Retrospective review reveals few complications of ovarian pedicle tie in 15,927 cats undergoing ovariohysterectomy at a large HQHVSN clinic and training facility in the United States: 2017–2018

Karla Rigdon-Brestle, DVM1,*; Veronica H. Accornero, PhD2; Michelle Amtower, DVM1; Margaret R. Slater, PhD, DVM2

1Spay Neuter Alliance, American Society for the Prevention of Cruelty to Animals, Asheville, NC
2Strategy and Research, American Society for the Prevention of Cruelty to Animals, New York, NY
*Corresponding author: Dr. Rigdon-Brestle (Karla.Brestle@aspca.org)
https://doi.org/10.2460/javma.21.09.0405

OBJECTIVE
To determine the rate of complications associated with the ovarian pedicle tie procedure in cats undergoing ovariohysterectomy and examine whether cat characteristics or surgeon experience level were associated with complications.

ANIMALS
15,927 cats that underwent ovariohysterectomy with the ovarian pedicle tie procedure between January 1, 2017, and December 31, 2018.

PROCEDURES
Data were extracted from electronic and paper medical records. Complications were coded by a veterinarian blinded to surgeon experience level. Complications (pedicle drop or tear, pedicle hemorrhage, and pedicle-related death) were summarized as counts and percentages. Univariate associations between cat characteristics (eg, age, weight, reproductive status, and ownership) and surgeon experience level (clinic veterinarian vs training veterinarian or veterinary student) and each outcome were estimated separately for veterinarian and student training clinics.

RESULTS
A pedicle drop or tear occurred in 0.3% (n = 49) of cats and was significantly more likely among veterinary students. Most (41/49 [84%]) pedicle drops and tears did not result in hemorrhage. Only 19 of 15,927 (0.12%) cats had pedicle-related hemorrhage, and in all instances, hemorrhage was corrected intraoperatively without serious complication or death. Cat characteristics and surgeon experience level were not related to pedicle hemorrhage.

CLINICAL RELEVANCE
Results support previous evidence that the ovarian pedicle tie procedure is safe in cats undergoing ovariohysterectomy when performed by experienced surgeons or novice surgeons under supervision. Given the reduced anesthetic time associated with the procedure, the ovarian pedicle tie should be considered an acceptable standard practice in all practice settings.

Ovariohysterectomy is a standard component of preventive care provided for many female cats. This procedure is traditionally a common one; techniques have continued to evolve to make the overall surgery safer and more efficient. High-quality, high-volume spay-neuter (HQHVSN) clinics across the country have employed these techniques, contributing to efforts in the field to address unnecessary euthanasia in companion animals. Although these programs have historically elicited some concern about quality of care, owing to their emphasis on efficiency, they have been at the forefront of promoting high-quality care. In 2008, the Association of Shelter Veterinarians (ASV) convened a spay-neuter task force charged with developing veterinary medical care guidelines in this practice area to encourage existing programs to ensure acceptable levels of care by recognizing and adhering to these guidelines. Through review of the scientific literature and expert opinion, the document established recommendations for anesthesia, surgery, and perioperative care. Attainable benchmarks through an endorsed standard of care remains a focal point for the ASV task force, which updated the guidelines in 2016 on the basis of current scientific evidence. The techniques and methods represented throughout the guidelines are generally recognized as routinely safe to perform and equally practicable whether used by veterinary
students or seasoned practitioners. In fact, studies\textsuperscript{3-4} have shown that the mortality rates of surgeries performed in high-volume clinics are very low, approaching those seen in human surgeries, and that complication rates for cats and dogs undergoing sterilization in shelter-based clinics using techniques described in these guidelines are also very low, with no difference between veterinary students and veterinarians.

The ovarian pedicle tie (OPT) procedure,\textsuperscript{5} also known as autoligation of the ovarian pedicle, is frequently used in HQHVSN clinics for female cats undergoing ovariohysterectomy (OVH). In cats, the OPT has been shown to be 30% faster when compared to the traditional approach of using suture to ligate the ovarian pedicle.\textsuperscript{6} The reduction in surgery time achieved with the OPT not only allows an increased number of spay surgeries to be performed but also has potential health benefits for cats undergoing OVH by reducing anesthetic time. Although OVH is generally considered to be safe, 1 study\textsuperscript{7} found the odds of any type of complication occurring with elective OVH increased by an estimated 2% with each additional minute under anesthesia. The OPT also has the advantages of limiting foreign material (ie, suture) in patients and potentially reducing postoperative pain by decreasing manipulation and inflammation at the ligature site.\textsuperscript{8} It also requires no specialized or expensive equipment, making it accessible to all veterinarians. In one of the few published studies specific to the pedicle tie, Miller et al\textsuperscript{9} found the procedure to be safe, with a very low rate of hemorrhage-related complications (0.281% of cats). Although the ASV guidelines support the OPT as an acceptable approach to OVH for all settings, there remains concern about the safety of this procedure among some in general veterinary practice, particularly with regard to the potential for life-threatening hemorrhage.

The purpose of the study reported here was to evaluate the safety of the OPT, as an alternative to the traditional method of ovarian pedicle ligation, in cats undergoing OVH by surgeons with varied experience in an HQHVSN clinic. Specifically, we sought to determine the rate of pedicle-related complications (pedicle drop or tear, pedicle-involved hemorrhage, and pedicle-related death) in female cats undergoing the OPT procedure, leveraging the extensive dataset available from an HQHVSN clinic and training program that performed > 25,000 sterilization surgeries each year. A secondary aim was to examine whether characteristics of the cat or experience level of the surgeon (clinic veterinarian vs training veterinarian or veterinary student) were associated with pedicle-related complications.

### Materials and Methods

The study was conducted as a retrospective study of female cats undergoing elective OVH at the American Society for the Prevention of Cruelty to Animals Spay Neuter Alliance (ASNA; formerly known as the Humane Alliance) between January 1, 2017, and December 31, 2018. Cats were excluded if they did not undergo surgery owing to poor health or other reasons or did not undergo the OPT procedure (eg, pedicles were ligated with suture because of anatomic anomalies or concerns about tissue integrity) or if the medical record was largely incomplete or missing.

Surgical procedures were performed by ASNA clinic veterinarians, graduate veterinarians undergoing training, and veterinary student externs at 2 clinics at the ASNA campus in Asheville, NC. The veterinary clinic housed both an HQHVSN clinic for partner rescue organizations and the public and a training program in HQHVSN procedures for practicing veterinarians and their teams. The student clinic was devoted solely to externship training in HQHVSN procedures for fourth-year veterinary students. The training curriculum was specifically designed to address the needs of participants while providing comprehensive supervision of individuals undergoing instruction. Instructors assigned to trainees examined the proficiency of participants and verified competency at each phase of the procedure. The veterinarian training program was a 1-week program and had a trainee-to-instructor ratio of 2:1, with registered veterinary technicians and veterinary assistants monitoring anesthesia for patients. The student externship program was a 2-week program with a student-to-instructor ratio of 4:1; the typical scenario was 2 student surgeons in the operating room with a student monitoring anesthesia for each patient. All trainees received instruction in HQHVSN techniques and concepts, although there was less focus on speed and more guidance and support from instructing veterinarians in the student clinic, because students were expected to be building a good basic knowledge foundation and surgical skills. Also, all trainees observed surgery demonstrations by team instructors and completed a knot-tying lab with their assigned instructor to practice the OPT procedure and surgical knots on models prior to using these skills in surgeries performed at ASNA. In addition to acting as instructors, clinic veterinarians also performed surgeries for high-risk and overflow cases in both clinics.

Patients were a mixture of owned, shelter, rescue, and community cats (unowned, outdoor, free-roaming cats) and were determined to be sufficiently healthy for surgery via physical exam. A visual exam was performed in lieu of a physical exam on community cats. The general protocol for all surgeries followed the ASV guidelines.\textsuperscript{2} OPT was the standard for feline OVH in both the student and veterinarian clinics regardless of age, size, estrus, or pregnancy.

During the physical exam, patients were administered gabapentin solution PO (50 mg to cats weighing ≤ 4.5 kg and 100 mg to cats weighing > 4.5 kg) when such handling was feasible.\textsuperscript{9} If gabapentin administration was not feasible, anesthesia was still induced with the standard induction protocol. Anesthesia was typically induced about 2 hours following the physical exam with a combination of tiletamine-zolazepam, butorphanol, and dexmedetomidine. The combination was prepared by reconstituting tiletamine-zolazepam (Telazol) with 2.5 mL of butorphanol and 2.5 mL of dexmedetomidine as diluents. Each milliliter of the reconstituted solution contained
100 mg of tiletamine-zolazepam, 5 mg of butorphanol, and 250 µg of dexmedetomidine. The combination was administered at a dose of 0.035 mL/kg, IM. All patients received meloxicam (0.1 mg/kg, SC) during surgical preparation, and all patients were evaluated for additional analgesia as needed. Patients undergoing surgery by students were intubated and maintained on isoflurane in oxygen for the duration of the procedure, whereas patients undergoing surgery by veterinarians received 100% oxygen by mask. The patient's surgical site was prepared by clipping the hair and scrubbing the skin with warmed 2% chlorhexidine scrub and solution. All patients were monitored by registered veterinary technicians or veterinary students and with the aid of pulse oximetry for the duration of the surgery.

Surgery was performed via a ventral midline incision, using a spay hook to retrieve the uterus. The ovarian pedicles were autoligated by means of an OPT, except when anatomic anomalies (eg, ectopic ovarian tissue low on the pedicle) prevented the use of the OPT; in these cases, the pedicles were ligated with suture instead. With the OPT, the ovary was first exposed, and the suspensory ligament and ovarian artery were identified. The suspensory ligament was then transected or torn, and an aperture was created in the broad ligament adjacent to the pedicle. A mosquito hemostat held in the closed position was placed parallel to the pedicle, pointing away from the ovary. The tip was passed under the pedicle, and the hemostat was then rotated 180 degrees. The pedicle was clamped with the tip of the hemostat and then transected between the ovary and the hemostat, and the ovary and uterus were laid aside. The surgeon then pushed the knot off the tip of the hemostat. The knot was manually tightened, and the pedicle was inspected for hemorrhage. The uterus was ligated with a single strangle knot, a 2-pass binding knot of the friction knot category, using 3-0 or 2-0 (depending on the size of the patient) polydioxanone. The closure was secured with a single cruciate suture in the body wall (or with additional cruciate sutures for extended incisions) of 3-0 or 2-0 (depending on the size of the patient) polydioxanone. A bupivacaine splash block was then applied, and the subcutaneous and subcuticular tissues were closed with 3-0 or 4-0 (depending on the size of the patient) polydioxanone in a continuous pattern. The skin incision was sealed against contamination with surgical glue, and a standard tattoo was applied with a linear score adjacent to the incision. All patients received warmed fluids SC and were monitored in a designated recovery area with padding, blankets, and warming devices used to prevent hypothermia during the recovery period. Atipamezole was used for reversal at the discretion of the attending veterinarian after 45 minutes. All patients were kept in the clinic overnight prior to release the following morning. Owners, caregivers, and shelter staff were instructed in proper observation and postoperative care and were provided contact information for a 24-hour emergency hotline. The ASNA provided free in-clinic follow-up care directly or via partner clinics, as needed.

Medical record review

Clinic records were reviewed for all cats presenting to ASNA clinics for sterilization between January 1, 2017, and December 31, 2018. Data extracted from the electronic medical record system included surgery date, reason surgery was not performed, species, sex, age, body weight, pregnancy and estrus status, and ownership status (owned, shelter, community cat, or foster). Ownership status was included as a variable of interest because unowned cats, particularly community cats, may have unknown health concerns owing to incomplete medical histories and limited presurgical medical exams that could put them at greater risk for complications. Pedicle-related complications, other cat characteristics, and preexisting conditions that could potentially impact pedicle-related complications (eg, lactation, postpartum, fatty ovarian tissue, friable ovarian tissue, pyometra or mucometra, adhesions to the pedicle or ovary) and surgeon experience level (clinic veterinarian, training veterinarian, or veterinary student) were ascertained from review of paper treatment sheets and surgical logs. Complications and preexisting conditions were only written on the treatment sheet and surgical log if observed by the surgical team; if no such observations were recorded, they were assumed absent and coded accordingly. Postdischarge complications were not considered in the present study because detailed recheck records were not available for all animals. However, deaths occurring after discharge, as reported to ASNA by owners or by other treating veterinary clinics, were documented electronically and on the paper treatment sheet and were reviewed to determine whether the death could have been related to problems associated with pedicle ligation.

A trained research assistant first reviewed the paper treatment sheet for each identified case, entering data on cat characteristics, preexisting conditions, and surgeon experience level into the study database, and flagged any records with potential complications on the basis of key terms and criteria established by the investigators. These records were then scanned into an electronic format, with the surgeon and training program obscured, for review and coding of complications. Death records, including necropsy reports when available, were similarly prepared and scanned for review. Pedicle-related complications were coded by a single primary reviewer, a senior veterinarian at ASNA (KR-B), blinded to surgeon experience level and training program. For quality assurance, another veterinarian at ASNA (MA) performed a second review, and any coding discrepancies were discussed and resolved between the two veterinarians.

Statistical analysis

Commercially available software was used for all analyses (Stata, version 16; StatCorp LLC). Counts and percentages were calculated for each categorical (yes-no) outcome variable: pedicle drop or tear, pedicle-involved hemorrhage, and pedicle-related death. Counts and percentages were also used to summarize cat characteristics (except for weight and
age), preexisting conditions, and surgeon experience level. Mean and SD were calculated for cat weight because weight was normally distributed, and median and range were calculated for cat age. Fisher exact tests were used to compare cat characteristics and surgeon experience level across training programs, as well as to estimate univariate associations between each complication outcome and the following categorical variables: estrus, pregnant, postpartum, lactating, fatty ovarian tissue, friable ovarian tissue, pyometra or mucometra, pedicle or ovary adhesions, ownership status, and surgeon experience level. Comparisons of cat weight across clinics and for each pedicle-related complication (yes-no) were made using a 2-sample t test; Mann-Whitney tests were used for comparisons of cat age owing to its nonnormal distribution. For all analyses, values of P < 0.05 were considered significant.

Results

A total of 17,493 female cats were presented to ASNA for sterilization during the 2-year study period. Of these, 1,499 did not undergo surgery, primarily because of health concerns or because they were identified as previously having been sterilized and were excluded from the study. An additional 6 cats were excluded owing to an incomplete or missing treatment record, and 21 cats that did not undergo OPT (ie, the ovarian pedicle was ligated with suture instead) owing to anatomical anomalies that resulted in insufficient exposure or tissue quality for autoligation (eg, ectopic tissue, ovarian cysts, adhesions, severely hyperplastic tract, bruised pedicles, extremely friable ovaries, or a dead fetus pushing cranially in the horn) were also excluded. Suture ligation was also performed in another 40 cats, but the

Table 1—Pedicle complications and cat and surgeon characteristics for 15,927 cats that underwent ovariohysterectomy with the ovarian pedicle tie procedure between January 1, 2017, and December 31, 2018, at 1 of 2 clinics (veterinarian clinic, 8,782 cats; student clinic, 7,145 cats) at the American Society for the Prevention of Cruelty to Animals Spay Neuter Alliance.

| Variable                        | All cats       | Veterinarian clinic | Student clinic | P value |
|---------------------------------|----------------|--------------------|---------------|---------|
| Complication                    |                |                    |               |         |
| Pedicle drop or tear            | 49 (0.3)       | 8 (0.1)            | 41 (0.6)      | < 0.001 |
| Pedicle hemorrhage              | 19 (0.1)       | 11 (0.1)           | 8 (0.1)       | 1.00    |
| Pedicle-related death           | 0 (0.0)        | 0 (0.0)            | 0 (0.0)       | NA      |
| Cat characteristic              |                |                    |               |         |
| Age (mo)                        | 7 (1–137)      | 8 (1–137)          | 6 (2–120)     | < 0.001 |
| Weight (kg)                     | 2.49 (0.85)    | 2.65 (0.78)        | 2.29 (0.90)   | < 0.001 |
| Estrus                          |                |                    |               |         |
| No                              | 12,319 (77.4)  | 6,381 (72.7)       | 5,938 (83.1)  |         |
| Yes                             | 3,608 (22.7)   | 2,401 (27.3)       | 1,207 (16.9)  |         |
| Pregnant                        |                |                    |               |         |
| No                              | 14,470 (90.9)  | 7,921 (90.2)       | 6,549 (91.7)  |         |
| Yes                             | 1,457 (9.2)    | 861 (9.8)          | 596 (8.3)     |         |
| Postpartum                      |                |                    |               | < 0.01  |
| No                              | 14,197 (89.1)  | 7,881 (89.7)       | 6,316 (88.4)  |         |
| Yes                             | 1,730 (10.9)   | 901 (10.3)         | 829 (11.6)    |         |
| Lactating                       |                |                    |               | < 0.001 |
| No                              | 15,329 (96.3)  | 8,519 (97.0)       | 6,810 (95.3)  |         |
| Yes                             | 598 (3.8)      | 263 (3.0)          | 335 (4.7)     |         |
| Fatty ovarian tissue            |                |                    |               | < 0.001 |
| No                              | 15,562 (97.7)  | 8,688 (98.9)       | 6,874 (96.2)  |         |
| Yes                             | 365 (2.3)      | 94 (1.1)           | 271 (3.8)     |         |
| Friable ovarian tissue          |                |                    |               | < 0.001 |
| No                              | 14,816 (93.0)  | 8,300 (94.5)       | 6,516 (91.2)  |         |
| Yes                             | 1,111 (7.0)    | 482 (5.5)          | 629 (8.8)     |         |
| Pyometra or mucometra           |                |                    |               | 1.00    |
| No                              | 15,862 (99.6)  | 8,746 (99.6)       | 7,116 (99.6)  |         |
| Yes                             | 65 (0.4)       | 36 (0.4)           | 29 (0.4)      |         |
| Pedicle or ovary adhesions      |                |                    |               |         |
| No                              | 15,920 (99.9)  | 8,781 (99.99)      | 7,139 (99.92) | 0.05    |
| Yes                             | 7 (0.04)       | 1 (0.01)           | 6 (0.08)      |         |
| Ownership status                |                |                    |               | < 0.001 |
| Owned                           | 7,359 (46.2)   | 6,410 (73.0)       | 949 (13.3)    |         |
| Shelter                         | 5,820 (36.5)   | 1,427 (16.3)       | 4,393 (61.5)  |         |
| Community cat                   | 2,585 (16.2)   | 911 (10.4)         | 1,674 (23.4)  |         |
| Foster                          | 163 (1.0)      | 34 (0.4)           | 129 (1.8)     |         |
| Surgeon experience level        |                |                    |               | < 0.001 |
| Clinic veterinarian             | 6,106 (38.3)   | 4,639 (52.8)       | 1,467 (20.5)  |         |
| Training veterinarian           | 4,143 (26.0)   | 4,143 (47.2)       | NA            |         |
| Veterinary student              | 5,678 (35.7)   | NA                 | 5,678 (79.5)  |         |

Data are reported as number (%) of cats, except that age is reported as median (range) and body weight is reported as mean (SD). Information on age was available for only 15,926 cats (8,781 cats that underwent ovariohysterectomy at the veterinarian clinic). NA = Not applicable.
reason was not specified in the record. Because complications were not indicated for these cats, it was assumed that the pedicles were ligated with suture for anatomical reasons or as a preventative measure owing to concerns about the integrity of the autoligation. These cats were also excluded. The remaining 15,927 cats were included in the study. Of these, 8,782 were sterilized through the veterinarian clinic and 7,145 were sterilized through the student clinic.

Age of cats included in the study ranged from 1 to 137 months (median, 7 months; Table 1). Mean body weight was 2.49 kg (SD, 0.85 kg). Most cats were privately owned or shelter owned. There were significant differences in cat characteristics between the veterinarian and student clinics. Cats sterilized through the student clinic were younger and weighed less, with a higher percentage of postpartum and lactating cats and cats with fatty and friable ovarian tissue, compared with cats sterilized through the veterinarian clinic. There were considerably more shelter-owned and community cats seen through the student clinic and more privately owned cats seen through the veterinarian clinic. The veterinarian clinic also sterilized more pregnant cats and cats in estrus. Additionally, consistent with the structure of the training clinics, there were no student surgeons in the veterinarian clinic and no veterinarian trainees in the student clinic.

In 49 (0.3%) cats, the pedicle was dropped (8) or torn (41; Table 1) by the surgeon. Most (41/49 [84%]) of these incidents did not result in hemorrhage or other complications and were corrected immediately with suture ligation. Pedicle dropping or tearing was approximately 5 times as common in the student clinic and was significantly more common in the student clinic than in the veterinarian clinic. In 2 cases (both with veterinary students as surgeon in the student clinic), gauze fibers became entangled in the pedicle tie, and the pedicle was ligated with suture without further complications. None of the cat characteristics (age, weight, reproductive status, fatty ovarian tissue, friable ovarian tissue, pyometra or mucometra, pedicle or ovary adhesions, or ownership status) were significantly associated with pedicle dropping or tearing in the veterinarian clinic or the student clinics (Table 2). However, in the student

Table 2—Results of univariate analysis of whether pedicle dropping or tearing was associated with cat characteristics or surgeon experience level for the cats in Table 1.

| Variable                        | No drop or tear | Drop or tear | P value | No drop or tear | Drop or tear | P value |
|---------------------------------|-----------------|--------------|---------|-----------------|--------------|---------|
| **Veterinarian clinic**         |                 |              |         |                 |              |         |
| Age (mo)                        | 8 (1–137)       | 10 (4–14)    | 0.8     | 6 (2–120)       | 9 (2–60)     | 0.2     |
| Weight (kg)                     | 2.65 (0.78)     | 2.65 (0.41)  | 1.0     | 2.29 (0.90)     | 2.53 (1.03)  | 0.09    |
| Estrus                          |                 |              |         |                 |              |         |
| No                              | 6,375 (72.7)    | 6 (75.0)     | 1.0     | 5,905 (83.1)    | 33 (80.5)    | 0.7     |
| Yes                             | 2,399 (27.3)    | 2 (25.0)     |         | 1,199 (16.9)    | 8 (19.5)     |         |
| Pregnant                        |                 |              |         |                 |              |         |
| No                              | 7,913 (90.2)    | 8 (100.0)    | 1.0     | 6,510 (91.6)    | 39 (95.1)    | 0.6     |
| Yes                             | 861 (9.8)       | 0 (0.0)      |         | 594 (8.4)       | 2 (4.9)      |         |
| Postpartum                      |                 |              |         |                 |              |         |
| No                              | 7,874 (89.7)    | 7 (87.5)     | 0.6     | 6,278 (88.4)    | 38 (92.7)    | 0.6     |
| Yes                             | 900 (10.3)      | 1 (12.5)     |         | 826 (11.6)      | 3 (7.3)      |         |
| Lactating                       |                 |              |         |                 |              |         |
| No                              | 8,512 (97.0)    | 7 (87.5)     | 0.2     | 6,770 (95.3)    | 40 (97.6)    | 1.0     |
| Yes                             | 262 (3.0)       | 1 (12.5)     |         | 334 (4.7)       | 1 (2.4)      |         |
| Fatty ovarian tissue            |                 |              |         |                 |              |         |
| No                              | 8,681 (99.0)    | 7 (87.5)     | 0.08    | 6,835 (96.2)    | 39 (95.1)    | 0.7     |
| Yes                             | 93 (1.1)        | 1 (12.5)     |         | 269 (3.8)       | 2 (4.9)      |         |
| Friable ovarian tissue          |                 |              |         |                 |              |         |
| No                              | 8,294 (94.5)    | 6 (75.0)     | 0.07    | 6,478 (91.2)    | 38 (92.7)    | 1.0     |
| Yes                             | 480 (5.5)       | 2 (25.0)     |         | 626 (8.8)       | 3 (7.3)      |         |
| Pyometra or mucometra           |                 |              |         |                 |              |         |
| No                              | 8,738 (99.6)    | 8 (100.0)    | 1.0     | 7,075 (99.6)    | 41 (100.0)   | 1.0     |
| Yes                             | 36 (0.4)        | 0 (0.0)      |         | 29 (0.4)        | 0 (0.0)      |         |
| Pedicle or ovary adhesions      |                 |              |         |                 |              |         |
| No                              | 8,773 (99.99)   | 8 (100.0)    | 1.0     | 7,098 (99.9)    | 41 (100.0)   | 1.0     |
| Yes                             | 1 (0.01)        | 0 (0.0)      |         | 6 (0.1)         | 0 (0.0)      |         |
| Ownership status                |                 |              |         |                 |              |         |
| Owned                           | 6,403 (73.0)    | 7 (87.5)     | 1.0     | 942 (13.3)      | 7 (17.1)     | 0.8     |
| Shelter                         | 1,426 (16.3)    | 1 (12.5)     |         | 4,369 (61.5)    | 24 (58.5)    |         |
| Community cat                   | 911 (10.4)      | 0 (0.0)      |         | 1,664 (23.4)    | 10 (24.4)    |         |
| Foster                          | 34 (0.4)        | 0 (0.0)      |         | 129 (1.8)       | 0 (0.0)      |         |
| Surgeon experience level        |                 |              |         |                 |              |         |
| Clinic veterinarian             | 4,635 (52.8)    | 4 (50.0)     | 1.0     | 1,465 (20.6)    | 2 (4.9)      | 0.01    |
| Training veterinarian           | 4,139 (47.2)    | 4 (50.0)     |         | NA              | NA           |         |
| Veterinary student              | NA              | NA           |         | 5,639 (79.4)    | 39 (95.1)    |         |

In the veterinarian clinic, there were 8,774 cats without a pedicle drop or tear and 8 cats with a pedicle drop or tear. In the student clinic, there were 7,104 cats without a pedicle drop or tear and 41 cats with a pedicle drop or tear. See Table 1 for remainder of key.
Nineteen (0.12%) cats had hemorrhage involving the pedicle (Table 1), with comparable rates for the veterinarian and student clinics. Four of these instances also involved bleeding from other sources, including the uterus (n = 1), suspensory ligament (1), broad ligament (1), and an unidentified source (1). In all but 1 instance, hemorrhage was identified and addressed intraoperatively by ligating the pedicle with suture; in the remaining instance, hemorrhage was resolved by tightening the autoligation. All cats recovered without further complications, although 1 of these cats was slow to recover from anesthesia. Five additional cats had evidence of hemorrhage, but the source of bleeding could not be determined. If bleeding was assumed to be pedicle involved, the rate of pedicle hemorrhage would have been 0.15% (24/15,927). None of the cat characteristics or surgeon experience level were significantly associated with pedicle hemorrhage (Table 3).

In the veterinarian clinic, there were 8,771 cats without pedicle hemorrhage and 11 cats with pedicle hemorrhage. In the student clinic, there were 7,137 cats without pedicle hemorrhage and 8 cats with pedicle hemorrhage. See Table 1 for remainder of key.

Table 3—Results of univariate analysis of whether pedicle hemorrhage was associated with cat characteristics or surgeon experience level for the cats in Table 1.

| Variable                      | Veterinarian clinic | Student clinic | P value | P value |
|-------------------------------|--------------------|----------------|---------|---------|
| Age (mo)                      | 8 (1–137)         | 12 (4–36)     | 0.1     | 6 (2–120) |
| Weight (kg)                   | 2.65 (0.78)       | 2.96 (0.54)   | 0.2     | 2.29 (0.90) |
| Estrus                        | 6,374 (72.7)      | 7 (63.6)      | 0.5     | 5,932 (83.1) |
| Pregnant                      | 2,397 (27.3)      | 4 (36.4)      | 0.3     | 1,205 (16.9) |
| Postpartum                    | 7,912 (90.2)      | 9 (81.8)      | 0.6     | 6,641 (91.7) |
| Lactating                     | 859 (9.8)         | 2 (18.2)      |         | 596 (8.4) |
| Fatty ovarian tissue          | 8,770 (97.0)      | 10 (90.9)     | 0.3     | 6,804 (95.3) |
| Friable ovarian tissue        | 262 (3.0)         | 1 (9.1)       |         | 333 (4.7) |
| Pyometra or mucometra         | 8,677 (98.9)      | 11 (100.0)    | 0.5     | 6,666 (96.2) |
| Pedicle or ovary adhesions    | 94 (1.1)          | 0 (0.0)       |         | 271 (3.8) |
| Ownership status              |                    |                |         |         |
| Owned                         | 8,770 (99.9)      | 11 (100.0)    |         | 7,131 (99.9) |
| Shelter                       | 1 (0.01)          | 0 (0.0)       |         | 6 (0.1) |
| Community cat                 | 7,132 (87.9)      | 8 (72.7)      | 0.4     | 1,466 (20.5) |
| Foster                        | 1,000 (12.1)      | 3 (27.3)      |         | 1,671 (23.4) |
| Surgeon experience level      |                    |                |         |         |
| Clinic veterinarian           | 4,636 (52.9)      | 3 (27.3)      | 0.1     | 1,466 (20.5) |
| Training veterinarian         | 4,135 (47.1)      | 8 (72.3)      |         | NA     |
| Veterinary student            | NA                | NA            |         | NA     |

Discussion

Results of the present study support previous evidence that the OPT procedure is safe in cats undergoing OVH when performed by experienced surgeons or novice surgeons under supervision. The overall complication rate was low, and development of pedicle-involve hemorrhage was not significantly associated with any of the cat characteristics.
examined or with surgeon experience level. Also, all identified hemorrhages were detected and corrected intraoperatively, without serious complications or death. Given the reduced anesthetic time associated with the procedure, we suggest that the OPT should be considered an acceptable standard practice in all practice settings.

OVH is the most commonly performed surgical procedure in small animal practice, and hemorrhage is one of the most common complications encountered during OVH. Clearly, efforts that reduce the incidence of hemorrhage are invaluable in protecting patient safety. Results of the present study support prior studies that show the OPT in cats undergoing OVH is associated with a very low risk of hemorrhage. Pedicle-related hemorrhage occurred in only 19 of 15,927 (0.12%) cats in the present study, a rate comparable to that reported by Miller et al (0.28%) in a study of OPT performed by experienced surgeons. In the only other study focused on the OPT, 2.7% of cats undergoing the autoligation technique experienced hemorrhage, compared with 5.7% of those undergoing traditional suture ligation, although the difference was not statistically significant. The rate of OPT-related hemorrhage in that study may be higher than rates in our study and that of Miller et al (0.28%) owing to their sole use of veterinary students as surgeons and their inclusion of all torn pedicles as hemorrhage complications. Other reports of hemorrhage complications in cats are sparse, but 1 study found a rate similar to that reported by Showers et al, with 4% of cats undergoing traditional OVH with student surgeons at a teaching hospital having intraoperative hemorrhage. Differences in hemorrhage rate among studies could be attributable to variations in student experience, program structure, and level of supervision. Similar to our findings, none of the cats experiencing hemorrhage across these studies died as a result, regardless of approach, which is consistent with other reports that intraoperative hemorrhage, while potentially life-threatening and concerning for the surgeon, rarely leads to serious morbidity or mortality.

The OPT is a readily developed skill in that most veterinary practitioners routinely perform a variation of the technique when neutering male cats and, potentially, male puppies via autoligation of the spermatic cord. The familiarity of hand memory allows for accelerated dexterity in experienced surgeons, but novice surgeons can quickly become adept with practice. Although a previous study identified no significant differences between veterinary students and veterinarians in minor or major complications of gonadectomy in dogs or cats at shelters, our study did find a higher incidence of pedicle dropping or tearing in the student clinic, compared with the veterinarian clinic, and within the student clinic, a higher incidence among veterinary students, compared with clinic veterinarians. These differences were presumably due to the lesser degree of tissue-handling experience available to the veterinary students, although variations in patient characteristics could have also contributed. The level of student experience may reflect heavily on their ability to successfully use this and other techniques. Persistence practice of this surgical technique will enhance the surgeon’s skill level and likely markedly reduce the rate of complications. Nevertheless, despite an increased occurrence of pedicle dropping or tearing, there were not statistically significantly more hemorrhage complications among veterinary students. In fact, of all 49 cats (15,927) in which a pedicle drop or tear was encountered, only 8 (16%) reportedly had hemorrhage. Pedicle tears are known to be a leading cause of intraoperative hemorrhage during OVH, although our findings suggest that most pedicle drops or tears do not result in bleeding.

Patient characteristics considered in the present study for potential associations with pedicle-related complications focused primarily on age, weight, and indicators of reproductive status. Owing to increased vascularity, estrus and pregnancy are thought to potentially increase the risk for hemorrhage during OVH, although this is not well researched. Fudge et al found greater blood loss during OVH in pregnant versus nonpregnant cats, although the amount of blood loss was low for both groups and did not result in any significant complications. Additionally, in 2 studies of morbidity and mortality in HGHVS clinicals, reported data allowed us to estimate that pregnancy was a co-occurring condition in 25% to 35% of the female cat deaths. Pregnancy and estrus status were not related to hemorrhagic complications in the present study, nor were age and body weight, similar to findings from other OPT studies. Our study sample was overall relatively young, which may have influenced the results. Also, given the very low number of cats with complications, the statistical power to detect associations between cat characteristics and complications may have been limited. In light of this and the lack of other available research, potential risk factors for hemorrhage and other complications in OVH deserve further consideration in future studies.

Our findings should be interpreted in the context of certain study limitations. First, as is common with retrospective medical record review studies, information was sometimes missing or unclear. For 40 cats, the reason the pedicles were ligated with suture in place of autoligation was not indicated. Based on the experience of the investigators, these suture ligations were assumed to be a preventative measure related to an anatomical anomaly or concern for knot integrity, because no complications were mentioned, and the cats were omitted from the study. It is possible, however, that for some of these cats, the suture ligation was in response to a pedicle tear or hemorrhage that was not recorded on the treatment sheet. Additionally, the source of the bleeding was not evident for 5 cats with hemorrhage. However, even if hemorrhage was assumed to be pedicle related in all of these cats, the rate of hemorrhage would remain relatively low, and the overall conclusions of the study would not change.

Also, the present study focused on complications occurring prior to discharge, because detailed recheck
records were not available for all animals. It is possible that cats had hemorrhage-related complications after they were discharged from the clinic that were not captured. However, when hemorrhage occurs, it most often presents acutely during the intraoperative period, and all cats were kept overnight for observation and examined prior to discharge, which would have likely revealed signs of clinically important bleeding. Postdischarge deaths were recorded and coded, although it is also possible owners and shelters failed to report postdischarge complications or deaths that could have been pedicle related. Also, necropsy reports were unavailable for 3 of the 10 deceased cats. Surgical logs for these cats indicated cardiac or respiratory issues so it is unlikely the cause of death was pedicle or hemorrhage related.

Inherent to the retrospective design, animals were not assigned randomly at the clinic or surgeon experience level. Although data were analyzed separately by clinic to account for differences in animal characteristics across clinics, there were potential differences in the characteristics of animals assigned to clinic veterinarians versus training veterinarians or veterinary students in each clinic. Owing to the small number of cases with pedicle-related complications in this sample, we were unable to fit multivariate models that considered both surgeon and cat characteristics. Often, clinic veterinarians were assigned the higher-risk cases and may have assumed surgery responsibility for other animals that developed a complication early on. This could have resulted in an underestimation of complication rates for the trainees. Additionally, because OPT is standard protocol at ASNA, a comparison of complication rates with the traditional suture approach was not possible in this study.

In summary, study findings support other available evidence that the OPT is a reliable and safe technique for feline OVH. Although used most often among HQHVSN clinic surgeons, the technique should be considered a standard approach in general practice settings as well owing to its efficiency and low complication and mortality rates. Our results suggest the OPT procedure is safe for experienced surgeons new to the technique as well as for novice surgeons under supervision. In light of these findings, we suggest that the OPT procedure should be included routinely in veterinary medical curricula and that private practitioners should feel confident using this approach.

Acknowledgments

No external funding was used in this study. The authors declare that there were no conflicts of interest.

We thank Julie Levy, DVM, PhD, DACVIM, DABVP, for her input on study design and Lauren Pavone for her contributions to data coding and quality assurance.

References

1. Looney AL, Bohling MW, Bushby PA, et al. The Association of Shelter Veterinarians’ 2016 veterinary medical care guidelines for spay-neuter programs. J Am Vet Med Assoc. 2018;251:322–327. doi:10.2460/javma.251.3.322
2. Griffin B, Bushby PA, McCobb E, et al. The Association of Shelter Veterinarians’ 2016 veterinary medical care guidelines for spay-neuter programs. J Am Vet Med Assoc. 2018;253:1294–1299. doi:10.2460/javma.253.10.1294
3. Levy JK, Bard KM, Tucker SJ, Diskant PD, Dingman PA. Perioperative mortality in cats and dogs undergoing spay or castration at a high-volume clinic. Vet J. 2017;224:11–15. doi:10.1016/j.tvjl.2017.05.013
4. Kreisler RE, Shaver TL, Holmes JL. Outcomes of elective gonadectomy procedures performed on dogs and cats by veterinary students and shelter veterinarians in a shelter environment. J Am Vet Med Assoc. 2018;252:1294–1299. doi:10.2460/javma.252.10.1294
5. ASPCAPro. Video: knots & ties in spay/neuter surgery. Available at: https://www.aspca.org/resource/video-knots-ties-spayneuter-surgery. Accessed August 31, 2021.
6. Miller KP, Rekers W, Ellis K, Ellingsen K, Milovancev M. Pedicle ties provide a rapid and safe method for feline ovariohysterectomy. J Feline Med Surg. 2016;18:160–164. doi:10.1117/1098612X15576589
7. Muraro L, White RS. Complications of ovariohysterectomy procedures performed in 1860 dogs. Tierärztliche Praxis Ausg. K Kleintiere Heimtiere. 2014;42:297–302. doi:10.1055/s-0038-1623776
8. Griffin B, DiGangi BA, Bohling MW. A review of neutering cats. In: August J, ed. Consultations in Feline Internal Medicine. 6th ed. Elsevier Saunders; 2010: 776–792.
9. Pankratz KE, Ferris KK, Griffith EH, Sherman BL. Use of single-dose oral gabapentin to attenuate fear responses in cage-trap confined community cats: a double-blind, placebo-controlled field trial. J Feline Med Surg. 2018;20:535–543. doi:10.1111/j.1098612X17719399
10. Ko JC, Berman AG. Anesthesia in shelter medicine. Top Companion Anim Med. 2010;25:92–97. doi:10.1053/j.tcam.2010.03.001
11. Brodbelt DC, Blissitt KJ, Hammond RA, et al. The risk of death: the confidential enquiry into perioperative small animal fatalities. Vet Anaesth Analg. 2008;35:365–373. doi:10.1111/j.1467-2995.2008.00397.x
12. Berzon JL. Complications of elective ovariohysterectomies in the dog and cat at a teaching institution: clinical review of 853 cases. Vet Surg. 1979;8:89–91. doi:10.1111/j.1532-950X.1979.tb00615.x
13. Bushby PA. Preventing and managing spay/neuter complications (Procedures). Available at https://www.dvm360.com/view/preventing-and-managing-spayneuter-complications-proceedings. Accessed February 11, 2022.
14. Showers AL, Horvath SJ, Pontius D, Forman MR, Hanthorn SA. Comparison of hemorrhagic complications with double-ligated versus auto-ligated feline ovarian pedicles by fourth-year veterinary students. J Vet Med Educ. 2020;48:679–685. doi:10.3138/jvme-2020-0011
15. Bohling MW. Complications in spay and neuter surgery. In: White S, ed. High-Quality, High-Volume Spay and Neuter and Other Shelter Surgeries. Wiley-Blackwell; 2020:339–361. doi:10.1002/9781119466006.ch17
16. Adin CA. Complications of ovariohysterectomy and orchietomy in companion animals. Vet Clin North Am Small Anim Pract. 2011;41:1023–1039. doi:10.1016/j.cvsm.2011.05.004
17. Freeman LJ, Ferguson N, Fellenstein C, Johnson R, Constable PD. Evaluation of learning curves for ovariohysterectomy of dogs and cats. J Vet Anaesth Analg. 2017;25:322–327. doi:10.2460/javma.251.3.322
18. Fudge JM, Page B, Mackrell A, Lee I, Jeffery U. Blood loss and coagulation profile in pregnant and non-pregnant queens undergoing elective ovariohysterectomy. J Feline Med Surg. 2021;23:487–497. doi:10.1111/j.1098612X20959610

JAVMA | JUNE 2022 | VOL 260 | NO. 52