PREVALANCE, RISK FACTORS, TREATMENT AND OUTCOMES OF COLIC IN HORSES IN NAIROBI COUNTY, KENYA

Dr. Gitari Anderson Nyagah, BVM (Nairobi)

A thesis submitted in partial fulfillment of the requirements for Master of Veterinary Surgery, University of Nairobi

Department of Clinical Studies,
Faculty of Veterinary Medicine,
University of Nairobi.

2016

DECLARATION

This thesis is my original work and has not been presented for award of a degree in any other University.

Dr. Anderson Gitari (BVM) Signed_______________Date___________________

This thesis has been submitted for examination with our approval as University Supervisors:

1. Dr. James Nguhiu-Mwangi, BVM, MSc, PhD Signed_____________ Date________
2. Dr. Eddy Mosoti Mogoa, BVM, MSc, PhD Signed_____________ Date________
3. Dr. Vijay S. Varma, BVSc, MS, PhD Signed___________________ Date________

DEDICATION

To My Late Grandmother Florence Lembi Kombo.

TABLE OF CONTENTS

DECLARATION .... **ii**

DEDICATION .... **iii**

TABLE OF CONTENTS .... **iv**

LIST OF TABLES .... **vii**

LIST OF FIGURES .... **ix**

LIST OF APPENDICES .... **x**

ACKNOWLEDGMENTS .... **xi**

ABBREVIATIONS .... **xii**

ABSTRACT .... **xiv**

CHAPTER ONE **1**

1.0 INTRODUCTION 1

1.2 Objectives 3

1.2.1 General objective 3

1.2.2 Specific objectives 3

CHAPTER TWO **4**

2.0 LITERATURE REVIEW 4

2.1 General background on colic 4

2.2 Risk factors for colic 4

2.2.1 Breed, age and sex 4

2.2.2 Diet, management and environmental factors 5

2.2.3 Gastrointestinal parasites 7

2.2.4 Other risk factors for colic 8

2.3 Types of Colic 9

2.3.1 Gas and spasmodic colic 9

2.3.2 Impaction colic 9

2.3.3 Right dorsal colitis 13

2.3.4 Enterocolitis 14

2.3.5 Displacement colic 14

2.4 Diagnosis of colic 18

2.4.1 History 19

2.4.2 Physical examination 19

2.4.3 Laboratory findings 22

2.4.4 Nasogastric intubation 23
2.4.5 Abdominal ultrasound..24
2.4.6 Gastroscopy and laparascopy 25
2.5 Treatment of equine colic 25
2.5.1 Use of analgesics in cases of colic...25
2.5.2 Decompression 30
2.5.3 Laxatives 30
2.5.4 Fluid Therapy 32
2.5.5 Motility Agents...32
2.5.6 Surgical procedures for treatment of colic 33
2.5.7 Euthanasia without Surgical Treatment 35
CHAPTER THREE...37
3.0 MATERIALS AND METHODS...37
3.1 Study area. 37
3.2 Study design...37
3.2.1 Cross sectional study 37
3.2.2 Prospective study 38
3.2.3 Retrospective study...39
3.3 Data management and analysis. 40
CHAPTER FOUR 43
4.0 RESULTS 43
4.1 Results of cross sectional study 43
4.1.1 Descriptive statistics for cross sectional study 43
4.1.2 Perceived prevalence rate of colic 44
4.1.3 Risk factors for colic as perceived by horse owners and trainers...........................48
4.1.4 Association between perceived risk factors and occurrence of colic 53
4.2 Results of prospective study 59
4.2.1 Descriptive analysis 59
4.2.2 Mean values of hematological parameters in spasmodic and impaction colic 59
4.2.3 Mean values of haematological parameters in horses that recovered and in those that died of colic. 60
4.2.4 Mean values of biochemical parameters in horses with colic 60
4.2.5 Mean values of biochemical parameters in horses that recovered or died from colic 64

4.3 The results of the retrospective study ... 66
4.3.1 Descriptive statistics on cases and types of colic ... 66
4.3.2 The types and use of analgesics in horses with colic ... 69
4.3.3 Nasogastric intubation and the use of metabolic stimulants for management of colic ... 72
4.3.4 Outcomes of colic in horses ... 72
4.3.5 Association between types of colic and various factors including treatment protocol, recurrence and outcomes ... 75
CHAPTER FIVE ... 77
5.0 DISCUSSION ... 77
CHAPTER SIX ... 85
6.0 CONCLUSIONS AND RECOMMENDATIONS ... 85
6.1 Conclusions ... 85
6.2 RECOMMENDATIONS ... 86
6.3 Further Research ... 87
CHAPTER SEVEN ... 88
7.0 REFERENCES ... 88
APPENDICES ... 109

LIST OF TABLES

Table 4. 1: Percentage of reponses by respondents on the reasons for keeping horses in the twenty one stables during a cross sectional study in Nairobi County, Kenya. 45

Table 4. 2: Perceived prevalence by respondents for occurrences of colic within a 12-month period among 429 horses in twenty one stables in Nairobi County, Kenya........47

Table 4. 3: Management-related risk factors for colic as perceived by the horse owners/trainers in Nairobi County, Kenya. 50

Table 4. 4: Percentages of the number of responses on each perceived risk factor for occurrence of recurrent episodes of colic in horses as mentioned by horse owners/trainers within Nairobi County, Kenya 51

Table 4. 5: Percentages of stables in which each type of dewormer is used as indicated by respondents in Nairobi County, Kenya 52

Table 4. 6: Association between management-related risk factors and occurrence of colic based on the number of colic cases that occurred in Nairobi County, Kenya 55

Table 4. 7: Association of perceived management-related risk factors based on the responses of horse owners/trainers in Nairobi County, Kenya...56

Table 4. 8: Frequencies of various perceived possible remedies for reducing incidence of colic in horses as indicated by in Nairobi County, Kenya 58

Table 4. 9: Comparative mean haematological values between horses with impaction colic and those with spasmodic colic in Nairobi County..61

Table 4. 10: Comparative mean values of haematological parameters between horses that recovered from colic and those that died of colic in Nairobi County 62

Table 4.11: Comparative mean values of biochemical parameters between horses with impaction colic and those with spasmodic colic in Nairobi County...................63

Table 4. 12: Comparative mean values of biochemical parameters between the horses that died and those that recovered from colic in Nairobi County..............................65

Table 4. 13: Percentages of types of colic cases in horses that were treated from January 2004 to December 2014 in Nairobi County, Kenya 67

Table 4. 14: Percentages of types of intestinal displacements in horses that were treated from January 2004 to December 2014 in Nairobi County, Kenya..............................68

Table 4. 15: Frequencies of use of various categories of analgesics during the treatment of colic in horses treated from January 2004 to December 2014 in Nairobi County, Kenya...70

Table 4. 16: Frequencies of use of various individual and combinations of analgesics during the treatment of colic in horses treated from January 2004 to December 2014 in Nairobi County..71

Table 4. 17: Number and percentages of deaths from each type of colic in eleven year period in Nairobi County, Kenya...73

Table 4. 18: Overall number and percentages of horses that had recurrent and non-recurrent colic episodes as well as those that died or recovered among the cases treated from January 2004 to December 2014 in Nairobi County, Kenya 74

Table 4. 19: Association between the type of colic and several factors in the treatment of colic in horses in Nairobi County 76

LIST OF FIGURES

Figure 4. 1: Percentages of various responses by respondents on reasons for keeping horses in the twenty one stables during a cross sectional study to determine prevalence of and risk factors for colic in horses in Nairobi County, Kenya. 46

Figure 4. 2: Percentages of types of colic cases found in horses that were treated from January 2004 to December 2014 in Nairobi County, Kenya 67

Figure 4. 3: Percentages of types of intestinal displacements in horses that were treated from January 2004 to December 2014 in Nairobi County 68

Figure 4. 4: Percentages of horses that died from each type of colic in the eleven year period in Nairobi County, Kenya 73

Figure 4. 5: Percentages of horses that had recurrent and non-recurrent colic episodes as well as those that died or recovered among the cases treated from January 2004 to December 2014 in Nairobi County, Kenya.. 74

LIST OF APPENDICES

Appendix 1: Questionnaire 109

Appendix 2: Data collection sheet for prospective study 106

Appendix 3: Data collection sheet for retrospective study...107

Appendix 4: Publications, research article; Hematological and biochemical changes in horses with colic in Nairobi County, Kenya..108

ACKNOWLEDGMENTS

I thank the Andys Veterinary Clinic for awarding me financial and material support to pursue my postgraduate studies. I wish to acknowledge the time and personal commitment of my supervisors; Dr. James Nguhiu-Mwangi, Dr. Eddy Mogoa and Dr. Vijay Varma in guiding, mentoring and sharing their invaluable intellectual wisdom with me. I am grateful to the Chairman of the Department of Clinical Studies, University of Nairobi for his assistance and permission to use Departmental facilities to complete my thesis.

My gratitudes to the staff at the Andys Veterinary Clinic, Joe mwangi (Karari Stables), Mark Mburu (Almasi Stables), Dr. Willy Mwangi (University of Nairobi), Dhaval Shah (Lancet Laboratories) and Dr. Patsy Sercombe (Sercombe Veterinary Clinic) for the moral and technical support they provided during my thesis work.

To my loving Tuma Rashid, l am forever indebted to you for being there during the long late hours of working.

Above all l thank Jehova God for giving me the opportunity, strength and guidance to pursue my postgraduate studies.

ABBREVIATIONS

ALP	Alkaline Phosphatase
ALT	Alanine Aminotransferase
AST	Aspartate Aminotrasferase
BID	bis’ in die (Two times a day)
BW	Body Weight
CRI	Constant Rate of Infusion
DSS	Dioctyl Sodium Sulfosuccinate
EDTA	Ethylenediaminetetraacetic Acid
EFE	Epiploic Foramen Entrapments
fl	Femtoliters
g/l	grams per liter
g/dl	grams/deciliter
HAK	Horse Association of Kenya
IU/L	International Unit per Liter
IV	Intravenous
JAC	Jockey Association of Kenya
KVB	Kenya Veterinary Board
LDDLC	Left dorsal displacement of the large colon
LVC	Large Colon Volvulus
MCH	Mean Corpuscular Haemoglobin
MCHC	Mean Corpuscular Haemoglobin Concentration
MCV	Mean Corpusclar Volume
mmol/l	millimole per liter
n	Number
NSAIDs	Non- Steroidal Anti-inflammatory Drugs
P	Probability
PCV	Packed Cell Volume

PFR	Pelvic Flexure Retroflexion
pg	picograms
PGE2	Prostaglandin E2
POI	Post Operative Ileus
RDC	Right Dorsal Colitis
RDDLC	Right dorsal displacement of the large colon
RDW	Red cell Distribution Width
SD	Standard Deviation
SID	sem’el in die (Once a day)
TEC	Total Erythrocyte Count
TPC	Total Platelet Count
VMC	Ventral Midline Celiotomy
WBC	White Blood Cell Count
®	Registered Trade Mark

ABSTRACT

Colic is simply the manifestation of abdominal pain, mainly originating from a gastrointestinal tract problems, but could also involve organs of other systems within the abdominal cavity. The aetiology can be multifactorial and the condition impacts negatively on the welfare of the horse besides having a negative economic effect owing to inefficient performance and occasional deaths. The prevalence, risk factors and outcomes of colic in horses in Kenya is unknown. Therefore, this study was carried out in horse stables and Equine Practices in Nairobi County with the following objectives: 1. to determine the prevalence of colic in horses, 2. to determine the risk factors for colic in horses, 3. to determine haematological and biochemical parameters in horses with colic, and 4. to determine the treatment and outcomes of horses with colic.

The first and second objectives were determined by administering a questionnaire to horse owners or trainers in 21 stables within Nairobi County. The questionnaire consisted of simple non-subjective questions that were easy for horse owners and trainers to answer. The questionnaire was administered by the investigator (interviewer) who asked the horse owners or trainers (respondents) questions and filled it. The third objective was determined through a prospective study, which involved following-up cases of horses with colic from which blood samples for haematology and serum for biochemical analysis were collected. The haematological parameters measured were Total Leucocyte Count (TLC), Haemoglobin Concentration (Hb), Haematocrit (hct), Mean Corpuscular Volume (MCV), Mean Corpuscular Haemoglobin (MCH), Mean Corpuscular Haemoglobin Concentartion (MCHC), Platelet Count, and Leucocyte Differential Count. The biochemical parameters measured were Alkaline Phosphatase (ALP), Aspartate Aminotransferase (AST), Total Proteins, Serum Albumin, Serum Globulin, Blood Glucose and Serum Lactate. The fourth objective was determined through a retrospective study from records in six Equine Practices in Nairobi

County, covering 11-year period. This mainly focused on data relating to pain management, treatment and outcomes of colic.

There was 70% response rate from the questionnaire survey. The prevalence of colic from the questionnaire responses was 13.5%. But the incidence of colic from the retrospective study for the 11 years was 3.1%. Occurrence of spasmodic colic was 68%, impaction colic 27.8% and displacement colic 4.3%. The main risk factors found to be significantly associated with the occurrence of colic included: lack of activity of the horse ($\chi^2 = 10.8$, $p < 0.01$), overfeeding of grains ($\chi^2 = 4.54$, $p = 0.03$) and frequency of deworming ($\chi^2 = 4.07$, $p = 0.04$). Those that are likely to reduce incidences of colic include regular dental care (β-estimate = -0. 456, O.R. = 0.6), changing stabling conditions (β-estimate = -0. 142, O.R. = 0.9) and regular deworming at every 3 months (β-estimate = -0.301, O.R. = 0.7) and at every 12 months (β-estimate = -0. 947, O.R. = 0.4). Mean Corpuscular Haemoglobin (MCH) was significantly higher ($p = 0.03$) in horses with spamodic colic (916.8±1.3 pg) than in those with impaction colic (15.6±1.2 pg). The Mean Leucocyte Count (10^9/L) was significantly higher ($p = 0.02$) in horses with impaction colic (12.9±5.9) than in those with spasmodic colic (9.0±1.5)). Similarly, Mean Neutrophil Count (10^9/L) was significantly higher ($p = 0.02$) in horses with impaction colic (9.1±5.6) than in those with spasmodic colic (5.4±1.7). The mean values of blood glucose were significantly higher ($p = 0.02$) in horses with impaction colic (5.7±2.0 mmol/l) than in those with spasmodic colic (3.7±1.4 mmol/l). The only blood biochemical parameters that were significantly lower in horses that died than in those that survived were Total Protein ($p = 0.002$), albumin ($p < 0.01$) and globulin ($P = 0.04$). The most common pain management protocols used were the administration of single non-steroidal anti inflammatory drugs (NSAID) at 85.3%, which consisted mainly Flunixin Meglumine; followed by use of NSAID-OPIOID combinations at 6.4%, consisting mainly flunixin meglumine and butorphanol. Use of anti-spasmodics particularly buscopan was recorded in only 5.9% of the

cases. Type of colic seemed to significantly influence choice of analgesic protocol ($\chi^2 = 22.5$, $p < 0.001$), and the most significant protocol was analgesic combinations ($\chi^2 = 18.3$, $p < 0.001$). The type of colic strongly influenced the decision to perform nasogastric intubation ($\chi^2 = 265$, $p < 0.001$), but the intubation was weakly ($\chi^2 = 4.9$, $p = 0.03$) related to horse recovery from colic. Type of colic also strongly determined the need for use of metabolic stimulants particularly vitamin B complex (($\chi^2 = 99.3$, $p < 0.001$). Also strongly associated with the type of colic ($\chi^2 = 250$, $p < 0.001$), was recovery or death as outcomes of the affected horse. The possibility of recurrence of colic was weakly influenced ($\chi^2 = 4.6$, $p = 0.04$) by the type of colic.

The study concluded that the “perceived prevalence” of colic over a one year period, and the eleven year incidence of colic in horses in Nairobi County, Kenya, is fairly low. The perceived management risk factors are generally related to feeding practices, lack of activity, dental care and deworming practices. Spasmodic colic is common and displacement colic rare. The most common protocol for pain management is use of NSAIDs, particularly flunixin meglumine but combinations of analgesics may be more effective. Apart from Mean Corpuscular Haemoglobin (MCH), and slight leucocyte count and netrophil count changes, there were no major significant haematological changes in horses with colic. Total blood proteins including albumin and globulin levels could serve as possible guide to prognosis of colic in horses. The general prognosis of spasmodic colic in horses was fair or good, but poor for impaction and displacement colic. Further research should be carried out on more specific prognostic indicators of various types of colic as well as systematic study on physiological responses to various pain management protocols.

CHAPTER ONE

1.0 INTRODUCTION

Colic is a general term that implies abdominal pain and is one of the major causes of death in horses (Noah *et al.,* 1999). Colic occurrs from conditions affecting mainly the gastrointestinal tract, but could involve organs of other systems within abdominal cavity. It affects horse more commonly than other domestic animals, mainly as a result of the anatomical disposition of the gastrointestinal tract of the horse, the nature of digestion and management practices imposed by man are among the main multifactorial predisposing factors for colic (Krunkosky *et al*., 2008).

In a general population of 100 horses, 4 to 10 cases of colic may occur in a year. About 10 to 15% cases of colic in horses are recurrent episodes and some of the horses may have 2 to 4 episodes of colic in a year (Tinker *et al*., 1997a). About 80-85% of the reported cases are simple colic or ileus with no specific diagnoses and these normally responds to medical treatment or resolve spontaneously. For example, one study found that 30% of the colic cases were identified by owners and never reported to the veterinarians because some cases of colic were normally transient and resolve either spontaneously or are treated by the owners. In a general population of horses, impaction colic accounts for about 10% of the cases and while obstructing or strangulating conditions causing colic that require surgery make about 2-4% of the cases (White, 1990). Colic is responsible for more deaths in horses than any other group of diseases. A horse that survives an episode of colic takes 2 to 3 days recuperating, which results in signfiicant economic losses (Traub-Dargatz *et al.,* 2001).

Among the risk factors associated with colic include breed of the horse (Cohen *et al*., 1999), previous episodes of colic and management practices such as feed types, quantities of feed and feeding regime, level of activity of the horses and deworming practices (Tinker *et al*., 1997b). Arabian and thoroughbred horses tend to have high incidences of colic (Traub-Dargatz *et al*., 2001). Standardbred, gaited horses and Warmblood stallions appear to have more inguinal hernias due to the increased size of their inguinal rings which could lead to colic (Cohen *et al.*, 1999). Feeding low digestibility feeds with much fiber is likely to cause impaction colic, while lush pasture feeds cause tympany (Hudson *et al.,* 2001; Little and Blikslager, 2002). Feeding excessive amounts of grain increases the odds of developing colic (Proudman, 1992).

Internal parasites are associated with an increased risk of colic, in which *Strongylus vulgaris* and *Anoplocephala perfoliata* are the most potential cause of colic in the horse, while *Parascaris equorum* is recognized as a major parasitic pathogen in foals and weanlings causing poor growth and high risk of small intestinal impaction (Cribb *et al.,* 2006). Environmental and management factors, including whether the horses are cared for by the owners or by trainers determine if colic will occur or not (Reeves *et al.*, 1996; Hillyer *et al.,* 2002). Horses with previous episodes of colic and those that have recovered from abdominal surgeries are more likely to develop repeat incidences due to adhesions or bowel scarring with stricture (Cohen *et al*., 1995; Tinker *et al*., 1997a).

The key principles in the management and treatment of colic is pain management, gastrointestinal tract decompression, correction of biochemical and fluid imbalances, stimulation and maintainance of intestinal motility as well as reduction of gastrointestinal inflammation. Where pain is severe and non-responsive to medical treatment, immediate surgical intervention is indicated (White, 2006). The prevalence and incidence of colic in horses in Kenya, the associated risk factors, treatment practices and outcomes have not been determined previously. It was therefore decided that these factors relating to colic should be determined through retrospective and prospective studies, with the general purpose of advising the horse owners, trainers and equine practitioners on how to improve management of colic cases as well as its prevention.

1.2 Objectives

1.2.1 General objective

General objective was to determine the prevalence, risk factors, treatment and outcome of colic in horses in Nairobi county, Kenya. This was intended to provide information that will assist horse owners to manage their horses in a better way so that they can prevent or reduce occurrences of colic and to equip equine practitioners with information that would assist in management of colic cases.

1.2.2 Specific objectives

The study was carried out with the following specific objectives:

a) To determine the prevalence of colic in horses in Nairobi County, Kenya.

b) To determine the risk factors for colic in horses as perceived by horse owners/trainers in Nairobi County, Kenya.

c) To determine haematological and various biochemical parameters in horses with colic in Nairobi County, Kenya.

d) To determine the treatment and outcomes of management of horses with colic in Nairobi County, Kenya.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 General background on colic

Colic is simply a cascade of clinical signs resulting from abdominal pain. This pain may originate from problems affecting the gastrointestinal tract or any other system within the abdominal cavity. The pain is triggered by nerve stimulation and formation of chemical mediators that cause physiological changes such as increase in heart rate, pooling of blood, fluid sequestration in the gut, alterations in tissue perfusion and oxygenation. The physiological changes could serve as a guide to determine the cause of the disease and the severity of clinical symptoms (White, 2007).

While colic remains a major concern for horse owners and trainers, unlike before, early diagnosis and treatment has improved the prognosis of colic significantly. Colic mortality has considerably decreased and is only second to old age as a cause of death in horses (Tinker *et al.*,1997a; Mair *et al*., 2007).

2.2 Risk factors for colic

The risk factors for colic can be categorized into animal-level (intrinsic or internal) factors like breed, age and sex, among others and management-level (external) factors such as diet/feeding, general management and factors involving the environment of the horse.

2.2.1 Breed, age and sex

Colic may affect any breed of horses but studies have indicate an increased incidence in Arabian (Cohen *et al*., 1995) and Thoroughbred horses (Traub-Dargatz *et al*., 2001). There is an apparent increase in the incidence of inguinal hernias in Standardbreds, Gaited and Warmblood stallions due to the increased size of their inguinal rings (Schneider *et al*., 1982). Geldings or stallions and older horses appear to be at slightly higher risk of entrapment of the small intestine in the epiploic foramen, while periparturient mares are at a higher risk of suffering from large colon displacement or volvulus (Archer *et al.,* 2008). It has been reported that mares have a higher risk of colon displacement or volvulus during late pregnancy or early lactation period (Huskamp, 1982; Snyder *et al.,* 1989a).

Younger (less than 2 years) and older horses (more than 10 years) appear to be at less risk of simple colic (Tinker *et al.,* 1997b). Conversely, middle aged horses are at higher risk of colic than the older horses. However, older horses are more likely to require surgical intervention when they suffer from colic. Weanling and yearling horses are more likely to have ileocaecal intussusceptions while older horses (more than 12 years) are at increased risk of strangulating lipomas (Proudman, 1992).

2.2.2 Diet, management and environmental factors

Feeds and feeding regime are incriminated as contributors to colic. The type of hay, particularly poor quality hay predisposes horses to colon impaction because it is less digestible. Changes in the types of feed lead to alterations in colon microflora with the acid-sensitive fibrolytic bacteria population declining and lactic acid-producing bacteria increasing, with subsequent increase in lactic acid and decrease in colonic pH. The microflora of the stomach are primarily composed of *Lactobacillus* spp., *Streptococci* and lactate-utilizing bacteria. When a horse is in a fasting state (for example, during episodic feeding) and they are not receiving feed, their hindgut will have a decreased buffering capacity which results to a decrease in pH and subsequent microbial disruption (Clarke *et al*., 1990). In addition to episodic feeding, transportation, stress, surgical procedures and abrupt changes in diet have effect on the stability of the normal flora (Clarke *et* *al*., 1990). Diets high in readily fermentable carbohydrates are often fed to horses with high energy requirements. However, studies have demonstrated that feeding of high starch diets as opposed to diets with high fiber predisposes horses to develop gastrointestinal diseases like colic and laminitis. This has been primarily attributed to the disruption of the hindgut microflora (Clarke *et al*., 1990; Bailey *et al*., 2004). The change in bacterial populations interferes with fermentation efficiency and subsequently contributes to the occurrence of colic (Cohen *et al*., 1995). Lush pastures and other lush fodder have been incriminated as likely cause of tympany in some parts of the gastrointestinal tract, while Bermuda grass hay has been associated to an increased risk of ileal impaction (Little and Blikslager, 2002; Proudman and Holdstock, 2000). Grain diets are likely to decrease water content in the colon due to decrease in their fiber content, which binds to water and thus contributes to impaction colic. Grain increases gas production and is more likely to predispose to tympanic and displacement colic (Little and Blikslager, 2002).

Types and nature of feeds have been shown to contribute to the formation of enteroliths due to minerals along the intestinal tract accummulating around small nidus of foregn bodies such as wires or sand. Enteroliths eventually get dislodged from their formation sites to areas where they cause intestinal obstruction (Rakestraw and Hardy, 2006). Hard water consumed by some horses, alfalfa hay and a higher intestinal pH contribute to enterolithiasis from the mineral concentrations in colon ingesta (Hassel *et al.,* 2004). In recent years, it has been seen that there is an increased number of horses suffering from colic presented to veterinary hospitals due to enterolithiasis (Rakestraw and Hardy, 2006).

Studies have shown that horses cared for by trainers and managers have an increased risk of colic compared to those that receive care from the owners (Hillyer *et al.,* 2002). It has been reported that horses with drastic decrease in activity such as decreased regular exercise or sudden change to strict stall confinement as a result of injury or surgical recuperation have increased the risk for caecal and large colon impaction (Dabareiner and White, 1995). When horses spend days in paddocks without water, they have increased risk for impaction colic (Reeves *et al.*,1996). It has been reported that transportation of horses increases the risk of colic and therefore as a precaution, such animals are given laxatives before being transported (Uhlinger, 1992; Tinker *et al.,* 1997b; Hillyer *et al.,* 2002).

2.2.3 Gastrointestinal parasites

Strongylus vulgaris and *Anoplocephala perfoliata* in adult horses as well as *parascaris equorum* in foals and weanlings have been associated with increased episodes of colic (Relf *et al*., 2013). Strongyles reside mainly in the hindgut, the caecum and colon, attaching to the intestinal walls with larvae migrating into the blood vessels. In the mesenteric arteries they cause aneurysm, ruptured vessels and these predispose horses to colic. Studies have shown a decrease in colic after controlling small strongyle infestation in farms that previously have had high colic incidences (Uhlinger, 1992). *Strongyloides* is the only nematode parasite of horses that can be transmitted directly from the dam to the foal without first cycling through the environment (vertical transmission). Infective larvae of *Strongyloides westeri* appear in mare's milk during the first week after parturition, and the foal is infected while suckling (Lyons *et al.,* 1973). Contamination of pastures from dense populations of horses on the same pasture year after year contributes to heavy infestations. Horses have individual susceptibility to parasitism and within a population, a small number of individuals is usually responsible for shedding majority of parasite eggs. It has been shown that less than 20 per cent of the total horse population excrete greater than 80 per cent of all strongyle eggs in their faeces at any given point in time (Relf *et al.,* 2013).

All these factors that favour parasitic infestation will indirectly contribute to the increased risk of occurrence of colic in horses.

Live or dead ascarids can cause verminous intestinal impactions following application of antihelminthics (Southwood *et al.,* 1996). Tapeworm infestation has also been incriminated in increased risk of colic with high possibilities of predisposing to ileocaecal intussusception (Proudman and Holdstock, 2000).

2.2.4 Other risk factors for colic

2.2.4.1 Previous colic episodes

Horses that have had a prevous history of colic are at higher risk of repeat episodes (Tinker *et al.* 1997a; Cohen and Honnas, 1996). Horses that have had abdominal surgery are at higher risk of colic due to high chances of post-surgical adhesions or bowel scarring with stricture (Cohen *et al.* 1995). Repeat episodes of colic are likely to occur within the first 2-3 months following abdominal surgery, after which the incidence of colic decreases (Proudman *et al.*, 2005).

2.2.4.2 Cribbing

This is the act of aerophagia that creates negative pressure in the abdomen leading to movement of intestines into the potential space within the lesser omental sac. Cribbing has been associated with an increased risk of simple large colon obstruction and entrapment of the small intestine in the epiploic foramen (Archer *et al.*, 2004; Archer *et al.*, 2008).

2.2.4.3 Fever

A study in Virginia, Maryland, reported that horses with infection have changes in the function of the gastrointestinal tract predisposing them to colic. Although the reported causes of fever in these cases were varied, no specific relationship or cause for each colic was established. The study demonstrated that horses with fever within 14 days of a colic episode had twice the likelihood of having repeat episodes (Tinker *et al.*, 1997b).

2.3 Types of Colic

2.3.1 Gas and spasmodic colic

Gas and spasmodic colic makes up as much as 80-85% of colic in horses and intestinal function is affected due to increased peristaltic movements in the gastrointestinal tract. It is highly predisposed to by ingestion of excessive amounts of highly fermentable feeds, which cause build-up of gases in segments of the intestinal tract. Apart from increased amount of gas, there is also accelerated intestinal movements, both of which result in abdominal pain. Gas accumulation is often detected through auscultation. The pathophysiologic events are not well understood because research to detect intestinal or systemic responses is difficult in these cases. Although the intestine may appear not to be injured in obstruction, strangulation or enteritis, the resulting dysfunction causes responses from mediators such as prostaglandins. In spasmodic colic, signs are generally mild and respond well to antispasmodics and analgesic medication (Smith, 1996).

2.3.2 Impaction colic

This is intraluminal obstruction of the gastrointestinal tract and is characterized by blocking of normal transit of gastrointestinal contents. It is predisposed by coarse ingesta, sand, enteroliths, foreign bodies within the lumen, poor dentition, parasites, overeating, inadequate water intake, motility disorders and limited exercise **(**Dinev and Zlateva, 1999: Lopes, 2009).

2.3.2.1 Gastric impaction

Gastric impaction is rare and is associated with ingestion of excessive dry and fibrous feed, poor dental care, ingestion of foreign objects and changes in the normal function of the stomach. Feeds that tend to swell after ingestion such as barley, wheat and sugar beet pulp are likely to cause gastric impaction. Dental diseases have been likened to an increase of gastric impaction due to improper chewing of feed (Honnas and Schumacher, 1985; Owen *et al.*, 1987). Some of the clinical signs of gastric impaction ranges from acute and severe, while some of the clinical signs will be mild and chronic. This was shown in a report on 4 horses suffering from gastric impaction, where clinical signs of colic were moderate to severe and ranged between 8 and 12 hours in duration (Barclay *et al*., 1982). In another report on a pony with gastric impaction, colic was chronic (for a duration of 7 days) and was associated with prolonged recumbency, anorexia, and lethargy (Honnas and Schumacher, 1985). Additional signs in gastric impaction may include dysphagia, dropping of feed and bruxism. The diagnosis of gastric impaction is usually made at surgery in horses that have had uncontrollable colic or poor response to medical treatment (Honnas and schumacher, 1985: Owen *et al*., 1987).

2.3.2.2 Ileal impaction

Ileal impaction occurs when the ileum is blocked by suboptimal quality feeds such as coastal Bermuda hay and tapeworm infestation. Coastal Bermuda hay has relatively fine stems compared with other types of hay, the fiber and ligand content is high. Therefore mastication is insufficient and the hay is swallowed before the stem length has been reduced to a reasonable size, hence predisposing to impaction (Little and Blikslager, 2002; Proudman and Holdstock, 2000). Studies have also revealed that tapeworm infestation is an important risk factor for ileal impaction. Studies in England showed that the data based on risk analysis has suggested that more than 80% of the ileal impaction cases studied were supported by evidence of serologic or faecal tapeworm infestation (Proudman *et al*., 1998). Some of the clinical signs seen from horses with ileal impaction may include onset of moderate to severe colic with palpable loops of distended small intestines by rectal examination as the condition progresses. Nasogastric reflux may take considerable time to develop because the ileum is the most distal aspect of the small intestinal tract and this is found in approximately 50% of horses requiring surgical correction of impacted ileum (Hanson, 1998; Parks *et al*., 1989).

2.3.2.3 Large colon impaction

Dehydrated ingesta is a common cause of large colon impaction and obstruction is mostly seen at the anatomic narrowing of the colon, specifically the pelvic flexure and transverse colon. This may be associated with ingestion of rough fiber (straw, poor quality hay), ingestion of sand, poor mastication, systemic dehydration, changes in colon motility, prolonged stall confinement, abnormal narrowing of the colonic lumen and excessive use of non-steroidal anti-inflammatory drug (NSAID) therapy (Lopes *et al*., 2003). Horses with large colon impactions may have history of clinical signs which are mild and intermittent abdominal pain with a decrease in borborygmi (Owen *et al*., 1987). Diagnosis is made on the basis of transrectal palpation of an indentable mass in the pelvic flexure or left ventral colon (White, 1990; Dinev and Zlateva, 1999).

2.3.2.4 Caecal impaction

The caecum is a blind ended pouch where ingesta enters and exits through the same orifice. This lumen is only several inches in diameter and changes in caecal motility may contribute to impactions. Caecal impactions can be categorised as primarily (type 1) due to excessive accumulation of solid ingesta or can be secondarily (type 2) due to an apparent caecal dysfunction (White, 1990; Dabareiner and White, 1995; Blikslager, 2009). Horses with type 1 caecal impaction typically have onset of abdominal pain which takes 5 to 7 days and which seems to be similar to large colon impaction, and these impactions normally consist of solid ingesta (Blisksslager, 2009). Type 2 caecal impactions are often more difficult to detect because they are most frequently diagnosed in post-operative patients being treated for an unrelated condition, and the caecum is frequently fluid-filled (White, 1990; White and Dabareiner, 1997; Blikslager, 2009). It is important to differentiate caecal impaction from large colon impaction during rectal examination because caecal impactions have tendency to rupture before evidence of marked clinical abdominal pain or signs of systemic shock are seen. Medical management is often successful in treatment of horses with type 1 caecal impaction. However, immediate surgical management is the treatment of choice for caecal dysfunction (type 2 impaction) and this should be done as early as possible. The challenge still remains for early diagnosis because it may be difficult to evaluate the integrity of the caecal wall based only on clinical examination and rectal palpation (Hassel *et al.*, 2008).

2.3.2.5 Enterolith impaction

Enterolith impaction can be a common cause of colic in horses. These enteroliths are usually composed of ammonium magnesium struvite which are formed and found in the right dorsal colon. Previous reports have described enteroliths as being most common in horses 5–10 years of age (Blue, 1979). Some of the smaller enteroliths may be passed in faeces without clinical signs while large enteroliths may reside temporarily in the large colon without causing a problem. However, many times obstruction occurs when an enterolith moves distally to the narrower transverse colon. Ingestion of large quantities of alkalinizing feeds which are rich in protein, phosphorous and magnesium such as alfalfa are some of the contributory factors to the formation of enteroliths. Drinking water with high magnesium content has also been associated with formation of enteroliths. Intermittent colic may be a common historical finding in many horses with enterolithiasis. Diagnosis of enterolith obstruction is made based on the history, demographics (areas with water having high magnesium content), clinicopathological signs, rectal palpation, abdominal radiography and ultrasonography. Survival rates following celiotomy for treatment of enterolithiasis have been found to be considerably higher than previously reported (Rakestraw and Hardy, 2006).

2.3.3 Right dorsal colitis

Right dorsal colitis is a condition characterized by mucosal and submucosal ulceration, inflammation, oedema and thickening of the right dorsal colon, but may also affect other segments of the colon. In chronic disease, fibrosis and stricture formation may be seen and this has been associated with administration of excessive doses of non-steroidal anti-inflamnatory drugs (NSAIDs) with phenylbutazone being the most common (Jones, 2009). Clinical signs associated with right dorsal colitis include anorexia, weight loss, intermittent or sporadic episodes of acute abdominal pain and diarrhea (Andrew and Robertson, 1988). Surgical treatment has been advocated, but prognosis for affected horses remains poor. In previous reports, gastrointestinal lesions in horses with spontaneously occurring and experimentally induced right dorsal colitis were limited to the right dorsal colon (Andrew and Robertson, 1988; Karcher *et al*., 1990; Simmons *et al*., 1990). However ulceration of the gastric mucosa can develop in adult horses treated with NSAIDs (Snow *et al*., 1981) and similar gastric lesions may be seen in these horses without presentation of clinical signs (Simmon *et al*., 1990).

2.3.4 Enterocolitis

Enterocolitis also known as acute colitis, refers to the inflammation of the colon and/or caecum with acute onset of diarrhea. Infectious agents such as *Salmonella* species, *Clostridium* species and *Neorickettsia risticii* have been known to cause acute colitis. Other causes include parasite infestation, administration of some antimicrobials, cantharidin toxicosis, NSAIDs and excessive sand ingestion. It is a common cause of rapid, severe debilitation and death in horses with severe cases. Clinical signs include moderate to severe abdominal pain, profuse watery diarrhea, endotoxaemia, leucopaenia and hypovolaemia. Bacterial isolation from blood, tissues and five or more sequential daily faecal samples collected remains golden standard for diagnosis of Salmonella species infection in horses (van Duijkeren *et al*., 1995). Response to treatment of horses suffering from enterocolitis is good and usually gradual for a period of 7 to 14 days, with the untreated horses having over 90% fatality rate (McConnico, 2009).

2.3.5 Displacement colic

The equine large colon is prone to displacements as a result of its free movement within the abdomen owing to lack of mesenteric attachments to the body wall. These displacements are common causes of colic. They are classified into left dorsal displacement, right dorsal displacement and strangulating volvulus of the large colon (Rakestraw and Hardy, 2006).

2.3.5.1 Left dorsal displacement of the large colon

This is also called nephrosplenic or renosplenic entrapment and occurs when the large colon, left ventral and dorsal colon are oriented correctly, but migrate between the spleen and body wall, becoming entrapped dorsally over the nephrosplenic ligament (nephrosplenic space) (Hardy *et al*., 2000). Horses with Left dorsal displacement of the large colon (LDDLC) show variable degrees of pain, depending on the location of the colon, amount of gas distension, presence of secondary gastric distension, and the colon can often be palpated rectally in the nephrosplenic space between the spleen and left kidney. The findings in rectal palpation is diagnostic in 72% of cases as shown in one study (Hardy *et al*., 2000). Transabdominal ultrasonography usually confirms diagnosis of LDDLC and rules out non-surgical correction (Santschi *et al*., 1993). In a normal horse, the left kidney image can be seen deep through the spleen and the presence of the large colon in the nephrosplenic space interferes with the ability to view the image of the kidney because of the presence of gas in the large colon. Although the presence of gas-filled large colon dorsal to the spleen is consistent with LDDLC, this finding can also occur with other types of colonic disease (Hardy *et al*., 2000).

2.3.5.2 Right dorsal displacement of the large colon

This happens when there is impaction at the pelvic flexure, and causes colon to migrate cranially. As a result, the left and right ventral colon distend with gas and flip caudally, ventral to the caecum. This causes the right ventral and right dorsal portions of the colon to twist onto themselves near the base of the caecum and body wall, and the pelvic flexure ends up near the diaphragm. Horses with right dorsal displacement of the large colon (RDDLC) can exhibit variable degrees of pain depending on the location of the colon and degree of gas distension in the affected colon. Diagnosis of RDDLC is made based on clinical signs and rectal palpation. Some horses manifest nasogastric reflux and elevated glutamyl-transferase related to partial obstruction of the duodenum. If the case is presented early, medical therapy may be attempted using intravenous fluid therapy, analgesics and withholding of feeds. However, immediate surgical intervention is necessary when there is severe pain with marked large colon distension or secondary impaction (Rakestraw and Hardy, 2006). It has been found that it is difficult to make a definitive diagnosis of RDDLC without performing an exploratory laparotomy and this is due to the non-specific nature of the rectal and ultrasonographic findings (Gardner *et al*., 2005).

2.3.5.3 Pelvic flexure retroflexion

Although this condition is rare, both the pelvic flexure and the left colon retroflex forwards to lie near the diaphragm. It occurs as sequel to colonic displacements often with other accompanying abnormalities, which include volvulus, enteroliths and/or impaction (Hardy *et al.*, 2000).

2.3.5.4 Large colon volvulus

Large colon volvulus (LCV) is one of the painful and often most fatal causes of colic in the horse (Hardy, 2008). It is reported to cause 10-20% of colic cases that undergo surgery (Moore, 1996; Proudman *et al.*, 2002). This is seen when the large colon rotates around its longitudinal axis, usually with the ventral colon moving dorsomedially. Cases of LCV often present with acute and severe signs of colic or may occur secondary to displacement or impaction with chronic mild signs, followed by an acute degree of pain (Gibson and Steel, 1999; Rakestraw and Hardy, 2006). Volvulus greater than or equal to 360 degrees has been found to be significantly associated with poor survival and post-operative complications (French *et al.*, 2002; Proudman *et* *al.*, 2005). Survival after hospital discharge following LCV is reported to be between 35-74% (Harrison, 1988; Snyder *et al.*, 1989b; Mair *et al*., 2007; Ellis *et al.*, 2008). Survival following LCV is related to the degree of vascular compromise of the large colon and the severity of the subsequent systemic inflammatory response (Proudman *et al.*, 2005).

2.3.5.5 Epiploic foramen entrapments

The epiploic foramen or foramen of Winslow is the 4 cm-wide entry into the vestibule of the omental bursa from the peritoneal cavity, resulting in occlusion of blood supply. This has been associated with cribbing which causes negative abdominal pressure. The dorsal and craniodorsal boundary of the foramen is the visceral surface of the base of the caudate process of the liver. The portal vein contributes to the cranioventral border and the gastro-pancreatic fold becomes evident as a band where it forms the ventral border of the foramen. Strangulation is typically in a left to right direction. At surgery in most cases, strangulation in the epiploic foramen can be corrected by careful traction combined with pushing of the strangulated bowel in the same direction (Archer *et al.*, 2008).

2.3.5.6 Intussusceptions

This comprises of longitudinal displacement of intestine in which one segment invaginates into the lumen of an adjacent segment and continues to move caudally in the direction of peristalsis. Intussusception is believed to be as a result of abnormal motility patterns due to various causes such as sudden dietary changes, intestinal neoplasia, obstruction secondary to foreign bodies, previous jejunal resection and anastomosis, parasitism particularly ascarids and tapeworms in foals, maldigestion secondary to gastroduodenal ulcer disease and enteritis (Matsuda *et al.*, 2013). Intussusceptions that develop in horses are jejuno-jejunal, ileal-ileal, or ileocaecal (Vatistas *et al*., 1996). Although intussusception is palpable in only a minority (23%) of affected adult horses, distended loops of small intestine are palpable per rectum in 50% of the intussusception cases (Lores and Ortenburger, 2008).

2.3.5.7 Herniation

Inguinal-scrotal herniation is seen in horses with the jejunum and ileum as the incarcerated segments in most cases (Mezerova *et al*., 2008b). On rare occasions, the large colon is incarcerated and part of it introduced into the inguinal canal or scrotal sac. Inguinal-scrotal hernia is a more common finding in males (Moorman and Jann, 2009). Several authors have reported high prevalence of herniation in some breeds of horses (Mezerova *et al*., 2003; Shoemaker *et al*., 2004). In most of these hernias with jejunum and ileum incarcerated, good prognosis and high rate of survival is observed following surgery (Mezerova *et al*., 2008a). The large colon is rarely introduced into the inguinal canal or scrotal sac. Foals are more likely to develop inguinal herniation because the inguinal canal is shorter and wider than in the mature horses (Robinson and Carmalt, 2009). Congenital inguinal herniation occur in newborn colts and the hernia is usually reducible (Cox, 1987). Inguinal rupture is assumed to be the result of traumatic incidents and may occur in horses of any age (Velden Van der, 1988).

2.4 Diagnosis of colic

The main goal in examining a horse with colic is to identify and classify the cause of colic according to the pathophysiologic categories such as obstruction, strangulation, enteritis/colitis, peritonitis, infarction and according to the anatomic segment of the gastrointestinal tract that is involved. Some practitioners use response to analgesia and rectal examination as methods of determining the type of colic a horse is suffering from. Other factors that influence the choice of diagnostic tool is age, experience of the practitioner, value of the test, risks of the diagnostic tool to the horse and the veterinary practitioner, cost of the test and owner preference. Risk to personal safety and poor cooperation of the horse are some of the reasons why practitioners do not perform rectal examinations (Kassirer, 1976; Gough and Munroe, 1998; Lucas *et al*., 2009, Vandeweerd *et al.*, 2012). The financial situation of the horse owner is an important factor in deciding whether to carry out some tests such as haematology, biochemistry and ultrasonography (Everitt, 2011). Financial ability of the owner largerly plays a role not only in diagnostic decision-making but also in treatment options for colic in horses (Blikslager and Mair, 2014). Diagnosis of colic is a step-wise process that involves history taking, physical examination, laboratory findings, use of nasogastric intubation as well as use of imaging tools.

2.4.1 History

Thoroughly interrogated patient history gives useful information that may give clues on presence and possible cause of colic. This includes answers to important questions such as feeding and feed types, watering, deworming frequency, previous episodes of colic as well as other appropriate factors. Other useful information include intensity of the pain, duration of colic prior to examination, whether or not the clinical signs are intermittent or continuous, the animal's appetite and water intake, defaecation and whether or not analgesics have been administered (White *et al*., 2005).

2.4.2 Physical examination

Examination of horses with abdominal pain should begin by general observation from a distance while paying special attention to attitude, body condition, magnitude and frequency of the pain. The degree of pain must be interpreted carefully especially if the horse has received analgesic medication(s) prior to examination. Parameters such as temperature, heart rate and respiratory rate should be assessed before administration of analgesics. Cardiovascular parameters are widely used as indicators of disease severity (Parry *et al.*, 1983; Reeves *et al.*, 1989; Thoefner *et al.*, 2000). During physical examination, mild chemical restraint could be needed to ensure safety of the horse, clinician and handler, but in such situations interpretation should be done cautiously due to possibilities of masking the pain (White, 1990).

The heart rate is essential to monitor cases of colic because it has been found to be useful as a prognostic indicator, in which elevated rates suggest an emergency intervention to try and save a horse with colic (Rakestraw and Hardy, 2006; Mair *et al*., 2007). It is also essential to monitor the pulse. Weak pulse pressure is suggestive of shock, hypovolaemia, or cardiac compromise (Parry *et al*., 1983).

The colour of mucous membranes is a useful prognostic indicator (Furr *et al*., 1995; Stephen *et al*., 2004), because it shows the state of hydration and blood circulation. For example cyanosis of mucous membranes indicates poor peripheral perfussion of tissues, while brick red to purple colour suggests possibility of endotoxaemia (Radostits *et al*., 2009). Capillary refill time is also a good prognostic indicator, which when delayed more than 4 seconds suggests unfavourable prognosis if immediate intervention is not done (Parry *et al*., 1983; Stephen *et al*., 2004).

Although body temperature is not elevated in horses with colic unless there is infectious enteritis or colitis (Orsini and Kreuder, 2003), hypothermia indicates hypovolaemia, circulatory compromise and poor tissue perfusion, which in presence of increased heart rate may suggest severe disease. Increased respiratory rate corresponds to presence of severe pain, fever or respiratory compensation for metabolic acidosis. Extreme respiratory distress can occur secondary to diaphragmatic hernia and gastric or colonic distension leading to limitation of diaphragmatic excursions (Furr *et al.*, 1995).

Gastrointestinal borborygmi should be evaluated and assessed by ascultation of the abdomen, which is usually divided into right and left dorsal and ventral quadrants. Each quadrant should be auscultated for 30 to 60 seconds to assess the quality and frequency of sounds. It has been reported that the intestinal sounds were found to be absent in severe intestinal diseases such as strangulation and non-strangulating infarction, and increased in horses with enterocolitis, proximal enteritis and spasmodic colic (Wormstrand *et al.*, 2014). Presence of gastrointestinal borborygmi and constant abdominal pain, which is unresponsive to analgesic treatment may suggest that surgery could be required for intervention (White, 1990).

Abdominal distension seen in the paralumbar fossa is most often associated with distended large colon or caecum, but distended small intestine only causes moderate paralumbar fossa distension. Free gas within the abdominal cavity is seen secondary to rupture of intestinal lumen (White, 1987). In a study involving 219 horses, it was shown that abdominal distension was the most essential factor for decision-making on whether medical or surgical intervention would be the best option. Other factors that contributed to this decision are rectal findings and peritoneal fluid colour (Ducharme *et al.*, 1989). Rectal palpation could be the most useful method for determining the intestinal segment associated with the colic, but this depends on the level of cooperation of the horse. It could also be a good way of determining intestinal conditions requiring surgery (White, 1998).

2.4.3 Laboratory findings

Packed cell volume (PCV) is an important prognostic indicator in horses with colic (Puotunen-Reinert, 1986). Elevated PCV has been shown to be a negative prognostic indicator for survival of the horse. However, other reports suggest that PCV has no prognostic significance (Van der Linden *et al*., 2003). It is therefore not wise to use PCV as the sole determinant of prognosis. Nevertheless, it is an indicator of cardiovascular compromise, which is an important determinant for survival of the horse (Parry *et al*., 1983). Low white blood cell (WBC) count implies endotoxaemia and a probable indicator of devitalized intestine. Increased WBC is seen in impending colitis and peritonitis with signs of abdominal pain (Morris, 1991).

Total protein and albumin levels are important parameters in the management of horses with acute abdominal disease. A study showed that decreased serum total protein concentration at admission was associated with an increased risk of postoperative death in horses recovering from small intestinal surgery (Proudman *et al*., 2005). In a retrospective study of horses undergoing colic surgery, prognosis was found to be associated with total plasma protein, the type of lesion, preoperative PCV and the length of the surgical procedure (Pascoe *et al*., 1983). Hyperglycaemia is common in horses with colic and is associated with poor prognosis when considered together with changes in the heart rate and PCV (Hassel *et al*., 2009). Horses with higher blood glucose concentrations have been associated with a less favorable prognosis at admission in hospital (Parry *et al*., 1983).

Plasma or peritoneal lactate levels are important predictors for survival (Parry *et al*., 1983). Peritoneal lactate has been shown to be more useful predictor of intestinal ischaemia secondary to strangulating obstruction than blood lactate (Furr *et al*., 1995). Plasma lactate concentration is elevated significantly in non-surviving horses with large colon volvulus and lower in horses with viable colon (Johnston *et al.*, 2007). Horses with increased blood or peritoneal lactate were reported to have a high likelihood of needing intestinal resection, developing postoperative paralytic ileus and increased probability of death (Delesalle *et al.*, 2007).

Abdominal fluid analysis is also useful in determining if there is a need for surgery (Adams *et al.*, 1980). Protein concentrations and complete white blood cell count of peritoneal fluids are useful in determining the degree of intestinal injury (Reeves *et al.*, 1989). Increased protein concentration in abdominal fluid with no change in cell numbers is often due to simple obstruction with bowel distension. An increased number of white blood cells and ratio of neutrophils to monocytes (that is more than 70% neutrophils), will indicate a likelihood of bowel ischaemia or degeneration with leakage of bacteria. Excess numbers of red blood cells (RBC) in the peritoneal fluid shows that there is leakage of cells from capillaries and this is an indicator for intestinal injury, particularly venous strangulation with obstruction. Increase of haemoglobin concentrations suggests increased odds for surgery, but also improves sensitivity and specificity of the decision compared to just visual assessment of peritoneal fluid. Increased lactate concentration in peritoneal fluid compared to plasma lactate is also an indicator of intestinal compromise that indicates a surgical lesion. In addition, increase of lactate concentration from a series of peritoneal fluid measurements is an indicator of progressive intestinal injury (Delesalle *et al*., 2007). Bacteria in the peritoneal fluid is a clear indication of intestinal mucosal damage that allows their leakage through the intestinal wall (Weimann *et al*., 2002).

2.4.4 Nasogastric intubation

Passing of a nasogastric tube is both diagnostic and therapeutic. Presence of gastric reflux in the nasogastric tube suggests likelihood of small intestine obstruction, requiring surgical treatment. Proximal enteritis, obstructive ileus of the colon or duodenum can cause nasogastric reflux and this is often treated medically. Nasogastric reflux should be coupled with other physical examination findings to make a conclusive diagnosis (White, 1987).

2.4.5 Abdominal ultrasound

Ultrasonography is a valuable imaging tool for diagnosis of acute and chronic gastrointestinal disorders and diseases involving abdominal organs and urogenital tract. The common abdominal abnormalities diagnosed through ultrasonography are inguinal hernia, renosplenic entrapment of the large colon, sand colic, intussusception, enterocolitis, right dorsal colitis, and peritonitis. It contributes in a limited way to the diagnosis of gas and spasmodic colic, displacement and torsion of caecum or colon (Reef, 1998; Freeman, 2003). Changes in the position, motility and contents of the affected intestinal segments and secondary enlargement or atrophy of other abdominal structures can be indicative of gas distension or primary malposition of the caecum or colon. Ultrasonogram of nephrosplenic entrapment shows inability of imaging the left kidney and presence of ventral displacement of the spleen. The dorsal aspect of the spleen would appear as a straight border due to the dorsal displacement of the large colon over the nephrosplenic ligament (Santschi *et al.,* 1993).

The diameter of the pre-stenotic and affected segments of the small intestines involved in a strangulating lesion is usually greater than 3 cm. The wall thickness is often increased and the motility absent (Freeman, 2003). Impactions are characterized by round distended viscus devoid of visible sacculations with no peristalsis and the wall thickness is usually normal or slightly increased. Faecal impaction appears as a hyperechoic line casting an acoustic shadow from the mucosal surface, while sand impaction appears as small hyperechoic particles causing reverberation artifacts (Korolainen and Ruohoniemi, 2002).

2.4.6 Gastroscopy and laparascopy

Endoscopy reveals gastric ulcers and impaction and may provide information on the specific nature of the impaction. This is indicated in cases of chronic colic and rarely in acute colic (Blikslager, 2009). Laparascopy may be performed for abdominal exploration (Warmsley, 2007).

2.5 Treatment of equine colic

Treatment of colic involves management of pain, restoration of gastrointestinal motility, decompresion, treatment of hypovolaemia and the use of laxatives. This is done immediately after diagnosis has been made. The decision on which treatment should be used on individual patients or whether a case requires referral for specialized treatment or have surgical intervention should be done immediately. Each case should be judged on its own merit based on the history, intensity of pain, physical examination and laboratory findings (White, 2006). If surgical intervention is needed, this should be performed immediately to improve the prognosis.

2.5.1 Use of analgesics in cases of colic

A number of analgesic drugs and different protocols are employed for pain management in cases of horses with colic. These are described below.

2.5.1.1 Non-steroidal anti-inflammatory drugs

The mechanism of action of non-steroidal anti-inflammatory drugs (NSAIDs) is inhibition of cyclo-oxygenase (COX) activity, leading to inhibition of prostaglandin production (Warner and Mitchell, 2002). Prostaglandin (PG) E_2 and I_2 sensitize nerve endings to pain and are responsible for amplification of pain during bowel distention, ischaemia and inflammation (Moore *et al.*, 1995; King and Gerring, 1989). Different drugs produce varying levels of analgesia, possibly due to the different concentrations of the two types of cyclo-oxygenase, COX_1 and COX_2, in tissues (Morrow and Roberts, 2001). COX_1 regulates the production of prostaglandins necessary for normal organ and vascular function. The use of COX_2 inhibitors has been limited to experimental application in horses (Morton *et al.,* 2005; Tomlinson and Blikslager, 2005). COX_2 inhibitors produce analgesia through action in response to cytokines, serum factors, or growth factors and causes marked increase in prostaglandin production (Hersh *et al*., 2005). The common NSAIDs used in the management of colic are phenylbutazone, flunixin meglumine, ketoprofen and aspirin with varying levels of effectiveness (Tomlinson and Blikslager, 2005). Flunixin meglumine remains the drug of choice in the treatment of colic because it provides analgesia, inhibits endotoxin effects, and improves cardiovascular status without adversely effecting intestinal motility. The recommended dose is 1.1 mg/kg intravenously (IV), once or twice a day (Semrad *et al.*, 1985). Phenybutazone is not as effective as flunixin meglumine in managing visceral pain. However, there is evidence that it is more effective in decreasing the levels of prostaglandin E2 (PGE2) and therefore reducing the chances of ileus during endotoxaemia. This is achieved by combining the use of flunixin meglumine [0.25 to 0.5 mg/kg IV, "bis in die" (BID)] and phenylbutazone (0.5 mg to 1 mg IV, BID) through alternating administration of each drug every 6 hours (King and Gerring, 1989). Ketoprofen reduces chances of getting gastric ulcers but is less effective as an analgesic compared to flunixin meglumine. Eltenac reduces the deleterious effects of endotoxaemia in a similar way to flunixin meglumine, but has some adverse effects at 2 to 3 times the normal doses. Eltenac has not been used extensively for colic (Goodrich *et al.,* 1998).

Carprofen [0.7 mg/kg "semel in die" (SID) or BID] has been used as an anti-inflammatory after colic surgery because it is potentially less likely to cause ulcers. However, its efficacy has not been clinically or scientifically proven. Firocoxib was found to be an effective analgesic in experimental intestinal ischaemia model and did not inhibit mucosal barrier restoration (Cook and Blikslager, 2008). Meloxicam is a selective COX_2 inhibitor and can be used for colic. It has been shown that it does not inhibit healing of the intestinal mucosa after ischaemia (Beretta *et al.*, 2005).

2.5.1.2 Alpha-2 adrenergic agonists

Alpha-2 adrenergic agonists such as xylazine, romifidine and detomidine are sedatives that cause analgesia and muscle relaxation. All these have been used for control of abdominal pain in horses (Muir and Robertson, 1985). Analgesia by alpha-2 adrenergic agonists is via stimulation of central alpha-2 adrenoreceptors, which modulate the release of norepinephrine and directly inhibit neuronal firing. This causes sedation, analgesia, bradycardia and relieves pain in horses with colic (Muir and Robertson, 1985; Merritt *et al*., 1998). Xylazine reduces intestinal motility for up to 2 hours when administered at a dose of 1.1 mg/kg (Lowe *et al*., 1980; Adams *et al*., 1984; Roger and Ruckebusch, 1987; Mitchell *et al*., 2005). This has been shown to have a profound effect that gives relief from both somatic and visceral pain caused by distension or strangulation (Lowe *et al*., 1980; Muir and Robertson 1985; Jochle *et al*., 1989; Dabareiner and White 1995). Xylazine analgesia may only last for about 10-30 minutes or have minimal effect in horses suffering from strangulating lesions such as large colon torsion. In horses with large or small colon impactions, xylazine appears to be beneficial in relieving intestinal spasms around the obstructing mass and this allows passage of gas as well as rehydration of ingesta. This is often achieved at a dose of 0.1 to 0.3 mg/kg intravenously titrated to effect. Whenever a prolonged effect is desired, xylazine can be administered intramuscularly at 0.4 to 2 mg/kg (Mitchell *et al*., 2005).

In an experimental study in horses with caecal distension, detomidine produced complete cessation of colic for up to 3 hours with mean analgesia period of 45 and 105 minutes at 20 µg/kg and 40 µg/kg, respectively (Lowe and Hilfiger, 1986; Roger and Ruckebusch, 1987). Detomidine also reduces intestinal motility and can obscure signs of pain, which may make it difficult for the clinician to diagnose the cause of the colic. If signs of colic are observed 30 to 60 minutes after its administration, it may indicate severity of the disease that may necessitate surgery since it is a potent drug. The dosage can be titrated in 5 to 10 µg/kg BW increments (Dabareiner and White 1995).

2.5.1.3 Opioids

Opioids provide excellent analgesia and are part of a large superfamily of membrane-bound receptors that are coupled to G proteins in the brain, spinal cord, and peripheral nerves. Opioids combine reversibly with these receptors and alter the transmission and perception of pain. Opiods like morphine and oxymorphone are very potent analgesics but may cause excitation in horses not unless they are used in combination with xylazine. Butorphanol which is a partial agonist and antagonist provides the best pain relief with least adverse effects. It can also be used in combination with xylazine or detomidine. The dosage ranges from 0.05 to 0.1 mg/kg with the high dosage being necessary for severe colic (Gingerich *et al*., 1985; Muir and Robertson, 1985; Kohn and Muir, 1988). Visceral analgesia provided by butorphanol is inferior and of shorter duration than the one provided by xylazine and detomidine. Administration of butorphanol by continuous infusion (loading dose at 17.8 g/kg and infusion dosage at 23.7 g/kg/h for 24 hours) provides analgesia and reduces the adverse effects on gastrointestinal tract motility as well as behaviour. In horses that have had colic surgery, butorphanol given as continous rate of infusion (CRI) significantly delays the time to first passage of faeces and this is undesirable in horses with impaction colic (Sellon *et al*., 2004).

2.5.1.4 Spasmolytics

Spasmolytic drugs provide analgesia by reducing spasms of the intestine. Hyoscine-N-butylbromide is a central and peripherally acting anticholinergic widely used as a spasmolytic in the treatment of abdominal pain in horses and has a shorter pharmacological effect on intestine than other anticholinergics like atropine in horses (Davies and Gerring, 1983; Adams *et al*., 1984). Increased frequency of intestinal contractions or spasms occur in a part of intestine just before intraluminal obstruction such as impaction. The combination of hyoscine N-butylbromide and para-aminophenol derivative (dipyrone) is popularly used in Europe especially in the treatment of spasmodic colic and impactions (Keller and Faulstich, 1985; Roelvink *et al*., 1991).

2.5.1.5 Lidocaine

Lidocaine is an amide-linked local anaesthetic which produces analgesia by inhibiting the sympathetic response, blocking the effects of endotoxin, restoring intestinal coordination and decreasing inflammation (Nieto *et al*., 2000). Recently, lidocaine has been used to provide analgesia and enhance gastrointestinal tract motility in horses that have had colic surgery and thereby prevent postoperative ileus (POI). This is done with 2% lidocaine given as a bolus of 1.3mg/kg IV slowly over 5 to 10 minutes, followed by 0.05 mg/kg/minute in a balanced electrolyte solution for 24 hours, at an infusion rate of 5 ml/kg body weight/h (Cook and Blikslager, 2008).

2.5.2 Decompression

Decompressing distended stomach or intestines helps in reducing the intensity of abdominal pain. Nasogastric intubation helps to relieve gastric tympany or remove gastrointestinal reflux that is due to small intestinal obstruction or ileus. The nasogastric tube can be left in place for passive decompression after surgery or in horses with proximal enteritis but this should be regularly checked every 2 to 3 hours even with extreme distension because the stomach pressure may not force the fluid through the tube (White, 1987). The other site at which distension from gas can be relieved is through puncturing the caecum, which is done at the right paralumbar fossa mid-way between the last rib and the ventral prominence of the tuber coxae. Puncturing of the cecum is done with a 5 to 6 inch, 14 to 16 gauge needle or catheter over a needle is used and this is concurrent with rectal palpation as it helps to push the gas into the caecal base and facilitate removal of it as much as is possible. Once most of the gas is removed, saline or an antibiotic solution can be infused through the needle as it is pulled out of the caecum to avoid leaving a trail of contaminated material in the peritoneum or body wall (White, 1987).

2.5.3 Laxatives

The laxatives mostly used in the treatment of impactions include mineral oil, dioctyl sodium sulfosuccinate (DSS) and magnesium sulfate (Epsom salts). Laxatives should never be administered to horses with signs of proximal gastrointestinal obstruction because they remain in the stomach for a prolonged period of time and they never get to the obstruction site. This causes more distention of the stomach with concurrent increase in the severity of the abdominal pain. It is imperative to make sure that the tube is in the stomach because an accidental entry of mineral oil into the lungs could be fatal. Although rare, this complication has happened even to skilled equine practitioners (Davis *et al*., 2001).

Following the administration of laxatives preferably at 12 hour intervals, administration of water is recommended so that volume deficits can be restored from the action of osmotic and cathartic agents. Mineral oil serves as a laxative and a marker for progressive gastrointestinal transit, in which its successful passage within 12 to 18 hours after administration is considered as evidence of patency of the gastrointestinal tract. However, mineral oil can pass around some obstructions without softening them. It is a relatively safe non-toxic stool softener (Davis *et al.*, 2001).

Magnesium sulfate (Epsom salts) when mixed with water is a potent cathartic that has the ability to soften faecal materials. However, it should be administered with the knowledge that excess amounts may cause electrolyte derangements (most notably hypermagnesaemia). The preferred dosage is 0.5g/kg BW (Lopes *et al.*, 2002).

Dioctyl sodium sulfosuccinate (DSS) is a surfactant agent that can act as an irritant laxative and faecal softener. Toxicity results from gastric and small intestinal mucosal damage (Moffatt *et al.*, 1975). There are reports of magnesium toxicity due to enhanced absorption when administered concurrently with DSS (Henninger and Horst, 1997).

Psyllium hydrophilic mucilloid (Metamucil®, Procter and Gamble) acts as a bulk laxative and is widely used for impactions (Dabareiner and White, 1995). Bran has been used extensively for many years due to its purported laxative effects, but no change in faecal water content has been demonstrated with the feeding of wet or dry bran mash compared to other diets (Hintz, 1975). Enteral fluids are cost-effective and efficacious at assisting in the hydration and passage of contents in intestinal impactions (Lopes *et al*., 2002).

2.5.4 Fluid Therapy

According to the descriptions made by Lopes, et al (2002), fluid therapy should be considered in the treatment of hypovolaemia in horses with impactions that are unresponsive to analgesics and laxatives. Fluids can be administered either orally or intravenously. Treatment of hypovolaemia should begin by assessing the degree of dehydration of the patient. This is done thorough physical examination (checking of delayed skin tent and appearance of sunken eyes) and this can be confirmed by carrying out packed cell volume and total protein laboratory assessements. A horse that has a delayed skin tent of more than 4 seconds is at least 6% dehydrated, while a horse with sunken eyes is at least 10% dehydrated. Horses between these two extremes can be estimated as 8% dehydration. Once the degree of dehydration has been estimated, the percentage is multiplied by the horse's body weight to give the fluid deficit. It is recommended that the first half of the fluid deficit should be administered rapidly (up to 100 ml/kg, BW/h, or 50L/hr in an adult horse) and this is followed by the remainder at a slower rate of (3 to 5L/hr). Fluid administration should be monitored by repeated measurements of the PCV and the plasma protein. Once dehydration has been solved, a horse requires 50 ml/kg/day (approximately 1L/hr in an average horse) for maintenance. An alternative to intravenous fluids is continuous infusion of fluids via a small-bore nasal-esophageal feeding tube. Indwelling small-bore nasogastric tubes (Mila International, Florence KY) are available for continuous enteral fluid therapy in controlled circumstances. In one study, enteral fluids were found more effective at hydrating colonic contents than intravenous fluids combined with oral magnesium sulfate (Lopes *et al*., 2002).

2.5.5 Motility Agents

Bethanechol chloride is a direct acting muscarinic receptor agonist, which significantly increases gastrointestinal emptying with notable activity in the ileum, right ventral colon and caecum

(Lester *et al.,* 1998). Neostigmine methylsulfate is an indirect acting agent (cholinesterase inhibitor) that increases caecal emptying along with increased activity in the ileum, pelvic colonic flexure, right dorsal colon and caecum (Adams *et al.,* 1984; Lester *et al.,* 1998). Metoclopramide increases contractile activity in the pylorus, duodenum and jejunum (Kohn and Muir, 1988).

2.5.6 Surgical procedures for treatment of colic

Determination on whether a horse with colic requires surgery should be made promptly. Many veterinarians have used the response to analgesic treatment as an effective way to determine which colic case needs surgery (Peloso *et al*., 1996). Abdominal fluid analysis is also helpful in determining the need for surgery (Adams *et al*., 1980). Protein concentrations, RBC and WBC counts as well as differential leucocyte count are helpful in determining the degree of intestinal injury (Reeves *et al*., 1989). Therefore, indications for exploratory celiotomy will basically include severity of abdominal pain, which is unresponsive to analgesics, deterioration of the cardiovascular status and abnormalities in peritoneal fluid that are indicative of bowel circulatory compromise (Dabareiner and White, 1995). The factors that will influence surgical outcome include single or multiple sites of impaction, the duration of impaction prior to surgical intervention, any concurrent displacements or torsions, size of faecalith and occurence of postoperative complications (Specht and Colahan, 1988; Ragle *et al*., 1989).

It has been shown that the survival rate following surgery on the caecum and colon was 80% and this was significantly higher than survival rate for horses that had small intestinal surgery at 52% (Phillips and Walmsley, 1993).

Ventral midline celiotomy through the linea alba is the most common approach for equine abdominal surgery because it allows exteriorization of 75% of the intestinal tract. The ventral paramedian incision is the second most common approach used in colic operations and is made 10 cm to the right or left of the midline through the rectus abdominis muscle (Johnston *et al.*, 2007). The other rarely used approaches include the standing flank approach and inguinal approach, which give access to part of the intestinal tract. The standing flank method can be used in conjunction with a ventral midline incision for stallions with inguinal or scrotal hernias (Furr *et al*., 1995). Resection and anastomosis is indicated in intussusception, torsion and rupture of the colon. One study in a university hospital showed that 49% of the horses that had small intestinal anastomosis and recovered from anesthesia died later during the postoperative period due to a number of possible complications including: overinversion, anastomotic intussusception, infarction, haematoma, shortening of the mesentery, mesenteric defects, mesenteric haemorrhage and misalignment of bowel (MacDonald *et al.*, 1989). However there is enough clinical and research evidence that a single layer that is hand sewn (as opposed to staples) on end-to-end anastomosis is very effective. The goal should be to produce a large stoma (large intestinal passage) with minimal inversion. Lembert suture with minimal inversion and appositional patterns using fine suture material (3-0 or 4-0) with minimal exposure of knots, and suture to the serosal surfaces work well. Stomas of marginal size are prone to obstruction and this predisposes to postoperative ileus (Freeman, 2005).

Colotomy is indicated in impaction colic or enteroliths. Complications of colotomy are rare but the most common is haemorrhage from the incision edges which can be severe enough to cause melena and haemorrhagic shock (Honnas and Cohen, 1997). Colopexy is done to prevent recurrence of displacement and large colon volvulus (Hance, 1997) and colostomy is done in cases of rectal injury as by-pass to the rectum. Hernia repair is indicated in the repair of inguinal and diaphragmatic hernias (Dabareiner and White, 1995).

The technique for closure of a ventral midline incision is a matter of surgeons' preference. Use of continuous suture pattern with size 3 polyglycolic acid suture performs well in many clinical situations and closure of subcutaneous tissues and peritoneum can be omitted. Skin can be closed with polyglycolic acid suture size number 2-0 or 3-0 in a simple continuous pattern and these sutures do not need to be removed which is an advantagious in horses that are difficult to handle. In large breeds of horses (that are more than 700 kg) or mares in advanced stages of pregnancy or horses that have undergone a second exploratory surgery through a recent incision, retention sutures of 8 cm to 10 cm intervals can be used to support the ventral midline incision during recovery and the immediate postoperative period. The retention sutures are vertical mattress sutures with doubled number 2 nylon placed through polypropylene bolsters with far bites traversing all layers and close bites equal or less than 2.5 cm from the skin edge and only through the skin and subcutaneous tissues (Freeman, 2005).

2.5.7 Euthanasia without Surgical Treatment

The most common reasons for euthanasia without surgical treatment are the financial limitations imposed by the owner and/or poor prognosis. Some horses are euthanized because of the tendencies to experience recurrent colic. The age of the horse is also another reason for owners opting for euthanasia rather than surgical treatment (Southwood *et al.*, 2010).

Prognostic indicators have been used to predict with some degree of accuracy, the likelihood of survival from complicated surgery. The most notable prognostic indicators include heart rate, packed cell volume, plasma lactate, creatinine and glucose concentrations (Southwood *et al.*, 1996). These indicators reflect the level of pain and the patient's cardiovascular status, which are related to the extent of intestinal damage and duration of the disease. Horses that are admitted on an emergency basis with high plasma lactate concentration have a worse prognosis than those with lower lactate concentrations. Plasma lactate concentartions was particularly useful for predicting survival in horses with serious disease such as colitis or large colon volvulus. When these predictors points towards poor prognoses, then the most rational and logical decision is to euthanize the horse (Underwood *et al.,* 2008*).*

Precise and timely diagnosis is important to provide an accurate prognosis and this is difficult to obtain preoperatively in most cases of colic (Wormstrand *et al*., 2014).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area.

This study was carried out in Nairobi County Kenya, which is located at 1°17′S 36°49′E, and has a daily temperature range between 16^0C and 30^0C. The horse population in the County is approximately 3,200. It was purposively decided to carry out the study in Nairobi County because of its relatively high population of horses, Jockey Club of Kenya is in the County, and it was convenient for the study. Nairobi County also has more equine practitioners compared to other Counties in Kenya. These factors made it possible to obtain the required sample size for the study.

3.2 Study design.

The study was carried out in three phases, which included cross sectional study, prospective and retrospective studies.

3.2.1 Cross sectional study

The Cross Sectional study determined the prevalence and risk factors of colic as well as knowledge, attitudes and practices of horse owners/trainers on colic in horses. Information on these various aspects was obtained through a questionnaire administered to horse owners or trainers at the stables. The stables that qualified for the study were those with minimum of 3 and maximum of any number of horses. A total of 30 stables were purposively selected based on owners' willingness for their stables to be included in the study. The stables were selected from the lists obtained from the Jockey Club of Kenya, Polo Club and the Horse Association of Kenya. The questionnaires were administered by the investigator who interviewed the horse owners/trainers as respondents. The questionnaire targeted answers to questions specific for colic cases. For each stable, the cases of colic included those that had occurred within the previous 12 months at the date of filling the questionnaire. The assumption made was that the horse owners/trainers are familiar with the general signs of colic. The questionnaire, which is presented in Appendix 1 consisted of structured questions that sought the following information; breeds of horses, reasons for keeping horses, number of horses in a stable, type of feed used, quality of feed, frequency of feeding, deworming practice, level of activity in the stable, number of horses affected by colic, signs of colic, treatment given and outcomes of colic.

3.2.2 Prospective study

The prospective study was carried out to assess the haematological and biochemical values in horses with colic. The haematological parameters evaluated were total erythrocyte count (TEC), haemoglobin concentration, haematocrit, mean corpusclar volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), red cell distribution width (RDW), and platelet count, total leucocyte count (TLC) , neutrophils, lymphocytes, monocytes, eosinophils and basophils. The biochemical parameters evaluated were alanine aminotransferase (ALT), aspartate aminotrasferase (AST), total proteins, serum albumin, random glucose and serum lactate. Blood samples were obtained from the jugular vein of 27 horses that manifested signs of colic before any treatment was given. These colic cases were seen between November, 2015 and March, 2016. Diagnosis of colic was made by physical examination which included recognizing and assessing signs of abdominal pain, heart rate, respiratory rate and temperature (Appendix 2). Other parameters determined included the colour of mucus membranes, capillary refill time and presence or absence of borborygmi sounds. Rectal examination and nasogastric intubation were done as well as ultrasonography when appropriate and possible. A total of 10 ml of blood sample was collected from the jugular vein of each horse using direct venipuncture or a pre-placed IV catheter. Of this volume of blood, 4 ml was collected in vacutainer tubes with EDTA and 4 ml was collected in vacutainer tubes with clot activator and 2 ml in sodium fluoride tubes. The 4 ml of blood sample with EDTA for each horse with colic was used to analyze for total erythrocyte count (TEC) in 10^{12}/L, total platelet count (TPC) in 10^{9}/L, total leucocytes count (TLC) in 10^{9}/L, packed cell volume (PCV) in %, hemoglobin concentration (Hb) in g/dl and differential cell count (Neutrophils, Basophils, Eosinophils, Monocytes and Lymphocytes). The other 4 ml blood was assayed for alkaline phosphatase (IU/L), aspartate aminotransferase (AST) (IU/L), total protein (g/l) and serum lactate (mmol/l). The remaining 2 ml was assayed for random glucose (mmol/l). The hematological analysis was done using an automatic cell counter (Idexx Procyte DX Haematology Analyzer, Idexx laboratory, USA) following the manufacturer's instructions. The blood samples with the clot activator and sodium fluoride were immediately centrifuged at 3500 revolutions per minute for 10 minutes and serum was harvested. Serum samples were stored at minus 20ºC and analyzed using dry chemistry technology with Idexx catalyst DX chemistry analyzer (Idexx laboratory,USA) for alkaline phosphatase (ALP), aspartate aminotransferase (AST), total protein, serum albumin, random glucose and serum lactate.

Relevant treatment was instituted for colic and the horses closely monitored until either recovery or death. The cases were categorized as either impaction colic or spasmodic colic from their clinical presentation and physical examination

3.2.3 Retrospective study

The main objective of the retrospective study was to determine occurrence of colic from January 2004 to December 2014. It also determined the association between various treatments of colic and the outcomes (recovery or death of the affected horses). All the cases of colic covering the study period were retrieved from archived records in the custody of 6 equine practitioners in Nairobi County, who had valid Kenya Veterinary Board (KVB) registration (Appendix 3). The record of each case was scrutinized for specific information, which included case identification particulars, dates of colic occurrences, symptoms, diagnosis, definitive and supportive treatments in the management of the case. Laboratory specimens taken and their results, diagnostic aids, responses to treatment, repeat episodes, prognoses drawn and outcome of each case were recorded.

3.3 Data management and analysis.

Data from the questionnaire was entered into Microsoft Office Excel 2010. It was verified and validated to be correct entries as per the questionnaires. The prevalence of colic was calculated using Microsoft Office Excel and expressed as percentage occurrences based on the positive responses and total respondents in the questionnaires. Other parameters including risk factors of colic in the questionnaire were also expressed in percentages. The calculations were done using the following formula:

$$\frac{\textit{Number of positive responses for each specific parameter in the questionnaires}}{\textit{Total number of respondents}} \times 100$$

Analysis to show simple associations between the risk factors and occurrence of colic was done at significance level of $P < 0.05$. Univariate analysis was done between the risk factors and occurrence of colic based both on number of colic cases that occurred within the previous 12 months and on the number of positive responses for risk factors perceived by respondents to be predisposing horses to colic in the 21 stables where the questionnaires were administered. The risk factors that were found likely to influence occurrence of colic were further subjected to multivariate analysis in order to identify the most probable risk factors contributing either negatively (protective) against or positively (contributive) to incidences of colic.

Initially, all the haemotological and biochemical data were first categorized into those from impaction colic horses or spasmodic colic horses as well as from horses that recovered or those that died. The haematological and biochemical data were entered into Microsoft Office Excel 2010 then verified and validated to be correct entries as per the data collection sheets. This data was then imported into StatPlus pro 5.9.8 statistical package where normality tests were first computed using Shapiro Wilk normality test. Following this, means±SD were calculated and student t-test was then used to compare the means between the categories of colic as well as between those that recovered and those that died at $P<0.05$ significance level.

Data collected from the retrospective study was organized manually and coded as appropriate. It was entered into Microsoft Excel 2010. The data was exported to StatPlus pro 5.9.8 statistical package for analysis. Descriptive statistics were then computed and analysed for incidence of colic, types of colic (in percentage) and analgesics used in treatment of colic and mortality (in percentages). Incidence was calculated by dividing the number of horses with colic (numerator) and the total number of horses seen by the veterinarians (denominator). Mortality was calculated by the number of dead horses (numerator) and the total number of horses with colic (denominator).

Simple association between the type of colic and treatment, type of colic and outcome, type of colic and recurrence of colic, as well as between the treatment and outcome of colic were computed using Chi square statistic at $p < 0.05$ significance level. In these associations, Chi square calculations were determined by evaluating each of the risk factor (variable) against the occurrence of colic (outcome) in horses. The degrees of freedom (df) in each case was standard, and was being calculated by [(rows-1)(columns-1)], hence [(2-1) x (2-1) = 1]. Therefore, df was 1 for each association test.

CHAPTER FOUR

4.0 RESULTS

4.1 Results of cross sectional study

4.1.1 Descriptive statistics for cross sectional study

Thirty questionnaires were administered in the 30 stables where the cross sectional study was carried out. Out of these, only 70% (n = 21) were satisfactorily completed. The remaining 30% (n=9) were incomplete and could therefore not be used to compile the data. In 13 of the 21 stables in which the questionnaires were adequately completed, the horse owners/trainers were male and only in 8 stables were the owners/trainers female. The total number of horses in the 21 stables was 429. The lowest number per stable was 3 and the highest was 60, while the average number was 20.4±15.4. The average period the respondents had been keeping horses in their stables was 16.6±9.9 years and the average number of horses they had kept was 20.4±15.4. The respondents kept horses in these stables for various reasons. The main reasons were show jumping (38.1%, n = 8), polo (38.1%, n = 8) and racing (33.2%, n = 7). Other reasons but in lower percentages included use of horses for safari, leisure riding and breeding (Table 4.1 and Fig. 4.1).

All the respondents (horse owners/trainers) in this study indicated that they were familiar with the obvious signs of colic. A total of 57% (12/21) indicated they administered flunixin meglumine to relieve pain in horses with colic as the initial treatment, before calling a veterinarian for confirmatory diagnosis and further treatment. These respondents indicated that they call a veterinarian only when a horse is non-responsive to medication with flunixin meglumine followed by walking and lunging. The other 43% (9/21) of the respondents indicated that they call a veterinarian immediately they notice signs of colic without administering any first aid. Twenty stables (95.2%) had a veterinarian who attended to their horses, but one stable had no veterinarian for a while due to financial reasons.

4.1.2 Perceived prevalence rate of colic

The prevalence of colic was considered as “perceived” due to the fact that the information was gathered from horse owners/trainers who are not professionals, hence the responses could have some degree of subjectiveness. This prevalence was determined with 429 horses as the population of reference. The “perceived” prevalence of colic for the 12 month-period referred to by the questionnaire was 13.5% (n = 58) for all the 21 stables in which the questionnaires were satisfactorily completed. When considered per stable within the 12 months, some stables had no occurrences of colic, while in some, the highest number for occurrence of colic was 12. The average number of colic cases that occurred within the 12 months per stable was 2.7±3.3. The highest percentage of occurrence of colic in a single stable was 43.5%. The number and percentage of colic cases that occurred within the 12 months in each of the 21 stables are presented in Table 4.2.

Table 4. 1: Percentage of reponses by respondents on the reasons for keeping horses in the twenty one stables during a cross sectional study in Nairobi County, Kenya.

Reasons for keeping horses	**Number of responses (n = 21)**	**Percentage of responses (%)**
Show jumping	8	38.1
Polo	8	38.1
Racing	7	33.2
Leisure riding	3	14.6
Safari	2	9.5
Breeding	2	9.5

NB: Some stables kept horses for more than one purpose, hence the total percentages add up to more than 100.

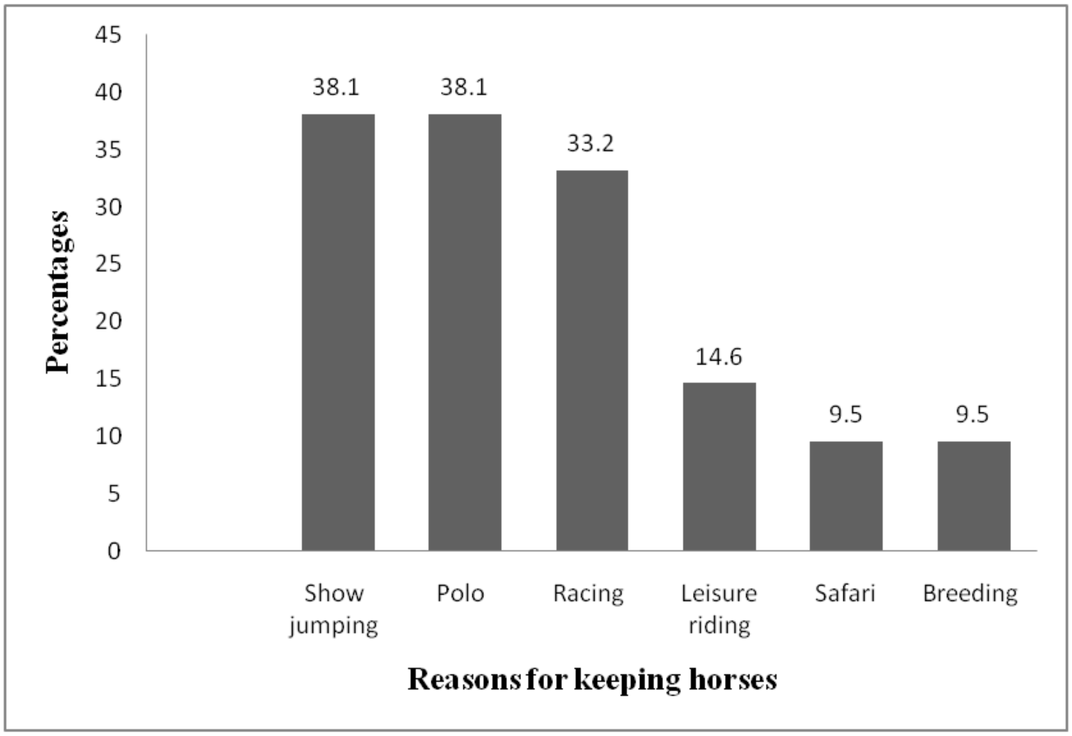

Figure 4. 1: Percentages of various responses by respondents on reasons for keeping horses in the twenty one stables during a cross sectional study to determine prevalence of and risk factors for colic in horses in Nairobi County, Kenya.

Table 4. 2: Perceived prevalence by respondents for occurrences of colic within a 12-month period among 429 horses in twenty one stables in Nairobi County, Kenya

Stable number	Total number of horses per stable	Number of colic cases per stable	% colic cases per stable
1	23	10	43.5
2	14	2	14.3
3	33	12	36.4
4	20	3	15.0
5	21	0	0.0
6	20	2	10.0
7	15	1	6.7
8	60	5	8.3
9	9	2	22.2
10	10	0	0.0
11	28	5	17.9
12	28	0	0.0
13	20	3	15.0
14	58	5	8.6
15	20	5	25.0
16	8	0	0.0
17	6	0	0.0
18	4	1	25.0
19	5	1	20.0
20	3	0	0.0
21	24	1	4.2
TOTAL	429	58	13.5

4.1.3 Risk factors for colic as perceived by horse owners and trainers

4.1.3.1 Horse owners'/trainers' perception on causes of colic

Horses in all the stables were frequently dewormed and all the respondents in these stables indicated that lack of deworming is a likely cause of colic. Respondents in 80.6% (n = 17) of the stables indicated that changing hay increases likelihood of colic in horses. Free range grazing was mentioned as a likely cause of colic by respondents in 57.1 % (n = 12) of the stables, while lack of execise was also a probable cause of colic by respondents in 52.4 % (n = 11) of stables. Other management related risk factors for colic mentioned by respondents included changing the grain [42.9% (n=9)], change of feeding schedule [33.3 % (n =7)] and overfeeding of grains [14.3 % (n = 3)] as seen in Table 4.3.

4.1.3.2 Horse owners/trainers perception on causes of recurrent episodes of colic

There were variations of answers by the respondents from the 21 stables on the factors they thought were the most contributory to the occurrence of recurrent episodes of colic in horses. Some of the respondents incriminated more than one factor as a predisposing cause of colic. Therefore the total number of factors mentioned were 28, from which the percentages were calculated. A total of 25% (n = 7) of the responses incriminated lush/green succulent pastures as the main cause of recurrent episodes of colic, while 17.9% (n = 5) incriminated poor quality hay as the most probable factor. Other responses in equal proportions of 10.7% (n = 3) indicated that inadequate water, cribbing and reduced level of activity could predispose horses to recurrent episodes of colic. The rest of the factors were thought to have minimal contribution to the occurrence of recurrent episodes of colic in horses (Table 4.4). There was only 7.1 % (n = 2) of the respondents who indicated that they had no knowledge of any factor that would predispose horses to recurrent colic.

4.1.3.3 Deworming practices

All the respondents from the 21 stables said that they dewormed their horses regularly, of which 76.2 % (n = 16) said that they dewormed them every 3 months and 23.8 % (n = 5) every 12 months. From the responses, it was found that various dewormers are used for the horses in the 21 stables. The most common (61.9%, n = 13) was the use of doramectin alternated with ivermectin-praziquantel combination, while doramectin alone was used in 23.8 % (n = 5) of the stables. The rest of the dewormers were used in lower frequencies as shown in Table 4.5.

Table 4. 3: Management-related risk factors for colic as perceived by the horse owners/trainers in Nairobi County, Kenya.

Management-related risk factors	**Number of positive responses for causing colic (n = 21)**	**Percentage of positive responses for causing colic (%)**
Frequency of deworming	21	100
Changing Hay	17	80.6
Free range feeding/grazing	12	57.1
Lack of exercise	11	52.4
Changing the type of grain	9	42.9
Overfeeding of grains	3	14.3
Changing or moving stables	3	14.3
Regular dental care	2	9.5

NB: Some of the respondents mentioned more than one management-related risk factors as possible predisposing factors for colic. Hence total percentages more than 100%.

Table 4. 4: Percentages of the number of responses on each perceived risk factor for occurrence of recurrent episodes of colic in horses as mentioned by horse owners/trainers within Nairobi County, Kenya

Perceived risk factor for recurrent episodes of colic	**Number of positive responses for each perceived risk factor on recurrent colic episodes**	**Percentage (%) of positive responses for perceived risk factors on recurrent colic episodes**
Lush /succulent green pastures	7	25
Poor quality hay	5	17.9
Inadequate water	3	10.7
Cribbing/winding sucker	3	10.7
Reduced level of horse activity	3	10.7
Feeding on weeds	2	7.1
Don't know (No idea)	2	7.1
Gastric ulcers	1	3.6
Mouldy feeds	1	3.6
Worms	1	3.6
Total	28	100

Table 4. 5: Percentages of stables in which each type of dewormer is used as indicated by respondents in Nairobi County, Kenya

Type of dewormer	**Number of stables per dewormer (n = 21)**	**Percentage (%) of total number of stables per deormer**
Doramectin /Ivermectin-praziquantel	13	61.9
Doramectin	5	23.8
Doramectin/Albendazole	1	4.8
Ivermectin-praziquantel	1	4.8
Levamisole-Oxyclozanide	1	4.8
Total	21	100

4.1.4 Association between perceived risk factors and occurrence of colic

4.1.4.1 Association between perceived risk factors and occurrence of colic based on number of colic cases within 12 months

Analysis to test for association between different management-related risk factors and the number of colic cases was done based on the number of colic cases per stable within the previous 12 months from the date the questionnaires were administered. Among the factors that were found to be significantly associated with occurrence of colic included overfeeding horses with grains ($\chi^2 = 4.54$, $p = 0.03$) in which horses fed on rations of large amounts of grains were reported by respondents to have increased incidences of colic compared to those fed on small amounts; frequency of deworming ($\chi^2 = 4.07$, $p = 0.04$) in which more regularly dewormed horses tended to have low incidence of colic than those only occasionally dewormed; and level of activity of the horses ($\chi^2 = 10.8$, $p < 0.001$) with horses that lacked or had diminished activity had likelihood of higher incidences of colic than those with increased levels of activity (Table 4.6).

4.1.4.2 Univariate analysis for positive responses on perceived risk factors and occurrence of colic in the 21 stables

Results of linear regression did not show significant association ($p > 0.05$) between any one of the perceived management-risk factors and the occurrence of colic in the 21 stables where the questionnaires were administered. The linear regression demonstrated the risk factors that had positive and negative contribution to likelihood of occurrences of colic in horses. The risk factors that are likely to have a negative (protector) influence on the occurrences of colic by reducing its incidences are regular dental care (β-estimate = -0.456, O.R. = 0.6) and changing the conditions of the stables (β-estimate = -0.142, O.R. = 0.9). Regular deworming of horses for example every 3 months (β-estimate = -0.301, O.R. = 0.7) or 12 months (β-estimate = -0.947, O.R. = 0.4) also has a negative influence on occurrences of colic with a likelihood of reduced incidences. The risk factors that were likely to have a positive (contributor) influence on the occurrences of colic by increasing its incidences included changing of feeding schedule (β-estimate = 0.506, O.R. = 1.7), changing the type of hay (β-estimate = 0.502, O.R. = 1.7) and lack of or diminished activity (β-estimate = 0.511, O.R. = 1.7). Other risk factors with likelihood of positive influence, hence possibly increasing incidences of colic are presented in Table 4.7.

4.1.4.3 Multivariate analysis for positive responses on perceived risk factors and occurrence of colic in the 21 stable

The risk factors that were found to have a likelihood of either negatively (protective) or positively (contributive) influence the occurrence of colic in horses were subjected to multivariate analysis, which suggest only three of them as the most probable factors that would have an influence on incidences of colic. The risk factor negatively influencing occurrence of colic, thus probability of being protective against occurrence of more incidences of colic, is change in stable conditions (β-estimate = -0.282, O.R. = 0.7). The risk factors positively influencing occurrence of colic, thus probability of contributing to occurrence of more incidences of colic are change in feeding schedule (β-estimate = 0.572, O.R. = 1.7) and reduced level of activity (β-estimate = 0. 257, O.R. = 1.2).

Table 4. 6: Association between management-related risk factors and occurrence of colic based on the number of colic cases that occurred in Nairobi County, Kenya

Management-related risk factor	No of horses with colic	No. of horses without colic	Chi square	p-Value
Overfeeding with grains	13	45	4.54	0.03*
Changing the type of grains	30	190	0.01	0.94
Frequency of deworming	60	324	4.07	0.04*
Lack of activity	44	196	10.8	< 0.001*
Changing hay	55	335	1.25	0.26
Free range feeding	4	25	0.00	0.99
Changing feeding schedule	19	102	0.69	0.41
Regular dental care	5	56	1.72	0.19
Changing/moving stables	3	38	1.49	0.22

* Significant at $p < 0.05$

Table 4. 7: Association of perceived management-related risk factors based on the responses of horse owners/trainers in Nairobi County, Kenya

Management related risk factors	B estimate	s.e	Odds Ratio	p-Value
Changing feeding schedule	0.506	0.351	1.7	0.167
Changing stabling conditions	-0.142	0.540	0.9	0.795
Changing hay	0.502	0.524	1.7	0.351
Regular dental care	-0.456	0.725	0.6	0.537
Changing type of grain	0.347	0.360	1.4	0.348
Overfeeding of grain	0.364	0.455	1.4	0.435
Free range feeding	0.340	0.540	1.4	0.537
Lack/diminished activity	0.511	0.370	1.7	0.184
Deworming frequency				
Deworming every 3 months	-0.301	0.716	0.7	0.680
Deworming every 12 months	-0.947	0.756	0.4	0.230

4.1.4.2 Perception on possible remedies for reduction of incidences of colic

Some of the respondents from the 21 stables mentioned more than one remedy that could contribute to the reduction of occurrence of colic in horses. Supply of adequate clean water and good quality feed were the main important factors (each at 18.5%) perceived by respondents to contribute to the reduction of occurrence of colic in horses. The other two factors each mentioned by 11.1% (n=3) of the respondents, were avoidance of lush pasture and post-prandial supervision. The rest of the 9 factors perceived to contribute to reduced occurrence of colic in horses, were each mentioned by less than 10% of the respondents. (Table 4.8). Some of these factors were feed or feeding-related, which included avoidance of hay or pasture with weeds, avoidance of mouldy hay, and having a regular feeding schedule which was 2 to 3 times daily. The feeds mentioned by the respondents included horse meal, bran (both soaked in molasses) and crushed or cooked barley. Horse meal, bran and barley were given twice daily while hay was given *ad libitum* (Table 4.8)

Table 4. 8: Frequencies of various perceived possible remedies for reducing incidence of colic in horses as indicated by in Nairobi County, Kenya

Perceived remedies for colic	Number of responses per suggested factor	Percentage (%) of responses per factor
Adequate clean water	5	18.5
Good quality feed	5	18.5
Avoidance of lush pasture	3	11.1
Postprandial supervision	3	11.1
Regular feeding schedule	2	7.4
Adequate exercise	2	7.4
Avoidance of weeds in pasture	1	3.7
Consistent feeding	1	3.7
High fiber diet	1	3.7
Soaking hay before feeding	1	3.7
Improved knowledge of colic	1	3.7
Regular dental care	1	3.7
Good and routine management practices	1	3.7
Total	27	99.9

4.2 Results of prospective study

4.2.1 Descriptive analysis

A total of 27 horses manifesting signs of colic were examined in this phase of the study. The cases were presented between November, 2015 and March, 2016. The horses were adults from 9 stables comprising of 15 females and 13 males. During this period, only one horse had recurring episodes of colic. There were 18.5 %(n = 5) deaths. The findings from the history and physical examination of the reported cases pointed to spasmodic and impaction colic. Spasmodic colic was diagnosed in 55.6 % (n=15) of the cases while impaction colic was in 40.7 % (n =11) of the cases and that of torsion at 3.7 % (n=1). Only one horse had torsion and this was excluded from subsequent analysis. Spasmodic colic was diagnosed based on findings of presence of increased borborygmi sounds in both sides of the abdomen, passing of gas and increased frequency of defaecation. Impaction colic was diagnosed based on findings of reduced borborygmi, bloated abdomen, presence of reflux through nasogastric intubation and rectal examination. Postmortem of the 5 horses that died revealed torsion (1) at the jejunum and impaction at transverse colon (n = 2) and pelvic flexure (n = 2) as the cause of death.

4.2.2 Mean values of hematological parameters in spasmodic and impaction colic

Haematological values of horses with spasmodic colic were compared with those of horses with impaction colic. The mean haematological values between horses with spasmodic colic and those with impaction colic were very similar, hence the differences were largely not significant ($p > 0.05$) (Table 4.9) except for the mean corpuscular haemoglobin (MCH), total leucocyte count and neutrophil count. The mean corpuscular haemoglobin was significantly higher ($p = 0.03$) in horses with spamodic colic (16.8±1.3 pg) than in those with impaction colic (15.6±1.2 pg). The mean leucocyte count was significantly higher ($p = 0.02$) in horses with impaction colic

[12.9±5.9 (10^9/L)] than in those with spasmodic colic [9.0±1.5 (10^9/L)]. Similarly, neutrophil count was significantly higher ($p = 0.02$) in horses with impaction colic [9.1±5.6 (10^9/L)] than those with spasmodic colic [5.4±1.7(10^9/L)].

4.2.3 Mean values of haematological parameters in horses that recovered and in those that died of colic.

The mean values of the haematological parameters in horses that recovered from colic and in those that died of colic were closely related with no significant differences ($p > 0.05$) between them as shown in Table 4.10. Although the differences were not significant, overall the mean values of total leucocytes were higher in the horses that died of colic than those that recovered. Similarly, the haematocrit and platelet mean values appeared to be much higher in the horses that died of colic than in those that survived, however the difference was not significant.

4.2.4 Mean values of biochemical parameters in horses with colic

The mean values of blood glucose were significantly higher ($p = 0.02$) in horses with impaction colic (5.7±2.0 mmol/l) than in those with spasmodic colic (3.7±1.4 mmol/l). There were no significant differences in the mean values of alkaline phosphatase (ALP), aspartate aminotransferase (AST), total protein, albumin and serum lactate between the horses that had impaction colic and those that had spasmodic colic (Table 4.11). Despite there being no significant differences, the mean values of alkaline phophatase and aspartate aminotransferase were relatively higher in horses with impaction colic than in those with spasmodic colic. However, mean total proteins was relatively lower in impaction colic than in spasmodic colic cases.

Table 4. 9: Comparative mean haematological values between horses with impaction colic and those with spasmodic colic in Nairobi County

Haematological parameters	**Type of colic**	**Means±SD**	**p-Value**
Erythrocyte count (10^{12}/L)	Impaction Spasmodic	9.6±1.4 8.9±2.1	0.20
Hemoglobin concentration (g/dl)	Impaction Spasmodic	14.9±1.8 18.4±3.2	0.95
Hematocrit (L/L)	Impaction Spasmodic	0.42±0.07 0.42±0.1	0.98
Mean corpuscular volume (fl)	Impaction Spasmodic	43.2±5.6 46.3±2.8	0.13
Mean corpuscular hemoglobin (pg)	Impaction Spasmodic	15.6±1.2 16.8±1.3	**0.03***
Mean corpuscular hemoglobin concentration (g/dl)	Impaction Spasmodic	36.3±2.8 36.0±2.3	0.81
Red blood cell width (%)	Impaction Spasmodic	26.4±9.9 20.9±8.0	0.15
Total platelet count (10^9/L)	Impaction Spasmodic	162.5±196.1 160.1±130.5	1.0
Lymphocyte count (10^9/L)	Impaction Spasmodic	3.3±1.3 2.8±1.3	0.37
Monocyte count (10^9/L)	Impaction Spasmodic	0.6±0.8 0.6±0.4	0.89
Eosinophils count (10^9/L)	Impaction Spasmodic	0.20±0.1 0.2±0.2	0.17
Basophil count (10^9/L)	Impaction Spasmodic	0.1±0.04 0.1±0.04	0.27
Total leucocyte counts (10^9/L)	Impaction Spasmodic	12.9±5.9 9.0±1.5	0.02*
Neutrophil count (10^9/L)	Impaction Spasmodic	9.1±5.6 5.4±1.7	0.02*

*****Significant at $p < 0.05$

Table 4. 10: Comparative mean values of haematological parameters between horses that recovered from colic and those that died of colic in Nairobi County

Hematological parameters	Outcome	Means±SD	p-Value
Erythrocyte count (10^{12}/L)	Died	9.1±3.1	1.0
	Recovered	9.1±1.8	
Hemoglobin concentration (g/dl)	Died	14.3±2.2	0.7
	Recovered	14.9±2.7	
Hematocrit (L/L)	Died	11.3±21.9	0.39
	Recovered	0.4±0.1	
Mean corpuscular volume (fl)	Died	40.6±5.3	0.14
	Recovered	45.7±4.0	
Mean corpuscular hemoglobin (pg)	Died	17.1±5.2	0.8
	Recovered	16.4±1.3	
Mean corpuscular hemoglobin concentration (g/dl)	Died	41.5±7.2	0.22
	Recovered	36.0±2.4	
Red blood cell width (%)	Died	29.6±11.4	0.35
	Recovered	23.3±9.0	
Total platelet count (10^9/L)	Died	417.3±326.8	0.22
	Recovered	139.4±109.0	
Lymphocyte count (10^9/L)	Died	2.3±1.8	0.5
	Recovered	3.0±1.3	
Monocyte count (10^9/L)	Died	0.4±0.2	0.14
	Recovered	0.6±0.6	
Eosinophils count (10^9/L)	Died	0.12±0.2	0.86
	Recovered	0.14±0.2	
Basophil count (10^9/L)	Died	1.1±2.2	0.40
	Recovered	0.1±0.04	
Total leucocyte counts (10^9/L)	Died	18.1±7.2	0.13
	Recovered	10.4±4.4	
Neutrophil count (10^9/L)	Died	14.2±9.3	0.12
	Recovered	6.7±4.9	

Significant at $p<0.05$

Table 4.11: Comparative mean values of biochemical parameters between horses with impaction colic and those with spasmodic colic in Nairobi County

Biochemical parameters	**Type of colic**	**Means±SD**	**p-Value**
Alkaline phosphatase (ALP) IU/L	Impaction	89.0±69.8	0.2
	Spasmodic	55.0±31.1	
Aspartate aminotranseferase (AST) IU/L	Impaction	453.4±225.3	0.9
	Spasmodic	436.5±222.6	
Total protein g/l	Impaction	67.9±17.8	0.45
	Spasmodic	73.0±13.3	
Albumin g/l	Impaction	30.4±7.2	0.19
	Spasmodic	34.5±8.1	
Globulin g/l	Impaction	37.5±7.2	0.8
	Spasmodic	38.5±8.1	
Blood glucose mmol/l	Impaction	5.7±2.0	0.02*
	Spasmodic	3.7±1.4	
Blood lactate mmol/l	Impaction	7.4±2.9	0.12
	Spasmodic	5.7±1.6	

* Significant at $p < 0.05$

4.2.5 Mean values of biochemical parameters in horses that recovered or died from colic

There were significant differences in the mean values of total protein, albumin and globulin between horses that died of and those that survived from colic. The mean values of total protein were significantly lower ($p < 0.01$) in horses that died (57± 5.4 g/l) than in those that survived (72.5±14.8). Similary, the mean values of albumin were significantly lower ($p < 0.01$) in horses that died (24.7±2.1 g/l) than in those that survived (33.7±7.6 g/l). The mean values of globulin were significantly lower ($p = 0.04$) in horses that died (32.4±3.9 g/l) than in those that survived (38.7±9.1 g/l) from colic. On the other hand, and although not significant, alkaline phosphatase was relatively higher in horses that died than in those that survived from colic, while aspartate animontransferase was relatively higher in those that survived than in those that died (Table 4.12).

Table 4. 12: Comparative mean values of biochemical parameters between the horses that died and those that recovered from colic in Nairobi County

Biochemical parameters	Outcome	Means±SD	p-Value
Alkaline phosphatase IU/L	Dead	120±64.9	0.19
	Survived	66.4±49.4	
Aspartate aminotranseferase IU/L	Dead	413±10.3	0.61
	Survived	439.7±225.4	
Total protein g/l	Dead	57±5.4	0.002*
	Survived	72.5±14.8	
Albumin g/l	Dead	24.7±2.1	0.0001*
	Survived	33.7±7.6	
Globulin g/l	Dead	32.4±3.9	0.04*
	Survived	38.7±9.1	
Blood glucose mmol/l	Dead	6.9±2.2	0.08
	Survived	4.2±1.7	
Blood lactate mmol/l	Dead	6.3±3.3	0.98
	Survived	6.2±2.3	

*Significant at $p < 0.05$

4.3 The results of the retrospective study

4.3.1 Descriptive statistics on cases and types of colic

A total of 4 veterinary practitioners in Nairobi County had records from which cases of colic in horses could be retrieved. From the records of these practitioners, 12,077 cases of horses had been treated for various diseases between January 2004 and December 2014. Of these cases, 3.1% (n=375) had colic which had been treated during this period. The incidence of colic over the 10 years in which the records were considered was therefore 3.1%. Among these 375 cases of colic, 68.0% (n = 255) had suffered spasmodic colic, 27.7% (n = 104) had impaction colic and 4.3% (n = 16) had colic resulting from intestinal displacements (Table 4.13 and Fig. 4.2). From the records, 75.0% (12/16) of the cases of intestinal displacements involved volvulus and 12.5% (2/16) were right dorsal displacement of the large colon (RDDLC). The other types of intestinal displacements were left dorsal displacement of the large colon (LDDLC) and intestinal strangulation caused by a lipoma (Table 4.14 and Fig. 4.3). All the horses with intestinal displacements died and the records indicated that diagnoses were made at postmortem. The overall mortality rate among all the 375 cases of colic was 5.6% (n = 21).

Table 4. 13: Percentages of types of colic cases in horses that were treated from January 2004 to December 2014 in Nairobi County, Kenya

Types of colic	**Number of horses with each type of colic (n=375)**	**Percentages (%) of colic cases**
Spasmodic colic	255	68.0
Impaction colic	104	27.7
Intestinal displacements	16	4.3
Total	375	100

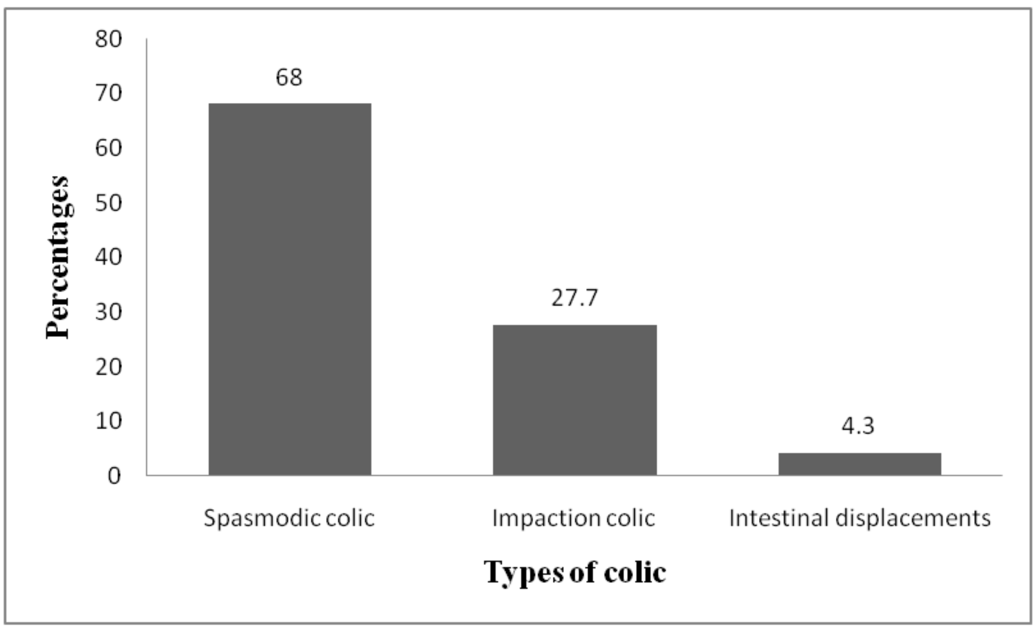

Figure 4. 2: Percentages of types of colic cases found in horses that were treated from January 2004 to December 2014 in Nairobi County, Kenya

Table 4. 14: Percentages of types of intestinal displacements in horses that were treated from January 2004 to December 2014 in Nairobi County, Kenya

Types of intestinal displacements	**Number of horses with type of intestinal displacement (n=16)**	**Percentages (%) of intestinal displacement cases**
Volvulus	12	75
Right dorsal displacement	2	12.5
Left dorsal displacement	1	6.3
Strangulating lipoma	1	6.3
Total	16	100

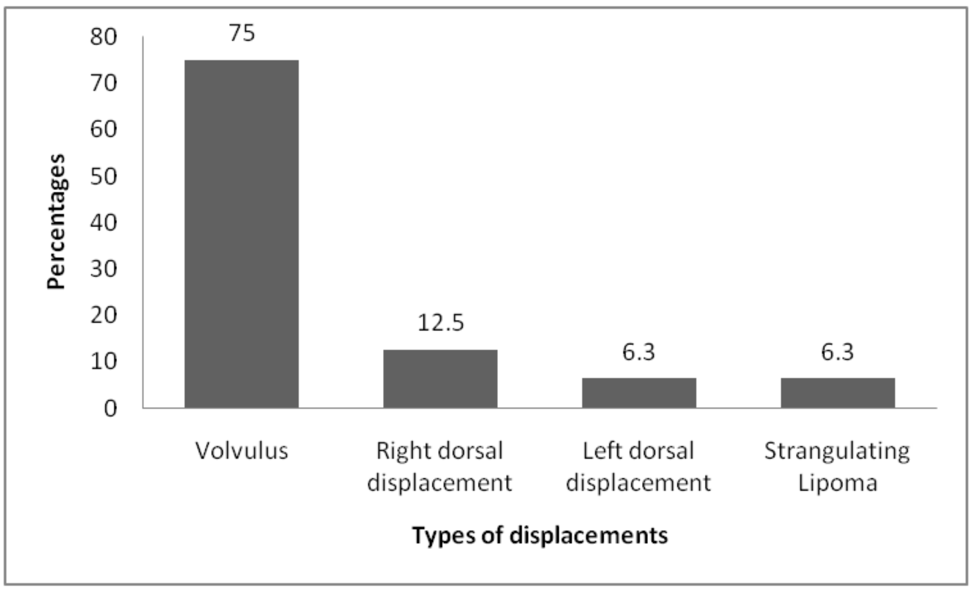

Figure 4. 3: Percentages of types of intestinal displacements in horses that were treated from January 2004 to December 2014 in Nairobi County

4.3.2 The types and use of analgesics in horses with colic

Pain management for colic cases in horses was done using either single or combinations of analgesics. The most commonly used protocol was single non-steroidal anti-inflammatory drug (NSAID) therapy in 85.3% (n = 320) of the 375 colic cases, which was mainly Flunixin meglumine in 81.9% (n = 307) of the cases. The next commonly used protocol was the combination of a NSAID and an opioid in 6.4% (n = 24) of the cases, and this was mainly Flunixin meglumine and Butorphanol. Spasmolytics were employed in 5.9% (n = 22) of the cases in which the main spasmolytic used was buscopan, which was used only in cases of spasmodic colic. The rest of the protocols were used in frequencies of less than 1% in the whole 11-year period as shown in Table 4.15.

With respect to the use of individual analgesic drugs and their combinations, flunixin meglumine was the most used drug (81.9%, n = 307), followed by butorphanol and flunixin meglumine combination (6.4%, n= 24), buscopan (5.9%, n = 22) and ketoprofen (3.5%, n= 13). The rest of the specific drugs each used in less than 1% of the cases of colic during the 11 years, are as presented in Table 4.16. Flunixin meglumine and ketoprofen were the only NSAIDs that were used. Ketoprofen was in the records only from 2014 but not in the records of earlier years. The records revealed that use of spasmolytics was employed in cases of spasmodic colic and the only spasmolytic used was buscopan (5.9%, n = 22).

Table 4. 15: Frequencies of use of various categories of analgesics during the treatment of colic in horses treated from January 2004 to December 2014 in Nairobi County, Kenya

Protocols for pain management	**Number of colic cases in which used**	**Percentages (%) of use of various protocols for pain management**
NSAIDs	320	85.3
NSAIDs-Opioids	24	6.4
Spasmolytics	22	5.9
NSAIDs-Opioids-Sedatives	3	0.8
Sedatives	2	0.5
NSAIDs-Sedatives	1	0.3
NSAIDs-NSAIDs	1	0.3
Opioids	1	0.3
Opioids-Sedatives	1	0.3
Total	375	100

Table 4. 16: Frequencies of use of various individual and combinations of analgesics during the treatment of colic in horses treated from January 2004 to December 2014 in Nairobi County.

Single and combinations of analgesics	**Number of colic cases used in (n=375)**	**Percentages (%) of use of various analgesics**
Flunixin meglumine	307	81.9
Butorphanol-Flunixin meglumine	24	6.4
Spasmolytics	22	5.9
Ketoprofen	13	3.5
Xylazine Hydrochloride	2	0.5
Xylazine-Butorphanol-Flunixin	2	0.5
Xylazine-Flunixin	1	0.3
Butorphanol	1	0.3
Ketoprofen-Flunixin	1	0.3
Detomidine-Butorphanol-Flunixin	1	0.3
Butorphanol	1	0.3
Total	375	100

4.3.3 Nasogastric intubation and the use of metabolic stimulants for management of colic

Among the 375 horses with colic, only 30.9% (n =116) were intubated as part of the management of the conditions causing colic. Gastric intubation was done as part of decompression treatment in impaction colic and all the types of displacement colic. Majority of the horses (69.1%, n=259), which includes spasmodic colic (n=255) and impaction colic (n=4) were not intubated. All the equine practitioners used mineral oil (Liquid parafin) and water as laxatives, which were introduced into the horse through nasogastric tube.

Use of metabolic stimulants, which was exceptionally vitamin B complex, was done in 22.1% (n = 83) of the horses with colic. The remaining 77.9% (n = 292) of the horses with colic were treated without inclusion of any metabolic stimulants.

4.3.4 Outcomes of colic in horses

The various outcomes of the cases of colic are presented in Tables 4.17, 4.18 and Figures 4.4 and 4.5. Out of the 375 horses with colic over the 11-year period, 94.4% (n = 354) recovered fully after receiving various forms of treatments, but 5.6% (n = 21) died. The deaths were from torsion and volvulus which accounted for 57.1% (12/21), impaction colic in 28.6 % (6/21), right dorsal displacement of the large colon (RDDLC) in 9.5% (n=2) and strangulating lipoma in 4.8% (1/21) of the horses. About 6.1% (n=23) of the horses had recurrent episodes of colic among the 375 cases in the 11 year period, while 93.9% (n = 352) were new occurrences of colic.

Table 4. 17: Number and percentages of deaths from each type of colic in eleven year period in Nairobi County, Kenya

Type of colic	Number of horses that died	Percentages (%) of horses that died
Volvulus	12	57.1
Impaction	6	28.6
Right dorsal displacement	2	9.5
Lipoma	1	4.8
Total	21	100

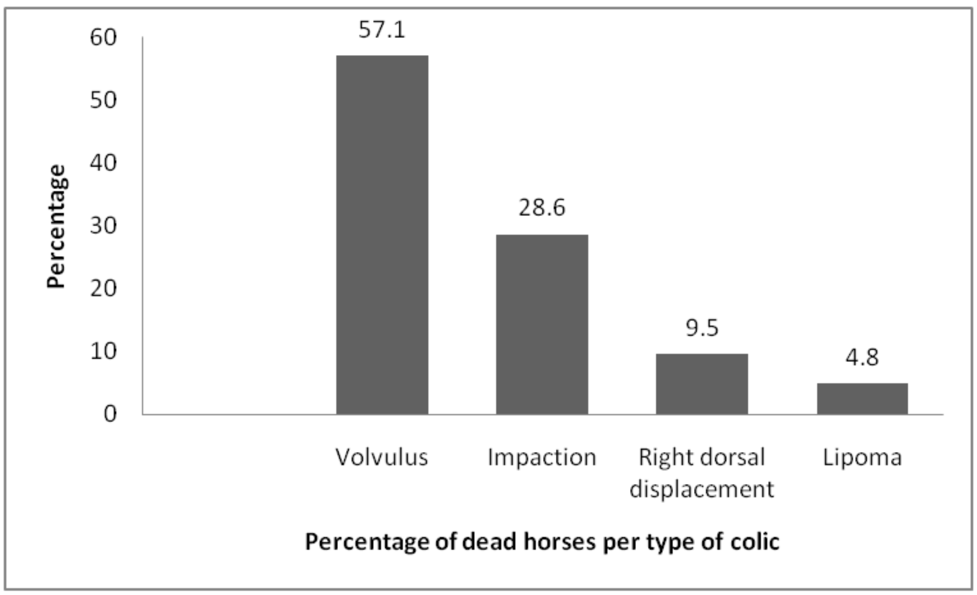

Figure 4. 4: Percentages of horses that died from each type of colic in the eleven year period in Nairobi County, Kenya

Table 4. 18: Overall number and percentages of horses that had recurrent and non-recurrent colic episodes as well as those that died or recovered among the cases treated from January 2004 to December 2014 in Nairobi County, Kenya

Nature of occurrence and outcomes of colic cases	**Number of cases (n=375)**	**Percentages (%) of recurrent and non-recurrent cases of colic**
Recurrent	23	6.1
Non-recurrent	352	93.9
Total	375	100
Died	21	5.6
Recovered	354	94.4
Total	375	100

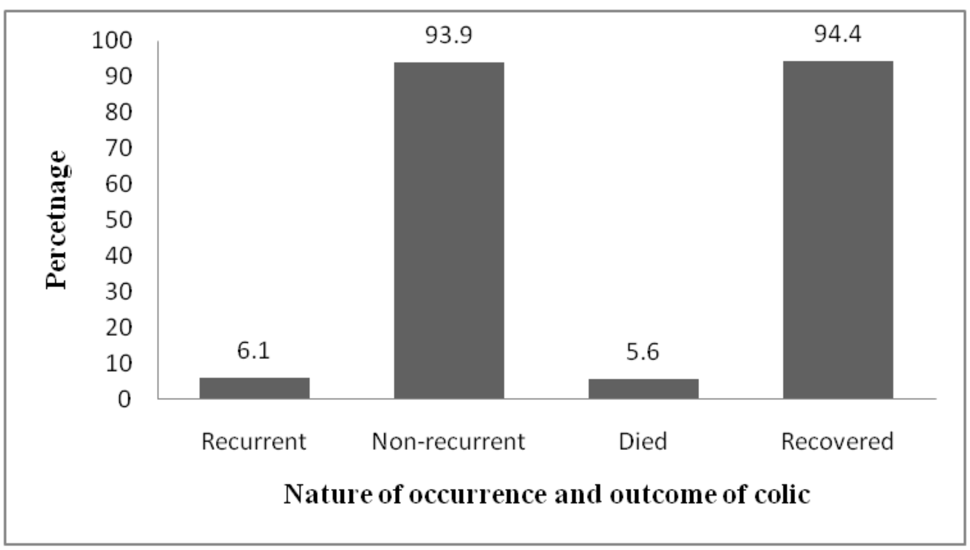

Figure 4. 5: Percentages of horses that had recurrent and non-recurrent colic episodes as well as those that died or recovered among the cases treated from January 2004 to December 2014 in Nairobi County, Kenya

4.3.5 Association between types of colic and various factors including treatment protocol, recurrence and outcomes

Test of simple association using Chi Square statistics, indicated that the type of colic seemed to significantly ($p < 0.05$) influence the the management protocols chosen, recurrence of the condition and the final outcome of the condition (Table 4.19). The type of colic that a horse had significantly influenced strongly ($\chi^2 = 265$, $p < 0.001$) the decision on whether or not to perform nasogastric intubation as part of its management, but weakly ($\chi^2 = 4.9$, $p = 0.03$) influence recovery of the horse. Also strongly associated with the type of colic was the possible final outcome of the horse that suffered the colic ($\chi^2 = 250$, $p < 0.001$), thus influencing the probability of recovery or death. Type of colic also seemed to strongly (($\chi^2 = 99.3$, $p < 0.001$) determine the need for use of metabolic stimulants, particularly vitamin B complex. There was moderate significant association ($\chi^2 = 22.5$, $p < 0.001$) between the type of colic that the horse had and the decision on the most suitable analgesic protocol, including whether to use combination ($\chi^2 = 18.3$, $p < 0.001$) or single analgesic therapy ($\chi^2 = 1.74$, $p = 0.42$). This association was stronger between the type of colic and use of combined analgesics than between type of colic and use of single analgesics. The possibility for recurrence of colic was weakly influenced ($\chi^2 = 4.6$, $p = 0.04$) by the type of colic.

Table 4. 19: Association between the type of colic and several factors in the treatment of colic in horses in Nairobi County

Colic-associated factors	**Chi-square**	**p-value**
Nasogastric intubation	265	< 0.001*
Outcome of horse with colic	250	< 0.001*
Use of vitamin B complex	99.3	<0.001*
Protocol of analgesia to be used	22.5	< 0.001*
Analgesic combination	18.3	< 0.001*
Rate of recovery with gastric intubation	4.91	0.03*
Recurrence of colic	4.46	0.04*
Use of NSAID	1.74	0.42*

*Significant at $p < 0.05$

CHAPTER FIVE

5.0 DISCUSSION

The response rate of 70% from the questionnaire survey in this study was higher than that of a similar study carried out in UK, which was 67% (Ebony *et al*., 2014). This could probably be attributed to the fewer numbers of questionnaires in the current study and the fact that they were administered personally by the investigator to purposively selected stables. The tendency in Kenya for likelihood of men being the owners or trainers of horses, may explain why there were more male than female respondents in the current study. The social status of horse owners in Kenya is probably what influences the keeping of horses mainly for show jumping, polo and racing.

The 13.5% prevalence of colic registered in the current cross sectional study is higher than the 4% to 10% reported as the expected rate of colic episodes in a general population of 100 horses per year (Kaneene *et al.,* 1997; Tinker *et al.,* 1997a). This could probably be attributed to the fact that in the current study, the prevalence was based on responses by the horse owners/trainers, in which case some of the colic episodes may not have been confirmed by veterinarians. This can therefore be considered as “perceived prevalence” because it depended on horse owners'/trainers' perspective, rather than on cases that were confirmed by veterinary professionals. The current study showed lower rate of recurrent colic episodes compared to a similar study previously estimated 10-15% recurrent colic cases in horses that had experienced previous episodes of abdominal pain, with some of the horses averaging 2 to 4 colic episodes per year (Tinker *et al.*, 1997a). The low recurrence in the current study could probably be attributed to less likely predisposing risk factors, particularly because high plane grain feeding is not a common practice with the horse owners in Kenya.

The finding of spasmodic colic as the most common type in this study is in agreement with the general report on the incidence of colic in horses, which states that the commonest type is the one of unknown origin followed by gas colic (Traub-Dargatz *et al*., 2001). Spasmodic colic is of unknown origin and is also thought to be associated with accumulation of gas in the gastrointestinal tract. It is reported to constitute 69-72% of all colic in a general population of horses (Archer and Proudman, 2006). The 27.7% prevalence of impaction colic found in this study is lower than the expected 30% reported in a general population of equines. It however occurs when more than one risk factor such as the type of feed, lack of water, disturbed intestinal motility, old age and parasites are present together (Sabev and Kanakov, 2008).

The 3.1% incidence of colic found through the retrospective study of the 10 year records was lower than in a previous 10 year study (Voigt *et al*., 2009), but compares closely with the 4.2% found in a year's study in the United States of America (Traub-Dargatz *et al*., 2001). This is likely to be attributed to the level of risk factors between the area of current study, which may have low risk compared to the level of high risk factors in areas where higher colic incidence was reported. However, the order of occurrence in the types of colic is similar to the one reported previously in which spasmodic colic has the highest incidence followed by impaction and obstructive or displacement colic (Traub-Dargatz *et al*., 2001; Voigt *et al*., 2009). However, although the obstructing and displacement colic of which intestinal strangulation is part of have low rate of occurrence, it has been reported that if a combination of several risk factors are present, the incidence of these types of colic could increase (White, 1990).

The fact that colic can be transient with some rate of spontaneous recovery such as the 28.7% reported previously by Hillyer et al. (2003), may be the reason for the high percentage of horse owners who treated cases of colic on their own without involving veterinarians as established in the current study. The other reason for this practice by the horse owners would be due to the fact that use of analgesics gives temporary relief from some types of colic and hence they tend to avoid calling veterinarians, assuming they will save on the professional costs. They resolve to give first aid using analgesics coupled with walking and lunging the horse (Tinker *et al.*, 1997a), and only call the veterinarian if the horse does not respond to these treatments over a period of time.

The association of colic with various perceived risk factors found in the current study is similar to most of the previous reports (Gonçalves *et al*., 2002). These reports indicate that types of feed, excessive concentrates or grains, sudden changes in feeding schedules, reduced activity of the horse, infrequent deworming of horses and provision of inadequate water are all associated with increased rate of colic (Dabareiner and White 1995; Tinker *et al.*, 1997b; Cohen *et al.*, 1999; Gonçalves *et al*., 2002; Little and Blikslager, 2002; Voigt *et al*., 2009). The finding in this study that dental care is likely to reduce the incidence of colic in horses agrees with the findings of Olusa and Akinrinmade (2014) who reported that dental problems tend to increase the risk of colic and they cited specifically dental caries and sharp enamel points as examples. Similarly, reduced risk for colic by regularly deworming horses was reported previously (Archer and Proudman, 2006). However, while changes in stabling conditions was found in the current study to reduce incidences of colic, it differs with previous reports where increased incidences were reported (Cohen *et al*., 1995). This could be explained by the fact that the changing in stabling that predisposes to colic is when horses are moved from regular pasture grazing to being housed in stables, but horses in the Nairobi County that were under study are normally in stables, hence being moved to a new stable would not significantly increase risk of colic. Poor quality hay or coarse roughages/fibers with low digestibility have been associated with impaction colic (White and Dabareiner, 1997). The finding in the current study that the number of horses per stable as well as whether or not horses are cared for by owners or trainers, to be some of the factors that contributed in some way to the occurrence of colic, agrees with similar previous reports (Hillyer *et al*., 2002). The authors reported that these factors predispose horses to colic.

Higher total leucocyte and neutrophil counts in impaction colic and in horses that died than in those that recovered, can be attributed to the fact that impaction applies intense pressure from the lumen to the walls of the involved gastrointestinal tract segment. When impaction persists over time, the pressure may result in slight degree of ischaemia, devitalization and degeneration of walls of the intestine. Subsequently, some bacteria die and release endotoxins into circulation and some bacteria leak into blood, thus triggering a rise in neutrophils and total leucocyte count as has been suggested previously **(**Morris, 1991; Weimann *et al.*, 2002). This may be the same reason for the death of some of the impaction cases of colic, while those with spasmodic colic recovered.

The significantly higher mean values of blood glucose in horses with impaction than in those with spasmodic colic is similar to the previous findings in other studies that reported hyperglycaemia, but the types of colic were not designated in those previous studies (Hassel *et al*, 2009). The reason for the hyperglycaemia is not well known, but it is suggested that horses with colic develop temporary insulin resistance that leads to blood glucose elevation. It was further suggested that the cases of colic with hyperglycaemia have worse prognosis for survival (Hassel *et al*, 2009). Although the blood lactate in impaction colic was not significantly different from spasmodic colic, it was nevertheless higher. This has been associated with poorer prognosis for survival in cases of colic with lactate at greater than 8 mmol/l (Moore *et al*., 1976).

The significantly lower serum levels of total protein, albumin and glubulin in horses that died compared to those that recovered agrees with reports of a retrospective study, which cited total plasma protein as one of the factors that influenced survival in horses that underwent surgery for treatment of colic (Pascoe *et al.*, 1983). Similarly in another study, it was stated that decreased serum total protein concentration was associated with an increased risk of postoperative death in horses recovering from small intestinal surgery. The decrease in plasma protein is an indication of loss of these proteins through damaged intestinal walls (Proudman *et al.*, 2005).

The observation in this study that flunixin meglumine as an NSAID was the most used pain management drug is in agreement with most previous reports showing that this is the drug of choice for management of abdominal pain (Zimmel, 2003; Moore and Leise, 2009). Flunixin meglumine has been cited as the most appropriate analgesic in equine colic due to the fact that it is the best inhibitor of visceral pain (Moore and Leise, 2009), it can provide analgesia for 8-12 hours, it can control inflammation and endotoxaemia as well as resolve most of the simple medical types of colic (Zimmel, 2003). It functions by blocking production of prostaglandins for 8-12 hours after a single dose injection (Semrad *et al.* 1985). One other reason for common use of flunixin meglumine is the mere ease of availability. But the effective masking of pain in conditions causing colic that may require surgery could be risky for the outcome of the case (Moore and Leise, 2009).

Like in other studies, butorphanol tartrate was found to have been rarely used in management of colic and this could possibly be attributed to the fact that it affects intestinal motility when given in high doses, which could be deleterious (Moore and Leise, 2009). It reduces small intestinal motility, yet has minimal effect on pelvic flexure activity (Merritt *et al.*, 1989; Merritt *et al.*, 1998). However, it was more commonly used in combination with flunixin meglumine. The finding that in Kenya Ketoprofen started being used for management of pain in colic cases recently and only rarely, is in agreement with the report stating that although it is an NSAID with similar analgesic effects as flunixin meglumine, it is not widely used for treatment of horses with colic (Zimmel, 2003). Pain relief is not only important for treatment of colic but also to make the horse more comfortable for proper examination (Abrahamsen, 2009). The use of Buscopan (N-butylscopolammonium bromide) in the current study was found to be confined to spasmodic colic only, which is consistent with the general practice since it is an anticholinergic that provides pain relief through its antispasmodic action as well as transient decrease in intestinal motility. It relieves abdominal pain by relaxing the smooth muscles and hence it is used in spasmodic colic, flatulent colic and impaction colic, but does not provide appreciable relief from colic on its own. It temporarily increases heart rate for up to 30 minutes following its administration due to its parasympatholytic effects (Moore and Leise, 2009; Abrahamsen, 2009). Therefore, antispasmodic drugs indirectly provide analgesia by reducing spasms of the intestine (Keller and Faulstich, 1985).

In spite of effectiveness of these analgesics in controlling pain, the primary treatment for colic should also be directed towards decompression of the distended stomach or intestine through nasogastric intubation, softening of ingesta by use of laxatives, enteral fluid therapy and restoration of the normal gut movement (Lopes *et al.*, 2003; Lopes, 2009).

The use of nasogastric intubation in cases of impaction colic and the finding of significant association between intubation and improvement of recovery from impaction colic, is consistent with the fact that the nasogastric tube serves as a means of decompression and provides readily available route for administration of laxatives and water directly into the stomach (Hanson *et al.*, 1998; Lopes *et al.*, 2002). Hydration of the colon or administration of substances that will increase drawing of water into its lumen such as magnesium sulphate, will soften colonic contents and subsequently resolve the impaction. Similarly, anything that increases motility and oral water intake is helpful in resolving impaction (Dabareiner and White 1995: White and Lopes, 2003). Adminstration of vitamin B complex as a metabolic stimulant as was done in the horses with impaction colic in this study, helps in energy metabolism and slightly reduces accumulation of lactic acid (Topliff *et al.*, 1981).

The finding that the outcome of colic in this study was associated with the type of colic that a horse had, can be attributed to whether the type of colic responds to medical treatment or requires surgical intervention. This is the reason why spasmodic colic was associated with high recovery rate compared to impaction colic and intestinal displacement colic. Spasmodic colic responds well to medical treatment and hence has high rate of recovery, similar to the findings in the current study. Colic conditions requiring surgery are reported to have a recovery rate that is slightly lower than those needing medical treatment (Van der Linden *et al*., 2003; Mair and Smith, 2005; Voigt *et al.*, 2009 and Wormstrand *et al*., 2014).

Other studies showed that large colon volvulus is the most common cause of strangulation obstruction, with strangulating diseases of the small intestine causing the highest mortality rate (MacDonald *et al.*, 1989; White, 1990; Proudman *et al.*, 2002). The death of all cases of intestinal displacement colic and some of those with impaction colic in the current study can be attributed to the fact that the equine practices in Nairobi County, Kenya, do not perform surgeries for colic. However, some impactions may not resolve for several days, while others will not resolve with medical therapy (Dabareiner and White, 1995). Hence all cases of colic in horses requiring surgery, either die or are euthanized. This is however in contrast with previous study, which reported that the overall prognosis for the life of a horse and for its return to use after large colon displacement is good (Baird *et al.*, 1991; Hardy *et al*., 2000). These authors indicated that approximately 93% of horses treated medically or surgically survived until they were discharged from hospital. However, it has been shown that case fatality for specific diseases varies from few deaths in cases of simple colic to as high as 75% in colic due to some forms of strangulated intestine (White, 1990).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the findings of the current study, the following conclusions can be made:

a) The prevalence of colic in horses in Nairobi county was found to be higher (13.5%) than that reported in most other parts of the world.

b) The incidence of colic based on 11 years records in the retrospective study was low (3.1%) and similar to the ones reported in other parts of the world.

c) The commonest type of colic in horses in Nairobi County Kenya is spasmodic colic followed by impaction colic.

d) The main risk factors predisposing horses to colic in the stables in Nairobi County Kenya are related to management practices, feeds and feeding practices, in which the main predisposing feed is excessive feeding of grains.

e) The only significant haematological changes observed in horses with colic were slightly elevated leucocyte and neutrophil counts in impaction colic as compared to spasmodic colic. These same parameters were higher in horses that died than in those that recovered from colic.

f) Blood glucose was higher in horses with impaction colic than in those with spasmodic colic and this is a useful factor to consider in the making of prognoses of the types of colic affecting horses.

g) Total serum protein was lower in horses that died of colic than in those that recovered and this is also a useful factor to consider in the making of prognoses of the types of colic affecting horses.

h) The most common pain management protocol for colic in horses in Nairobi County, Kenya is the use of NSAIDs, mainly flunixin meglumine, followed by flunixin-butorphanol combination.

i) Nasogastric intubation is a common aid to management of colic and is mainly done in cases of impaction and displacement colic in order to enhance administering of liquid paraffin as a laxative, as well as aid in decompression of the stomach in cases of gas accumulation.

j) Surgery for horses with colic in Nairobi County, Kenya is not commonly done, possibly due to impeding poor prognoses. The veterinarians and horse owners tend to prefer euthanasia for such cases.

6.2 RECOMMENDATIONS

The following recommendations can be made from the study:

a) That the horses showing abdominal pain should be examined promptly by competent veterinarians for accurate diagnosis and treatment to improve on the possible outcomes, particularly for cases needing surgical intervention. Early diagnosis of colic in horses could result in good outcomes for cases needing surgical interventions.

b) That the possible risk factors such as types of feeds and feeding regime should be regulated to avoid excesses and sudden changes in order to reduce occurrence of colic.

c) Analgesic combination therapy, especially flunixin meglumine and butorphanol, should be employed because it provides better pain management protocol than use of single analgesic drugs. This is likely to enhance analgesia and reduce the overall doses for single analgesics in order to minimize side effects that may arise from use of large doses of any one of the drugs.

6.3 Further Research

Suggested areas of further research are:

a) More studies need to be carried out on the prognostic indicators of colic such as serum amyloid A.

CHAPTER SEVEN

7.0 REFERENCES

Abrahamsen, E.J. (2009): Options for Managing Colic Pain. In: Hagyard Equine Medical Institute's Pain Management Seminar , Ocala Equine Hospital, Florida.

Adams S.B., Fessler J.F. *and* Rebar, A.H. (1980): Cytologic interpretation of peritoneal fluid in the evaluation of equine abdominal crises. *Cornell Veterinarian* **70**: 232-246.

Adams, S.B., Lamar, C.H. and **Masty, J. (1984):** Motility of the distal portion of the jejunum and pelvic flexure in ponies: effects of six drugs. *American Journal of Veterinary Research* **45**: 795-799.

Andrews, F.M. and **Robertson, J.T. (1988):** Diagnosis and surgical treatment of functional obstruction of the right dorsal colon in a horse. *Journal of the American Veterinary Medical Association* **193**: 956-958.

Archer, D.C and **Proudman, C.J. (2006)**: Epidemiological clues to preventing colic. *Veterinary Journal* **172**: 29-39.

Archer, D.C., Freeman, D.E., Doyle, A.J., Proudman, C.J. and **Edwards, G.B. (2004):** Association between cribbing and entrapment of the small intestine in the epiploic foramen in horses: 68 cases (1991-2002). *Journal of the American Veterinary Medical Association* **224**: 562-564.

Archer, D.C., Pinchbeck, G.K., French, N.P. and **Proudman, C.J. (2008):** Risk factors for epiploic foramen entrapment colic: an international study. *Equine Veterinary Journal* **40**: 224-30

Bailey, S. R., Marr, C. M. and **Elliott, J. (2004):** Current research and theories on the pathogenesis of acute laminitis in the horse. *Veterinary Journal.* **167:** 129-142.

Baird A.N., Cohen, N.D. and **Taylor, T.S. (1991)**: Renosplenic entrapment of the large colon in horses: 57 cases (1983 - 1988). *Journal of the American Veterinary Medical Association* **198**: 1423 – 1426.

Barclay, W.P., Foerner, J.J., Phillips, T.N. and **MacHarg, M.A. (1982):** Primary gastric impaction in the horse. *Journal of the American Veterinary Medical Association* **181**:682-683.

Beretta, C., Garavaglia, G. and **Cavalli, M. (2005):** COX-1 and COX-2 inhibition in horse blood by phenylbutazone, flunixin, carprofen and meloxicam: an in vitro analysis. *Pharmacology Research* **52**: 302-306.

Blikslager, A.T. (2009): Cecal impaction. In: Robinson, N.E., Sprayberry, K.A. (eds). Current Therapy in Equine Medicine, 6th ed. St. Louis: Saunders Elsevier, pp 405– 406.

Blikslager, A. and **Mair, T. (2014**): Trends in management of horses referred for evaluation of colic: 2004–2013. In: Eleventh International Colic Research Symposium, 8th-10th July, 2014.Dublin, Ireland. p12.

Blue, M.G. (1979): Enteroliths in horses: a retrospective study of 30 cases. *Equine Veterinary Journal* **11**:76–84.

Clarke, L. L., Roberts, M. C. and **Argenzio, R. A. (1990):** Feeding and digestive problems in horses. Physiologic responses to a concentrated meal. *Veterinary Clinics of North America: Equine Practice* **6**: 433-450.

Cohen, N.D., Gibbs, P.G. and **Woods, A.M.** (**1999): ** Dietary and other management factors associated with colic in horses. *Journal of the American Veterinary Medical Association* **215**: 53-60.

Cohen, N.D. and **Honnas, C.M. (1996):** Risk factors associated with development of diarrhea in horses after celiotomy for colic: 190 cases (1990-1994). *Journal of the American Veterinary Medical Association* **209**: 810-813.

Cohen, N.D., Matejka, P.L., Honnas, C.M. and **Hooper, R.N. (1995):** Case-control study of the association between various management factors and development of colic in horses. Texas Equine Colic Study Group. *Journal of the American Veterinary Medical Association* **206**: 667-673.

Cook, V.L *and* Blikslager, A.T. (**2008):** Use of systemically administered lidocaine in horses. *Journal of the American Veterinary Medical Association* **232**:1144–1148.

Cox, J.E. (1987): Surgery of the reproductive tract in large animals, 3rd (ed)., Liverpool, Liverpool University Press, pp 59-64.

Cribb, N.C., Cote, N.M., Boure, L.P. and **Peregrine, A.S. (2006):** Acute small intestinal obstruction associated with *Parascaris equorum* infection in young horses: 25 cases (1985–2004). *New Zealand Veterinary Journal* **54**: 338-343.

Dabareiner, R.M. and **White, N.A. (1995):** Large colon impaction in horses: 147 cases (1985-1991). *Journal of the American Veterinary Medical Association* **206**: 679-685.

Davis, J.L, Ramirez, S, Campbell, N. and **Jones, S.L. (2001):** Acute and chronic mineral oil pneumonitis in two horses. *Equine Veterinary Education* **13**: 230-234.

Davies, J.V. and Gerring, E.L. (1983): Effects of spasmolytic analgesic drugs on the motility patterns of the equine small intestine. *Research in Veterinary Science* **34**: 334-339.

Delesalle, C., Dewulf, J., Lefebvre, R.A., Schuurkes, J.A., Proot, J., Lefere, L. and **Deprez, P. (2007):** Determination of lactate concentrations in blood plasma and peritoneal fluid in horses with colic by an Accusport analyzer. *Journal of Veterinary Internal Medicine* **21**:293-301.

Dinev, D. and **Zlateva, N. (1999)**: Topical approaches in diagnostics and treatment of ileus in horses. *Trakia Journal of Sciences* **6**: 68-70.

Ducharme, N.G., Pascoe, P.J., Lumsden, J.H. and **Ducharme, G.R**. (**1989)**: A computer-derived protocol to aid in selecting medical versus surgical treatment of horses with abdominal pain. *Equine Veterinary Journal* **21**: 447-450.

Ebony, E.E., Claire, N. O. and **Debra, C.A. (2014):** Prevalence of and risk factors for colic in horses that display crib-biting behaviour. *BMC Veterinary Research* **10**: 1186/1746-6148

Ellis, C.M., Lynch, T.M., Slone, D.E., Hughes, F.E. and **Clarke, C. K. (2008):** Survival and complications after large colon resection and end-to-end anastomosis for strangulating large colon volvulus in 73 horses. *Veterinary Surgery* **37:** 786-790.

Everitt, S. (2011): Clinical Decision Making in Veterinary Practice. University of Nottingham. equine antroduodenal motility. *Equine Veterinary Journal* **7**: 21-23.

Freeman, D.E. (2005): Survival and the Cost of Our Mistakes; *American Association of Equine Practioners*. Focus meeting. Quebec, Canada

Freeman, S.L. (2003): Diagnostic ultrasonography of the mature equine abdomen. *Equine Veterinary Education* **15**: 319-330.

French, N.P., Smith, J., Edwards, G.B. and **Proudman, C.J. (2002):** Equine surgical colic: Risk factors for postoperative complications. *Equine Veterinary Journal* **34**: 444-449.

Furr, MO., Lessard, P. and **White, N.A. (1995):** Development of a colic severity score for prediction of the outcome of equine colic. *Veterinary Surgery* **24**: 97-101.

Gardner, R.B., Nydam, D.V., Mohammed, H.O., Ducharme, N.G. and **Divers, T.J. (2005):** Serum gamma glutamyl transferase activity in horses with right or left dorsal displacements of the large colon. *Journal of Veterinary Internal Medicine* **19**: 761-764.

Gibson, K.T. and **Steel, C.M. (1999)**: Strangulating obstructions of the large colon in mature horses. *Equine Veterinary Education* **11**: 234-242.

Gingerich, D.A., Rourke, J.E. and Chatfield, R.C. (1985): Butorphanol tartrate: a new analgesic to relieve the pain of equine colic. *Veterinary Medicine* **80**:74-77.

Goncalves, S., Julliand, V. and **Leblond, A. (2002)**: Risk factors associated with colic in horses. *Veterinary Residence* **33**: 641-52.

Goodrich, L.R., Furr, M.O. and **Robertson, J.L**. (**1998)**: A toxicity study of eltenac, a nonsteroidal anti-inflammatory drug in horses. *Journal of Veterinary Pharmacology and Therapeutics* **21:** 24-33.

Gough., M. and **Munroe, G. (1998)**: Decision making in the diagnosis and management of bone spavin horses. *In Practice* **20**: 252–259.

Hance, S.R. 1997: Colopexy.*Veterinary Clinics of North America*. *Equine Practice* **13**: 351-358.

Hanson, R.R., Wright, J.C., Schumacher, J., Baird, A.N., Humburg, J. and **Pugh, D.G. (1998):** Surgical reduction of ileal impactions in the horse: 28 cases. *Veterinary Surgery* **27**: 555–560.

Hanson, R.R. (1998): Surgical reduction of ileal impactions in the horse: 28 cases. *Veterinary Surgery* **27:**555-560.

Hardy, J., Minton, M. and **Robertson, J.T. (2000):** Nephrosplenic entrapment in the horse: a retrospective study of 174 cases. *Equine Veterinary Journal* **32**: 95-97.

Hardy, J. (2008): Specific diseases of the large colon. In: The Equine Acute Abdomen, Ed: White, N.A., Moore, J.N. and Mair, T.S. (eds). Teton NewMedia, Jackson. pp 639-642.

Harrison, I.W. (1988): Equine large intestinal volvulus. A review of 124 cases. *Veterinary surgery* **17**: 77-81.

Hassel, D.M., Hill, A.E. and **Rorabeck, R.A.** (**2009):** Association between hyperglycemia and survival in 228 horses with acute gastrointestinal disease. *Journal of Veterinary Internal Medicine* **23**:1261-1265.

Hassel, D.M., Rakestraw, P.C., Gardner, I.A., Spier, S.J. and **Snyder, J.R.** (**2004)**: Dietary risk factors and colonic pH and mineral concentrations in horses with enterolithiasis. *Journal of Veterinary Internal Medicine* **18**:346-349.

Hassel, D.M., Smith, P.A. and **Nieto, J.E. (2008):** Di-tri-octahedral smectite for the prevention of post-operative diarrhea in equids with surgical disease of the large intestine: results of a randomized clinical trial. *Veterinary Journal* **182**: 210–215.

Henninger, R.W. and **Horst, J.** (**1997): ** Magnesium toxicosis in two horses. *Journal of the American Veterinary Medicine Association* **211**: 82-85.

Hersh, E., Lally, E and **Moore, P.(2005):** Update on cyclooxygenase inhibitors: has a third COX isoform entered the fray. *Current Medical Research and Opinion* **21**:1217-1226

Hillyer, M.H., Taylor, F.G., Proudman, C.J., Edwards, G.B., Smith, J.E. and **French, N.P.** (**2002)**: Case control study to identify risk factors for simple colonic obstruction and distension colic in horses. *Equine Veterinary Journal* **34**:455-463.

Hintz, H.F. (**1975)**: Digestive physiology of the horse. *Journal of the South African Veterinary Association* **46:**13-17.

Honnas, C.M. and **Cohen, N.D. (1997)**: Risk factors for wound infection following celiotomy in horses. *Journal of the American Veterinary Medical Association* **210**:78-81.

Honnas, C.M. and **Schumacher, J. (1985)**: Primary gastric impaction in a pony. *Journal of the American Veterinary Medical Association* **187**:501-502.

Hudson, J.M., Cohen, N.D., Gibbs, P.G. and **Thompson, J.A. (2001)**: Feeding practices associated with colic in horses. *Journal of the American Veterinary Medical Association* **219**:1419-1425.

Huskamp, B. (**1982):** The diagnosis and treatment of acute abdominal conditions in the horse; the various types and frequency as seen at the animal hospital in Hochmoor. In: Proceedings of the Equine Colic Research Symposium1, September 20th, 1982, University of Georgia, pp 261-272.

Jochle, W., Moore, J.N., Brown, J., Baker, G.J., Lowe, J.E., Fubini, S., Reeves, M.J., Watkins, J.P. and **White, N.A. (1989):** Comparison of detomidine, butorphanol, flunixin meglumine and xylazine in clinical cases of equine colic. *Equine Veterinary Journal* **7:** 111-116.

Johnston, K., Holcombe, S.J. and **Hauptman, J.G.** (**2007)**: Plasma lactate as a predictor of colonic viability and survival after 360 degrees volvulus of the ascending colon in horses. *Veterinary Surgery* **36**: 563-567.

Jones, S.L. (**2009)**: Right dorsal ulcerative colitis. In: Robinson, N.E., Sprayberry, K.A., (eds). Current Therapy in Equine Medicine, 6th ed. St. Louis: Saunders Elsevier pp 430–432.

Kaneene, J.B., Ross, W.A. and **Miller, R.** (**1997)**: The Michigan equine monitoring system. II. Frequencies and impact of selected health problems. *Preventive Veterinary Medicine* **29**:277-292.

Karcher, L.F., Dill, S.G. and **Anderson, W.I. (1990):** Right dorsal colitis. *Journal of Veterinary Internal Medicine* **4**: 247-253.

Kassirer, J. P. (1976): The principles of clinical decision making: an introduction to decision analysis. *Yale Journal of Biology and Medicine* **49**: 149–164.

Keller, H. and **Faulstich, A**. (**1985)**: Treatment of colic in the horse with Buscopan (hyoscine butylbromide with dipyrone). *Tierarztliche Umschau* **40**:581-584.

King, J.N. and **Gerring, E.L. (1989):** Antagonism of endotoxin-induced disruption of equine bowel motility by flunixin and phenylbutazone. *Equine Veterinary Journal* **7:**38-42.

Kohn, C.W. and **Muir, W.W. (1988):** Selected aspects of the clinical pharmacology of visceral analgesics and gut motility modifying drugs in the horse. *Journal of Veterinary Internal Medicine* **2**: 85-91.

Korolainen, R. and Ruohoniemi, M. (**2002):** Reliability of ultrasonography compared to radiography in revealing intestinal sand accumulation in horses. *Equine Veterinary Journal* **34**: 499-540.

Lester, G.D., Merritt, A.M., Neuwirth, L., Vetro-Widenhouse, T., Steible, C. and **Rice, B. (1998):** Effect of alpha 2-adrenergic, cholinergic, and nonsteroidal anti-inflammatory drugs on myoelectric activity of ileum, cecum, and right ventral colon and on cecal emptying of radiolabeled markers in clinically normal ponies. *American Journal Veterinary Research*; **59**: 320-327.

Little, D. and **Blikslager, A.T. (2002):** Factors associated with development of ileal impaction in horses with surgical colic: 78 cases (1986-2000). *Equine Veterinary Journal* **34**: 464-468.

Lopes, M.A., Hepburn, R.J. and **McKenzie, H.C. (2003):** Enteral fluid therapy for horses. *Compendium on Continuing Education for Practicing Veterinarian* **25**: 390 –397.

Lopes, M.A., Walker, B.L., White, N.A. and **Ward, D.L. (2002)**: Treatments to promote colonic hydration: enteral fluid therapy versus intravenous fluid therapy and magnesium sulphate. *Equine Veterinary Journal* **34**:505-509.

Lopes, M.A. (2009): Intraluminal obstruction of the large colon. In: Robinson, N.E., Sprayberry, K.A., (eds). Current Therapy in Equine Medicine, 6th (ed). St. Louis: Saunders Elsevier, pp 407–412.

Lores, M. and Ortenburger, A.I. (2008): Use of cecal bypass via side-to-side ileocolic anastomosis without ileal transection for treatment of cecocolic intussusception in three horses. *Journal of the American Veterinary Medical Association* **232**: 574-577.

Lowe, J.E., Sellers, A.F. and **Brondum, J. (1980):** Equine pelvic flexure impaction. A model used to evaluate motor events and compare drug response. *Cornell Veterinarian* **70**: 401-412.

Lowe, J.E. and **Hilfiger, J. (1986):** Analgesic and sedative effects of detomidine compared to xylazine in a colic model using i.v. and i.m routes. *Acta Veterinaria Scandinavica* **82:** 85-95

Lucas, M., Day, L. and **Fritschi, L. (2009):** Injuries to Australian veterinarians working with horses. *Veterinary Record* **164**: 207–209.

Lyons, E.T., Drudge, J.H. and **Tolliver, S.C. (1973):** On the life cycle of Strongyloides westeri in the equine.*Equine Journal of Parasitology* **59**:780.

MacDonald, M.H., Pascoe J.R., Stover, S.M. and **Meagher, D.M. (1989)**: Survival after small intestine resection and anastomosis in horses. *Veterinary* Surgery, **18**, 415–423.

Mair, T.S., Smith, L.J. and **Sherlock, C.E. (2007)**: Evidence-based gastrointestinal surgery in horses. *Veterinary Clinics of North America:Equine Practice* **23**: 267–292.

Mair, T.S. and **Smith, L.J. (2005)**: Survival and complication rates in 300 horses undergoing surgical treatment of colic. Part 1: Short-term survival following a single laparotomy. *Equine Veterinary Journal* **37**: 296-302.

Matsuda, K., Shimada, T., Kawamura, Y., Sakaguchi, K., Tagami, M. and **Taniyama, H. (2013)**: Jejunal intussusception associated with lymphoma in a horse. *Journal of Veterinary Medical Science* **75**: 1253-6.

McConnico, R.M. (2009): Acute equine colitis. In: Robinson, N.E., Sprayberry, K.A., (eds). Current Therapy in Equine Medicine, 6th ed. St. Louis: Saunders Elsevier pp 418–423.

Merritt, A.M., Burrow, J.A. and **Hartless, C.S. (1998**): Effect of xylazine, detomidine, and a combination of xylazine and butorphanol on equine duodenal motility. *American Journal of Veterinary Residence* **59**: 619–623.

Merritt, A.M., Campbell-Thompson, M.L. and **Lowrey, S. (1989**): Effect of butorphanol on on equine antroduodenal motility.*Equine Veterinary Journal* **21**: 21-23.

Mezerova, J., Zert, Z., Kabes,. R. and **Jahn, P. (2003**): Hernia inguinalis incarcerata in horses: 43 cases. *Pferdeheilkunde* **19**: 263–268.

Mezerova, J., Zert, Z., Kabes, R. and **Ottova, L. (2008a**): Analysis of therapeutic results and complications after colic surgery in 434 horses. *Veterinarni Medicina* **53**: 12–28.

Mezerova, J., Zert, Z., Kabes, R. and **Ottova, L. (2008b):** Analysis of clinical and perioperative findings in 576 horses subjected to surgical treatment of colic. *Veterinarni Medicina* **53**: 29–42.

Mitchell, C.F., Malone, E.D., Sage, A.M. and **Niksich, K. (2005):** Evaluation of gastrointestinal activity patterns in healthy horses using B mode and Doppler ultrasonography. *Canadian Veterinary Journal* **46**: 134-140.

Moffatt, R.E., Kraimer, L.L., Lerner, D. and **Jones, R. (1975):** Studies of dictoctyl sodium sulfosuccinate toxicity: clinical, gross and microscopic pathology in the horse and guinea pig. *Canadian Journal of Comparative Medicine* **39:** 438-441.

Moore, J.M., Owen, R. and **Lumsden, J.H.** (**1976)**: Clinical evaluation of blood lactate levels in equine colic. *Equine Veterinay Journal* **8**: 49-54.

Moore, R.M., Muir, W.W. and **Cawrse, M. (1995):** Systemic and colonic venous plasma eicosanoid and endotoxin concentrations, and colonic venous serum tumor necrosis factor and interleukin-6 activities in horses during low-flow ischemia and reperfusion of the large colon. *American Journal of Veterinary Research* **56**: 656-663.

Moore, R.M. and **Leise, B.S. (2009):** Diagnosis and treatment of selected diseases of the cecum and colon in horses. In: Proceedings of the 11th International Congress of World Equine Veterinary Association, 24 – 27 September. Guarujá, SP, Brazil. pp

Moore, R.M. (1996): Equine Large Colon Volvulus. In: Proceedings of American College of Veterinary Surgeons Annual Symposium. pp 236-237.

Morrow, J. and **Roberts, L. (2001):** Lipid-derived autocoids. In: Hardman, J., Limbird, L., Gilman ,A.G., (eds). The pharmacological Basis of Therapeutics. 10th ed. New York: McGraw-Hill pp 669-686.

Moorman, V.J. and **Jann, H.W. (2009):** Polypropylene mesh repair of a unilateral, congenital hernia in the inguinal region in a Thoroughbred filly. *Canadian Veterinary Journal* **50**: 613–616.

Morris, D.D. (**1991)**: Endotoxemia in horses. A review of cellular and humoral mediators involved in its pathogenesis. *Journal of Veterinary Internal Medicine* **5**: 167-181.

Morton, A.J., Campbell, N.B., Gayle, J.M., Redding, W.R. and **Blikslager, A.T. (2005)**: Preferential and non-selective cyclooxygenase inhibitors reduce inflammation during lipopolysaccharide-induced synovitis. *Research in Veterinary Science* **78**: 189-192.

Muir, W.W. and **Robertson, J.T. (1985):** Visceral analgesia: effects of xylazine, butorphanol, meperidine, and pentazocine in horses. *American Journal of Veterinary Research* **46**: 2081-2084.

Nieto, J.E., Rakestraw, P.C., Snyder, J.R. and **Vatistas, N.J. (2000):** In vitro effects of erythromycin, lidocaine, and metoclopramide on smooth muscle from the pyloric antrum, proximal portion of the duodenum, and middle portion of the jejunum of horses. *American Journal Veterinary Research* **61**:413–419.

Olusa, T.A.O and **Akinrinmade, J.F. (2014):** Do dental abnormalities predispose horses to colic? *Journal of Veterinary Medicine and Animal Health* **6:**192-197.

Orsini, J.A. and **Kreuder, C. (2003):** Abdominocentesis and peritoneal fluid analysis. In: Orsini, J.A., Divers, T.J. (eds). Manual of Equine Emergencies: Treatment and Procedures. 2nd Edition. Philadelphia: Saunders pp 83-86.

Owen, R.A., Jagger, D.W. and **Jagger, F. (1987):** Two cases of equine primary gastric impaction. *Veterinary Record* **121**: 102-105.

Parks, A.H., Doran, R.E., White, N.A., Allen, D. and **Baxter, G.M. (1989):** Ileal impaction in the horse: 75 cases. *Cornell Veterinarian* **79**: 83-91.

Parry, B.W., Anderson, G.A. and **Gay, C.C**. (**1983)**: Prognosis in equine colic: a comparative study of variables used to assess individual cases. *Equine Veterinary Journal* **15**: 211-215.

Pascoe, P.J., McDonell, W.N., Trim, C.M. and **Van, G.J.** (**1983)**: Mortality rates and associated factors in equine colic operations - a retrospective study of 341 operations. *Canadian Veterinary Journal* **24**:76-85.

Peloso, J., Cohen, N. and **Taylor, T. (1996):** When to send a horse with clinical signs of colic: Is it surgical, or is it referrable? A survey of the opinions of 117 equine Veterinary Specialists.

In: Proceedings of the Annual Convention of the American Association of Equine Practitioners pp 250-253.

Phillips, T.J. and Walmsley, J.P. (1993): Retrospective analysis of the results of 151 exploratory laparotomies in horses with gastrointestinal disease. *Equine Veterinary Journal* **25**: 427–431.

Proudman, C.J. (1992): A two year prospective survey of equine colic in general practice. *Equine Veterinary Journal* **24**: 90-93.

Proudman, C.J., Edwards, G.B., Barnes, J. and **French, N.R.** (**2005):** Factors affecting long-term survival of horses recovering from surgery of the small intestine. *Equine Veterinary Journal* **37**: 360-365.

Proudman, C.J., French, N.P. and **Trees, A.J.** (**1998):** Tapeworm infection is a significant risk factor for spasmodic colic and ileal impaction colic in the horse. *Equine Veterinary Journal* **30:** 194–199.

Proudman, C.J., Smith, J.E., Edwards, G.B. and **French, N.P. (2002):** Long-term survival of equine surgical colic cases. Part 1: Patterns of mortality and morbidity. *Equine Veterinary Journal* **34**: 432–437.

Proudman, C.J. and **Holdstock, N.B. (2000):** Investigation of an outbreak of tapeworm associated colic in a training yard. *Equine Veterinary Journal* **32**: 37-41.

Proudman, C.J., Edwards, G.B., Barnes, J. and **French, N.P. (2005):** Modelling long-term survival of horses following surgery for large intestinal disease. *Equine Veterinary Journal* **37**: 366-370.

Puotunen-Reinert, A. (**1986):** Study of variables commonly used in examination of equine colic cases to assess prognostic value. *Equine Veterinary Journal* **18**: 275-277.

Radostits, O.M., Gay, C.C., Blood, D.C. and **Hinchcliff, K.W. (2009):** Veterinary Medicine, 10th (Ed), A Textbook of the diseases of cattle, sheep, pigs, goats and horses, WB, Saunders, London, pp197-209.

Ragle, C.A., Meagher, D.M., Lacroix, C.A., and **Honnas, C.M.** (**1989)**: Surgical treatment of sand colic. Results in 40 horses. *Veterinary Surgery* **18**: 48-51.

Rakestraw, P.C. and **Hardy, J. (2006):** Large intestine. In: Auer, J.A, Stick, J.A., (eds). Equine Surgery, 3rd ed. St. Louis: Saunders Elsevier, pp 436 – 478.

Reef, V.B. (**1998):** Adult abdominal ultrasonography. In: W.B. Saunders Co, ed. Equine Diagnostic Ultrasound 1st ed. Philadelphia pp 273-363.

Reeves, M.J, Curtis, C.R. and **Salman, M.D. (1989);** Prognosis in equine colic patients using multivariable analysis. *Canadian Journal of Veterinary Research* **53:**87-94.

Reeves, M.J., Salman, M.D. and **Smith, G. (1996):** Risk factors for equine acute abdominal disease (colic): Results for a multi center case-control study. *Preventive Veterinary Medicine* **26**: 285-301.

Relf, V. E., Morgan, E. R., Hodgkinson, J. E. and **Matthews, J.B. (2013**): Helminth egg excretion with regard to age, gender and management practices on UK Thoroughbred studs, *Equine Journal of Parasitology* **140** : 641-652.

Robinson, E. and **Carmalt, J.L. (2009):** Inguinal Herniation of the ascending colon in a 6-month-old Standardbred colt. *Veterinary Surgery* **38,** 1012–1013.

Roelvink, M.E., Goossens, L. and **Kalsbeek, H.C. (1991):** Analgesic and spasmolytic effects of dipyrone, hyoscine-N-butylbromide and a combination of the two in ponies. *Veterinary Record* **129**: 378-380.

Roger, T. and **Ruckebusch, Y. (1987):** Colonic alpha2-adrenoceptor-mediated responses in the pony. *Journal of Veterinary Pharmacology and Therapeutics* **10**: 310-318.

Sabev, S. and **Kanakov, M.D. (2008):** Case of large colon impaction in a horse. *Trakia Journal of Sciences* **6**: 68-70.

Santschi, E.M., Slone, D.E. and **Frank, W.M. (1993):** Use of ultrasound in horses for diagnosis of left dorsal displacement of the large colon and monitoring its nonsurgical correction. *Veterinary Surgery* **22**: 281-284.

Schneider, R.K., Milne, D.W. and **Kohn, C.W. (1982):** Acquired inguinal hernia in the horse: a review of 27 cases. *Journal of the American Veterinary Medical Association* **180**: 317-320.

Sellon, D.C., Roberts, M.C. and **Blikslager, A.T. (2004):** Effects of continuous rate intravenous infusion of butorphanol on physiologic and outcome variables in horses after celiotomy. *Journal of Veterinary Internal Medicine* **18**: 555–563.

Semrad, S.D., Hardee, G.E. and **Hardee, M.M. (1985):** Flunixin meglumine given in small doses: Pharmacokinetics and prostaglandin inhibition in healthy horses. *American Journal of Veterinary Research* **46**: 2474-2479.

Shoemaker, R., Bailey, J., Janzen, E. and **Wilson, D.G. (2004**): Routine castration in 568 draught colts: incidence of evisceration and omental herniation. *Equine Veterinary Journal* **36**: 336–340.

Simmons, T.R., Gaughan, E.M. and **Ducharme, N.G. (1990):** Treatment of right dorsal ulcerative colitis in a horse. *Journal of the American Veterinary Medicine Association* **196**: 455-458.

Smith, B.P. (**1996):** Alterations in alimentary and hepatic function. In: Smith, B.P., (ed). Large Animal Internal Medicine, 2nd ed. St. Louis: Mosby pp118 –141.

Snow, D.H., Baxter, P. and **Rose, R.J. (1981):** Muscle fibre composition and glycogen depletion in horses competing in an endurance ride. *Veterinary Record* **108**: 374–378

Snyder, J.R., Pascoe, J.R., Meagher, D.M. and **Spier, S.J. (1989a):** Predisposing factors and surgical evaluation of large colon volvulus in the horse. In: Proceedings of the Annual Convention of the American Association of Equine Practitioners pp **34**: 21-27.

Snyder, J.R., Pascoe, J.R., Olander, H.J., Spier, S.J., Meagher, D.M. and **Bleifer, D.R. (1989b)** Strangulating volvulus of the ascending colon in horses. *Journal of the American Veterinary Medical Association* **195**, 757-764.

Southwood, L.L, Gassert, T. and **Lindborg, S**. (**2010):** Colic in geriatric compared to mature nongeriatric horses. Part 1: Retrospective review of clinical and laboratory data. *Equine Veterinary Journal* **42:** 621-627.

Southwood, L.L., Ragle, C.A. and **Snyder, J.R.** (**1996)**: Surgical treatment of ascarid impactions in horses and foals. In: Proceedings of the American Association of Equine Practitioners **42**: 258.

Specht, T.E. and **Colahan, P.T. (1988):** Surgical treatment of sand colic in equids: 48 cases (1978-1985). *Journal of the American Veterinary Medical Association* **193**: 1560-1564.

Stephen, J.O., Corley, K.T., Johnston, J.K. and **Pfeiffer, D. (2004):** Factors associated with mortality and morbidity in small intestinal volvulus in horses. *Veterinary Surgery* **33**: 340-348.

Thoefner, M.B., Ersboll, A.K., and **Hesselholt, M. (2000):** Prognostic indicators in a Danish hospital-based population of colic horses. *Equine Veterinary Journal* **32:** 11-18

Tinker, M.K., White, N.A. and**Less ard, P. (1997a):** Prospective study of equine colic incidence and mortality. *Equine Veterinary Journal* **29**: 448-453.

Tinker, M.K, White, N.A. and **Lessard, P. (1997b):** Prospective study of equine colic risk factors. *Equine Veterinary Journal* **29**: 454-458.

Tomlinson, J.E. and **Blikslager, A.T. (2005)**: Effects of cyclooxygenase inhibitors flunixin and deracoxib on permeability of ischaemic-injured equine jejunum. *Equine Veterinary Journal* **37**, 75-80.

Topliff, D.R., Potter, G.D., Kreider, J.L. and **Creagor, C.R. (1981**): Thiamin supplementation for exercising horses. In: Proceedings of the 7^{th} Equine Nutrition Physiology Symposium. Warrenton, VA, p 167.

Traub-Dargatz, J.L., Kopral, C.A., Seitzinger, A.H., Garber, L.P., Forde, K. and **White, N.A. (2001)**: Estimate of the national incidence of and operation-level risk factors for colic among horses in the United States, spring 1998 to spring 1999. *Journal of the American Veterinary Medical Association* **219**: 67-71.

Uhlinger, C. (1992): Investigations into the incidence of field colic. *Equine Veterinary Journal* **13**: 11-18.

Underwood, C., Southwood, L.L., McKeown, K.P. and **Knight, D.** (**2008): Complications and survival associated with surgical compared with medical management of horses with duodenitis-proximal jejunitis. *Equine Veterinary Journal* **40**: 373-378.

Van der Linden, M.A., Laffont, C.M. and **Sloet van Oldruitenborgh-Oosterbaan, M.M. (2003)**: Prognosis in equine medical and surgical colic. *Journal of Veterinary Internal Medicine* **17**: 343-348.

Vandeweerd, J.M., Vandeweerd, S., Gustin, C., Keesemaecker, G., Cambier, C., Clegg, P., Saegerman, C., Reda, A., Perrenoud, P. and **Gustin, P. (2012):** Understanding veterinary practitioners decision-making process: implications for veterinary medical education. *Journal of Veterinary Medicine Education* **39:** 142–151.

Van Duijkeren, E., Flemming, C. and **Oldruitenborgh-Oosterbaan, M.S. (1995):** Diagnosing Salmonellosis in horses; culturing of multiple versus single fecal sample. *Veterinary Quarterly* **17:** 63-66.

Vatistas, N.J., Snyder, J.R., Wilson, W.D., Drake, C. and **Hildebrand, S. (1996):** Surgical treatment for colic in the foal (67 cases): 1980-1992. *Equine Veterinary Journal* **28**: 139-45.

Velden van der, M.A. (1988): Surgical treatment of acquired inguinal hernia in the horse: A review of 51 cases. *Equine Veterinary Journal* **20**: 173-7.

Voigt, A., Sauleza, M.N., Donnellana, D.C. and Gummow, B. (2009): Causes of gastrointestinal colic at an equine referral hospital in South Africa (1998–2007), *Journal of South Africa Veterinary Association* **80**: 192–198.

Walmsley, J.P. (2007): Laparoscopy in horses with abdominal pain. *Equine Veterinary Education* **19**: 64-66.

Warner, T.D and Mitchell, J.A. (**2002):** Cyclooxygenase-3 (COX-3): filling in the gaps toward a COX continuum? In: Proceedings of the National Academy of sciences of the United State of America **99**:13371-13373.

Weimann, C.D., Thoefner, M.B. and **Jensen, A.L**. (**2002)**: Spectrophotometric assessment of peritoneal fluid haemoglobin in colic horses: an aid to selecting medical vs. surgical treatment. *Equine Veterinary Journal* **34**: 523- 527.

White, N.A., Elward, A. and **Moga, K.S. (2005):** Use of web-based data collection to evaluate analgesic administration and the decision for surgery in horses with colic. *Equine Veterinary Journal* **37**: 347-350.

White, N.A. (2006): Equine Colic. In: Proceedings of Annual Convention of the American Association of Equine Practitioners **52**: 2nd-6th December,San Antonio,Texas,USA. pp 109-174.

White, NA. (2007): Equine Colic: A Real Pain in the Gut**.** In: Proceedings of the European Veterinary Conference. Voorjaarsdagen, Amsterdam **75**: 251-253.

White, N.A. (**1990)**: Examination and diagnosis of the acute abdomen. In: White, N,A., (ed). The Equine Acute Abdomen. Philadelphia, PA: Lea and Febiger, pp 619-623.

White, NA. (1998): Rectal examination for the acute abdomen. In: White, N.A., Moore, J.N., (eds). Current Techniques in Equine Surgery and Lameness. Philadelphia, PA: W.B. Saunders pp262-270.

White, N.A. (1987): When equine colic calls for surgical intervention. *Equine veterinary journal* **29**; 448-453.

White, N.A. and **Dabareiner, R.M. (1997):** Treatment of impaction colics. *Veterinary Clinics of North America: Equine Practice* **13**: 243-259.

White, N. and **Lopes, M. (2003):** Large colon impaction. In: Current Therapy in Equine Medicine. Robinson, E., (ed). W.B.Saunders, Philadelphia pp 131-135.

Wormstrand, B.J., Ihler, C.I., Diesen, R. and **Krontveit, R.I. (2014)**: Surgical treatment of equine colic - a retrospective study of 297 surgeries in Norway 2005–2011. *Acta Veterinaria Scandinavica* **56**: 1-9.

Zimmel, D.N. (**2003):** Hemostatic disorders. In: Robinson, N.E., (ed). Current Therapy in Equine Medicine 5. Philadelphia, PA: WB Saunders pp 351–35.

APPENDICES

Appendix 1:

Questionnaire

Project Title: Prevalence, risk factors, treatments and outcomes of colic in horses in Nairobi County, Kenya.

A. Horse owners and Trainers.

Date (day/month/year) ________________ Owner/Trainer_______

Gender___________ Location: _____

1. What breeds of horses do you keep in your stable?

   a) ❑ Thoroughbred
   b) ❑ Appaloosa
   c) ❑ Arab cross
   d) ❑ Pony
   e) ❑ Warm blood
   f) ❑ Other ___________

2. What reason do you keep your horses for?
   a) ❑ Racing
   b) ❑ Show Jumping
   c) ❑ Polo
   d) ❑ Other ______________________

3. How long have you had horses?

   a) ❑ < 1 year
   b) ❑ 1-3 years
   c) ❑ 4-6 years
   d) ❑ 7-9 years
   e) ❑ > 9 years

4. How many horses are you keeping in your stable?

   a) ❑ 1-5
   b) ❑ 6-10
   c) ❑ 1-15
   d) ❑ 16-20

e) ❑ > 20

5. What do you Feed your horses?

a) ❑ Hay
b) ❑ Free range
c) ❑ Horse meal (Type)_____
d) ❑ Other ____________

6. Does the type and quality of feed predispose your horses to colic?

a) ❑ Yes b) ❑ No

If Yes, Please explain____
____
____

7. Do you have a regular feeding schedule for your horses?
a) ❑ Yes b) ❑ No
Please explain____
____

8. Does the change in feeding schedule predispose your horse to colic?

a) ❑ Yes b) ❑ No

9. Does the change in hay (from a different source) predispose your horse to colic?

a) ❑Yes b) ❑ No

Please explain____

____

10. Does the change in type of grain predispose your horse to colic?

a) ❑ Yes b) ❑ No

If yes, please explain____
____
____

11. Have you accidentally overfed your horse with grain ?

a) ❑ Yes b) ❑ No

If yes, what feed and what was the outcome?

____

____

____

12. Have you had cases of colic in your stable as a result of poor or irregular dental care?

a) ❑ Yes b) ❑ No

If Yes, Please explain

____

____

____

____

13. Do you maintain regular internal parasite control program?

a) ❑ Yes b) ❑ No

If yes, how often and what products do you use?

____

____

____

14. Does the change in stabling condition (moving a horse to a different stable) cause colic?

a) ❑Yes b) ❑ No

15. Does the level of activity of your houses predispose them to colic?

a) ❑Yes b) ❑No

If Yes, Please explain________________________________

____

16. Are there other practices that have predisposed your horse to colic in your stable?

____
____
____

17. How many cases of colic do you get in a year from your stable?

a) ❑ 1
b) ❑ 2
c) ❑ 3
d) ❑ 4
e) ❑ 5
f) ❑ Other____

18. Have you observed repeat episodes of colic with any of the horses?

a) ❑ Yes b) ❑ No

19. If yes, how many horses have had repeat episodes of colic?

a) ❑ 1
b) ❑ 2
c) ❑ 3
d) ❑ 4
e) ❑ 5
f) ❑ > 5

20. Are there times you have known the cause of colic in any of the horses?

a) ❑ Yes
b) ❑ No

If yes, what were the causes? _______________________

21. Which of the following signs have you seen from horses suffering from colic in your stable?

a) Sweating ❑ Yes ❑ No
b) Pawing ❑ Yes ❑ No
c) Yawning ❑ Yes ❑ No
d) Flank Watching ❑ Yes ❑ No
e) Lying down ❑ Yes ❑ No
f) Rolling ❑ Yes ❑ No
g) Stretching ❑ Yes ❑ No
h) Distended belly ❑ Yes ❑ No
i) Abnormal defecation ❑ Yes ❑ No
j) Other__________

22. Do you always give medication to your horse when they get colic?

a) ❑ Yes b) ❑ No

If yes, what medication do you give? ______________________________________

23. Does the horse recover?

a) ❑Yes b) ❑ No

If No, what happened? ____

24. How do you give this medication?

a) ❑ Intravenous b) ❑Intramuscular c) ❑Subcutaneous d) Other________

25. Where did you learn how to inject a horse? ____

26. Is there a veterinarian who attends to your horses when they have colic?

a) ❑Yes b) ❑ No

27. At what point do you usually call a veterinary doctor when you have a case of colic?
____
____
____

28. Have you ever had any of your horses die of colic?

a) ❑ Yes b) ❑ No

If yes, how many horses in the last 3 years? _____________________________

If possible give the numbers every year the horses have died_________

29. Did you know the causes of death?

a) ❑ Yes b) ❑ No

a) If yes, what was the cause of death? _______________________________

b) How did you know the cause of death? ___________________________

30. What do you think can be done to reduce cases of colic in your stable?

Appendix 2:

Data collection sheet for prospective study

Owner: ________________________________**Case No:** _______________
Breed:__________________**Age:** ________________________ **Sex:**__________________

Treatment used: __________________________

	Clinical Signs noted
Vital Signs (beats per minute)	
Heart Rate (beats per minute)	
Respiratory rate (Breaths per minute)	
Temperature (degree centigrade)	
Gum color (mucus membrane)	
Capillary refill time	
Feces (Normal, amount , hard fecal balls, Absent)	
Pain Level: Looking at belly (Yes: No)	
Stretching (Yes:No)	
Pawing (Yes : No)	
Sweating (Yes :No)	
Lying down and rolling(Yes : No)	
Distended abdomen (Yes :No)	

Appendix 3:

Data collection sheet for retrospective study

University of Nairobi Department of Clinical studies Faculty of Veterinary Medicine, University of Nairobi Date……………… Veterinary Doctor……………………KVB Reg. No……………. Patient ID…………………..Breed…………………………Sex……   Age……………………….Color…………………..
Type Of Colic/Diagnosis:
Treatment and Duration of Treatment:
Outcome :

Appendix 4

Publications

P-ISSN: 2304-3075; E-ISSN: 2305-4360

International Journal of Veterinary Science

www.ijvets.com; editor@ijvets.com

Research Article

Hematological and Biochemical Changes in Horses with Colic in Nairobi County, Kenya

Gitari AN*, Nguhiu-Mwangi J, Mogoa EM, Varma VJ, Mwangi WE, Konde AM and Rashid FK

Department of Clinical Studies, Faculty of Veterinary Medicine, University of Nairobi, P.O. Box 29053-00625 Nairobi, Kenya.
***Corresponding author:** drgitari@gmail.com

Article History: Received: April 05, 2016 Revised: September 15, 2016 Accepted: September 21, 2016

ABSTRACT

This was a prospective study, which involved following up cases of colic and from which blood samples for haematology and serum for biochemical analysis were collected. The haematological parameters measured were total erythrocyte count (TEC), haemoglobin concentration (Hb), Haematocrit (hct), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentartion (MCHC), red blood cell distribution width (RDW), platelet count, Total leucocyte count (TLC) and leucocyte differential count. The biochemical parameters measured were alkaline phosphatase (ALP), aspartate aminotransferase (AST), total proteins, serum albumin, serum globulin, blood glucose and serum lactate. The data obtained from the reported cases of colic was then imported into StatPlus pro 5.9.8 statistical package and means±SD were calculated and student t-test was then used to compare the means from horses that had impaction colic with those that had spasmodic colic as well as the means of those horses that recovered with those of the horses that died. The level of significance was at $P<0.05$.

Mean corpuscular haemoglobin (MCH) was significantly higher ($p=0.03$) in horses with spasmodic colic (16.8±1.3 pg) than in those with impaction colic (15.6±1.2 pg). The mean leucocyte count (10^9/L) was significantly higher ($p=0.02$) in horses with impaction colic (12.9±5.9) than in those with spasmodic colic (9.0±1.5). Similarly, mean neutrophil count (10^9/L) was significantly higher ($p=0.02$) in horses with impaction colic (9.1±5.6) than in those with spasmodic colic (5.4±1.7). The mean values of blood glucose were significantly higher ($p=0.02$) in horses with impaction colic (5.7±2.0 mmol/l) than in those with spasmodic colic (3.7±1.4 mmol/l). The blood biochemical parameters that were significantly lower in horses that died than those that survived were total protein ($P=0.002$), albumin ($P<0.01$) and globulin ($P=0.04$). Apart from Mean corpuscular hemoglobin (MCH), and slight leucocyte and neutrophil changes, there were no major significant haematological changes in horses with colic. Total blood proteins including albumin and globulin levels could serve as possible guides to prognosis of colic in horses. The general prognosis of spasmodic colic in horses was good, but fair to poor for impaction.

Key words: Horses, Colic, Hematology, Biochemistry, Diagnostic, Prognostic, Indicators

Cite This Article as: Gitari AN, J Nguhiu-Mwangi, EM Mogoa, VJ Varma, WE Mwangi, AM Konde and FK Rashid, 2016. Haematological and biochemical changes in horses with colic in Nairobi County, Kenya. Inter J Vet Sci, 5(4): 250-255. www.ijvets.com (©2016 IJVS. All rights reserved)

INTRODUCTION

Complete blood count (CBC) and biochemical profiles are commonly performed by equine veterinarians as the foundation of diagnostic evaluation with Packed Cell Volume (PCV), hematocrit, total protein; total leukocyte count, blood glucose and blood lactate being good prognostic indicators in horses suffering from acute abdominal disease. Packed Cell Volume (PCV) is an important prognostic indicator in horses with colic (Puotunen-Reinert, 1986). Elevated PCV has been shown to be a negative prognostic indicator for survival of the horse. However, other reports indicate that PCV has no prognostic significance (Van er Linden *et al*., 2003). It is therefore not wise to use PCV as the sole determinant of prognosis. Nevertheless, PCV is an indicator of cardiovascular compromise, which is an important determinant of survival (Parry *et al*., 1983). Low White Blood Cell Count (WBC) implies endotoxaemia and a probable indicator of devitalized intestine. Increased WBC is seen in impending colitis and peritonitis with signs of abdominal pain (Morris, 1991).

Total protein and albumin levels are important parameters in the management of horses with acute abdominal disease. A study showed that decreased serum total protein concentration at admission was associated with an increased risk of postoperative death in horses recovering from small intestinal surgery (Proudman *et al*., 2005). In another retrospective study of horses undergoing colic surgery, prognosis was found to be associated with

Cite This Article as: Gitari AN, J Nguhiu-Mwangi, EM Mogoa, VJ Varma, WE Mwangi, AM Konde and FK Rashid, 2016. Haematological and biochemical changes in horses with colic in Nairobi County, Kenya. Inter J Vet Sci, x(x): xxxx. www.ijvets.com (©2016 IJVS. All rights reserved)

Total plasma protein, the type of lesion, preoperative PCV and the length of the surgical procedure (Pascoe *et al*., 1983). Hyperglycemia is common in horses with colic and is associated with poor prognosis, when considered together with changes in heart rate and PCV (Hassel *et al*., 2009). Horses with higher blood glucose concentrations have been associated with a less favorable prognosis at admission in hospital (Parry *et al*., 1983).

Plasma or peritoneal lactate levels are an important predictor for survival. In one study, blood lactate was found to be an important predictor of survival (Parry *et al*., 1983). Peritoneal lactate has been shown to be more useful predictor of intestinal ischemia secondary to strangulating obstruction than blood lactate (Furr *et al*., 1995). Plasma lactate concentration is elevated significantly in non-surviving horses with large colon volvulus and lower in horses with viable colon (Johnston *et al*., 2007). Horses with increased blood or peritoneal lactate were reported to have a high likelihood of needing intestinal resection, developing postoperative ileus and increased probability of death (Delesalle *et al*., 2007).

Abdominal fluid analysis is also useful in determining if there is a need for surgery (Adams *et al*., 1980). Protein concentrations and complete white blood cell count of peritoneal fluid are useful in determining the degree of intestinal injury (Reeves *et al*., 1989). Increased protein concentration in abdominal fluid with no change in cell numbers is often due to simple obstruction with bowel distension. An increased number of white blood cells and ratio of neutrophils to monocytes (that is more than 70% neutrophils), will indicate a likelihood of bowel ischemia or degeneration with leakage of bacteria. Excess numbers of red blood cells (RBC) in the peritoneal fluid shows that there is leakage of cells from capillaries and this is an indicator for intestinal injury, particularly venous strangulation with obstruction. Increase of haemoglobin concentrations increases the odds that surgery is needed and increases the sensitivity and specificity of the decision compared to just visual assessment of peritoneal fluid. Increased peritoneal fluid lactate concentration compared to plasma lactate is also an indicator of intestinal compromise that indicates a surgical lesion. Increase of lactate concentration from a series of peritoneal fluid measurements is also an indicator of progressive intestinal injury (Delesalle *et al*., 2007). Bacteria in the peritoneal fluid are a clear indication of intestinal mucosal damage that allows their leakage through the intestinal wall (Weimann *et al*., 2002).

MATERIALS AND METHODS

Study area

This study was carried out in Nairobi County Kenya, which is located at 1°17′S 36°49′E, and has a daily temperature range between 16^0C and 30^0C. The horse population in the County is estimated to be 3,200 according to the Kenyan chapter of the international stud book committee. It was purposively decided to carry out the study in Nairobi County because of its relatively high population of horses, it is where the Jockey Club of Kenya is located, and it was convenient for the study. Nairobi County also has more equine practitioners compared to other Counties in Kenya. These factors made it possible to obtain the required sample size for the study.

Study design

The prospective study was carried out to assess the haematological and biochemical values in horses with colic. The haematological parameters evaluated were total erythrocyte count (TEC), haemoglobin concentration, haematocrit, mean corpusclar volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), red cell distribution width (RDW), and counts of platelets, Total leucocyte count (TLC), neutrophilis, lymphocytes, monocytes, eosinophilis and basophils. The biochemical parameters evaluated were alanine aminotransferase (ALT), aspartate aminotransferase (AST), total proteins, serum albumin, random glucose and serum lactate. The study period for all the horses that had colic was November, 2015 to 31st march, 2016. The 27 horses that had manifested signs of colic and were reported had their blood samples taken from the jugular vein before any treatment was given. Diagnosis of colic (Appendix 1) was made by physical examination which included recognizing and assessing signs of abdominal pain, heart rate, respiratory rate and temperature. Other parameters determined included the colour of mucus membranes, capillary refill time and presence or absence of borborygmi sounds. Rectal examination and nasogastric intubation were done. Spasmodic colic was diagnosed based on findings of presence of increased borborygmi sounds (more than 3) in both fields of the abdomen, passing of gas and increased frequency of defaecation. Impaction colic was diagnosed based on findings of reduced borborygmi, bloated abdomen, presence of reflux through nasogatric intubation and rectal examination. Horses that did not show these signs of colic were excluded. A total of 10 ml of blood sample was collected from the jugular vein of each horse using direct venipuncture or a pre-placed IV catheter. Of this volume of blood, 4 ml was collected in vacutainer tubes with EDTA and 4 ml was collected in vacutainer tubes with clot activator and 2 ml in sodium fluoride tubes. The 4 ml of blood sample with EDTA for each horse with colic was used to analyze for total erythrocyte count (TEC) in 10^{12}/L, total platelet count (TPC) in 10^9/L, total leucocytes count (TLC) in 10^9/L, packed cell volume (PCV) in %, hemoglobin concentration (Hb) in g/dl and differential cell count (Neutrophils, Basophils, Eosinophils, Monocytes and Lymphocytes). The other 4 ml blood was assayed for alkaline phosphatase (IU/L), aspartate aminotransferase (AST) (IU/L), total protein (g/l) and serum lactate (mmol/l). The remaining 2 ml was assayed for random glucose (mmol/l). The hematological analysis was done using an automatic cell counter (Idexx Procyte DX Haematology Analyzer, Idexx laboratory, USA) following the manufacturer's instructions. The blood samples with the clot activator and sodium fluoride were immediately centrifuged at 3500 revolutions per minute for 10 minutes and serum was harvested. Serum samples were stored at -20ºC and analyzed using dry chemistry technology with Idexx catalyst DX chemistry analyzer (Idexx laboratory,USA) for alkaline phosphatase (ALP), aspartate aminotransferase (AST), total protein, serum albumin, random glucose and serum lactate.

Relevant treatment was instituted for colic and the horses closely monitored until either recovery or death. The cases were categorized as either impaction colic or spasmodic colic from their clinical presentation and physical examination.

Initially, all the haemotological and biochemical data were first categorized into those from impaction colic horses or spasmodic colic horses as well as from horses that recovered or those that died. The haematological and biochemical data were entered into Microsoft Office Excel 2010 then verified and validated to be correct entries as per the data collection sheets. This data was then imported into StatPlus pro 5.9.8 statistical package where normality tests were first computed using Shapiro Wilk normality test. Following this, means±SD were calculated and student t-test was then used to compare the means between the categories of colic as well as between those that recovered and those that died at $P<0.05$ significance level.

RESULTS

Descriptive analysis

A total of 27 horses manifesting signs of colic were examined in this phase of the study. The cases were presented between November, 2015 and March, 2016. The horses were adults from 9 stables comprising of 15 females and 12 males. During this period, only one horse had recurring episodes of colic. There were 18.5% (n = 5) deaths. The findings from the history and physical examination of the reported cases pointed to spasmodic, impaction colic and torsion. Spasmodic colic was diagnosed in 55.6% (n=15) of the cases while impaction colic was in 40.7% (n=11) of the cases and that of torsion at 3.7% (n=1). The case of torsion was excluded from the analysis to restrict comparison to between impaction and spasmodic colic only. Postmortem of the 5 horses that died revealed torsion (1) at the jejunum and impaction at the transverse colon (2) and pelvic flexure (2) as the cause of death.

Mean values of hematological parameters in spasmodic and impaction colic

Haematological values of horses with spasmodic colic were compared with those of horses with impaction colic. The mean haematological values between horses with spasmodic colic and those with impaction colic were very similar, hence the differences were largely not significant (P>0.05) (Table 1), except for the mean corpuscular haemoglobin (MCH), total leucocyte count and neutrophil count. The mean corpuscular haemoglobin was significantly higher (p = 0.03) in horses with spasmodic colic [16.8±1.3 pg] than in those with impaction colic [15.6±1.2 pg]. The mean leucocyte count was significantly higher (p = 0.02) in horses with impaction colic [12.9±5.9 (10^9/L)] than in those with spasmodic colic [9.0±1.5 (10^9/L)]. Similarly, neutrophil count was significantly higher (p = 0.02) in horses with impaction colic [9.1±5.6 (10^9/L)] than those with spasmodic colic [5.4±1.7 (10^9/L)].

Mean values of haematological parameters in horses that recovered and those that died of colic

The mean values of the haematological parameters of the horses that recovered from colic and of those that died of colic were closely related with no significant differences (P>0.05) between them as shown in Table 2. Although the differences were not significant, overall, the mean values of total leucocytes were higher in the horses that died of colic than those that recovered. Similarly, the haematocrit and platelet mean values appeared to be much higher in the horses that died of colic than in those that survived, despite this difference being not significant.

Mean values of biochemical parameters in horses with colic

The mean values of blood glucose were significantly higher (P=0.02) in horses with impaction colic (5.7±2.0 mmol/l) than in those with spasmodic colic (3.7±1.4 mmol/l). There were no significant differences in the mean values of Alkaline phosphatase (ALP), Aspartate aminotransferase (AST), Total protein, Albumin and Serum lactate between the horses that had impaction colic and those that had spasmodic colic (Table 3). Despite there being no significant difference, the mean values of Alkaline phophatase and Aspartate aminotransferase were relatively higher in horses with impaction colic than in those with spasmodic colic. In addition, mean total proteins were relatively lower in impaction colic than in spasmodic colic cases.

Mean values of biochemical parameters in horses that recovered or died from colic

There were significant differences in the mean values of total protein, albumin and globulin between colicky horses that died and those that survived. The mean values of total protein were significantly lower (P<0.01) in horses that died (57± 5.4 g/l) than in those that survived (72.5±14.8). Similarly, the mean values of albumin were significantly lower (P<0.01) in horses that died (24.7±2.1 g/l) than in those that survived (33.7±7.6 g/l). The mean values of globulin were equally significantly lower (P=0.04) in horses that died (32.4±3.9 g/l) than in those that survived (38.7±9.1 g/l) the colic. On the other hand, and although not significant, alkaline phosphatase was relatively higher in horses that died than in those that survived from colic, while aspartate aminotransferase was relatively higher in those that survived than in those that died (Table 4).

DISCUSSION

In this prospective study there was higher total leucocyte and neutrophil counts in impaction colic, as well as in the horses that died as compared to those that recovered and this can be attributed to the fact that impaction applies intense pressure from the lumen to the walls of the involved segment of the gastrointestinal tract. When impaction persists over time, the pressure may result in slight degree of ischaemia, devitalization and degeneration of walls of the intestine. Subsequently, some bacteria die and release endotoxins into circulation and bacteria leak into blood, thus triggering a rise in neutrophils and total leucocyte count as has been suggested previously (Morris, 1991; Weimann *et al.*, 2002). This may be the same reason for the death of some of the impaction cases of colic while those with spasmodic colic recovered.

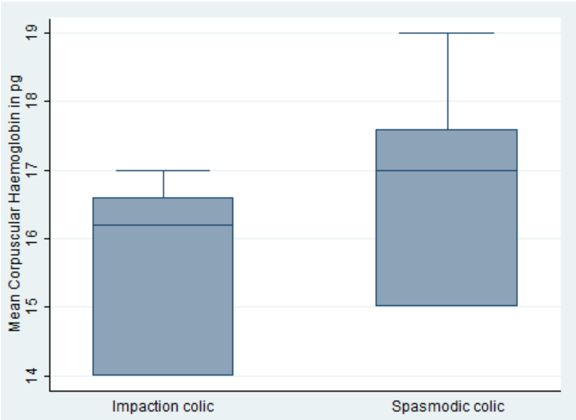

Fig. 1: A Box-and Whiskers plot comparing the means of the mean corpuscular haemoglobin (pg) between horses with impaction colic and spasmodic colic, in which the difference was significant (p=0.03).

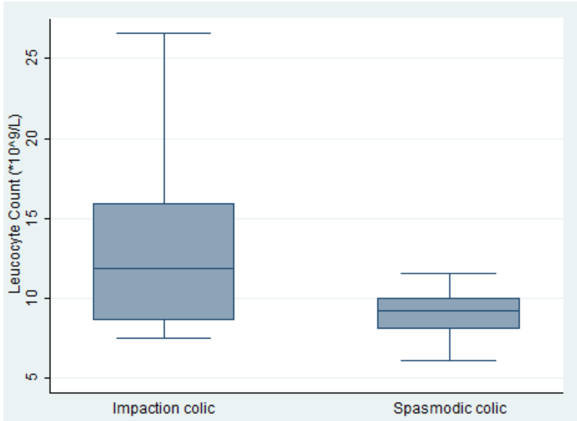

Fig. 2: A Box-and Whiskers plot comparing the means of leucocyte counts (10^9/L) between horses with impaction and spasmodic colic, in which the difference was significant (p=0.02).

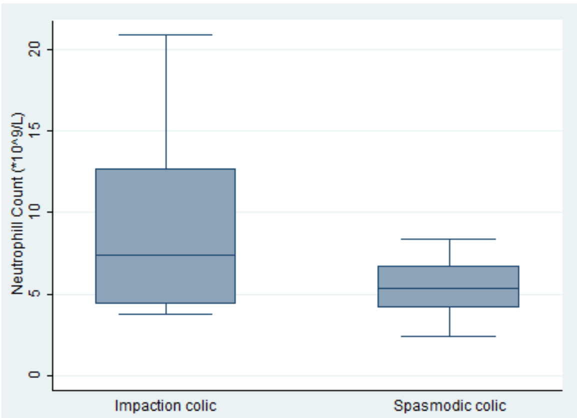

Fig. 3: A Box-and Whiskers plot comparing the means of neutrophil counts (10^9/L) between horses with impaction and spasmodic colic, in which the difference was significant (p=0.02).

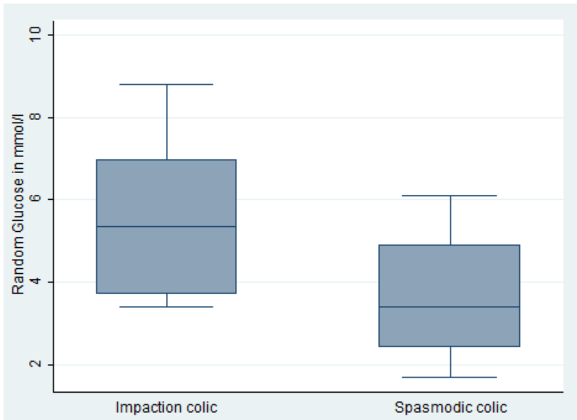

Fig. 4: A Box-and Whiskers plot comparing the means of random glucose (mmol/l) between horses with impaction and spasmodic colic, in which the difference was significant (p=0.02).

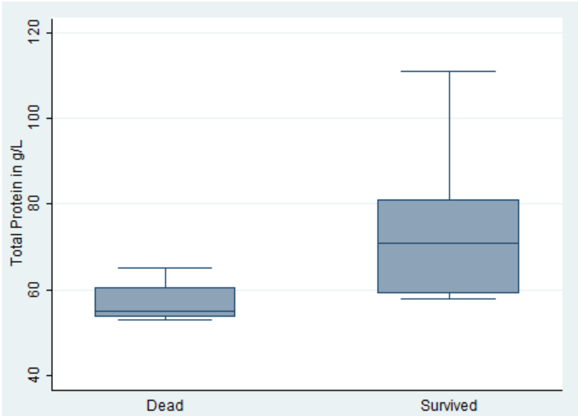

Fig. 5: A Box-and Whiskers plot comparing the means of total protein (g/l) between horses with impaction and spasmodic colic, in which the difference was significant (p=0.002).

Alkaline phosphatase (ALP) which is an enzyme present in intestinal mucosa although not significant was increased in horses with impaction than those with spasmodic colic and this was similar to a study that indicated an increase in serum ALP is associated with greater intestinal damage which leads to a likelihood of probability for surgery and a worse prognosis (Saulez *et al*., 2004).

Muscle enzyme Aspartate aminotransferase (AST) although not significant was relatively high in horses with impaction colic than those with spasmodic colic. This is similar to a study that found increase in pre-operative AST concentration were significantly associated with lesions associated with intestinal ischaemia and subsequent decrease of survival probability in horses in hospitals. Preoperative increase in AST enzyme activities will assist in finding out the severity and prognosis of horses with colic and make an informed decision if they should be going through celiotomy (Krueger et al., 2014).

The significantly higher mean values of blood glucose in horses with impaction when compared to those with spasmodic colic is similar to the previous findings in other studies that have reported hyperglycaemia in cases of colic even though in those studies, the types of colic were not designated (Hassel *et al.*, 2009). The reason for the hyperglycaemia is not well known, but it is suggested that the horses with colic develop temporary insulin resistance that leads to blood glucose elevation. It was further suggested that the cases of colic with hyperglycemia have worse prognosis for survival (Hassel *et al.*, 2009). A study related hyperglycemia in critically ill patients due to a consequence of deregulation of

Table 1: Comparative mean haematological values between horses with impaction colic and those with spasmodic colic in Nairobi county between November 2015 and March 2016.

Haematological parameters	Type of colic	Means±SD	P Value
Erythrocyte count (10^{12}/L)	Impaction	9.6±1.4	0.20
	Spasmodic	8.9±2.1	
Hemoglobin concentration (g/dl)	Impaction	14.9±1.8	0.95
	Spasmodic	18.4±3.2	
Hematocrit (L/L)	Impaction	0.42±0.07	0.98
	Spasmodic	0.42±0.1	
Mean corpuscular volume (fl)	Impaction	43.2±5.6	0.13
	Spasmodic	46.3±2.8	
Mean corpuscular hemoglobin (pg)	Impaction	15.6±1.2	
	Spasmodic	16.8±1.3	**0.03***
Mean corpuscular hemoglobin concentration (g/dl)	Impaction	36.3±2.8	0.81
	Spasmodic	36.0±2.3	
Red blood cell width (%)	Impaction	26.4±9.9	0.15
	Spasmodic	20.9±8.0	
Total platelet count (10^9/L)	Impaction	162.5±196.1	1.0
	Spasmodic	160.1±130.5	
Lymphocyte count (10^9/L)	Impaction	3.3±1.3	0.37
	Spasmodic	2.8±1.3	
Monocyte count (10^9/L)	Impaction	0.6±0.8	0.89
	Spasmodic	0.6±0.4	
Eosinophils count (10^9/L)	Impaction	0.20±0.1	0.17
	Spasmodic	0.2±0.2	
Basophil count (10^9/L)	Impaction	0.1±0.04	0.27
	Spasmodic	0.1±0.04	
Total leucocyte counts (10^9/L)	Impaction	12.9±5.9	0.02*
	Spasmodic	9.0±1.5	
Neutrophil count (10^9/L)	Impaction	9.1±5.6	0.02*

	Spasmodic	5.4±1.7

*Significant at P<0.05.

Table 2: Comparative mean values of haematological parameters between horses that recovered from colic and those that died of colic in Nairobi County from November 2015 to March 2016

Hematological parameters	Outcome	Means±SD	P Value
Erythrocyte count (10^{12}/L)	Died	9.1±3.1	1.0
	Recovered	9.1±1.8	
Hemoglobin concentration (g/dl)	Died	14.3±2.2	0.7
	Recovered	14.9±2.7	
Hematocrit (L/L)	Died	11.3±21.9	0.39
	Recovered	0.4±0.1	
Mean corpuscular volume (fl)	Died	40.6±5.3	0.14
	Recovered	45.7±4.0	
Mean corpuscular hemoglobin (pg)	Died	17.1±5.2	0.8
	Recovered	16.4±1.3	
Mean corpuscular hemoglobin concentration (g/dl)	Died	41.5±7.2	0.22
	Recovered	36.0±2.4	
Red blood cell width (%)	Died	29.6±11.4	0.35
	Recovered	23.3±9.0	
Total platelet count (10^9/L)	Died	417.3±326.8	0.22
	Recovered	139.4±109.0	
Lymphocyte count (10^9/L)	Died	2.3±1.8	0.5
	Recovered	3.0±1.3	
Monocyte count (10^9/L)	Died	0.4±0.2	0.14
	Recovered	0.6±0.6	
Eosinophils count (10^9/L)	Died	0.12±0.2	0.86
	Recovered	0.14±0.2	
Basophil count (10^9/L)	Died	1.1±2.2	0.40
	Recovered	0.1±0.04	
Total leucocyte counts (10^9/L)	Died	18.1±7.2	0.13
	Recovered	10.4±4.4	
Neutrophil count (10^9/L)	Died	14.2±9.3	0.12
	Recovered	6.7±4.9	

Significant at P<0.05.

Table 3: Comparative mean values of biochemical parameters between horses with impaction colic and those with spasmodic colic in Nairobi County from November 2015 to March 2016

Biochemical parameters	Type of colic	Means±SD	P Value
Alkaline phosphatase (ALP) IU/L	Impaction	89.0±69.8	0.2
	Spasmodic	55.0±31.1	
Aspartate amino-transeferase (AST) IU/L	Impaction	453.4±225.3	0.9
	Spasmodic	436.5±222.6	
Total protein g/l	Impaction	67.9±17.8	0.45
	Spasmodic	73.0±13.3	
Albumin g/l	Impaction	30.4±7.2	0.19
	Spasmodic	34.5±8.1	
Globulin g/l	Impaction	37.5±7.2	0.8
	Spasmodic	38.5±8.1	
Blood glucose mmol/l	Impaction	5.7±2.0	0.02*
	Spasmodic	3.7±1.4	
Blood lactate mmol/l	Impaction	7.4±2.9	0.12
	Spasmodic	5.7±1.6	

* Significant at P<0.05.

Table 4: Comparative mean values of biochemical parameters between the horses that died and those that recovered from colic in Nairobi County from November 2015 to March 2016

Biochemical parameters	Outcome	Means±SD	P Value
Alkaline phosphatase (ALP) IU/L	Dead	120±64.9	0.19
	Survived	66.4±49.4	

Aspartate amino-transeferase (AST) IU/L	Dead	413±10.3	0.61
	Survived	439.7±225.4	
Total protein g/l	Dead	57±5.4	0.002*
	Survived	72.5±14.8	
Albumin g/l	Dead	24.7±2.1	0.0001*
	Survived	33.7±7.6	
Globulin g/l	Dead	32.4±3.9	0.04*
	Survived	38.7±9.1	
Blood glucose mmol/l	Dead	6.9±2.2	0.08
	Survived	4.2±1.7	
Blood lactate mmol/l	Dead	6.3±3.3	0.98
	Survived	6.2±2.3	

*Significant at $P<0.05$

glucose homeostasis manifested by peripheral insulin resistance, hyperinsulinemia, increased gluconeogenesis and impaired peripheral insulin-mediated glucose uptake (Vanhorebeek *et al.*, 2007). Study of 269 horses with colic presented to a referral hospital within the United Kingdom showed about 50% of horses that had blood glucose concentrations higher than the normal range of 3.5-7.4mmol/l and higher glucose concentrations at the time of admission were associated with non survival (Hollis *et al.*, 2007). Although the blood lactate in impaction colic was not significantly different from spasmodic colic, it was nevertheless higher. This has been associated with poorer prognosis for survival in cases of colic with lactate at greater than 8 mmol/l (Moore *et al*., 1976). Studies have indicated that several blood lactate analysis are more useful prognostic indicator than just single lactate analysis. Hospitalized horses with increased blood lactate concentration from serial measurements were seen in non survivors compared to survivors, however this difference tend to be small (Tennent-Brown, 2012).

The significantly lower serum levels of total protein, albumin and glubulin in horses that died compared to those that recovered agrees with reports of a retrospective study, which cited total plasma protein as one of the factors that influenced survival in horses that underwent surgery for treatment of colic (Pascoe *et al.*, 1983). Similarly in another study, it was stated that decreased serum total protein concentration was associated with an increased risk of postoperative death in horses recovering from small intestinal surgery. The decrease in plasma protein is an indication of loss of this protein through damaged intestinal walls (Proudman *et al.*, 2005).

Conclusion

It can be concluded from this study that the only significant haematological changes observed were slight elevation of leucocyte and neutrophil counts in impaction colic compared to spasmodic colic. Similar elevation of these parameters were also present in horses that died of colic compared to those that recovered from colic. Blood glucose was higher in horses with impaction colic than in those with spasmodic colic and this could be a useful prognostic factor to consider when managing impaction colic. Another factor that could be useful to consider in determining prognosis for survival particularly in cases with cases that may have devitalized intestine is total plasma or serum proteins. It is suggested that probably abdominal fluid analysis could be useful in diagnosis and prognosis of colic cases as suggested previously (Adams *et al*., 1980; Reeves *et al*., 1989; Weimann *et al*., 2002).

REFERENCES

Adams, SB, JF Fessler and AH Rebar, 1980. Cytologic interpretation of peritoneal fluid in the evaluation of equine abdominal crises. Cornell Vet, 70: 232-246.

Delesalle C, J Dewulf, RA Lefebvre, JA Schuurkes, J Proot, L Lefere and P Deprez, 2007. Determination of lactate concentrations in blood plasma and peritoneal fluid in horses with colic by an Accusport analyzer. J Vet Internal Med, 21: 293-301.

Hassel DM, AE Hill and RA Rorabeck, 2009. Association between hyperglycemia and survival in 228 horses with acute gastrointestinal disease. J Vet Internal Med, 23: 1261-1265.

Hollis AR, RC Boston and KT Corley, 2007. Blood glucose in horses with acute abdominal disease. J Vet Internal Med, 21: 1099-1103.

Johnston K, SJ Holcombe and JG Hauptman, 2007. Plasma lactate as a predictor of colonic viability and survival after 360 degrees volvulus of the ascending colon in horses. Vet Surg, 36: 563-567.

Krueger CR, **A** Ruple-Czerniak and ES Hackett, 2014. Evaluation of plasma muscle enzyme activity as an indicator of lesion characteristics and prognosis in **horses** undergoing celiotomy for acute gastro-intestinal pain. BMC Vet Res, 101186/1746-6148.

Moore JM, R Owen and JH Lumsden, 1976. Clinical evaluation of blood lactate levels in equine colic. Equine Vet J, 8: 49-54.

Morris DD, 1991. Endotoxemia in horses A review of cellular and humoral mediators involved in its pathogenesis. J Vet Internal Med, 5: 167-181.

Parry BW, GA Anderson and CC Gay, 1983. Prognosis in equine colic. a comparative study of variables used to assess individual cases. Equine Vet J 15: 211-215.

Pascoe PJ, WN McDonell, CM Trim and GJ Van, 1983. Mortality rates and associated factors in equine colic operations - a retrospective study of 341 operations. Can Vet J, 24: 76-85.

Proudman CJ, GB Edwards, J Barnes and NP French, 2005. Modelling long-term survival of horses following surgery for large intestinal disease. Equine Vet J, 37: 366-370.

Puotunen-Reinert A, 1986. Study of variables commonly used in examination of equine colic cases to assess prognostic value. Equine Vet J, 18: 275-277.

Reeves MJ, CR Curtis and MD Salman, 1989. Prognosis in equine colic patients using multivariable analysis. Can J Vet Res, 53: 87-94.

Saulez MN, **CK** Cebra and SJ Tornquist, 2004. The diagnostic and prognostic value of alkaline phosphatase activity in serum and peritoneal fluid from horses with acute colic. J Vet Internal Med, 18: 564-7.

Tennent-Brown, BS, 2012. Interpreting lactate measurement in critically ill horses. diagnosis, treatment, and prognosis. Compendium Continuing Education for Veterinarians, 34. E2.

Van der Linden MA, CM Laffont and MM Sloet van Oldruitenborgh-Oosterbaan, 2003. Prognosis in equine medical and surgical colic. J Vet Internal Med, 17: 343-348.

Vanhorebeek I, L Langouche, G Van den Berghe, 2007. Tight blood glucose control with insulin in the ICU. Facts and controversies Chest, 132.268–278.

Weimann CD, MB Thoefner and AL Jensen, 2002. Spectrophotometric assessment of peritoneal fluid haemoglobin in colic horses. An aid to selecting medical vs surgical treatment. Equine Vet J, 34: 523-527.