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ORIGINAL STUDY

Prospective investigation of factors associated with success on the American College of Veterinary Emergency and Critical Care certification examination (2016-2018)

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Offprints will not be available from the authors.

Abstract

Objective: To assess the association of candidate attributes and residency training factors with success on the American College of Veterinary Emergency and Critical Care (ACVECC) board certification examination and to develop multivariable models of first-attempt success.

Design: Prospective survey-based study.

Setting: Post-assessment ACVECC examination candidates.

Animals: None.

Interventions: None.

Measurements and main results: Comprehensive surveys were distributed to ACVECC examination candidates in 2016 to 2018 after completion of their assessments, but prior to publication of examination results. Unique anonymous candidate identification numbers were used to match survey responses to outcome data from the office of the ACVECC Executive Secretary. After curation to retain only the first response from each candidate, there were 97 unique candidate responses available for analysis. Univariate analyses identified multiple factors associated with first-attempt success and multiple differences between academic and private practice residency programs. Multivariable logistic regression modeling suggested that 5 factors were independently associated with first-attempt success on the ACVECC examination, specifically younger age, more weeks of study prior to the examination, training at a facility with more ACVECC Diplomates, training at a facility with more ACVECC residents, and having no requirement to manage both Emergency Room (ER) and Critical Care (CC) cases simultaneously.

Conclusions: Numerous resident and training center factors are associated with success in the ACVECC board certification examination. Residents and training centers might be able to use these data to enhance training, but caution must be exercised because these data are associative only.

KEYWORDS

ACVECC examination, education, residency training, statistical modeling, success

1 | INTRODUCTION

The annual board certification examination for the American College of Veterinary Emergency and Critical Care (ACVECC) is undertaken after successful completion of an approved 3-year approved residency training program and all required credentials. The certification process aims to identify competent candidates who will maintain the standards of patient care provided by Diplomates of the ACVECC. The examination presently consists of 3 sections that test the candidate's knowledge of physiology, pathophysiology, and the diagnosis and management of the disease. The first section utilizes a short answer format based on clinical vignettes, whereas the other 2 sections are multiple-choice questions inclusive of recent pertinent literature. Although the examination has gradually been iterated and changed to administration using electronic testing software during a 2-year transition from 2017 to 2018, the current examination structure and format have been in place since 2009. Use of a modified-Angoff rating system to help determine the pass point for the examination^{1,2} has also been in place since 2010.

The success rates for the ACVECC board certification examination are not routinely published or circulated outside of the ACVECC community but are likely of interest to prospective trainees, current residency candidates, and to the wider veterinary Emergency and Critical Care (ECC) community. The 2018 ACVECC Residency Standards indicate that both the Residency Training and the Credentials Committees of the ACVECC are charged with providing prospective residents with the pass rates for the certification examination for individual programs to which they might apply. However, these might be challenging to evaluate without the context of the overall pass rates for the examination across all residency training centers. The ACVECC Board of Regents and the examination and residency training committees have dual responsibilities to ensure minimum standards in order to maintain public and professional confidence in the status of Diplomates, while providing a rigorous yet fair examination that has an achievable passing standard. Although acknowledging the need for minimum standards of examination performance to confer Diplomate status, concerns about success rates and the quality of training that residency programs provide have previously been raised internally within the ACVECC membership. In addition, consistent with data from human medical training programs, some ACVECC candidates attempt the examination multiple times without success.³

In an effort to address those concerns, the authors published a retrospective evaluation of candidate performance on the ACVECC certification examination from 2010 to 2015 and assessed the association of residency training programs with first-attempt examination success.⁴ That study documented an overall pass rate of 64.3%, with a median of 63.8% across the 6-year-period. First-attempt success rates for small animal residents trained in academic programs were signifi-

cantly higher than for residents trained in private practice. The reasons for this difference were uncertain, and the authors speculated that it may have been a combination of candidate factors, such as prior academic performance, the distribution of examination questions across topic areas, and training center factors such as numbers of Diplomates or the amount of time dedicated to rounds and other didactic programs. The retrospective design of the previous study and the limited data available for analysis precluded answering these questions. This is the knowledge gap that the present study aimed to fill. The objectives of the present study were to assess the association of candidate attributes and behaviors and of residency training factors with success on the ACVECC board certification examination and to develop models to predict first-attempt success. It was hypothesized that previous academic aptitude and extensive examination preparation (candidate factors), as well as greater resource availability and time expenditure on resident training (training program factors), are associated with success.

2 | METHODS

Anonymized examination performance data from 2016 to 2018 inclusive were obtained from the Office of the Executive Secretary of the ACVECC. Specifically, data regarding candidate residency type, date of completion of the residency training program, and date of passing the certification examination were requested. These data included the relevant randomized examination numbers provided to candidates to enable the merging of datasets.

In addition, during each year of the study (2016, 2017, and 2018), an identical anonymized computerized survey (Data S1) was distributed to all ACVECC residents that completed the board certification examination between the date of the examination and the date of release of the final results. The survey was approved by the University of Missouri Institutional Review Board (MU IRB #2006735C), and participation was voluntary and not incentivized. The survey asked questions in 4 main topic areas: (1) indicators of previous academic performance or achievement, including veterinary school grade point average (GPA) and class rank, attainment of a higher degree (eg, MS, PhD); (2) candidate examination preparation duration, intensity, and practice; (3) candidate subjective judgments on the efficacy of their residency training program, self-study, and on the nature and conduct of the examination; (4) information regarding their residency training program, including numbers and types of cases, availability and numbers of supervisors, fellow residents and other specialists, and amount and type of didactic training provided. Information regarding candidate age, gender, residency type, and examination success was also requested. Candidates were instructed to leave any nonapplicable questions blank.

With regards to GPA, there was no straightforward means for non-North American candidates to equate other grading standards with GPA and, hence, non-North American candidates likely left that question blank. Academic programs were defined as any program at an institution with the terms “University,” “College,” or “School” in the name. All other residency training programs were designated Private Practice.

The datasets from the Office of the ACVECC Secretary and from the candidate surveys were combined into a single spreadsheet using the year and the unique candidate identifiers (Data S2). These records were manually curated to identify any obvious errors and follow-up data requests sent to the Office of the ACVECC Secretary for clarification. Incomplete, blank, or clearly erroneous entries were deleted. Candidate identifying numbers were used to distinguish responses provided by the same candidate in more than 1 year, with only the earliest response being retained in the final database, which was then coded to enable statistical analysis. This was cross-checked with data from the office of the ACVECC Executive Secretary. Candidates for whom ACVECC records indicated they had sat the examination prior to the year of the survey or who self-identified as having sat the examination more than once (Q12, Data S1) were automatically coded as unsuccessful at the first attempt. Continuous data such as age or weeks spent on clinics are expressed as median and interquartile range (IQR). Ordinal data such as class rank or study time estimates and nominal data such as type of residency training program are expressed as number or percentage in each category. Correlations between continuous and ordinal variables were assessed by calculation of Spearman's rank (r_s), while correlations between subjective ordinal variables (candidate assessments of residency training and examination) were performed by calculation of Kendall's tau-b (τ_b). The strength of correlation was assessed as follows: < 0.5 weak, 0.5–0.6 mild, 0.6–0.7 moderate, 0.7–0.8 strong, 0.8–0.9 very strong, 0.9–1.0 excellent. Univariate comparisons of continuous and ordinal data were performed with the Mann-Whitney *U*-test, while comparisons of nominal or dichotomous data were performed using chi-square or Fisher's exact test.

Survey responses were compared by candidate success or failure on their first attempt at the examination and by residency training center type (academic vs private practice). These comparisons were not corrected for multiple comparisons, because multivariable logistic regression was subsequently performed to identify independent predictors of first-time examination success. The residency training center type was excluded from multivariable modeling because it was anticipated that this variable would confound identification of other independent predictors. Additionally, associations with examination success that were independent of center type were deemed both more generalizable and potentially modifiable by both residents and training centers.

For the multivariable logistic regression modeling of first-time examination success, potential independent predictor variables were chosen as follows: associated with success in univariate analyses at $P < 0.05$ and with an event to predictor ratio $> 5:1$. Potential exploratory models were built by entering predictor variables in a forward stepwise fashion with potential predictors retained only if sig-

nificantly associated with outcome at $P < 0.05$. Predictors with the largest effect sizes were prioritized. For the final model, all variables were simultaneously entered. Missing data were excluded on a case-wise basis; that is, all available data were analyzed. Classification tables were used to assess model accuracy. Calibration of the final model was determined using the Hosmer–Lemeshow goodness-of-fit (model rejected if $P < 0.05$), and model utility assessed by calculation of the Nagelkerke R^2 value. The ability of the final model to discriminate the outcome was determined by calculating area under receiver-operating characteristic curves (AUROC). Statistical analyses were performed with commercial software.^{a,b} Alpha was set at 0.05.

3 | RESULTS

The initial response rates for the survey were 42.9% (36/84) in 2016, 43.8% (39/89) in 2017, and 44.8% (39/87) in 2018, equivalent to an overall response rate of 43.8%. The survey database initially contained 114 records prior to the removal of 17 entries from candidates that had responded in a previous year, leaving 97 unique candidate responses: 36 from 2016, 31 from 2017, and 30 from 2018. Within this final database of survey responses, the first-attempt success rates for the ACVECC examination were 41.7% (15/36) in 2016, 61.3% (19/31) in 2017, and 80.0% (24/30) in 2018. The first-attempt pass rate based solely on the survey responses across all 3 years was 59.8% (58/97). In comparison, the actual overall pass rates for the ACVECC examination across all candidates per data from the office of the Executive Secretary was 59.2% (154/260). The corresponding annual pass rates were 57.1% (48/84) in 2016, 55.1% (49/89) in 2017, and 65.5% (57/87) in 2018.

3.1 | Demographics and candidate factors

Of the 84 responses for which the information was available, 2 (2.4%) were from large animal candidates; the remaining 82 (97.6%) were small animal candidates. Most responses were from women (80/97, 82.5%), with 17 of 97 (17.5%) from men. The median age of candidates responding was 33 years (31–35). Candidates were a median of 6 years from veterinary school graduation (4–8). The median GPA lay between 3.60 and 3.79 (3.40–4.00), while the median class rank was categorized as Top 20% (Top 35% to Top 10%). Advanced degrees, predominantly MS ($n = 21$) had been obtained by 26 of 94 candidates responding. Only 3 responses came from candidates who already had board certification in another discipline (ACVIM, ACVS, ACVAA; all $n = 1$).

Of all responses, 61.9% (60/97) were from those that undertook academic residencies and 38.1% (37/97) from those completing private practice residencies. Most responses were from candidates taking the examination for the first time (74/97, 76.3%), with 12 (12.4%) responses from those on their second attempt and 7 (7.2%) from those on their third attempt. There were 4 (4.1%) responses from candidates that had completed the examination more than 3 times (4 times, $n = 2$, 9 times, $n = 2$). Correspondingly, most responses (64/97, 66.0%) came

from candidates that had completed their residency programs within the year preceding the examination, and 90 of 97 (92.8%) responses came from candidates within 3 years of completion. Thirty-two candidates reported a delay in sitting the examination, of which a delay in acceptance of the publication required for credentials delayed 34.4% (11/32). Candidates spent a median of 6 to 8 weeks (4-8) studying for the examination and reported studying for a median of > 8 hours per day (6 to > 8). Most candidates studied predominantly from textbooks rather than from journals, with 47 of 97 using 80% textbooks and 34 of 97 using 60% textbooks.

3.2 | Residency training program factors

At the residency training centers were a median of 3 to 4 (1-4) ACVECC Diplomates mentoring a median of 3 to 5 (3-8) residents. In addition to ACVECC Diplomates, a median of 11 (7-12) other specialties were represented at residency training centers. Candidates reported spending a median of 40 weeks (35-42) on clinics per year, with a median of 12 weeks (10-17) off clinics per year. During rotations, residents overlapped with ACVECC Diplomates a median of 60% (50-80) of the time. On emergency receiving (ER) rotations, candidates reported seeing a median of 6 cases (5-10) per day and managing 4 cases (3-6) per day while on critical care (CC) rotations. Most candidates (74/97, 76.3%) were required to manage CC cases and see ER cases simultaneously. Candidates reported managing a median of 10 patients (5-15) that were mechanically ventilated during their residency. Most candidates (51/97, 52.6%) did not manage any renal replacement therapy cases during their residency. The median was 0 (0-4), and most candidates (54/97, 55.7%) had no cases where they acted as the primary surgeon; the median was 0 (0-3). Candidates reported attending a median of 3 hours (2-4) of didactic rounds per week, 80% of which (50-100) were attended by an ACVECC Diplomate. Candidates also reported attending a median of 7 hours (4-10) of cage-side rounds per week, 90% (60-100) of which were attended by an ACVECC Diplomate.

3.3 | Candidate subjective assessments

Candidate views on the examination and on their preparedness for the assessment were mixed. Most candidates (69/97, 71.1%) agreed that the examination fairly represented their residency training. Similarly, most respondents (61/96, 63.5%) agreed that their residency program had adequately prepared them for the examination, although a larger proportion (72/97, 74.2%) felt that their own studying had prepared them for the examination. Most candidates (71/97, 73.2%) felt that the examination had been fairly administered, but only 58 of 97 (59.8%) felt that the examination tested material crucial for an ACVECC Diplomate to know. Candidates successful at their first attempt were more likely to agree that their residency adequately prepared them ($P = 0.030$), that the examination was fairly administered ($P = 0.038$), and that examination tested material crucial for an ACVECC Diplomate to know ($P = 0.002$).

3.4 | Associations between variables

There was a strong positive correlation between candidate GPA and DVM class rank r_s 0.709 ($P < 0.001$), and a strong inverse correlation between the number of weeks on and off clinics r_s -0.705 ($P < 0.001$). There was a moderate correlation between candidate age and time since graduation, r_s 0.647 ($P < 0.001$). There was a mild correlation between the number of ACVECC Diplomates and the number of residents at the RTC, r_s 0.578 ($P < 0.001$). In addition, candidate subjective assessments of how well the exam represented the residency and how well the residency had prepared them were moderately correlated, r_b 0.603 ($P < 0.001$), while how well the residency had prepared them and whether the exam tested knowledge essential for a Diplomate of the ACVECC to possess were mildly correlated, r_b 0.539 ($P < 0.001$). All other significant correlations identified were weak (ie, coefficients < 0.5).

3.5 | Associations with first-attempt success

Univariate statistical analyses suggested that first-time success on the ACVECC examination was associated with a variety of candidate and training program factors (Table 1). Candidates more likely to pass on their first attempt were younger, graduated veterinary school and completed residency more recently, had a higher GPA, and a higher veterinary school class rank. Successful candidates on average spent fewer weeks on clinics, managed more mechanical ventilation and renal replacement therapy cases, and were not required to manage ER and CC cases simultaneously. Successful candidates were more likely to have trained at academic training centers with larger numbers of ACVECC Diplomates, more ACVECC residents, and greater numbers of other veterinary specialists. Successful candidates also spent more weeks studying prior to the examination.

Multivariable logistic regression modeling suggested that 5 factors were independently associated with first-attempt success on the ACVECC examination, specifically younger age, more weeks of study prior to the examination, training at a facility with more ACVECC Diplomates, training at a facility with more ACVECC residents, and having no requirement to manage both ER and CC cases simultaneously (Table 2). There was no evidence of multicollinearity within this model (all between variable $R^2 < 0.6$). The Hosmer-Lemeshow test statistic was 7.539 ($P = 0.480$), indicating that the model was well-fitted. The model had a Nagelkerke's R^2 of 0.718, suggesting that 71.8% of the variation in the data was explained by factors in the model, which classified 83.5% cases correctly. The AUROC for this model was 0.940 (95% CI, 0.896-0.983; $P < 0.0001$; Figure 1).

3.6 | Associations with academic residency programs

Numerous variables were significantly associated with an academic residency program (Table 3). Residents trained at academic centers

TABLE 1 Univariate statistical analyses of factors associated with first-attempt success. For clarity, only variables that were significantly different are displayed. Continuous variables are expressed as median (IQR), while ordinal variables as presented as n candidates per category

Variable	Passed 1st attempt (n = 58)	Did not pass 1st attempt (n = 39)	P-value	Statistical test
Age	31 (30-33.5)	35 (32-38)	<0.0001	M-W
Years since graduation	5 (4-7)	8 (6-9)	<0.0001	M-W
n, MV cases	12 (8.5-19.5)	6 (3-10)	<0.0001	M-W
n, RRT cases	1 (0-9.5)	0 (0-2)	0.0040	M-W
n, RTC specialties	12 (10-12)	7 (5-11)	<0.0001	M-W
DVM GPA	3.8-4.0: 21 3.6-3.79: 18 3.4-3.59: 7 3.2-3.39: 5 3.0-3.19: 2 2.6-2.79: 1 < 2.4: 1	3.8-4.0: 6 3.6-3.79: 7 3.4-3.59: 13 3.2-3.39: 9 3.0-3.19: 4 2.6-2.79: 0 < 2.4: 0	0.0017	M-W
DVM class rank	Top 5%: 14 Top 10%: 15 Top 20%: 14 Top 35%: 6 Top 50%: 7 Bottom 50%: 2	Top 5%: 3 Top 10%: 5 Top 20%: 13 Top 35%: 7 Top 50%: 5 Bottom 50%: 4	0.0088	M-W
Years since end residency	<1: 52 1-2: 6 2-3: 0 > 3: 0	<1: 12 1-2: 12 2-3: 8 > 3: 7	<0.0001	M-W
Study time (weeks)	<2: 0 2-4: 1 4-6: 10 6-8: 34 > 8: 13	<2: 12 2-4: 5 4-6: 17 6-8: 13 > 8: 3	<0.0001	M-W
n ACVECC Diplomates at RTC	1-2: 12 3-4: 27 ≥5: 19	1-2: 29 3-4: 8 ≥5: 2	<0.0001	M-W
n ACVECC residents at RTC	1-2: 2 3-5: 34 6-8: 13 ≥9: 9	1-2: 13 3-5: 17 6-8: 6 ≥9: 3	0.0023	M-W
RTC type	Academia: 47 Practice: 11	Academia: 13 Practice: 26	<0.0001	Fisher's exact
Managed ER and CC simultaneously	N: 19 Y: 39	N: 4 Y: 35	0.0142	Fisher's exact

Abbreviations: CC, critical care; ER, emergency receiving; GPA, grade point average; MV, mechanical ventilation; M-W, Mann-Whitney *U*-test; RRT, renal replacement therapy; RTC, residency training center; Y, years.

were younger, had higher GPA, and higher class ranks. Residents in academic training programs spent fewer weeks on clinics in total, were required to manage fewer CC cases per day, and were less likely to be required to manage ER and CC cases simultaneously. Residents in academic centers managed more mechanical ventilation and renal replacement therapy cases, yet managed fewer cases as the primary surgeon. Residents at academic centers had the opportunity to interact with a greater number of ACVECC Diplomates, ACVECC residents and other specialists, and spent more time in weekly didactic rounds. In preparation for the examination, residents trained at academic training centers spent more weeks studying.

4 | DISCUSSION

In the present study, first-attempt success on the ACVECC board certification examination was independently associated with both can-

didate and residency training center factors. Rationally, it might be expected that the most academically gifted residents, trained at programs that provided them with an excellent practical and theoretical education who were fortunate enough to be able to dedicate an extended period to self-study, are most likely to pass the certification examination. Indeed, multivariable modeling suggested that younger residents, trained in larger facilities with more ACVECC specialists and greater numbers of fellow residents, where they were able to concentrate on either emergency receiving or on the management of the critically ill or injured were more likely to successfully pass the certification examination at the first attempt. In addition, residents who had the opportunity to devote many weeks to private study prior to the ACVECC examination were also more likely to be successful.

A previous study identified an association between academic training centers and first-time ACVECC examination success⁴ but was unable to identify the factors that underpinned this association. The present study reconfirmed this association between academic

TABLE 2 Multivariable logistic regression model for first-attempt success

Variable	Model parameter estimate (ln OR)	SE	Wald statistic	P-value	Odds ratio	95% CI
Intercept [constant]	6.74	8038.6	0.00	0.999	847.07	–
Age (Y) (continuous)	-0.25	0.1	4.77	0.029	0.78	0.63-0.98
Weeks of study [Ref. category] ^a	–	–	12.67	0.013	–	–
Weeks of study [Cat. 2 vs Ref.]	15.31	40193	0.00	1.000	4.47×10 ⁶	0.00-∞
Weeks of study [Cat. 3 vs Ref.]	19.38	40193	0.00	1.000	2.60×10 ⁸	0.00-∞
Weeks of study [Cat. 4 vs Ref.]	21.20	40193	0.00	1.000	1.60×10 ⁹	0.00-∞
Weeks of study [Cat. 5 vs Ref.]	23.51	40193	0.00	1.000	1.63×10 ¹⁰	0.00-∞
n, DACVECCs [Ref. category] ^b	–	0.4	7.39	0.055	–	–
n, DACVECCs [Cat 2. vs Ref.]	1.40	0.9	2.28	0.131	4.06	0.66-25.01
n, DACVECCs [Cat 3. vs Ref.]	3.59	1.6	5.02	0.025	36.06	1.57-829.47
n, Residents [Ref. category] ^c	–	–	8.13	0.043	–	–
n, Residents [Cat 2. vs Ref.]	4.38	1.6	7.37	0.007	80.12	3.38-1898.0
n, Residents [Cat 3. vs Ref.]	3.98	1.9	4.49	0.034	53.60	1.35-2127.7
n, Residents [Cat 4. vs Ref.]	1.72	2.0	0.75	0.386	5.59	0.11-272.7
Managed ER+CC [Binary Y = 1, N = 0]	-3.70	1.5	6.09	0.014	0.03	0.00-0.47

Abbreviations: CC, critical care; DACVECC, Diplomate of the American College of Veterinary Emergency and Critical Care; ER, emergency receiving; ln, natural logarithm; OR, odds ratio; SE, standard error; Y, years.

^aThe reference category for weeks of study was < 2.

^bThe reference category for number of ACVECC Diplomates was 1–2.

^cThe reference category for number of residents was 1–2.

residencies and examination success and, moreover, identified multiple differences in the characteristics of both the residents and residency programs. Training center type was purposefully not included in the multivariable modeling of examination success to avoid confounding. All of the parameters that were independently associated with first-attempt examination success were also significantly different between training center types. Specifically, academic training centers had greater numbers of ACVECC Diplomates and residents in training; residents in academic centers were younger, were less likely to be required to manage ER and CC cases simultaneously, and spent more time studying prior to the examination. As such, the present study suggests that the association of examination success with training center type is due to associations with resident and training center factors.

Residents in academic centers may also enjoy other potential advantages that may further enable their success. Specifically, residents in academic training centers were responsible for fewer critical care patients and hence might have had longer to discuss, study, and assess each case. Residents in academic training centers also had more opportunities to manage mechanical ventilation and renal replacement ther-

apy cases. This might have provided them with tangible advantages if their ACVECC examination featured questions relating to the management of cases of respiratory failure or acute kidney injury. Residents in academic centers spent fewer weeks on clinics overall and were also more likely to be able to concentrate on either ER or CC on any given day rather than attempting to juggle the conflicting demands of 2 roles. This might have provided them with more opportunities to read and discuss the literature relevant to their cases, with the potential to improve clinical decision-making and knowledge retention.^{5,6} In addition, having a larger cohort of residents with whom to collaborate, work, and learn from might also be beneficial to those residents with converging learning styles who enjoy group work,⁷ while having more time for each case might aid those with assimilating learning styles who enjoy having opportunities to think things through.⁸

In the present study, resident age was inversely associated with first-attempt examination success; that is, residents who successfully passed the ACVECC examination at the first attempt were significantly younger than those who did not. Age has been examined as a variable in several similar studies in human medical specialties, with most studies

TABLE 3 Features of residents and residency training factors at academic training centers compared to those at private practice residency training centers. For clarity, only variables that were significantly different are displayed. Continuous variables are expressed as median (IQR), while ordinal variables as presented as n candidates per category

Variable	Academic residency (n = 60)	Practice residency (n = 37)	P-value	Statistical test
Age	32 (30.3-34.8)	35 (32-37.5)	0.0004	M-W
Weeks on clinics	36 (32-40)	40 (38.5-44.8)	0.0038	M-W
Weeks off clinics	12 (10-17)	12 (7.25-12)	0.0345	M-W
Years since residency	<1: 49 1-2: 8 2-3: 2 > 3: 1	<1: 151-2: 10 2-3: 6 > 3: 6	<0.0001	M-W
n, CC cases/day	4 (3-6)	5 (4-7)	0.0045	M-W
n, MV cases (total)	12 (8-20)	6 (3-10)	<0.0001	M-W
n, RRT cases (total)	2 (0-10)	0 (0-0)	<0.0001	M-W
n, Sx cases (total)	0 (0-1)	3 (0-10)	0.0002	M-W
n, RTC specialties	12 (11-12)	6 (4.5-8.5)	<0.0001	M-W
DVM GPA	3.8-4.0: 21 3.6-3.79: 18 3.4-3.59: 10 3.2-3.39: 5 3.0-3.19: 2 2.6-2.79: 0 < 2.4: 1	3.8-4.0: 6 3.6-3.79: 7 3.4-3.59: 10 3.2-3.39: 9 3.0-3.19: 4 2.6-2.79: 1 < 2.4: 0	0.0015	M-W
DVM Class Rank	Top 5%: 16 Top 10%: 15 Top 20%: 16 Top 35%: 6 Top 50%: 5 Bottom 50%: 2	Top 5%: 1 Top 10%: 5 Top 20%: 11 Top 35%: 7 Top 50%: 7 Bottom 50%: 4	0.0002	M-W
Study time (weeks)	<2: 0 2-4: 1 4-6: 13 6-8: 34 > 8: 12	<2: 12-4: 5 4-6: 14 6-8: 13 > 8: 4	0.0021	M-W
Rounds (h/week)	3 (3-4)	3 (2-4)	0.0169	M-W
n, ACVECC Diplomates at RTC	1-2: 15 3-4: 24 ≥ 5: 21	1-2: 26 3-4: 11 ≥ 5: 0	<0.0001	M-W
n, ACVECC residents at RTC	1-2: 5 3-5: 32 6-8: 12 ≥ 9: 11	1-2: 10 3-5: 19 6-8: 7 ≥ 9: 1	0.0075	M-W
Managed ER and CC simultaneously	N: 19Y: 41	N: 4Y: 33	0.0261	Fisher's exact test

Abbreviations: CC, critical care; ER, emergency receiving; GPA, grade point average; h, hours; MV, mechanical ventilation; M-W, Mann-Whitney U-test; RRT, renal replacement therapy; RTC, residency training center; Sx, surgical; Y, years.

finding no association.⁹⁻¹¹ In 1 study of maintenance of certification examinations, a negative association with age was identified, as was documented by Driscoll et al.¹² It is possible that younger residents are better able to study and retain the information required to successfully pass the board certification examination. It is also possible that this association is confounded by another variable, such as training center type. Our study methodology might also have contributed to this association because of the inclusion of a small number of candidates in the survey in 2016 who had already attempted the examination more than once and, hence, were older but whose response in 2016 was the first record available. Interestingly, a recent survey of well-being among veterinarians suggested that older veterinarians were more likely to have positive mental health.¹³ The present study suggests that time since

residency completion is associated with first-attempt examination success. It is reasonable to hypothesize that the time interval between the training and the examination designed to test the knowledge acquired during that training period is related. Comparably, delays in sitting the certification examination after completion of residency were associated with lower candidate performance on the American Osteopathic Board of Internal Medicine certification examination.¹⁴

In the present study, the duration of the period spent preparing for the examination was independently and positively associated with first-attempt examination success. Few studies have directly evaluated the impact of the duration of the study period on board certification examination success rates. One study of human radiologists suggests that a lower total number of months spent studying was associated

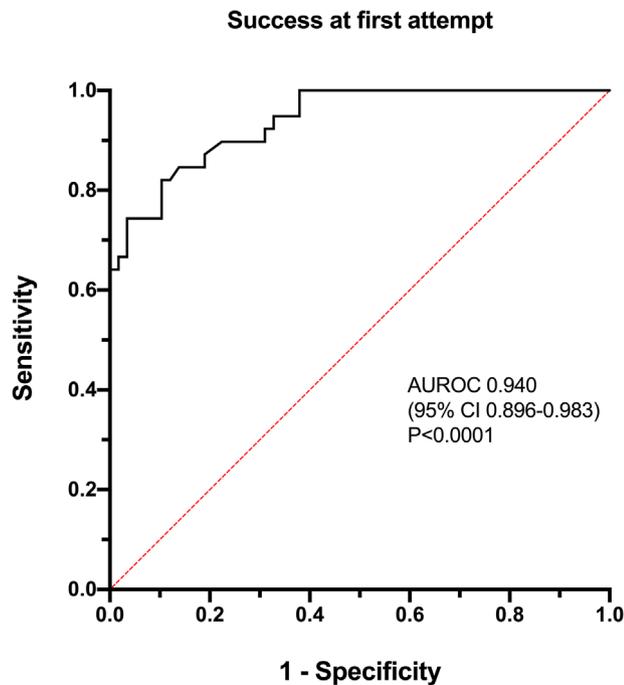


FIGURE 1 A receiver-operating characteristic (ROC) curve of the 5-factor multivariable model of first attempt success on the ACVECC board-certification examination. AUROC, area under the ROC curve; CI, confidence interval

with success.¹⁵ Although initially this would appear to run counter to the findings of the present study, the median duration of study in successful candidates on the ACVECC examination was 6 to 8 weeks. The authors of the study on the radiology examination concluded that short-duration, high-quality study was most effective, which would likely equate well with the 6 to 8 weeks common in successful candidates in the present study. In addition to the duration of the revision period, the type of preparation and the attitude to study and reading throughout the residency is likely also important to board certification examination success. In a study of general surgery residents, reading consistently for patient care throughout the year, a regimen of daily studying and use of textbooks was associated with higher in-training examination scores.¹⁶

The number of ACVECC Diplomates employed and the number of ACVECC residents training at the Residency Training Committee (RTC) were independently associated with first-attempt success. In human medicine, training within programs alongside larger numbers of other residents and other specialties increases the likelihood of success.¹⁷ This may reflect enhanced competition between residents and the benefits of cross-training, collaboration, and peer-learning/teaching that may result from training in a multidisciplinary facility.^{18,19} Program size has been positively correlated with examination success rate on board certification examinations for the American Boards of Family and Internal Medicine, Pediatrics, and Surgery.²⁰⁻²³ Hypotheses for this association include greater availability of resources to invest in curriculum development and learning materials and the ability to recruit faculty and educators with specific expertise, who are then encouraged

and incentivized to emphasize teaching and learning within academia. Similar findings to those of the present study have been reported for human physicians where examination success rates were positively associated with the ratio of full-time equivalent faculty to the number of residents.²⁴ That study also suggested that a formal mentoring program was positively correlated with success, something that the ACVECC has already adopted within its resident training guidelines.

Although substantially more females than males completed the survey, no gender bias was identified in success on the ACVECC examination. This is reassuring because gender bias in medical examinations using a true-false-abstain format has been previously reported.²⁵ Likewise, with negative marking, multiple-choice examinations in other fields are also biased in favor of males. The ACVECC examination does not employ true-false-abstain questions or use negative grading strategies. The ACVECC examination is not immune from potential gender bias; however, because the examination employs multiple-choice format questions that can favor males. Males may be more test-wise than females,²⁶ wherein some correct answers may be obtained through recognition of unintentional cues in the questions themselves such that performance is independent of the candidate's knowledge of the subject matter.^{27,28} In addition, females may change their answers more frequently than males²⁹ and may do so more frequently from incorrect to correct.³⁰

Previous academic aptitude as measured by the DVM GPA and DVM class ranking data was associated with success in the univariate analyses only. Various studies in human medical training suggest that previous academic performance is associated with examination success during and postresidency.^{16,31-34} However, concerns have been expressed in the medical literature about whether test performance should be used to guide resident selection,³⁵ particularly because single factors such as academic performance are not universally predictive of performance in residency.³⁶ Interestingly, while previous academic performance might predict first-attempt success, it may be a less valid predictor of successful completion of the examination across all residents.³³ In the human medical field, emergency medicine attracts above average candidates, although not those with the very best medical licensing examination scores.³⁷ Consistent with this, the ECC residents in the present study were very academically able, with more than half of residents reporting GPA values ≥ 3.6 , and correspondingly more than half of the residents were in the top 20% of their veterinary school classes.

The present study might offer valuable insights for residents and residency training programs seeking to maximize the likelihood of success on the board certifying examination. From a resident perspective, the data suggest that large training facilities with multiple ACVECC Diplomates, a large resident cohort and multiple other specialists may enhance their chances of success. Such residency training programs might also offer a balance of on- and off-clinics time, enable the development of skills in mechanical ventilation and renal replacement therapy, enable residents to focus on either ER or CC on any given day, and set aside plenty of time for rounds, board review sessions, and other didactic training sessions. From a residency training center perspective, selecting candidates with strong academic credentials may enhance the likelihood of success in the ACVECC examination. In this



regard, the findings of the present study are consistent with a study of human orthopedic residents that demonstrated performance on the US medical licensing examination, and the number of honors in medical school clerkships was positively correlated with American Board of Orthopedic Surgery examination scores.³⁸ There are several important caveats to the foregoing, however. The data presented here are associative, not causal. There is no guarantee that a highly qualified and academically gifted resident attending a residency training center that offers a comprehensive and balanced program will be successful on the examination. Likewise, it is absolutely possible for a candidate with a lower GPA or class rank training in a smaller facility with a single ACVECC Diplomate mentor without access to mechanical ventilation or dialysis to successfully pass the examination.

Other candidate, examination, and residency training center factors that were not evaluated or assessed here might play a role in determining the outcome of the examination process. For instance, candidates were not asked about race or ethnicity,^{39,40} access to childcare,²⁴ study locations,⁴¹ or burnout,⁴¹ yet all of these factors have been associated with outcome in medical board certification examinations. Other factors that have been considered in the medical literature that were not assessed in the present study include debt burden,⁴¹ salary,²⁴ vacation,²⁴ or hours of work. Additional investigation of these factors in veterinary residency programs within ECC and other specialties will be necessary to better gauge the association of these factors on residency training, examination success, and career paths.

It must be recognized that success on the ACVECC examination and excellence in clinical medicine are not synonymous. Residency training is a practical discipline involving the application of knowledge and the development of technical mastery. These elements are not assessed by the ACVECC examination and, hence, technical and medical excellence may be attained without success on a written test. The board certification examination serves as the gateway to a career as a recognized veterinary specialist. However, questions remain as to whether the board certification examination should be a rigorous and difficult capstone examination or whether successful residency training itself is the goal. Ultimately, it could be argued that training compassionate, empathetic, and skillful veterinary medical professionals is the overarching aim of residency training. In human medicine, there is some evidence that success on the board certification examination can predict important facets of residents' future careers, however. Career longevity of human residency-trained emergency physicians is associated with higher income, satisfaction with training decision, and with board certification in emergency medicine.⁴² Clinicians in physical medicine and rehabilitation who fail initial certification examinations are at higher risk of disciplinary action from a state medical licensing board during their careers.⁴³ Examination success and performance may influence future career earnings and job satisfaction in general internists.⁴⁴ Reassuringly, pharmacotherapy specialist examination candidates report that studying for the examination improved the care they provide,⁴⁵ while data from the human emergency medicine field suggests that residency-trained emergency physicians maintain medical knowledge over the course of their careers.⁴⁶

Ideally, residency programs would primarily equip trainees with the skills and expertise necessary for them to be effective, caring clinicians while also enabling them to comfortably pass the certification examination. In the short term, however, we speculate that first-attempt examination success is important to both residents and residency training centers. Arguably, for the ECC specialty and the veterinary profession as a whole, career longevity and satisfaction may be more important metrics than first-attempt examination success. It is unknown if residency performance or examination success rates correlate with other measures of career achievement in ECC, but this would be a worthwhile topic for future studies. Likewise, the potential impact on future career success or longevity of the amount of time spent on clinics or the development of expertise managing both ER and CC patients simultaneously during residency training is uncertain. The association between the type and structure of residency training programs and career success warrant additional study in order to better understand how to equip future ECC specialists with the skills necessary for a long and enjoyable career.

The multivariable model generated here was accurate, discriminating, and well-calibrated. From a modeling perspective, there was a high event to variable ratio within the dataset (11.6:1). Although multivariable modeling can combine factors to enhance accuracy and discrimination, the output from the modeling is only as good as the data included. In addition, a tightly fitted model reduces generalizability to other datasets. Multiple resident and training center factors were not explored in our dataset. It is possible that these factors play a role as large, or larger, than the factors incorporated into the assessments presented. The data presented are retrospective and, hence, model what happened previously and will not necessarily translate into future predictions. This is particularly important because the examination is not fixed but, rather, iterates and evolves every year; hence, the factors identified here may become more or less important over time. Most of the data quantified here and incorporated into the models were obtained from candidate surveys. Candidates were surveyed shortly after they completed their examinations and, in most cases, the same year as they completed their residency programs. However, there is a risk of incomplete, inaccurate, or biased recall. Candidates were surveyed prior to knowledge of their examination results to limit 1 source of bias; however, the answers provided may well have been influenced by their subjective assessments of the examination conduct and their subjective assessment of their likelihood of a successful outcome. To reduce recall bias, some survey questions directed candidates to provide information relevant to their most recent attempt at the examination, rather than their first attempt. It is possible that candidates adjusted their study methods or the duration of their study period in response to an unsuccessful attempt at the examination. This might have reduced the strength of association between certain candidate factors and first-attempt success rates. In contrast, associations between residency training programs factors and first-attempt success would not have been affected by the data collection methods used.

Some of the questions asked for objective data, such as class rank, while others, such as the 5 questions regarding residents' impressions of their residency training programs and the examination (Q17-21 on

the survey, Data S1), were inherently subjective. Such assessments were not incorporated into the multivariable models because of their subjectivity. However, even ostensibly objective data such as the percentage of time ACVECC Diplomates overlapped on clinics might have been colored by the candidates' perspectives on the overall quality of their training program, or by the passage of time. It should also be noted that the surveys requested information regarding the size of the residency training program, including the numbers of residents, Diplomates, and other specialists. The figure likely reflected the numbers of these personnel at the completion of the residency program, but it is possible that this figure changed during the residents' training, through growth and expansion of the program or through loss of colleagues and mentors as a result of retirement or turnover. Such changes might impact the strength of association between program size and examination success or might affect the efficacy of translation of this finding into strategies for residency training program success.

Participation in the survey was voluntary. Response rates were considered adequate, comparable with other surveys in the medical literature,⁴⁷ and were consistent across the 3 years of the present study. However, it should be acknowledged that the response rates were lower than the 60% rate recommended by some medical journals.^{48,49} This 60% value is a rule-of-thumb, without statistical basis, however. In general, as the survey response rate decreases, so increases the risk of nonresponse bias, although the risk may be overstated.⁵⁰ It might have been possible to increase response rates through combining a mailed survey with electronic follow-up.⁵¹ Response rates might also have been augmented by prenotification, repeated invitations, or the use of incentives.⁴⁷ None of these approaches were felt to be feasible, ethical, or achievable within the narrow time window during which the survey could be conducted (post-examination but pre-results). Importantly, none of the respondents to the survey knew what the outcome of their examination was at the time they completed the survey. This should have helped to reduce the impact of any biases in their responses, particularly when compared to an objective, binary outcome like examination success.

In conclusion, the present study suggests that numerous resident and training center factors are associated with first-attempt success in the ACVECC board certification examination. In particular, the number of ACVECC Diplomates and residents at the training facility, the amount of study time prior to the examination, and the opportunity to focus on either ER or CC cases appear to be independently related to success at the first attempt. A number of differences in both resident and training center factors were identified between academic and private practice programs that may underpin the previously documented link between academic training centers and success on the examination. Residents and residency training centers might be able to use the data presented here to enhance the training provided to residents and to maximize the likelihood of examination success, but caution must be exercised because these data are associative and not causal.

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ENDNOTES

^a Prism 8.4.1, GraphPad, La Jolla, CA.

^b SPSS 26, IBM, Armonk, NY.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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