Indicators of surgical stress and influence of clinical experience, simulation models, and cadaveric laboratory on the stress response of third-year veterinary students performing first elective surgery

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OBJECTIVE
To evaluate the role of simulation models and previous surgical experience on subjective and objective stress levels of students performing their 1st elective surgery within the veterinary curriculum.

SAMPLE
141 third-year veterinary students

METHODS
Using a pre–post experimental design, salivary alpha-amylase, and cortisol were evaluated as markers of physiologic stress response before students’ first elective surgery. Student self-reported State-Trait Anxiety Inventory (STAI) scores and quantitative measures of experience were correlated to biomarker results.

RESULTS
No association was found for change in salivary biomarkers of stress, alpha-amylase, and cortisol, between baseline and presurgical samples accounting for gender, age, type of elective surgery performed, previous surgical experience, or simulation model use. Salivary cortisol levels were markedly elevated falling between the 66th and 99th percentile compared to an age and gender-matched population. Salivary alpha-amylase levels were also 2 to 3 times higher than those recorded by other health professionals. Veterinary student STAI scores were high falling between the 65th and 73rd percentile compared to working adults in the general population.

CLINICAL RELEVANCE
Veterinary students’ salivary cortisol, alpha-amylase, and STAI scores fell into the upper 2/3rds of the general population, demonstrating a high level of stress. Simulation models and previous surgical experience were not associated with decreased stress. Further evaluation of the implementation of high-fidelity simulation models and the role of stress on performance is indicated.

Keywords: stress and learning, veterinary student education, cortisol levels, alpha-amylase levels, spay, and neuter

Stressful learning environments are inevitable in the health professions and impacts on student mental health can be significant. This impact has been reported at multiple levels in the workplace and has been shown to influence a professional’s mental health, efficiency, and quality of life. Eustress or acute stress can be correlated to manageable stress that falls within an individual’s coping mechanisms. This type of stress has been shown to increase efficacy and focus on a task. In contrast to eustress, distress can impair focus, memory, and motor skills. In some individuals, induction of stress can enhance short-term memory and improve performance. In others, stress can result in longer reaction times and impaired attentional processing. Research in human medicine demonstrates that distress can impair focus, memory, and motor skills. In a study by Arora et al, high levels of stress were measured subjectively through the State Trait Anxiety Inventory (STAI, MindGarden) and objectively using...
salivary cortisol levels.\textsuperscript{10} Results of this study correlated a high level of stress with an increased number of errors performed in a surgical trainer, increased time to perform surgical exercises and poorer instrument efficiency.\textsuperscript{10} Other studies have shown decreased concentration and declining motor skills in subjects placed in high-stress environments.\textsuperscript{6}

Cortisol is a hormone that is produced in response to stress from the hypothalamus–pituitary–adrenal axis (HPA).\textsuperscript{11} Cortisol rises and falls through natural circadian rhythms, external stressors, or periods of intense focus.\textsuperscript{11} Previous studies have demonstrated circulating cortisol levels in the bloodstream being equivalent to those in saliva and correlate well with stress exposure.\textsuperscript{5,12} Salivary amylase also serves as a biological marker of stress-reactive bodily changes.\textsuperscript{13} In some studies, salivary amylase levels were more significantly increased and reacted more rapidly than cortisol.\textsuperscript{14,15} A single veterinary study demonstrated a temporary decrease in student stress levels, particularly alpha-amylase (sAA), after a mindfulness activity before surgery.\textsuperscript{16} Hands-on surgical training is part of the program’s third-year veterinary curriculum and student feedback shows it as one of the most beneficial, although stressful, experiences students undergo. Further understanding of the baseline stress levels of veterinary students is required to assess the need for additional training resources. Baseline stress levels can then be used for future implementation of simulation models and tailoring of surgical training.

Currently, there is a paucity in veterinary literature describing the stress levels of students performing surgery. However, objective assessments of veterinary student stress levels have been investigated and depict alarming statistics.\textsuperscript{17,18} In 1 study, two-thirds of students reported feeling overwhelmed by the curriculum workload, and over half of the veterinary class reported difficulty sleeping, an inability to concentrate, chronic fatigue, and depression.\textsuperscript{17} In comparison to medical students, veterinary students report higher levels of anxiety and depression, affecting 50% of the surveyed class at admission.\textsuperscript{17,18} Levels of anxiety and depression were shown to increase throughout the first 3 semesters of the veterinary curriculum affecting up to 70% of students.\textsuperscript{18} Research suggests curricular changes and developing student resilience through targeted support programs may help alleviate veterinary student stress levels.\textsuperscript{18} However, further work is needed to develop programs to support veterinary student stress levels both in the classroom and on the clinic floor.

The primary aim of this study is to evaluate the stress response of third-year veterinary students performing their first elective ovariohysterectomy or castration surgery using the salivary biomarkers cortisol and sAA. The secondary aim of this study is to evaluate if the use of a low-fidelity vascular pedicle simulation model or primary surgical experience outside of the university, decreases veterinary student stress responses. The tertiary aim of the study is to compare perceived stress levels before performing surgery using the STAI survey, to objective measurements of sAA and cortisol as markers of physiologic stress. The authors hypothesize that students who have spent more time practicing with the vascular pedicle simulation model, or with more surgical experience outside the university, will demonstrate a subjective and objective decrease in stress response.

\section*{Methods}

\subsection*{Study design and data collection}

Study approval was obtained from the university’s Institutional Review Board (IRB #2021H0409) and written consent was obtained from all subjects. All 150 third-year Doctor of Veterinary Medicine students were invited to participate in the study. Students received enrollment information through email, an informational session at orientation, and through the small animal operative practice course’s online portal. Demographic data was provided voluntarily by participants and included gender and age.

Participation in the study required the collection of 2 salivary samples and the completion of 2 separate surveys. The STAI was used as a subjective marker of participant stress before the live surgery laboratory. Salivary cortisol and sAA levels were measured as objective markers of participant physiologic stress. The study was designed with a pre–post sample set up with participants serving as their own control for baseline levels of sAA and cortisol biomarkers. Participants were instructed not to eat or drink 60 minutes before salivary sample collection. A quantitative survey was administered before the live elective surgery session. This survey evaluated the number of hours and sessions utilizing the provided spay and neuter simulation models and hours of previous spay and neuter experience under the supervision of a licensed veterinarian. The study was divided into 2 phases. Phase I encompassed a cadaveric celiotomy laboratory that served as a baseline for participants before phase II, the live spay and neuter laboratory. The celiotomy cadaveric laboratories took place during weekdays during February 2022. The live spay and neuter laboratories took place from March through April 2022 and students were divided into groups attending a morning or afternoon session. Spay and neuter laboratories were placed toward the end of the spring semester and were completed before final exams. At the completion of the study, students received a $5 gift card for providing salivary samples and completing surveys.

\subsection*{Vascular pedicle simulation model}

Throughout the spring semester, from January to May 2022, students were provided access to a low-fidelity vascular pedicle simulation model (Figure 1). This model included the use of surgical instruments required for vascular pedicle ligation, an online video for step-by-step instruction, and access to clinical instructors for guidance. The model consisted of synthetic molds of the uterus, ovaries, kidneys, ureters, small and large intestines, and bladder. The organs were covered from view and ovarian pedicles were attached to the model to simulate removal of the
uterus using a spay hook, palpation of the suspensory ligament, and exteriorizing the ovaries and uterus for routine ovariohysterectomy. Use of the simulation model was recommended but not required.

**Phase I: cadaveric celiotomy laboratory**

In the first phase, all participants attended a cadaveric celiotomy laboratory in preparation for live spay and neuter laboratory sessions. Student goals for the laboratory included aseptic scrubbing, gowning, gloving, and draping, abdominal approach, abdominal explore, ovariohysterectomy, or prescrotal castration, and incisional closure. This laboratory served as each participant’s baseline for a pre–post study design. Before entering this cadaveric celiotomy laboratory participants signed consent forms and were oriented to the process of saliva collection. Sample collection occurred between 8–9 AM for the morning session and 12 noon–1 PM for the afternoon session. Saliva was collected using the passive drool method (Saliva collection aids and cryovials, Salimetrics). Saliva was collected over 1 minute with a goal collection volume of 75 μL for cortisol and 25 μL for sAA. Identifying features were removed from data samples and exchanged with numerical data. Samples were frozen at −20°C after collection.

Procedural techniques for orchiectomy and ovariohysterectomy were practiced in the cadaveric celiotomy laboratory in preparation for the live spay and neuter laboratories. Due to finite cadaveric resources, cadavers were not always able to be sized similarly to live patients. For orchiectomies, students performed a prescrotal neuter through a single skin incision using a scalpel blade and manual debridement of the spermatic fascia. A 3-clamp technique was used with 2 circumferential ligations for castration and closure was routine. For ovariohysterectomies, students performed a routine abdominal midline approach, the ovarian pedicles were ligated with a 3-clamp technique with 2 circumferential ligations. The broad ligament was manually broken down and the uterine body was ligated with 1 circumferential and 1 transfixing ligation. The abdomen was closed routinely. Students were required to check in with instructors (surgery faculty, laboratory faculty, and surgery residents) for essential portions of the procedure before advancing to the next step. Check points for orchiectomy included planning of skin incision, clamp placement for 3-clamp technique, evaluation for hemostasis of spermatic cord after transection of testicle and placement of ligations, closure of subcutaneous tissues, and closure of skin. Check points for ovariohysterectomy included planning of skin incision, confirmation of the linea alba before entering the abdomen, confirmation of the ovary and suspensory ligament before performing

![Figure 1](image-url) — (A) Vascular pedicle model with covering to simulate removal of ovaries and uterus for routine ovariohysterectomy. (B) Contents of vascular pedicle model to include suspensory ligament (SL), ovaries (OV), uterine body (UB), bladder (BL), ureters (UR), kidneys (KD), small intestines (SI), and large intestines (LI).
the 3-clamp technique, confirmation of hemostasis for ovarian pedicle, confirmation of hemostasis for the uterine stump, evaluation of closure of linea alba, subcutaneous tissue, and skin.

**Phase II: live surgery spay and neuter laboratory**

In the second phase, all participants attended a live spay and neuter laboratory. The inclusion of shelter animals in this teaching laboratory was approved by the university’s Institutional Animal Care and Use Committee (IACUC #2009A0012 – Veterinary Small Animal Teaching Protocol – Renewal 4). Students rotated through 3 roles as primary surgeon, assistant surgeon, and anesthetist. Surgical procedures (orchectomy and ovariohysterectomy) were performed as described above for the cadaveric celiotomy laboratory, which served as a surgical rehearsal for the live surgery laboratory. Three to 4 veterinarians (board-certified surgeons, surgical residents, and laboratory staff) and 3 to 4 veterinary technicians supervised 7 elective surgeries at a time. Students checked in based on the previously set check points before advancing to the next of the procedure. Groups with large intact canine spays received the most assistance from scrubbed in surgeons based on observed surgical performance and surgeon confidence. Surgeries and saliva samples were collected before scrubbing in, for the student in the primary surgeon role. Salivary sample collection, timeline, and storage were identical to the phase I laboratory. Participants concurrently filled out the STAI and a quantitative survey assessing laboratory simulation model use and spay and neuter primary surgical experience.

**Salivary cortisol and alpha-amylase analysis**

Once all participants had completed pre- and post-salivary sample collection, samples were shipped overnight on dry ice to the testing center for analysis (SalivaLab, Salimetrics). Samples were tested in duplicate, and results were provided in mean values. Cortisol levels were reported in ug/dL and sAA in U/mL. The reference range for salivary cortisol was derived from the laboratory’s reference ranges, current literature, and database for seasonal changes in diurnal salivary cortisol (CIRCORT). The reference range for sAA was derived from the laboratory’s sAA reference ranges and recent publications.

**State trait anxiety inventory survey analysis**

The STAI was administered before the live elective surgery laboratory (License to reproduce, MindGarden). The S-anxiety scale (STAI Form Y-1) consisted of 20 statements to determine how participants felt in a current stressful situation. Qualities evaluated by the STAI S-anxiety scale are apprehension, tension, nervousness, and worry. The T-anxiety scale (Form Y-2) consisted of 20 statements to determine how the participants would feel in a future stressful situation. After the completion of the surveys, identifying features were removed from data samples and exchanged with numerical data. S and T anxiety surveys were scored blindly. The reference ranges were determined from the STAI manual (minimum 20, maximum 80) and referenced publications.

**Statistical analysis**

Based on the results of a pilot study, a sample size calculation was performed to determine that 122 students/group would provide ≥80% power to detect a mean ± SD difference of 0.3 ± 0.1 between pre–post groups for cortisol levels. Descriptive statistics were used to report the characteristics of study participants. Paired t-test and Mann-Whitney U tests were used to determine differences between pre- and post-sAA and cortisol samples. ANOVA was used to compare simulation practice hours and primary surgical experience to physiologic parameters of stress at baseline. Repeated measures ANOVA was used to compare these and other variables with the change in physiologic parameters of stress from baseline to presurgical. Kendall’s τ B correlation was also performed to assess differences in subjective (STAI) and objective stress levels (sAA and cortisol variables). For all statistical analyses performed, \( P < .05 \) was considered to be statistically significant. Data analyses were completed using statistical analysis software (SAS version 9.4, SAS Institute). Cortisol values were converted from ug/dL to nmol/L for comparison to the CIRCORT database. A log-based algorithm for cortisol conversion into percentiles was completed using statistical analysis software (R project for statistical computing, The R Foundation).

**Results**

**Study population**

One hundred and forty-one students (94% of the class) elected to participate in the study with 118 female students (84%) and 23 male students (16%). The female-to-male ratio of the population was approximately 20:1. Students varied in age from 23 years to 44 years, with the mean student being a 26-year-old female. The majority of students were females between 21–30 years old (110 students, 78%), followed by males between 21–30 years (19 students, 13%), then females 31–44 years old (8 students, 6%), and males 31–44 years old (4 students, 3%).

**Vascular pedicle simulation model**

The majority of students, 76% (107 students), reported using the vascular pedicle simulation model. The minority of students, 24% (34 students), did not use the vascular pedicle simulation model. Two hours was the median time spent practicing with models. The number of hours students spent practicing with models is depicted (Figure 2).

**Prior surgical experience**

The number of hours of primary elective surgery experience (spay and neuter) under the direct supervision of a licensed veterinarian was self-reported by the 3rd year veterinary students. The majority of
students, 69% (97 students), reported primary elective surgery experience, while 31% (44 students) had not performed surgery before. The number of hours of prior surgical experience is depicted (Figure 2).

**Salivary cortisol**

The baseline and elective surgery laboratory mean (± SD) for salivary cortisol for males and females are depicted (Table 1). Percentiles were calculated using a conversion algorithm for comparison to the CIRCORT database (R Console, The R Foundation). For baseline cortisol samples, students fell between the 66th and 93rd percentile compared to an age and gender matched population. For live surgery cortisol samples, students fell between the 66th and 99th percentile for an age and gender matched population. The secondary aim of this study is to evaluate if the use of a vascular pedicle simulation model or primary surgical experience outside the university decreases veterinary student surgical stress responses. This aim was evaluated through univariate analysis (α = 0.05), which demonstrated that there were no influences on changes in baseline cortisol (presample) and live surgery cortisol levels (postsample) based on age, gender, type of surgery performed (spay or neuter), time of day (AM vs PM), previous live surgery experience, use of simulation model, and accounting for live surgery + simulation model experience (Table 2). Univariate analysis demonstrated a significant influence (P > .001) for time of day (AM vs PM) on baseline cortisol and live surgery cortisol levels. This correlation is depicted graphically for the baseline sample and live surgery cortisol samples (Figure 3).

**Alpha amylase**

The baseline and elective surgery laboratory means (± SD) for sAA for males and females are depicted (Table 3). Univariate analysis found that there were no influences on changes in baseline sAA (presample) and live surgery sAA levels (postsample) based on gender, type of surgery performed (spay or neuter), time of day (AM vs PM), previous live surgery experience, use of simulation model, and accounting for live surgery + simulation model experience (Table 2). Univariate analysis demonstrated an influence of age on change in sAA for the live surgery sample compared to baseline.

**State-Trait Anxiety Inventory**

The state anxiety and trait anxiety mean, SDs, and percentiles are listed (Table 4). This survey was taken by student surgeons before scrubbing in for the live elective surgery. Percentiles were calculated using the conversion algorithm in the State-Trait Anxiety Inventory for Adults Manual for comparison to published data. Students fell within the 66th through 73rd percentile for S-anxiety and 65th through 72nd for T-anxiety compared to an age and gender matched population.

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![Hours practicing with models](image1.png)

**Table 1**—Baseline and elective surgery laboratory means (SD) for salivary cortisol for males and females.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Baseline cortisol mean (µg/dL) ± SD</th>
<th>Live surgery cortisol mean (µg/dL) ± SD</th>
<th>Baseline cortisol percentile*</th>
<th>Live surgery cortisol percentile*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult males 21–30 (AM)</td>
<td>8</td>
<td>0.6 (0.2)</td>
<td>0.4 (0.2)</td>
<td>79</td>
</tr>
<tr>
<td>Adult males 21–30 (PM)</td>
<td>11</td>
<td>0.2 (0.1)</td>
<td>0.3 (0.17)</td>
<td>86</td>
</tr>
<tr>
<td>Adult females 21–30 (AM)</td>
<td>57</td>
<td>0.5 (0.3)</td>
<td>0.5 (0.27)</td>
<td>76</td>
</tr>
<tr>
<td>Adult females 21–30 (PM)</td>
<td>53</td>
<td>0.2 (0.1)</td>
<td>0.2 (0.1)</td>
<td>86</td>
</tr>
<tr>
<td>Adult males 31–44 (AM)</td>
<td>2</td>
<td>0.7 (0.3)</td>
<td>0.5 (0.37)</td>
<td>93</td>
</tr>
<tr>
<td>Adult males 31–44 (PM)</td>
<td>2</td>
<td>0.2 (0.2)</td>
<td>0.2 (0.16)</td>
<td>87</td>
</tr>
<tr>
<td>Adult females 31–44 (AM)</td>
<td>4</td>
<td>0.3 (0.1)</td>
<td>0.5 (0.11)</td>
<td>66</td>
</tr>
<tr>
<td>Adult females 31–44 (PM)</td>
<td>4</td>
<td>0.2 (0.1)</td>
<td>0.3 (0.06)</td>
<td>87</td>
</tr>
</tbody>
</table>

Percentiles were calculated using conversion algorithm for comparison to the CIRCORT database (reference ranges and seasonal changes in diurnal salivary cortisol).

* Data converted to nmol/L and median values for percentile analysis comparison with CIRCORT database.
The tertiary aim of the study is to compare perceived stress levels before performing surgery using the STAI survey, to objective measurements of sAA and cortisol as markers of physiologic stress. This comparison was performed using Kendall’s τB correlation. There was no correlation between sAA levels at the time of live surgery laboratory and STAI survey results. There was a weak positive correlation between salivary cortisol levels at the time of live surgery and S-anxiety STAI survey levels with $P = .05$.

**Discussion**

This study evaluated the stress response of third-year students performing their first elective spay or neuter surgery in veterinary school. Despite clinical suspicion, student practice with the vascular pedicle simulation model and additional primary surgical experience outside the university did not demonstrate a subjective or objective decrease in stress response, rejecting the author’s hypotheses. Furthermore, no associated change in cortisol stress levels was found when comparing baseline levels to live surgery laboratory levels accounting for gender, age, or type of elective surgery performed. sAA similarly did not demonstrate associated change when comparing baseline levels to live surgery levels accounting for gender or type of elective surgery performed. However, sAA univariate analysis demonstrated the influence of age on change in sAA for live surgery samples compared to baseline. This finding was unexpected as changes have been reported with age and sAA in infants and toddlers with developing immunity but not in adults in several studies.23,24 Due to the discrepancy between the current study and the sAA literature, the authors acknowledge the correlation between sAA and age may be erroneous.
and attributed to potential sampling error or single timepoint evaluation.

sAA was evaluated as a salivary biomarker to determine changes in activation of the sympathetic nervous system, in response to a stressful surgical event. Health professions research has supported sAA as a surrogate marker for stress response with excellent reliability and stability.\(^\text{25,26}\) Baseline sAA levels were extremely elevated in this study compared to reported values in the literature. Veterinary students’ baseline for sAA was 160 U/mL, which is 3.3X higher than baseline levels reported in 1st year law students.\(^\text{29}\) These values are 2X higher and 1.3X higher than baseline values for male and female army nurses.\(^\text{27}\) However, baseline and presurgical values collected from veterinary students were equivalent to army nurses before a high-fidelity combat casualty simulation.\(^\text{25}\) sAA has recently entered the veterinary literature reported in a single study evaluating veterinary students and stress before and during elective surgery.\(^\text{16}\) The pilot study for veterinary students demonstrated a 1.3X increase in median sAA before surgery compared to the current study’s presurgical sample.\(^\text{33}\) Differences in sAA levels between veterinary students at different universities may be due to variations in sample size, sample processing, or environmental conditions. Nonetheless, these veterinary studies demonstrate an alarming concordance for stress levels 2 to 3X higher than other professionals and the general population.\(^\text{16,25,27}\)

Cortisol is elevated in times of stress through HPA axis activation.\(^\text{11}\) Salivary sampling has been demonstrated to have reliability and validity in detecting cortisol levels.\(^\text{7,28}\) Cortisol follows a circadian rhythm with the highest detectable levels found after an individual has woken up.\(^\text{29}\) Levels slowly decline throughout the day and are lowest while sleeping.\(^\text{29}\) Authors results replicate naturally occurring circadian rhythms in healthy individuals with significantly higher cortisol levels detected in morning laboratory sessions compared to afternoon laboratory sessions (Figure 3).\(^\text{20}\)

Cortisol has been evaluated in varying populations and workplaces.\(^\text{20,27,50}\) Tseng et al evaluated cortisol levels as a stress correlate for 3rd-year medical students in clinics.\(^\text{30}\) Presurgical cortisol values of veterinary students were 5X higher than those detected in 3rd-year medical students on surgery rotations.\(^\text{30}\) Similarly, veterinary students demonstrated 3X higher baseline cortisol values than novice human surgeons performing initial laparoscopic simulation procedures.\(^\text{31}\) One difference in curricular comparison that could explain these findings is that 3rd-year veterinary students have a significantly higher level of primary surgical responsibility than 3rd-year medical students. In the 3rd year of veterinary school students frequently learn how to perform elective spay and neuter procedures. On completion of their clinical year, 4th year, graduates are expected to have a level of surgical proficiency for decision-making and performance of first-line surgical techniques.\(^\text{32}\) This is in contrast to 3rd-year medical students who may be exposed to virtual surgical cases and real-time patient care but are not tasked with primary surgeon responsibilities until residency or fellowship training.\(^\text{33}\) Although potentially explained by the difference in surgical roles, the elevations of cortisol levels are extensive and concerning for extreme stress levels present in veterinary students. In comparison to baseline levels of cortisol in army nurses, veterinary students’ baseline cortisol is 2X higher.\(^\text{27}\) When compared to army nurses before an active combat simulation, cortisol levels in veterinary students were persistently 1.5 to 2X higher.\(^\text{27}\) To date, salivary cortisol levels have been evaluated in 1 other veterinary student study.\(^\text{16}\) Median salivary cortisol levels before surgery were similarly elevated between Stevens et al and this study with veterinary students falling between the 76th through 95th percentile compared to an age-matched population (CIRCORT database).\(^\text{16,20}\) The current study demonstrated veterinary students falling into the 76th percentile for female and 86th percentile for male veterinary students. Variations in cortisol stress percentiles between studies may be attributed to samples taken before surgery in comparison to a true baseline. Variations in sample size, gender, and environmental factors.\(^\text{16}\)

This study did not demonstrate a decrease in cortisol or sAA levels secondary to exposure to a low-fidelity simulation model (Figure 1) or previous primary surgeon experience. Although cortisol and sAA levels were not directly evaluated during the use of simulation models, the effects on baseline stress levels and live surgical stress levels were not significant. Low-fidelity simulation, student self-reporting of model use, and unknown level of deliberate practice are factors authors contribute to the lack of significance and validity of simulation models in this study.

Simulation models provide an avenue for experiential learning with repetition of technical skill sets and communication skills.\(^\text{34,35}\) Furthermore, high-fidelity simulation models have been shown to decrease the incidence of medical errors in varying clinical situations.\(^\text{10,36}\) Studies demonstrate the degree of stress evoked by a high-fidelity simulation model is greater than a low-fidelity simulation model.\(^\text{37,38}\) Increased anxiety and emotional response provoked by medical simulation contribute to learning, cognition, and memory.\(^\text{38}\) Simulation models have been especially successful in adult learning models for medical professionals.\(^\text{39}\) Studies evaluating general human surgeons demonstrate stress affecting technical and nontechnical skills in the operating room.\(^\text{40}\) Training for human anesthesia residents has accommodated for situational stress through high-fidelity simulation models leading to improved performance and exposure to less common life-threatening situations.\(^\text{41}\) The veterinary literature has limited information describing the role of stress on surgical performance. Recently, implementation of a high-fidelity canine simulation model (SynDaver Surgical Canine, SynDaver Labs) has been implemented into select veterinary programs.\(^\text{42}\) Au Yong et al demonstrated an increased confidence level, knowledge of the steps of the procedure, and fewer loose ligations when used for an ovariohysterectomy.
simulation for veterinary students before elective live surgery. Authors support continued implementation of high-fidelity models for further evaluation of effects on surgical performance and stress levels in veterinary students.

The STAI was evaluated as a subjective parameter for evaluating stress levels in veterinary students. The S-Anxiety scale detects feelings of apprehension, tension, nervousness, and worry and increases with psychological stress. The T-anxiety scale reflects the probability that S-anxiety will be experienced in the future and correlates to future responses to stress. Individuals with high levels of S- and T-anxiety tend to interpret wider ranges of situations as anxiety-inducing and are more likely to respond with high emotions in stressful situations. Veterinary students scored between the 66th and 73rd percentile for S-anxiety levels compared to a working adult population. Students scored equally high in T-anxiety percentiles ranging from 65th to 72nd percentiles. These results demonstrate a set of learners with high self-reported stress levels within the upper 2/3rds of levels found in working adults. Clinically, authors have appreciated behavioral changes associated with high stress in the majority of veterinary students during the live surgery laboratory. Most commonly observed behaviors include an inability to recall previously mastered information, loss of motor skills under pressure (eg, hand ties, ligations), and lack of ability to discuss the next steps of surgical procedure (eg, ovariohysterectomy, prescrotal castration). A comparison of current STAI scores to other health professionals confirms an alarming level of anxiety in veterinary students with an average S-anxiety score of 44 and T-anxiety score of 38. These anxiety levels are similar to nurses working through the COVID-19 pandemic and nursing students caring for terminal patients.

A weak positive correlation was found between students’ S-anxiety scores and live surgery salivary cortisol levels. The literary review demonstrated mixed results with several studies demonstrating a negative correlation between high STAI and low cortisol levels. Other studies found a correlation with elevated sAA and high STAI scores but no correlation to cortisol levels. Van Eck et al found a similar weak positive correlation to the current study between high STAI anxiety levels and small but significant cortisol elevations in a population of working adults. Schlotz et al showed subjects scoring higher on STAI may process stressful information in a way that induces responses of the HPA axis producing elevated cortisol levels in the face of higher performance pressure. The variation in the literature and current study may be explained by inaccurate STAI reporting and sampling of cortisol and sAA at a single time point, which may have not detected peak and trough levels of salivary biomarkers. Further research is needed to understand the relationships between perceived anxiety and stress, the effects of performance pressure, and the induction of the HPA axis.

Overall, veterinary students showed markedly elevated cortisol levels, sAA levels, and STAI scores relative to the general population. Male veterinary students were in the 86th percentile and female veterinary students were in the 76th percentile for cortisol levels when matched to the general population. STAI anxiety scores were similarly elevated in the 66th percentile for males and 73rd percentile for female veterinary students when compared to age-matched working adults. These results place veterinary students in the upper 2/3rds of the general population for cortisol and anxiety levels, signifying learners with high levels of sustained stress. As educators, this brings stress and learning into the conversation. Previous studies demonstrated exposure to stress results in excessive circulating levels of glucocorticoids, which influence cognition in humans and animals. Individuals with high cortisol levels have impaired selective attention, decreased performance in working and declarative memory, and difficulty discriminating relevant and nonrelevant information. An inverted U-shaped relationship, Yerkes-Dodson law, describes relationships between stress levels and cognitive efficacy. This concept describes a moderate state of stress that results in peak efficiency for the learner compared to low or high extremes resulting in decreased cognitive efficiency. Cognitive appraisal theory works to explain different responses evoked in individuals in response to stress. The basis of cognitive appraisal theory describes the process of how an individual assesses the demands of the environment and then determines if resources are available that can be applied to the situation. If resources are found to be equal to, or in excess of what is required, the individual recognizes the situation as a challenge. The outcome of this situation frequently results in a gain of increased learning or self-esteem. However, if resources are insufficient, the participant regards the situation as less controllable and a threat. Significant variability between individuals has been found in response to stressors and performance.

Although veterinary students in this study have similarly elevated stress levels, variability between individuals in response to stress requires teaching tailored to maximize learner outcomes. Guadagnoli et al describe maximizing learner outcomes through a challenge point framework. This theory describes a target challenge level within the student’s skill level. This level optimizes and increases to match the individual’s learning curve and skill set. However, challenges of decreased student effort and learning have been associated with a challenge point below the learner’s skill level and a student feeling distressed and overwhelmed associated with a challenge point is above a learner’s skill level. As educators, cognitive and technical objectives must be appropriately challenging and inducive of moderate stress, for optimal learning outcomes to be achieved.

Overall, the findings of this study demonstrate an extensive degree of stress in veterinary students. Instructors must consider these elevated stress levels and implement ways to reduce learner stress in the face of a challenging curriculum. One avenue beginning to be explored in a veterinary setting is
resilience and a further understanding of resiliency training. Resilience is the ability of an individual to function in a stressful environment, adapt to adversity positively, and bounce back in the face of challenges. Mansfield et al described a multifaceted foundation of resilience to include requirements for personal and contextual resources, problem and time management strategies, and positive resilience outcomes. Two factors shown to be associated with individuals with higher resilience were mindfulness and self-compassion. Unfortunately, these characteristics were not found commonly in a population of veterinary students with only 5% categorized as having high resiliency and 30% falling in the lowest resiliency category. These statistics demonstrate a set of learners requiring additional resources and support. To overcome similar challenges for medical students, forms of Mindfulness Based Stress Reduction (MBSR) programs have been implemented. Although not yet applied to a veterinary setting, future implementation of MBSR programs and resiliency training may provide additional support and help decrease stress levels in a veterinary student population.

Limitations of this study include a single pre–post model data set for stress levels of veterinary students at a single university. Furthermore, this study was performed with a predominantly female population with a smaller number of participants being male and older than the average veterinary student. Although reflective of the current veterinary student population, this could make comparisons for these smaller groups of students less accurate. Students were not required to disclose prescribed medications and were requested not to eat or drink for 1-hour before testing. This lack of medication disclosure and lack of direct student observation 1 hour before sample collection, could have affected cortisol and sAA results. Additionally, baseline and live surgery laboratory salivary samples were taken as close to the same time point as possible to account for cortisol degradation based on natural circadian rhythms but despite best efforts, sample collection timing ranged from a minimum of several minutes between sessions to up to 1 hour. A single sample of saliva was collected at the cadaveric celiotomy and live surgery laboratories. Although run in duplicate for testing for each sample, multiple salivary samples collected at each laboratory could have detected more subtle changes in stress biomarkers. Blood pressure and heart rate were also not measured during the baseline laboratory or live surgery laboratory and could have provided a further correlation for students’ stress evaluation. Furthermore, baseline cortisol and sAA levels were taken during a cadaveric laboratory session. Authors acknowledge this may not have represented a true baseline for students compared to levels at home. However, due to strict timing for sample collection and sample processing, baseline samples were elected to be taken at the university. Another limitation of this study was that student stress levels were only evaluated as the primary surgeon and comparison of stress levels induced through the roles of assistant surgeon and anesthetist were not evaluated or compared in this study. Furthermore, the effect of a scrubbed in surgeon assisting students with elective surgical procedures was not evaluated, and whether the surgical support added or relieved stress for the surgeon could not be accurately determined. Veterinary students’ opinions were also not surveyed on strategies or techniques they felt could help improve stress levels. Additionally, the authors acknowledge student self-reporting of STAI survey, quantitative survey, and model use as further limitations of this study.

In conclusion, this study did not find a significant effect for changes in cortisol or sAA biomarkers of stress from baseline to elective live surgery based on gender, type of elective surgery, low-fidelity simulation model use, or previous primary surgeon experience. However, salivary cortisol levels and STAI placed veterinary students in the upper 2/3rd of the general population for cortisol and anxiety levels, signifying a population of learners with high levels of sustained stress. Medical education literature supports the implementation of simulation models, maximizing learner outcomes through a challenge point framework, and further evaluation of the role of stress on performance and learning. Veterinary educators must continue to adapt curricula and implement strategies shown to be successful within other health professions. Further research on stress, anxiety, and learning is required within the veterinary field to understand their implications, aim to find methods to decrease perceived stress, and support the development of the next generation of veterinarians.

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