) were placed in a lateral thoracic vein. The site of IVC placement was not recorded in 1 of 455 (0.2%) IVCs. Three hundred eighty-nine of 455 (85.5%) IVCs were the first placed in a horse, 56 of 455 (12.3%) were the second, 9 of 455 (2.0%) were the third, and 1 of 455 (0.2%) was the fourth IVC placed in a patient. Three hundred twenty-three of 455 (71.0%) IVCs required 1 attempt for successful placement, 37 of 455 (8.1%) required 2 attempts, and 6 of 455 (1.3%) required 3 attempts. The number of attempts for successful placement was not recorded in 89 of 455 (19.6%) IVCs. Horses were sedated at the time of IVC placement for 103 of 455 (22.6%) IVCs and were not sedated for IVC placement for 350 of 455 (76.9%). Sedation was not recorded for 2 of 455 (0.4%) IVCs.

The most common reason for IVC removal was routine removal, which occurred in 321 of 455 (70.5%) IVCs. The next most common reason for IVC removal was the white portion of the IVC showing (31/455 [6.8%]), followed by IVCs that were removed or partially removed by the patient (28/455 [6.2%]), IVC no longer flowing (16/455 [3.5%]), and reasons listed as “other” (12/455 [2.6%]), including fever, skin reaction, bleeding at or around the site, or thrombophlebitis. Twenty-two of 455 (4.8%) IVCs were never removed, as the horse died or was euthanized with the IVC in place, and the reason for removal was not recorded in 25 of 455 (5.5%) IVCs.
Personnel involved in IVC placement

Catheter sites were aseptically prepared by a veterinary student 87 of 455 (19.1%) times, technician 331 of 455 (72.7%) times, house officer 23 of 455 (5.1%) times, and faculty member 14 of 455 (3.1%) times. Catheters were placed most by technicians (328/455 [72.1%]), followed by veterinary students (87/455 [19.1%]), house officers (31/455 [6.8%]), and faculty members (9/455 [2.0%]). Veterinary students had no involvement in 353 of 455 (77.6%) catheter site preparations and IVC placements, partial involvement (either preparation or placement) in 30 of 455 (6.6%) IVCs, and were responsible for both site preparation and IVC placement in 72 of 455 (15.8%) IVCs.

Personnel involvement by case type

The case type for personnel involved in IVC site preparation and IVC placement can be seen in Figure 1. Site preparation by a student occurred most in cases in the colic/colitis group (41.4% [36/87]), followed by cases in the elective orthopedic group (14.9% [13/87]). Nonstudent personnel most commonly prepared IVC sites for patients in the elective orthopedic group (29.4% [108/368]), followed by cases in the colic/colitis group (22.3% [82/368]). Catheters placed by students were placed most commonly in cases in the colic/colitis group (48.3% [42/87]), followed by cases in the elective orthopedic group (14.9% [13/87]). Catheters placed by nonstudent personnel were most commonly placed in elective orthopedic cases (29.4% [108/368]), followed by the colic/colitis group (20.7% [76/368]).

Personnel involvement by catheter type

The personnel involved in IVC site preparation and IVC placement was also evaluated on the basis of catheter type (Figure 2). Site preparation performed by
Discussion

At our institution, there was no significant difference in complications from IVC placement when sites were aseptically prepared or when the IVC was placed by a veterinary student versus another personnel role. This finding is helpful in a teaching hospital setting, as it suggests that clients and hospital personnel should not be deterred from allowing veterinary students to gain experience in IVC placement in client-owned animals. Few studies have evaluated the effect of experience and training of veterinary personnel on IVC complications, and none have evaluated this variable in horses.17–19 In human medicine, placement of IVC by inexperienced personnel is a risk factor for complications, though studies in veterinary medicine have conflicting results.17,20–22

In dogs, IVCs placed by veterinarians with < 1 year of experience had an 84% higher rate of bacterial colonization than those placed by veterinarians with > 1 year of experience. When catheterization was performed by veterinary students in that group, the rate of bacterial colonization was 2 times higher than when it was performed by veterinarians with > 1 year of experience in practice.21 While IVC placement in dogs and cats is not typically performed using sterile technique, it is an interesting comparison that personnel with less experience still had a higher rate of bacterial colonization, suggesting that attention to cleanliness is a crucial skill that requires practice. In 121 catheters placed in dogs and cats, IVC placement by a student was not associated with increased risk of complications.22 In our study group, we documented the role of the individual who performed aseptic preparation of the IVC site as well as the role of the individual who placed each IVC and found that student completion of either or both of these tasks was not significantly associated with complications observed at the time of IVC removal or patient death. In small animals (dogs and cats), student success rate at placing IVCs ranges from 61% to 95%, but student success rate at placing IVCs in horses has not been evaluated directly.23 Interestingly, a relatively low proportion of the IVCs in our study were actually evaluated by a student, which may be due to a lack of student interest in equine practice, hesitancy on the part of students occurred most commonly for PU over the needle (62.0% [54/87]), followed by PTFE over the needle (32.1% [28/87]). Sites for IVC prepared by nonstudent personnel occurred most frequently for PU over the needle (52.7% [194/368]), followed by PTFE over the needle (38.6% [142/368]). Students most commonly placed PU over-the-needle IVCs (67.8% [59/87]), followed by PTFE over the needle (31.0% [27/87]). Similar to students, nonstudent personnel most commonly placed PU over-the-needle IVCs (51.4% [189/368]), followed by PTFE over the needle (38.9% [143/368]).

Complications

The overall complication rate was 15.6% (71/455). Of the 71 IVCs with recorded complications, subcutaneous swelling at the insertion site was the most frequent complication (55/455 [12.1%]), followed by a palpably firm vein at time of removal (12/455 [2.6%]), failure of the vein to distend normally (10/455 [2.2%]), heat or pain noted at time of removal (8/455 [1.8%]), and purulent discharge at the insertion site (5/455 [1.1%]).

Using a mixed-effects logistic regression model, variables at the horse level were analyzed for their effect on the presence or absence of any reported complication. Variables that were analyzed included the effects of patient age, patient weight, temperature at admission, presence or absence of fever, duration of hospitalization, breed, sex, case type, and number of IVCs per horse. None of these variables had a statistically significant effect on the probability that a complication would occur.

Variables at the catheter level were analyzed using the same method as above: number of days the IVC was in the vein, role of personnel who prepared the IVC site, role of personnel who placed the IVC, level of student involvement (none, partial, total), IVC type, IVC number, month of IVC placement, site of placement, number of attempts to place the IVC, use of sedation during IVC placement, and use of a stab incision during placement (Figure 3). Of these variables, only the use of sedation was statistically significantly associated with an increased OR (2.2; P = .007; 95% CI, 1.3 to 14.8) of complications. Specifically, the role of the personnel who prepared the site was not statistically significant (F[3, 451] = 0.28; P = .842); the role of the personnel who placed the IVC was also not statistically significant (F[3, 451] = 0.15; P = .718).
clinicians and clients to allow student involvement, or a lack of student confidence and willingness to perform the procedure. To improve student confidence and proficiency and reduce live animal and cadaver use in veterinary education, multiple educational models have been developed to aid in teaching jugular venipuncture and intravenous catheterization in horses.

When veterinary students who had not previously placed an IVC in a horse were first trained on a model, their first IVC placement in a live horse required fewer perforations of the skin than that of students trained on a live horse, though the time to confirmation of accurate IVC placement was no different between groups. This suggests that there could be a benefit to both veterinary students and horses if students were first trained in IVC placement on a model; however, the results of our study suggest that there is not a significantly increased risk to the horse if students are also permitted to learn and practice the procedure on live animals. As veterinary education evolves, students can benefit from both simulators and live animals when learning technical skills.

Aside from the effect of student involvement on IVC complications, the second objective of this study was to document the rate of IVC complications in our hospital and provide updated data regarding risk factors for complications associated with IVC placement. The complication rate was 15.6% (71/455), consistent with previously reported IVC complication rates of 8% to 29% in horses and dogs. The only variable with a statistically significant association with complications in our study was whether the horse was sedated when the catheter was placed. It is plausible that this is the result of IVC placement being inherently more traumatic in poorly behaved or needle-averse animals during the procedure and thus requiring sedation, as opposed to a direct effect of the sedation itself.

Thrombophlebitis is one of the most common complications of IVCs in horses, though the true frequency is unknown. In our study, only 3 of 455 (0.7%) catheters were removed due to confirmed thrombophlebitis. However, many of the specific complications identified in our study (eg, heat, pain on palpation, firmness in the vein) can be indicative of thrombophlebitis, though without ultrasound or culture, it could not be definitively diagnosed. Additionally, clinical signs of thrombophlebitis in some horses may not develop until the IVC has been removed, so it is likely that some horses with thrombophlebitis may have been missed in this study. In studies evaluating sick or critically ill horses, 18% to 29% of horses developed thrombophlebitis, and in 46 horses diagnosed with thrombophlebitis, 30 (65%) had systemic disease including colic, pneumonia, and enteritis. However, in a study group that included a wider variety of cases, clinically significant thrombophlebitis was only identified in conjunction with 0.8% (1/119) of IVCs. It is critical that IVC sites be examined multiple times daily while the IVC is in place, and after the IVC has been removed to ensure that thrombophlebitis is identified as quickly as possible.

Intravenous catheters used in horses are generally either PTFE or PU, and older studies also reference silicone. Silicone is considered the least thrombogenic material, followed by PU and then PTFE. Interestingly, Dolente et al identified that placement of a silicone IVC was significantly associated with development of thrombophlebitis, but it was hypothesized that this material was preferentially used in horses more prone to thrombophlebitis. In a group of 45 horses with IVCs, PTFE IVCs were 2.6 times more likely to be associated with venous disease than a PU IVC. In our study group, IVC type or material was not significantly associated with complications, but a number of factors may have biased these results. Most IVCs placed in horses in our hospital are made of PU (PU, 285/455 [62.6%]; vs PTFE, 170/455 [37.4%]). Moreover, in our hospital, when PTFE IVCs are placed, it is typically in healthy, elective cases that are considered low risk for thrombophlebitis. However, there were no statistically significant differences identified between case types or IVC material in frequency of complications.

Due to the retrospective nature of this study, there were a number of limitations. The data collected in this study were from 1 institution and as such may not be applicable to all institutions. Though the template in the medical record system was designed specifically for this study, collection of data relied on many hospital personnel and many IVCs had incomplete data, which reduced the number of study subjects. Since the study was not controlled, IVC selection and the individuals involved in placement and removal of IVCs were at the discretion of the hospital personnel, so it is possible that students were less likely to be involved in critical cases and certain types of IVCs were only selected for specific cases. However, the most common case types in which students were involved in IVC preparation and placement were colic and colitis cases. To obtain as many data as possible, personnel with a wide range of experience and training (eg, technicians, veterinary students, residents, interns, and faculty) were responsible for recording complications, which may have led to certain subtle changes (eg, swelling, reduced distention of a vein) being overlooked. Thrombophlebitis can also occur days after an IVC has been removed; thus, the true prevalence may have been higher since observations that occurred past IVC removal were not documented. Known risk factors, including systemic inflammatory response syndrome or endotoxemia, were challenging to confirm retrospectively and thus were not analyzed. Similarly, due to the large number of cases, classification of case type could have been performed in multiple ways, which may have affected results. Lastly, though the records were reviewed for evidence of IVC complications in patients that were euthanized or died with an IVC in place, it would have been ideal to use the “removal” template in these animals at the time of death to allow for more complete data collection.

These data serve as an updated reference for practitioners regarding the rate of complications associated with IVC placement in horses at a veterinary teaching hospital and the risk factors associated with them in a large group of hospitalized horses. More importantly, we were unable to find a statistically significant difference in the rates of IVC complications in IVCs placed and prepared by veterinary students when compared to nonstudent personnel.
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