Predictors of Clinic and Appointment Duration in a First-Come-First-Served, Student-Run, Free Medical Veterinary Clinic

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Abstract

Background: The Midwestern University College of Veterinary Medicine hosts student-run clinics that offer free veterinary services to underserved populations. This study sought to determine predictors of clinic and appointment durations and the feasibility of a capacity-based scheduling system using factors identified prior to physical examination.
Methods: Medical records, appointment duration, clinic duration, number of patients and number of owners were collected for 20 clinics over 21 months. Detailed patient signalment, history, and physical examination findings were coded for all clinics. Clinic duration was analyzed via linear regression. Appointment duration was analyzed via multiple multilevel mixed-effects linear regression clustered on date.
Results: There were 385 appointments, with 301 (78%) having complete start and end times. Median clinic duration was 8 hours (interquartile range [IQR] 2.7-3.5), with number of patients (B=5.4, p=0.001) being predictive, and estimated optimum number of patients being 16-17 in order to maximize patients seen while minimizing the chance of exceeding 2.5 hours for the clinic. Median appointment duration was 20 minutes (IQR 13-30), with the number of current concerns expressed by owner (B=1.8, p=0.005), number of abnormal findings on physical examination (B=1.9, p<0.001), number of procedures (B=3.0, p<0.001), number of tests (B=4.3, p=0.015) and appointment position (B=-0.8, p<0.001) being significant.
Conclusions: No variable available at check-in was found to explain more than 3% of the variation in appointment duration, and no variable available after the comprehensive history-taking process was found to explain more than 14% of variation. Even models that incorporated multiple variables from all stages were only able to explain one-fourth to one-third of the observed variation for either appointment or clinic duration. It is unlikely that a rubric constructed from information available prior to physical examination would be more helpful than number of patients, which explained 61% of clinic duration, for capacity-based scheduling.

Introduction

The Midwestern University College of Veterinary Medicine hosts monthly student-run clinics via the campus-wide interprofessional program, Health Outreach through Medicine and Education (HOME), that offer free veterinary services to medically underserved populations in the Phoenix metropolitan area.[1] This clinic is one of several university-based, student-run, veterinary clinics that operate in a similar manner, including the University of Minnesota College of Veterinary Medicine Veterinary Treatment Outreach for Urban Community Health (VeTouch) program[2] and the University of California Mercer Veterinary Clinic for the Homeless.[3] Clinics are conducted on a first-come-first-served (FCFS) basis by veterinary students under the guidance of an attending veterinarian. Urgent and emergent procedures are rare and handled on an as-needed ba-

sis. The clinic is scheduled from 6:00pm to 8:30pm and takes place on a mobile veterinary clinic that can accommodate three to four patients for examination at once. Due to high demand from pet owners, many of whom arrive at the clinic location hours before start time, volunteer non-medical personnel (NMP) create the appointment roster prior to arrival of veterinary personnel so that patients can be turned away in a timely manner once clinic capacity is reached. Teams of veterinary students, typically composed of one first-year student paired with a more experienced upperclassman, take a medical history for each patient, including current owner concerns and requested services. Patients are then examined by the same team, who present their findings, medical assessment, and plans for diagnosis and treatment to the attending veterinarian. The team executes the plan after approval.

The duration of medical case appointments can vary widely given the variability in conditions seen, which range from healthy animals in need of vaccines to sick animals with multiple health complaints.[4] While procedures that involve sedation are typically scheduled for surgical days that occur every other month, urgent or emergent cases that cannot be deferred occasionally present for care and are treated. Prediction of appointment duration is important in order to maximize the number of patients seen while allowing for an on-time conclusion of the clinic. An accurate rubric can also be used to incentivize or disincentivize cases in order to optimize the mix of cases available for student learning or encourage cases that are particularly beneficial for education. In addition to accuracy, it is important that a rubric is simple enough to be effectively deployed by NMP and students. Success with a rubric for scheduling surgical cases on the mobile clinic that was both simple and accurate inspired the attempt to do the same for medical cases.[4,5]

There is limited research on factors that aid in the prediction of FCFS clinic appointment duration, particularly in the veterinary literature, as most studies have focused on predicting attendance or human medical treatment duration rather than appointment length.[6–8] However, several studies in the human literature have found predictors of appointment duration suggesting the potential for the same in veterinary medicine.

A previous study suggested that the length of a patient's medication list has some ability to predict the duration of a pre-anesthetic appointment, demonstrating the potential utility of a history-based factor.[9] Another study of dental appointment duration found physical examination-based factors such as the presence of blood on probing, the number of teeth versus the number of implants, and the number of dental caries to be significant in the determination of periodontal maintenance appointment duration.[10]

There are three stages where factors contributing to appointment, and therefore clinic, duration can be assessed: patient check-in by NMP, the taking of a simplified history oriented mainly towards signs of disease by veterinary students, and physical examination (PE), referenced hereafter as check-in, history, and PE stages, respectively. Previously, a rubric predicated on the owner's presenting complaint and applied by NMP at check-in was employed by this clinic in an attempt to maximize the capacity-based scheduling. This rubric assigned a point value based on estimated complexity where 1-point appointments were the least complex (vaccine only), 2-point appointments were moderately complex (one medical concern), and 3-point appointments were the most complex (two or more medical concerns). Clinic capacity was determined by estimated appointment duration (20, 40, and 60 minutes for 1, 2, and 3 points, respectively) instead of absolute patient number. However, this rubric, which was able to only discriminate between the most simple and most complex appointments, was found to not be clinically useful for predicting appointment duration.[11] It was unclear whether the failure of this system was due to misapplication of the rubric by NMP, inaccurate reporting of presenting complaint by the owner, or failure of the rubric to employ variables predictive of actual appointment duration.

This study aimed to determine predictors of clinic and appointment duration to understand factors contributing to clinic capacity and to evaluate the feasibility of a capacity-based scheduling system using factors identified at the check-in or history stages of a patient encounter. A secondary aim was to determine which of the previously suggested causes might be responsible for failure of the previous rubric.

Methods

Veterinary medical records collected from March 2017 to November 2018 via the HOME program were included in this study. The first seven (March 2017 to September 2017) of the 20 clinics had point values assigned by NMP using the previously employed rubric,[4] while the remainder of the clinics did not have points assigned by NMP since the use of the rubric was discontinued after September 2017. All medical records used the Subjective, Objective, Assessment, Plan (SOAP) format.[11]

Predictors of Clinic Duration

Variables related to clinic duration were extracted from the records, including total clinic duration (from first appointment start time to final appointment end time), month of year (analyzed as both month and academic quarter), the total number of patients, and the total number of clients.

Predictors of Appointment Duration

Appointment duration was determined using encounter start (prior to history-taking) and end time (post-discharge) which were explicitly recorded in fields on the medical record. Variables available at check-in included patient species, sex, weight, age, and the number of patients per owner; owners may bring up to two animals or one full litter. History and requested service variables included number of requested vaccinations; request for microchips; and various owner-reported numbers of which are recent signs of illness, recent changes, and current concerns; and the total of these three owner-reported history variables. Recent signs of illness included sneezing, coughing or eye/nose discharge, and vomiting/diarrhea; recent changes included weight, activity, eating, drinking, and other; and current concerns included previous history relevant to current condition, presenting complaint(s), and requested service. A variable for the position of the patient's appointment in the appointment roster was also coded.

Examination variables included number of abnormal findings, caution status (concern that animal may bite), number of vaccines given, insertion of a microchip, number of diagnostic tests performed, number of services performed, number of medications administered, and number of medications dispensed. A variable was also created for the total procedures performed which summed the number of vaccines, microchip, diagnostic test, services, and medications administered.

Analyzing the Failure of the Discontinued Rubric

In order to determine whether the failure of the rubric previously employed by NMP to estimate appointment duration[4] was due to misapplication of the rubric by NMP or inaccurate reporting of presenting complaint by the owner, point values of 1 to 3 were assigned by two veterinary students experienced with the clinics (CB, LA) by retrospectively applying the complexity rubric to the information determined at the history (history points) and at the PE (PE points) stages.

Statistical Methods

Each appointment and clinic variable was visualized in relation to duration with scatter plot or boxplot and analyzed via regression using Stata 16 (StataCorp, College Station, Texas). Clinic variables were evaluated with univariable and multiple linear regression. Appointment variables were evaluated using univariable and multiple multilevel mixed-effects linear regression clustered on date and using the robust estimator of variance to control for unmeasured variables associated with clinic date. Variables with $p<0.20$ in univariable analyses were included in multiple variable analyses and models generated from backward stepwise regression. Competing multiple variable models were compared using Akaike information criterion (AIC), Bayesian information criterion (BIC), and estimated coefficient of determination (R^2) to determine the best quality model, and the use of random-effects parameters validated through a likelihood ratio test. The residuals were analyzed to identify those exceeding |2| and leverage for the clinic model was examined to identify observations with strong influence on regression coefficient estimates ((2 * predictors + 2)/number of observations). Multiple regression models were evaluated for multicollinearity using variance inflation factors (VIF). Records missing variables included in a given model were dropped from that model. The duration for each

points category (NMP, history, PE) was compared via Wilcoxon rank sum test to its estimate. Points assigned by NMP were compared to history points and to PE points, as well as history points to PE points using paired-samples sign tests to determine whether points assigned by the previously employed complexity rubric varied according to stage. A p-value of <0.05 was considered significant for all tests besides the univariable analyses used to build the multiple variable models.

This study was conducted as part of quality improvement efforts designed to improve delivery of veterinary medical care via FCFS clinics scheduled by Midwestern University College of Veterinary Medicine's mobile clinic and thus Institutional Review Board approval was not required.

Results

There were 20 clinics with a sum of 385 patient appointments held during the 21 months of study. Of these visits, 301 (78%) had both start and end times recorded. Four animals could not be examined due to temperament and were thus excluded from analyses involving examination findings. Patient demographics and appointment characteristics are described in Table 1. A subset of these appointments, 79 (26%), from the first seven clinics that had points values assigned by NMP was used for investigating hypotheses regarding why the previous rubric had failed. Median clinic duration was 2.1 (interquartile range [IQR] 2.0-3.1) hours and median appointment duration was 20 (IQR 13-30) minutes (Table 2).

Predictors of Clinic Duration

For clinic duration, the number of patients was significant (B=7.2, p=0.001) after removal of two outliers with high deleted t residuals and two values with high leverage, which also yielded the highest adjusted R^2 (0.61) and lowest AIC and BIC values as compared to models including any or all of the excluded values. A scatterplot of clinic duration by number of patients overlaid with a best fit line that excluded the two outlier and two high leverage clinics yielded an estimated optimum number of patients of 16-17 based on where the best fit line and the lower bound of the 95% confidence interval crossed the desired 150-minute

duration (Figure 1). Only the lower bound of the 95% confidence interval was considered due to the desire to maximize the number of patients seen. The number of owners, month of year and academic quarter were not significant.

Predictors of Appointment Duration

Variables found to be predictors of appointment duration in univariable analysis at the p≤0.20 level (Online Appendix) were further examined via multiple regression. In multiple variable analysis of appointment duration, exclusion of an outlier with high standardized residual and use of clinic date as a random effect yielded the highest quality models. The best model based on lowest BIC value and AIC value not more than two greater than the lowest AIC value included appointment position (B=-0.8, p<0.001), total procedures performed during PE (B=3.0, p<0.001), number of abnormal findings on PE (B=1.9, p<0.001), number of current concerns expressed at history taking (B=1.8, p=0.005), and the number of tests performed during the PE (B=4.3, p=0.016) and had a R^2 of 0.35 for level 1 and 0.28 for level 2 (Snijders/Bosker). The maximum VIF for any of the competing models was less than 1.5, indicating an absence of multicollinearity.

Analysis of the Failure of the Discontinued Rubric

The median NMP points value was 1 (IQR 1-1), while the median history points value was 1 (IQR 1-2) and the median PE points value 2 (IQR 1-3). Sign tests indicated that as compared to points assigned by NMP, points assigned at both the history (p<0.001) and PE (p<0.001) stages were higher. Points assigned at the PE stage were higher than points assigned at the history stage (p<0.001). Duration for appointments with points assigned by NMP was not different from their predicted value for 1- or 3-point appointments but was lower for 2-point appointments (p=0.017). Appointment durations for history points were not different from their predicted value for 1- and 3-point appointments but were lower for 2-point appointments (p<0.001). PE points were not different for 1-point appointments but were lower for 2- and 3-point appointments (p<0.001 each; Table 3).

Table 1. Patient and appointment variables grouped by stage

Variables	Records with Start and End Time (N=301) Median (IQR)	All Records (N=385) Median (IQR)
Known at check-in		
Age (months)	15 (4-48)	19 (5-54)
NMP points	1 (1-1)	1 (1-1)
Sex, female, N (%)	150 (50)	180 (47)
Species, dog, N (%)	177 (59)	226 (59)
Determined from history		
Number of current concerns	1 (1-3)	1 (1-3)
Number of recent changes	0 (0-0)	0 (0-0)
Number of recent signs	0 (0-0)	0 (0-0)
Total number findings from history	2 (1-3)	2 (1-3)
History points	1 (1-2)	1 (1-2)
Determined from physical examination		
Weight (pounds)		
Dog	11 (6-21)	12 (7-21)
Cat	9 (6-14)	9 (6-14)
Number of abnormal findings	1 (1-3)	1 (1-3)
Number of services provided	0 (0-1)	0 (0-1)
Number of tests performed	0 (0-0)	0 (0-0)
Number of medications administered	0 (0-1)	0 (0-1)
Number of medications dispensed	0 (0-0)	0 (0-0)
Number of vaccines administered	2 (1-2)	2 (1-2)
Animal marked caution, N (%)	15 (5)	27 (7)
Microchip implanted, N (%)	51 (17)	62 (16)
Total procedures	2 (2-3)	2 (2-3)

IQR: Interquartile range; NMP: Non-medical personnel

Discussion

This study determined that the only significant predictor of overall clinic duration was the number of patients, and that based on the best fit line, the estimated optimum number of patients for a clinic to conclude within the desired 150 minutes was between 14 and 16, although the coefficient of determination was relatively low. Multiple predictors were found for appointment duration, with the best model including appointment position, total procedures performed during PE, number of abnormal findings on PE, number of current concerns expressed at history taking, and the number of tests performed. However, of these variables, only the number of current concerns is known prior to the physical exam itself making a capacity-based scheduling system that uses factors identified at check-in or history stages unfeasible. For the investigation into the failure of the previous rubric, evidence supported all three hypotheses, including misapplication of the rubric by NMP, lack of knowledge on the part of the owners, and selection of a variable (current concerns) that was only modestly predictive.

Predictors of Clinic Duration

The number of patients was predictive of clinic duration, but only explained 61% of the observed variability and only after removal of two outlier

Table 2. Clinic variables

Characteristics	Median	IQR	Range
All Clinics (n=20)			
Duration (minutes)	128	125-186	121-244
Sum history points	30	25-39	25-46
Sum physical examination points	39	34-43	20-55
Count patients	18	16-22	12-30
Sum procedures	50	38-54	31-77
Sum abnormal findings	32	26-44	16-67
Count microchips	3	1-5	0-8
Sum number of services	5	2-9	0-17
Sum number of medications administered	8	5-10	1-18
Sum number of medications dispensed	0	0-0	0-3
Clinic Subset (n=7)			
Sum non-medical personnel points	20	16-24	5-26
Sum history points	26	20-37	18-39
Sum physical examination points	36	33-44	20-55

Clinic subset is the first seven clinics where non-medical personnel applied a point value to appointments using a rubric based on anticipated appointment complexity. History and physical examination (PE) points were calculated retrospectively using the same rubric applied to information available at the history and PE stages, respectively. IQR: Interquartile range

Figure 1. Clinic duration in minutes by number of patients
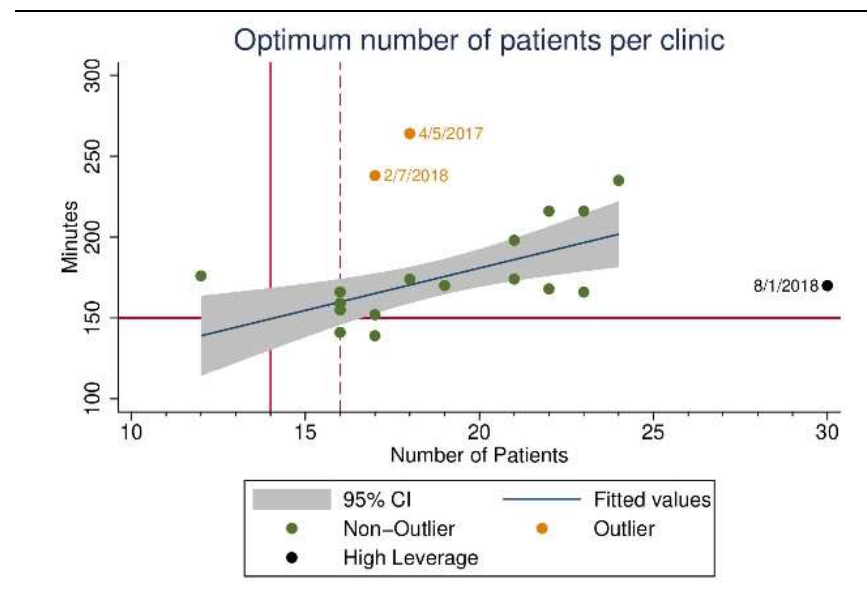
Outliers identified in orange and high leverage points identified in black excluded from best fit analysis. Horizontal line at desired number of minutes for clinic duration (150). Solid vertical line at intersection of horizontal and best fit lines at 16 patients and dashed vertical line at intersection of the horizontal line and lower bound of the 95% confidence interval (CI) at 17 patients.

Table 3. Median and interquartile (IQR) ranges of appointment duration in minutes

Points	Predicted Minutes	Non-Medical Personnel Points				History Points				Physical Examination Points			
		N (%)	Median Minutes	IQR	P-value	N (%)	Median Minutes	IQR	P-value	N (%)	Median Minutes	IQR	P-value
1	20	70 (86)	22.0	15.0-30.0	0.0528	64 (58)	22.5	18.9-26.1	0.6901	36 (32)	19.8	15.0-24.5	0.186
2	40	8 (10)	24.0*	15.0-29.5*	0.0172*	37 (33)	25.6*	21.2-30.1*	<0.001*	40 (36)	23.9*	19.9-27.9*	<0.001*
3	60	3 (4)	75.0	30.0-134.0	0.5930	10 (9)	40.9	16.1-65.7	0.0743	36 (32)	31.8*	24.2-39.5*	<0.001*

Appointments with points assigned by non-medical personnel at check-in, points assigned retrospectively after full history taken, and points assigned retrospectively after physical examination. Duration for each point class compared to the minutes predicted by the previously employed rubric. Appointment totals are not equal due to missing non-medical personnel points, and a history point value of 0 not included in table.
*p<0.05 using Wilcoxon signed rank test comparing observed median to predicted minutes; IQR: Interquartile range

and two high-leverage clinics (20% of clinics). This is not necessarily surprising for a process that has several sources of variability, including those related to patients, owners, and students. However, it was disappointing in light of the fact that a simple points-based rubric using only patient species, sex, age, and weight employed by the mobile clinic to schedule surgeries had an R^2 of 72%.[5] Neither the month of year nor academic quarter was significant, which was surprising, as student experience would be expected to increase as the school year progressed, theoretically decreasing clinic duration. This lack of significance may have been due to limits on the number of times students are able to volunteer within a year, reducing the amount of clinic-specific experience each student can gain.

There were also two clinics with an unusual number of patients, one small (12) and one large (30) that exerted high leverage and were therefore excluded from the model. Inclusion of the small high leverage point would have overestimated the time per patient while inclusion of the large would have underestimated the time per patient, both likely due to the same phenomena of shortened appointment duration observed for later patient positions.

Predictors of Appointment Duration

Even with the information available after a full PE, models explained only one-fourth to one-third of the observed variation. Number of abnormal findings on PE, total procedures, and appointment position were the variables most predictive of appointment duration, with only position being known prior to PE. Given that data for most of these variables are unavailable at the time of triage, the utility of these variables are low for predicting appointment duration. Appointment position was negatively correlated with appointment duration, with appointments at the beginning of the clinic generally longer than at the end. This is likely due to a learning curve present at the beginning of the night where underclassmen are learning how to complete PEs and write SOAP notes, students new to HOME clinics are adjusting to the paperwork and clinic flow, and veterinarians are utilizing PE findings for teaching moments. Appointment duration may also decrease towards the end of a clinic as clinicians intercede for a more timely clinic conclusion. A significant outlier was excluded from the appointment duration analysis based on the value of its residual. This appointment was unusual in that it was urgent and involved sedation and surgical debridement of an abscess that extended into the abdominal cavity.

Actual and Predicted Appointment Duration

Actual appointment duration as compared to predicted duration was not different for 1-point appointments assigned via all methods. However, no method was accurate for predicting the duration of 2-point appointments. PE points were not accurate for predicting the duration of 3-point appointments, although it is likely that the Wilcoxon sign rank test was non-significant for the other 2 methods simply because of small sample size. The median point value increased at each stage as the number of 2- and 3-point appointments increased from NMP to history and from history to PE. This may reflect the greater amount of information available at each stage. Duration variability increased as points increased, although this could be due to both greater variation in complexity and lower number of appointments with higher point values.

Analysis of the Failure of the Discontinued Rubric

Reasons for rubric failure were speculated to include misapplication of the rubric by NMP, mischaracterization of the presenting complaint by the owner, or selection of a non-predictive variable.[4] This study confirms that it is likely that all three of these factors played a role. The fact that the proportion of 1-point appointments was so different between NMP and history supports that the rubric was not applied correctly, as the simplified history-taking process utilized here that prompts for recent signs of illness (sneezing, coughing or eye/nose discharge, vomiting and diarrhea), recent changes (in weight, activity, eating, drinking, other), and owner-reported current concerns (previous history relevant to current condition, presenting complaint(s), requested services) should largely reveal information of which owners are already aware. However, the difference in point proportions between history and PE points also indicates that there were a significant number of concerns of which owners

were not aware. A lack of owner knowledge regarding common conditions has been previously documented.[12,13] Given the low coefficient of determination for the number of current concerns determined in univariable regression (0.12) it is not surprising that a rubric based on current concerns as a proxy for complexity would have limited clinical utility. This analysis also demonstrated that the point categorization did not correspond well to the duration even with knowledge gained at the PE level, particularly for 1- and 2-point appointments. This is likely because a PE and case presentation take a set amount of time regardless of the number of medical conditions, and that each additional concern adds a relatively minimal amount of time beyond the base exam. Different abnormal findings also have different levels of complexity, so it is likely that count data alone do not adequately capture the variability.

Applicability to Student-Run Free Clinics

The findings of this study demonstrate that using variables known at the time of triage has limited utility for predicting veterinary student-run clinic duration. However, this finding does not necessarily apply to non-veterinary free clinics. A previous study has indicated that the number of patient medications is predictive of human, medical, pre-anesthesia appointment duration.[9] While pre-anesthesia appointment data is not directly applicable to student-run free clinics, which are not procedure-based, both these studies may be taken into consideration to indicate that there may be factors that are useful for triaging at FCFS clinics and may help predict clinic and appointment duration.

Limitations

A significant limitation for the appointment duration analysis was the proportion of appointments with completed start and end times. It is possible that incomplete records may not have been randomly distributed as it is likely that the more busy a clinic or inexperienced the students, the less likely that the record would be complete. Incomplete NMP point assignments also complicated the comparison to predicted durations and to the duration of appointments categorized by history or PE. Despite these limitations the major-

ity of start and end times were filled out and the results congruent with the clinical experience of the authors. The incomplete assignment of points by NMP highlights the challenge that NMP faced when applying the complexity rubric.

Future directions for minimizing variability and maximizing the number of patients seen per clinic include the application of time-use study methods to determine sources of inefficiency, such as waiting on an attending veterinarian, as well as optimal configurations (both number and mix of years) for student teams.

Conclusions

No clinically meaningful variables available before physical examination were predictive of appointment or clinic duration. Models for appointment and clinic duration had limited ability to explain duration, indicating the presence of unmeasured variables or a highly stochastic process. This suggests that a rubric based on information available at the check-in or history stages, particularly a rubric simple enough for NMP and student use, is unlikely to be valuable for capacity-based scheduling of medical clinics. Efforts to develop a rubric were discontinued. The most credible failure of the rubric was due primarily to the selection of a non-predictive variable, but misapplication of the rubric by NMP and mischaracterization of the presenting complaint by the owner were likely to be contributing factors.

Disclosures

The authors have no conflicts of interest to disclose.

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