

# Sensitivity of commercial scanners to microchips of various frequencies implanted in dogs and cats

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**Objective**—To evaluate the sensitivity of 4 commercially available microchip scanners used to detect or read encrypted and unencrypted 125-, 128-, and 134.2-kHz microchips under field conditions following implantation in dogs and cats at 6 animal shelters.

**Design**—Cross-sectional study.

**Animals**—3,949 dogs and cats at 6 animal shelters.

**Procedures**—Each shelter was asked to enroll 657 to 660 animals and to implant microchips in 438 to 440 animals (each shelter used a different microchip brand). Animals were then scanned with 3 or 4 commercial scanners to determine whether microchips could be detected. Scanner sensitivity was calculated as the percentage of animals with a microchip in which the microchip was detected.

**Results**—None of the scanners examined had 100% sensitivity for any of the microchip brands. In addition, there were clear differences among scanners in regard to sensitivity. The 3 universal scanners capable of reading or detecting 128- and 134.2-kHz microchips all had sensitivities  $\geq 94.8\%$  for microchips of these frequencies. Three of the 4 scanners had sensitivities  $\geq 88.2\%$  for 125-kHz microchips, but sensitivity of one of the universal scanners for microchips of this frequency was lower (66.4% to 75.0%).

**Conclusions and Clinical Relevance**—Results indicated that some currently available universal scanners have high sensitivity to microchips of the frequencies commonly used in the United States, although none of the scanners had 100% sensitivity. To maximize microchip detection, proper scanning technique should be used and animals should be scanned more than once. Microchipping should remain a component of a more comprehensive pet identification program. (*J Am Vet Med Assoc* 2008;233:1729–1735)

Each year, millions of dogs and cats enter animal shelters in the United States, with most of these animals lacking any type of identification. The Humane Society of the United States estimates that only 30% of dogs and 2% to 5% of cats that enter animal shelters are returned to their owners each year,<sup>1</sup> and a 2004 survey of animal control agencies in Ohio found that only 16% of dogs and 1% of cats were returned to their owners.<sup>2</sup> One potential method for improving these reunification rates would be to increase the use of microchipping, which provides a permanent and unalterable method for identifying pets.

While many leading veterinary and animal welfare associations support the ISO standard of microchip identification of companion animals, this standard has not been adopted in the United States. As a result, currently in the United States, microchips of 3 different frequencies (125, 128, and 134.2 kHz) and 2 different

## ABBREVIATIONS

AKC CAR	American Kennel Club Companion Animal Recovery
ISO	International Organization for Standardization

communication protocols (encrypted and unencrypted) are being sold. Several new universal scanners that purportedly can detect or read all microchips sold in the United States have been introduced and distributed to veterinarians and shelters. There are concerns, however, that universal scanners may not be sufficiently sensitive to detect all microchips. In a previous study<sup>3</sup> evaluating sensitivity of 4 commercial scanners to 6 brands of microchips, we found that none of the scanners had 100% sensitivity for all microchips and that there were clear differences between scanners on the basis of op-

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erating frequency of the microchip, orientation of the microchip, and number of passes used to detect or read the microchip. Importantly, in that study, all scanning was done under controlled conditions *in vitro*, making it unclear whether the same results would be obtained when scanning microchips after they had been implanted in dogs and cats. The purpose of the study reported here, therefore, was to evaluate the sensitivity of 4 commercially available microchip scanners used to detect or read encrypted and unencrypted 125-, 128-, and 134.2-kHz microchips under field conditions following implantation in dogs and cats at 6 animal shelters.

## Materials and Methods

**Scanners**—The 3 universal scanners sold by the major microchip suppliers in the United States at the time of the study were used. In addition, a single-frequency scanner was included in the study because of its widespread presence in the market. The 3 universal scanners were distributed by Bayer Animal Health,<sup>a</sup> HomeAgain,<sup>b</sup> and the AKC CAR.<sup>c</sup> The Bayer and HomeAgain scanners were reported by the manufacturers to be able to read (ie, detect the microchip and display the microchip number) 125-kHz (encrypted and unencrypted), 128-kHz, and 134.2-kHz microchips. The AKC CAR scanner was reported by the manufacturer to be able to read 125-kHz (encrypted and unencrypted) and 128-kHz microchips, but could only detect 134.2-kHz microchips. The single-frequency scanner was distributed by Avid<sup>d</sup> and was reported by the manufacturer to be able to read 125-kHz (encrypted and unencrypted) microchips, but was not able to read or detect 128- or 134.2-kHz microchips. Scanners used in the present study were provided by the manufacturers, except that the Avid scanners were purchased from a third-party supplier. Each shelter that participated in the study was provided with 2 scanners of each type used in the study; scanners were used in the shelters only for the present study and were not used for any other scanning in the shelter.

**Microchips**—Six brands of microchips were used in the study. Microchips that were tested consisted of a single brand of encrypted 125-kHz microchips,<sup>e</sup> 2 brands of unencrypted 125-kHz microchips,<sup>f,g</sup> a single brand of 128-kHz microchips,<sup>h</sup> and 2 brands of 134.2-kHz microchips.<sup>i,j</sup> All microchips used in the study were provided by the manufacturers at no charge or at their typical price for animal shelters.

**Animal shelters**—Six animal shelters located throughout the United States (Animal Protective League, Cleveland; Charlotte-Mecklenburg Animal Control, Charlotte, NC; Dumb Friends League, Denver; Humane Society of Broward County, Fort Lauderdale, Fla; Maricopa County Animal Care and Control, Phoenix; and Michigan Humane Society, Bingham Farms, Mich) were included in the study. Participating shelters were selected in November and December 2007 and visited during this time by the primary investigator (LKL) to review the study guidelines and provide training on scanning techniques. The study was conducted at the shelters from January 1, 2008, through May 31, 2008.

Each shelter used only 1 of the 6 brands of microchips evaluated in the study, and shelters were chosen to participate, in part, on the basis of the microchip brand they currently used or a willingness to use a particular brand of microchip. In addition, shelters were chosen that were thought to have sufficient animals and personnel to complete the study in the time frame needed. The 3 shelters that used the 125-kHz microchips tested all 4 scanners. The 3 shelters that used the 128- and 134.2-kHz microchips tested only the 3 universal scanners; these shelters did not test the Avid scanner because it was not designed to read or detect microchips of these frequencies. Each shelter assigned a study coordinator to oversee all aspects of the study at that shelter, including randomization procedures, animal selection, microchip implantation, personnel training, scanning, and data collection and recording.

**Study protocol**—On the basis of a priori sample size calculations, each shelter was asked to enroll 657 to 660 animals (dogs and cats) that did not currently have any microchips in the study, and assigned microchips were implanted in 438 to 440 animals enrolled at each shelter. Microchips were not implanted in the remaining 219 to 220 animals enrolled at each shelter so that personnel scanning for microchips were blinded to implantation status for individual animals. At the 3 shelters assigned to use the 128- and 134.2-kHz microchips, which tested only the 3 universal scanners, animals enrolled in the study were randomly assigned by use of a random number generator<sup>k</sup> to treatment and control groups in blocks of 9 for a total of 657 animals. At the 3 shelters assigned to use the 125-kHz microchips, which tested all 4 scanners, animals enrolled in the study were randomly assigned to treatment and control groups in blocks of 12 for a total of 660 animals. A ratio of 2:1 was used for treatment to control animals within each block.

The study coordinator or assigned personnel at each shelter selected animals included in the study. Study coordinators were instructed to attempt to select a higher percentage of dogs than cats for the study to reflect the fact that more dogs than cats are currently microchipped in the United States, and were advised to not select ill or aggressive animals. The only restriction on animal selection was that animals that already had a microchip were ineligible for the study; there were no other restrictions on age, weight, or sex.

Animals enrolled in the study were scanned prior to microchip implantation to make sure they did not already have a microchip, and microchips used in the study were scanned before and after implantation to make sure they were functioning properly. For animals enrolled in the study, microchips were implanted by a veterinarian or registered veterinary technician or by trained shelter personnel. Microchips were implanted along the dorsal midline between the shoulder blades, and the microchip manufacturer's guidelines for implantation technique were followed. For all animals in each block, microchips were implanted at the same time.

After microchips were implanted in a block of animals, all animals in the block (animals in which a microchip had been implanted and control animals in which a

microchip had not been implanted) were scanned with each of the study scanners to determine whether the microchips were correctly detected and read. At shelters testing 3 scanners, 3 individuals were selected to scan all study animals; at shelters testing 4 scanners, 4 individuals were selected to scan all study animals. The primary investigator trained each study coordinator on the manufacturers' recommendations for scanning technique, and the study coordinator at each shelter subsequently trained all personnel at the shelter on scanning techniques. Written scanning guidelines developed by the authors that incorporated the manufacturers' recommendations for scanning technique were provided to the shelters for use during training (Appendix). Individuals scanning study animals were asked to follow these guidelines to ensure that animals were scanned in a systematic fashion. All scanning occurred under typical conditions at the shelter, meaning that collars were not specifically removed if present on the animals, computers were not removed from rooms where scanning was done, and animals could be placed on metal surfaces during scanning. To avoid potential operator bias that could have occurred if individuals scanning study animals used a single scanner type, investigators provided a randomization procedure for each shelter so that individuals scanning study animals were assigned different scanners to use on different animals. Individuals scanning study animals were blinded to whether any given animal did or did not have a microchip. Each person scanned any particular animal only 1 time with 1 scanner; each animal was scanned by 3 or 4 individuals depending on the number of scanners tested at the shelter.

The study coordinator at each shelter oversaw the scanning procedure. Shelter personnel would bring all animals scheduled for scanning to a central location, where each animal was scanned in the presence of the study coordinator, who recorded the study information. Only 1 person performing the scanning was present at any time, so that individuals assigned to scan animals were blinded to each others' results. Alternatively, individuals assigned to scan study animals were instructed to locate the animals in their cages and scan them there. In this instance, the study coordinator may or may not have been present to record the study information. If the study coordinator was not present, the person performing the scanning recorded the study information and gave it to the study coordinator when he or she had finished scanning the block of animals. Again, only 1 person performing the scanning was present at any time. However, an assistant could be present to restrain animals for scanning.

For each animal in the study, the study coordinator recorded the animal identification number, date, species, breed (mixed breed vs purebred), weight, age (rounded to nearest 3 months), sex (castrated male, sexually intact male, spayed female, or sexually intact female), whether a microchip was implanted (yes vs no), and, if a microchip was implanted, the microchip number and individual who had implanted the microchip. At the time each animal was scanned, information that was collected included date the animal was scanned, individual who had scanned the animal,

whether a microchip was detected (yes vs no), whether the correct microchip number was displayed (yes, no, or detected [for scanners that could only detect microchips but not read microchip numbers]), and scanner used. In those instances when scanning personnel recorded the data, the microchip number was written on a form and then checked against the animal information by the study coordinator. In those instances when the study coordinator recorded the data, the microchip number was read aloud by the individual performing the scanning, and the study coordinator determined whether the number was correct.

**Scanner battery change schedule**—To ensure that low battery power is not a factor in scanner performance, batteries in all scanners were changed every 2 weeks by the study coordinator. In addition, batteries were changed immediately if the scanner displayed a low battery indicator. All replacement batteries were new and had not been used previously; a single brand of battery was used.<sup>1</sup>

**Microchip failure**—If a microchip was implanted and successfully read after implantation but was not detected by any scanner during the scanning procedure, the shelter was directed to radiograph the animal. If the microchip was visible on radiographs, it was considered to have failed. If the microchip was not visible on radiographs, the microchip was assumed to have been improperly implanted. In either instance, the animal was removed from the study and replaced with a new animal.

**Statistical analysis**—For each scanner type, sensitivity to each microchip brand was calculated as the percentage of microchips of that brand that were successfully detected or read, and 95% confidence intervals were calculated by use of the normal approximation to the binomial. Scanner sensitivity was compared between scanners at each shelter and not between microchips at different shelters. Medians and ranges were calculated for continuous data, and proportions were calculated for categorical data. Control animals were included in descriptive statistics, but were not included in any other analyses.

For each microchip type, sensitivity was compared among scanners by means of the Cochran Q test<sup>4</sup> followed by the McNemar test<sup>4</sup> for pairwise comparisons. To adjust for the multiple comparisons that were performed, *P* values  $\leq 0.008$  for the McNemar test were considered significant when analyzing sensitivity to the 125-kHz microchips (4 scanners and 6 pairwise comparisons), and *P* values  $\leq 0.017$  were considered significant when analyzing sensitivity to the 128- and 134.2-kHz microchips (3 scanners and 3 pairwise comparisons).

Logistic regression was used to identify animal characteristics significantly associated with the odds that a microchip would not be detected, after adjusting for microchip and scanner. Variables considered were age (0 to 6 months, > 6 months to 2 years, and > 2 years), weight, species (dog vs cat), sex, neuter status (yes vs no), and breed (purebred vs mixed breed). A term for the interaction between species and weight was included to test the hypothesis that a microchip would

be more likely to be missed in heavier dogs because of their larger body surface area. A backward selection procedure was used, with variables omitted when the Wald *P* value was > 0.05. Analyses were stratified on the basis of microchip frequency (125 kHz vs 128 or 134.2 kHz) owing to the different number of scanners tested. Regression coefficients and SEs were obtained by means of generalized estimating equations<sup>5</sup> to account for correlations between scans performed on the same animal.

Logistic regression was also used to determine whether the level of experience of individuals scanning study animals was significantly associated with the odds that a microchip would not be detected. For this analysis, level of experience was categorized as animal or kennel assistant, veterinary technician, and administrative or other.

Standard statistical software was used for all analyses.<sup>m</sup> Except as needed to account for multiple comparisons, values of *P* ≤ 0.05 were considered significant.

## Results

**Animals**—A total of 2,632 animals (1,174 dogs and 918 cats) were implanted with microchips in the study, and 1,317 animals (859 dogs and 458 cats) were used as controls. For each of the 6 shelters in the study, information on age, weight, breed, sex, and neuter status was collected (Table 1).

**Scanner sensitivity**—Overall, the HomeAgain scanner had the highest sensitivities, ranging from 93.6% for 1 brand of 125-kHz microchips<sup>g</sup> to 98.4% for

1 brand of 134.2-kHz microchips<sup>j</sup> (Table 2). The Bayer scanner had sensitivities ≥ 97.0% for 4 microchips brands, but lower sensitivities for 2 brands of 125-kHz microchips<sup>g,e</sup> (88.2% and 92.1%). The AKC CAR scanner had sensitivities > 95% for the 128-kHz microchips and both brands of the 134.2-kHz microchips, but sensitivities for the 3 brands of 125-kHz microchips ranged from 66.4% to 75.0%. The Avid scanner had sensitivities ≥ 97.3% for the 3 brands of 125-kHz microchips, which were the only frequency it was capable of reading.

For all 3 brands of 125-kHz microchips, sensitivity differed significantly (*P* < 0.001) among scanners, with the AKC CAR scanner having significantly lower sensitivity than the other scanners in each case (Table 2). Sensitivity also differed significantly among scanners for the 128-kHz microchips (*P* = 0.006) and 1 brand of 134.2-kHz microchips<sup>i</sup> (*P* = 0.008), but differences in sensitivity were all < 4%. Sensitivity did not differ significantly (*P* = 0.163) among scanners for the other brand of 134.2-kHz microchips.<sup>j</sup>

For the 128- and 134.2-kHz microchips, percentage of animals in which microchips were detected with all 3 universal scanners ranged from 90.4% to 93.8% (Table 3). For the 3 brands of 125-kHz microchips, percentages of animals in which microchips were detected with all 4 scanners ranged from 52.3% to 64.1%. The low agreement for the 125-kHz microchips was largely attributable to the AKC CAR scanner, in that percentages of animals in which the 125-kHz microchips were detected with the 3 scanners other than the AKC CAR scanner were 81.8% (360/440), 86.1% (379/440), and 90.2% (395/438).

Table 1—Demographic characteristics of dogs and cats in 6 animal shelters enrolled in a study of the sensitivity of commercial scanners to microchips of various frequencies.

Microchip frequency	No. of animals		Age (y)		Weight (kg)*		No. (%) purebred		No. (%) male		No. (%) neutered	
	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control
125 kHz <sup>a</sup>												
Dogs	281	139	1 (0.25–12)	1 (0.25–10)	12.3 (1.4–40.0)	14.1 (1.5–39.1)	60 (21.4)	30 (21.6)	138 (49.1)	72 (51.8)	47 (16.7)	17 (12.2)
Cats	159	81	1.5 (0.25–13)	1.5 (0.25–15)	3.5 (0.6–7.7)	3.4 (0.1–7.8)	1 (0.6)	1 (1.2)	65 (40.9)	37 (45.7)	31 (19.5)	17 (21.0)
125 kHz <sup>f</sup>												
Dogs	295	153	0.75 (0.25–10)	0.75 (0.25–10)	11.4 (2.3–47.6)	10.4 (1.8–47.9)	67 (22.7)	32 (20.9)	152 (51.5)	86 (56.2)	99 (33.6)	51 (33.3)
Cats	143	67	1 (0.25–7)	1 (0.25–8)	3.2 (0.9–6.8)	3.6 (0.9–6.8)	3 (2.1)	0 (0)	64 (44.8)	33 (49.3)	83 (58.0)	37 (55.2)
125 kHz <sup>g</sup>												
Dogs	191	94	1 (0.25–9)	2 (0.25–8)	15.5 (1.4–55.5)	17.1 (1.5–38.2)	50 (26.2)	24 (25.5)	105 (55.0)	49 (52.1)	142 (74.4)	65 (69.2)
Cats	249	126	1 (0.25–12)	2 (0.25–13)	3.3 (0.5–9.0)	3.7 (0.5–7.2)	2 (0.8)	0 (0)	124 (49.8)	52 (41.3)	204 (81.9)	108 (85.7)
128 kHz <sup>h</sup>												
Dogs	299	146	1.5 (0.25–15)	1.5 (0.25–12.5)	14.5 (1.6–55.2)	13.6 (1.4–40.2)	110 (36.8)	54 (37.0)	166 (55.5)	81 (55.5)	13 (4.4)	8 (5.5)
Cats	139	73	1.5 (0.25–10)	1.5 (0.25–12)	3.1 (0.7–7.9)	3.3 (0.7–7.0)	5 (3.6)	2 (2.7)	65 (46.8)	32 (43.8)	26 (18.7)	7 (9.6)
134.2 kHz <sup>i</sup>												
Dogs	310	150	1.5 (0.25–12)	1.5 (0.25–14)	19.7 (2.4–50.0)	18.6 (1.6–46.0)	81 (26.1)	56 (37.3)	163 (52.6)	67 (44.7)	134 (43.2)	60 (40.0)
Cats	128	69	2 (0.25–12)	2.5 (0.25–13)	3.8 (0.5–9.1)	3.7 (0.5–9.8)	4 (3.1)	0 (0)	58 (45.3)	33 (47.8)	60 (46.9)	36 (52.2)
134.2 kHz <sup>j</sup>												
Dogs	338	177	0.25 (0.25–10)	1 (0.25–8)	7.3 (1.5–42.3)	15.8 (2.5–42.7)	285 (84.3)	145 (81.9)	153 (45.3)	72 (40.7)	55 (16.3)	53 (29.9)
Cats	100	42	0.25 (0.25–7)	0.5 (0.25–9)	1.0 (0.5–4.5)	2.7 (0.6–7.0)	3 (3.0)	1 (2.4)	48 (48.0)	19 (45.2)	2 (2.0)	7 (16.7)

\*Values are given as median (range). Microchips of the stated frequency were implanted in dogs and cats in the treatment group; no microchips were implanted in dogs and cats in the control group.

Table 2—Sensitivity of commercial scanners to 6 brands of microchips implanted in dogs and cats.

Microchip frequency	No. of animals	Sensitivity (95% CI)			
		AKC CAR <sup>c</sup>	Avid <sup>d</sup>	HomeAgain <sup>b</sup>	Bayer <sup>a</sup>
125 kHz <sup>e</sup>	440	75.0 <sup>a</sup> (71.0–79.1)	98.2 <sup>b</sup> (96.9–99.4)	95.9 <sup>b,c</sup> (94.1–97.8)	92.1 <sup>c</sup> (89.5–94.6)
125 kHz <sup>f,*</sup>	438	66.4 <sup>a</sup> (62.0–70.9)	97.3 <sup>b</sup> (95.7–98.8)	95.6 <sup>b</sup> (93.8–97.6)	97.0 <sup>b</sup> (95.4–98.6)
125 kHz <sup>g</sup>	440	66.6 <sup>a</sup> (62.2–71.0)	99.6 <sup>b</sup> (98.9–100.0)	93.6 <sup>c</sup> (91.3–95.9)	88.2 <sup>d</sup> (85.2–91.2)
128 kHz <sup>h</sup>	438	98.9 <sup>a</sup> (97.9–99.9)	NA	95.2 <sup>b</sup> (93.2–97.2)	97.0 <sup>a,b</sup> (95.4–98.6)
134.2 kHz <sup>i</sup>	438	95.9 <sup>a</sup> (94.0–97.8)	NA	94.8 <sup>a</sup> (92.7–96.8)	98.4 <sup>b</sup> (97.2–99.6)
134.2 kHz <sup>j</sup>	438	96.8 <sup>a</sup> (95.2–98.5)	NA	98.4 <sup>a</sup> (97.2–99.6)	98.4 <sup>a</sup> (97.2–99.6)

Sensitivity was calculated as the percentage of microchips that were successfully detected or read.  
<sup>\*</sup>Two animals were not included owing to 1 brand of scanner being used more than once.  
 NA = Not applicable; the Avid scanner was not designed to detect microchips of these frequencies. CI = Confidence interval.  
<sup>a–d</sup>In each row, values with different superscript letters are significantly ( $P < 0.05$ ) different.

Table 3—Percentages of animals in which microchips were detected with 4 commercial scanners (125-kHz microchips) or with 3 universal scanners (128- and 134.2-kHz microchips).

Microchip frequency	No. of animals	No. (%) with complete agreement
125 kHz <sup>e</sup>	440	282 (64.1)
125 kHz <sup>f</sup>	438	261 (59.6)
125 kHz <sup>g</sup>	440	230 (52.3)
128 kHz <sup>h</sup>	438	401 (91.6)
134.2 kHz <sup>i</sup>	438	396 (90.4)
134.2 kHz <sup>j</sup>	438	411 (93.8)

**Factors associated with scanner sensitivity**—After adjusting for microchip and scanner, the only animal characteristic significantly associated with odds that a microchip would not be detected during scanning was the animal's weight. For each 2.3-kg (5-lb) increase in body weight, the odds that a 125-kHz microchip would be missed increased by 5% (odds ratio, 1.05; 95% confidence interval, 1.03 to 1.07;  $P < 0.001$ ) and the odds that a 128- or 134.2-kHz microchip would be missed increased by 8% (odds ratio, 1.08; 95% confidence interval, 1.03 to 1.13;  $P < 0.001$ ). A significant interaction between body weight and species was not detected in either model.

The number of individuals scanning animals at each of the shelters ranged from 10 to 42. Median number of animals scanned by each person ranged from 19.0 to 204.5. After adjusting for microchip and scanner, level of experience of individuals scanning study animals was not significantly associated with the odds that a microchip would not be detected.

**Microchip failure and display of incorrect microchip numbers**—A total of 11 animals in the 6 shelters had negative scanning results for all scanners after a microchip was implanted. In 7 of the 11 animals, the microchip could not be identified on radiographs, suggesting that a microchip had not actually been implanted or that the microchip had been lost after implantation and before scanning. In an additional 2 animals, microchips were found on the cage floor. The remaining 2 animals were adopted before radiographs could be obtained; therefore in these 2 animals, it could not be determined whether negative scanning results were caused by improper implantation or microchip failure.

On 2 occasions, the wrong microchip number was displayed on the scanner during scanning. This occurred once when the Bayer scanner was used to scan an animal in which a 134.2-kHz microchip<sup>i</sup> had been implanted and once when the HomeAgain scanner was used to scan an animal in which a 125-kHz microchip<sup>f</sup> had been implanted. In both cases, the error could not be repeated with the same scanner or another brand of scanner, and the animals were not radiographed to confirm whether a second microchip was present.

**Low battery indicator**—At 3 of the 6 shelters, the HomeAgain scanner displayed a low battery indicator, and batteries had to be changed prior to the 2-week interval specified in the study protocol. This occurred 4 times at a shelter that was using a 125-kHz microchip<sup>f</sup> and once at a shelter that was using a 134.2-kHz microchip<sup>i</sup>. At the shelter using the 128-kHz microchip, 2 scanners were returned to HomeAgain during the study because of multiple low battery indications and freezing of the display screen during scanning. In both cases, the scanners were replaced immediately with identical scanners by the manufacturer. The only issue the manufacturer's technical support staff could identify was that 1 of the 4 batteries had a low charge. This shelter had to change batteries in the HomeAgain scanners prior to the expected 2-week interval approximately 7 times and experienced intermittent problems with the display screen freezing. Screen freezing during scanning could be resolved by removing 1 battery and immediately reinserting the same battery in the scanner. Another shelter had problems with the display screen of the HomeAgain scanner freezing during scanning. That shelter was advised by the manufacturer to remove the batteries overnight, which resolved the problem. None of the other 3 scanner brands displayed low battery indications during the study.

## Discussion

Results of the present study indicated that, similar to the case in our study when microchips were scanned in vitro under controlled conditions,<sup>3</sup> none of the scanners examined had 100% sensitivity for any of the microchip brands. In addition, there were clear differ-

ences among scanners in regard to sensitivity. Overall, the HomeAgain scanner performed the best, with sensitivities  $\geq 93.6\%$  for all 6 brands of microchips tested. The Bayer scanner performed well, with sensitivities  $\geq 92.1\%$  for all except 1 brand of 125-kHz microchip.<sup>8</sup> In our previous study,<sup>3</sup> this scanner also had lower sensitivity with this particular microchip in vitro. The Avid scanner performed well with all 125-kHz microchips (sensitivities  $\geq 97.3\%$ ), but was not designed to read or detect microchips of other frequencies. The AKC CAR scanner performed well with 128- and 134.2-kHz microchips, but performed poorly with all 3 brands of 125-kHz microchips. These findings were also consistent with results of the in vitro study.<sup>3</sup> Despite these differences among scanners, those scanners capable of reading or detecting 128- and 134.2-kHz microchips all had sensitivities  $\geq 94.8\%$ . For the 3 brands of 125-kHz microchips, 3 of the 4 scanners had sensitivities  $\geq 88.2\%$ .

Although microchipping provides a permanent form of animal identification, it is not an infallible system, and it is not realistic to expect 100% performance. To enhance pet-owner reunification in the event that a pet is lost, microchipping should be regarded as just 1 component of a comprehensive pet identification program, complementing other types of visual identification, such as tattoos and personal identification, license, and rabies tags.

On the basis of results of the present study and our previous in vitro study,<sup>3</sup> we recommend that animal shelters and veterinarians select a universal scanner that can read microchips of all frequencies with high sensitivities. Particularly in a shelter environment, animals should be scanned more than once to increase the likelihood of detecting a microchip if one is present. We also recommend that scanning be done according to the scanner manufacturer's protocol, passing the scanner over the entire animal more than once and with a slight circular or side-to-side rocking motion to maximize the likelihood of detecting a microchip regardless of microchip orientation. In addition, extra care should be taken when scanning heavier animals, in that in the present study, every 2.3-kg increase in body weight was associated with a 5% increase in the odds that a 125-kHz microchip would be missed and a 8% increase in the odds that a 128- or 134.2-kHz microchip would be missed. Lastly, although it may not be realistic in a shelter setting, in a veterinary office, it is ideal to scan animals without collars to avoid interference from any metal in the collar or tags.

Findings in the present study illustrate 2 additional points to consider when establishing a microchip scanning protocol for an animal shelter or veterinary facility. First, microchips that are presumed to be implanted correctly may not be adequately or securely implanted. Although uncommon, this occurred in 11 animals in the present study. Therefore, animal shelters should scan every animal immediately after a microchip has been implanted and prior to the animal's leaving the shelter. Additionally, veterinary clinic personnel should scan microchipped animals during every wellness examination to ensure microchip function. Second, battery life may be an issue with scanners, and a regular battery change schedule based

on scanner usage should be established. More research is needed to investigate battery life and its impact on scanner sensitivity, including the use of rechargeable batteries in scanners.

There were several limitations to the present study. First, only those scanners available at the time the study was conducted were evaluated, and findings cannot be extrapolated to older or newer scanner models, which may perform better or worse. Similar studies in the future would be valuable as microchip and scanner technology evolves. Second, it is also possible that some degree of bias was introduced into the study by allowing study coordinators at each participating shelter to select which animals were microchipped and which were used as controls, although we expect this would have had minimal effects on our results. Third, although every effort was made to ensure that individuals implanting microchips and scanning animals were fully trained, human error was present, as reflected in the 11 animals in which microchips were improperly implanted. It is likely that some microchips were missed during scanning because of human error. Fourth, several scanners had some type of malfunction during the study. Although malfunctions were quickly corrected, it was unclear how technologic issues, such as low battery charge, may have affected our findings. On the other hand, the study was designed to reflect field conditions, and both human error and technologic issues will be present to some degree. Hence, the findings provide clinically relevant information. Last, the present study was not designed to address other important issues such as microchip migration, the microchip registration process, microchip implant failure, scanner battery life, and long-term microchip function. All of these are important issues that need to be addressed in future research.

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- a. iMax Black Label Portable Reader, Datamars SA, Bedano, Switzerland; distributed by Bayer Animal Health ResQ Pet Identification System, Shawnee Mission, Kan.
  - b. Universal WorldScan Reader, Digital Angel Inc, Saint Paul, Minn; distributed by Schering-Plough HomeAgain LLC, Kenilworth, NJ.
  - c. Multi-System Pocket Scanner LID560, Trovan Ltd, represented by EID Ltd, Santa Barbara, Calif; distributed by the American Kennel Club Companion Animal Recovery ID System, Raleigh, NC.
  - d. MiniTracker I Universal Multi-Scan 125, Avid, Norco, Calif.
  - e. FriendChip microchip (encrypted 125 kHz), Avid, Norco, Calif.
  - f. HomeAgain microchip (unencrypted 125 kHz), Digital Angel Inc, Saint Paul, Minn; distributed by Schering-Plough HomeAgain LLC, Kenilworth, NJ.
  - g. 24PetWatch microchip (unencrypted 125 kHz), Allflex USA Inc, DFW Airport, Tex; distributed by PetHealth Inc, Rolling Meadows, Ill.
  - h. American Kennel Club Companion Animal Recovery ID system microchip (128 kHz), Trovan Ltd, represented by EID Ltd, Santa Barbara, Calif; distributed by the American Kennel Club Companion Animal Recovery ID System, Raleigh, NC.
  - i. Bayer ResQ microchip (134.2 kHz), Datamars SA, Bedano, Switzerland; distributed by Bayer Animal Health, Shawnee Mission, Kan.
  - j. HomeAgain microchip (134.2 kHz), Digital Angel Inc, Saint Paul, Minn; distributed by Schering-Plough HomeAgain LLC, Kenilworth, NJ.
  - k. MATLAB, Mathworks Inc, Natick, Mass.
  - l. Energizer Max batteries (9V and AAA), Energizer, St Louis, Mo.
  - m. SAS, version 9.1, SAS Institute Inc, Cary, NC.
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## Appendix

### Protocol for scanning dogs and cats for microchips

The same basic scanning protocol should be used for all types of scanners, maintaining a consistent speed, scanner orientation, scanning pattern, and scanning distance with all scanners. All appropriate areas should be included when scanning for microchips.

**Scanner orientation**—The Bayer, HomeAgain, and Avid scanners should all be held parallel to the animal. The AKC CAR scanner should be held perpendicular to the animal, and scanning should start with the scanner parallel to the animal's spine.

**Scanning distance**—The scanner should be held in contact with the animal during scanning.

**Scanning speed**—Scanning should be performed at a speed no faster than 0.5 feet/s.

**Areas to be scanned**—The standard implantation site is midway between the shoulder blades. Scanning should begin in and concentrate on this area. If a microchip is not detected in this area, the back, the sides, neck, shoulders, and forelimbs to the elbow region should be scanned.

**Scanning pattern**—The scanner should be moved over the areas to be scanned in a transverse (ie, side to side) S-shaped pattern. If a microchip is not detected, the scanner head should be rotated 90 degrees, and the area should be scanned in a longitudinal S-shaped pattern. Use of an S-shaped scanning pattern will maximize the ability of the scanner to detect microchips, regardless of microchip orientation. Care should be taken that the S-shaped pattern is not so large that areas of the body to be scanned are missed.

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2. Lord LK, Wittum TE, Ferketich AK, et al. Demographic trends for animal care and control agencies in Ohio from 1996 to 2004. *J Am Vet Med Assoc* 2006;229:48–54.
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