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Evaluation of Clinical, Laboratory and Ultrasonography Variables as Prognostic Indicators in Equine Colic Surgery

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ABSTRACT

Background: Equine colic surgery is an expensive procedure and availability of reliable prognostic indicators aid in decision making process. This study aimed to evaluate clinical, hemato-biochemistry, ultrasonography, surgery and peritoneal cytology/intestinal histology as prognostic indicators (based on strangulating vs non-strangulating lesion) for equine colic surgery.

Methods: Fifteen equines (13 females and 2 males; 5 Thoroughbred, 9 Marwari and one mule) operated for intestinal colic were investigated. The feeding history, pre and post-surgery clinical, hematological and biochemical findings were recorded. Pre and post-surgery ultrasonography, peritoneal cytology and intestinal histology were done. Three equine were euthanized intra-operatively and 12 were followed for short and long term outcome.

Result: On surgery, three equine were diagnosed for strangulating (right dorsal displacement of large colon, large colon volvulus and small colon strangulation) and 12 for non-strangulating colic [impaction (3), fecalith (5), sand colic (2), foreign body (1) and small intestine ileus (1)]. Detection of polymorphonuclear cells alone or with lymphocytes on peritoneal fluid cytology was indicator of good prognosis. Feeding of wheat straw is major predisposing factor for non-strangulating colic in Marwari breed but had favorable surgical prognosis (7/9=77.78%). While Thoroughbreds, not on wheat straw, are susceptible to strangulating colic that require early referral for favorable surgical outcome. Prolonged capillary refill time, injected mucous membranes, absent borborygymi, high serum creatine kinase and glucose are poor prognostic indicators for colic surgery. Thoroughbred equine with severe pain, elevated levels of Hb, neutrophils, packed cell volume (PCV), serum glucose and low peritoneal total protein are indicators of strangulating lesion. The equine colic surgery bears a very good short term (10/12=83.33%) and excellent (10/10=100%) long term outcome.

Key words: Colic, Creatine kinase, Glucose, Lactate, Prognostic, Strangulating, Survivability.

INTRODUCTION

Colic, of gastrointestinal origin, is the major cause of morbidity, mortality and premature deaths in horses (Cook and Hassel, 2014). Diagnostic approaches help to identify the nature and severity of most probable cause of colic, which helps for early referral; thereby, reducing the tissue injury and resulting endo-toxemia/systemic inflammatory response syndrome and thus improving the survival rates. Recent studies reveals elevated plasma levels of lactate (Henderson, 2013), creatine kinase and AST activity (Krueger *et al*., 2014) as important prognostic indicators. Mucous membrane is prognostic indicator of hypovolemic shock/endotoxemia with peritoneal fluid colour and lactate as indicators of strangulating and non-strangulating lesions (Shearer *et al*., 2018).

Surgical treatment of equine colic is resource-demanding and expensive; thus information on the prognosis is important both for owners as well as surgeons (Christophersen *et al*., 2014). This institute is working on the development of equine colic surgery including its diagnostic and prognostic aspects from the last a few years (Anand *et al*., 2017; Khosa *et al*., 2019a). The present study evaluated clinical, hemato-biochemical, ultrasonography and peritoneal cytology/intestinal histology as the prognostic indicators for equine colic surgery along with post-surgical outcome.

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MATERIALS AND METHODS

This prospective clinical study (duly approved by the Institutional Animal Ethics Committee) was conducted on 15 equines, at the Referral University Veterinary Hospital, during December 2018 to December 2019.

The parameters recorded included *Signalment* and *history* (age, breed, gender, weight, duration of colic, mental

state at presentation, pain and abdominal distension), *Feeding history* (feed type, recent change, history of diarrhea, de-worming and previous colic), *Physical examination* (borborygmi, nasogastric reflux/intubation, abdominocentesis and rectal examination), *Clinical Examination* (body temperature (p F), heart rate (HR, beats/min), Respiration rate (RR, breaths/min), Capillary refill time (CRT, /sec) and Mucous membrane color (MM)), *Hematology* and *Serum Biochemistry* [Hemoglobin (Hb), Total leukocyte count (TLC), Differential leukocyte count (DLC), Packed cell Volume (PCV), Platelets, lactate, total proteins, creatine kinase, alkaline Phosphatase (AKP), Na, K, Cl, Ca and glucose], *Abdominocentesis* and *peritoneal fluid analysis* (Peritoneal fluid, collected intra-operatively or post-operatively was analyzed for cytology, lactate, creatine kinase and total proteins), *Operative findings*, *Histopathology* of affected intestines and *Ultrasonography* (B-mode ultrasonography was done pre and post operatively using 2-5 MHz frequency curvilinear transducer of GE HEALTHCARE LOGIQ F8 system to assess peritoneal fluid and intestinal motility).

Surgical procedure

All 15 equines were operated from ventral midline incision in dorsal recumbency under general anaesthesia (inhalant) as described by Khosa *et al.* (2019a). Inj. Normal saline (@ 10 ml/kg/hour) was administered throughout the surgery.

Patient monitoring

Anaesthetic recovery was monitored till animal stood up. Supportive bandage (using broad cotton tape) was applied for 12-14 days (Fig 3). Clinical and hemato-biochemical parameters were recorded daily during hospitalization. Lukewarm water intake in small frequent amounts was encouraged 12 hr after surgery, while green fodder/grazing intake and light walk at 24hrs.

Post-operative treatment

Inj. piperacillin and tazobactam @50 mg/kg bid IV, inj. amikacin @5 mg/kg bid IM and Inj. Flunixin @ 1.1 mg/kg, once daily, IV for 7, 5 and 3 days, respectively were administered. Intravenous fluids with balanced electrolytes were administered for 2 to 3 days. Lignocaine was used as a prokinetic @1.3 mg/kg, slow IV with half of calculated dose as loading dose and rest @0.05 mg/kg/hr.

Follow up and clinical outcome

All the operated equines were followed for short (period of hospitalization after colic surgery *i.e* 3 to 5 days) and long term (period from discharge from the hospital upto 4 to 16 months) outcome.

Statistical analysis

The Microsoft excel 10 and SPSS 16 was used to calculate the descriptive statistics and student t-test to analyse significant difference between the survivors and non-survivors.

RESULTS AND DISCUSSION

Signalment (Table 1)

Majority of the operated equines were females (13/15= 86.66%). Gender itself was not associated with prevalence of colic but it has been associated with particular cause of colic such as uterine torsion in females (Khosa *et al*., 2019b) and scrotal hernia in intact males (Cook and Hassel, 2014).

Seven equines were presented in the month of December and January, which are winter months (temperature range 4 to 20°C) in the region of study. The other 8 equines were dispersed throughout the year. Winter season had been reported to be more likely for impactive colic due to decreased availability of green fodder and water intake (Southwood, 2013; Bihonegn and Bekele, 2018). However, for large colon volvolus, summer and spring season were reported as predisposing (Hackett *et al*., 2015); although, a volvolus case in the present study was presented in winter season.

Both young (≤2 yrs) and adult (>2 yrs) equines were almost equally presented for surgery with a mean±SD for age of 48.10±45.67 months (range 2 month to 13 years). The short and long term survival was better in young equines as compared to that in adult. Age has been reported to be asssociated with specific types of colic (Cook and Hassel 2014, Bihonegn and Bekele, 2018). In the present study, out of 15, 5 foals were less than 1 yr of age and had impaction (n=2) and fecalith in left ventral or small colon (n=3).

Out of 15 equines (5 Thoroughbred, 9 Marwari and one mule), 5 horses (3 Thoroughbred and 2 Marwari) died/ euthanized during hospitalization. Thoroughbred horses were found more sensitive to colic, may be because of having specific acute lesion rather than the non-specific impaction/Fecalith. Thoroughbred peri-parturient mares have been reported to be genetically related to large colon volvulus (Peterson *et al*., 2019).

Average duration of presentation for survivors was more than the non-survivors and was inversely related to survivability. In this study, out of 3 equines having strangulating lesions, (one with volvulus had colic <12 hrs and two had for >18 hrs) only one survived. It is emphasized that early referral of equine with strangulating lesions (Hackett *et al*., 2015) may improve the survival outcome. There was no linear relationship between the severity of pain and the type of lesion. All equines with strangulating lesions had severe pain and abdominal distension and were presented recumbent, but a few with fecalith, impaction or foreign body also showed severe pain.

Feeding history (Table 1)

Thoroughbred equines (n=5) were fed grams, oats, wheat bran, barley and berseem. In these, only one had impaction which survived. However, other 9 young/adult equines diagnosed with non-strangulating colic had the feeding history of wheat straw along with green fodder and wheat bran. The survival for wheat straw fed equines was more

Table 1: Survivability based on various parameters.

Parameters/signalment		Presented	Survivability	Non-survivability
Based on age of equine	≤ 2 years of age	8	6/8=75%	2/8=25%
	>2 years of age	7	4/7=57.14%	3/7=42.86%
Based on breed	Thoroughbred	5	2/5=40%	3/5=60%
	Marwari	9	7/9=77.78%	2/9=22.22%
	Mule	1	100%	0
Based on duration of presentation	Within 12 hours	1	100%	0
	Within 18 hours	2	50%	50%
	Within 24 hours	5	2/5=40%	3/5=60%
	Within 48 hours	9	5/9=55.55%	4/9=44.44%
	Later than 48 hours	6	5/6=83.33%	1/6=16.67%
Mental state of presentation	Recumbent	3	1/3=33.33%	2/3=66.66%
	Active	2	50%	50%
	Dull	10	80%	20%
Pain	Severe	8	50%	50%
	Moderate	7	85.71%	1/7=14.29%
Abdominal distention	Severe	7	4/7=57.14%	3/7=42.86%
	Moderate	7	5/7=71.43%	2/7=28.57%
	No	1	100%	0
Mucous membrane	Normal	2	2/2=100%	0
	Mild congested	2	2/2=100%	0
	Congested	8	5/8=62.50%	3/8=37.50%
	Injected	3	1/3=33.33%	2/3=66.67%
Physical examination parameters				
Borborygmi (n=13)	Absent	10	6/10=60.00%	4/10=40.00%
	Hypomotile	3	3/3=100%	0
Nasogastric reflux (n=10)	Absent	9	7/9=77.78%	2/9=22.22%
	>5 liters	1	0	100%
Abdomino-centesis (n=14)	Straw colored fluid	6	100%	0
	Serosanguineous fluid	2	1/2=50%	50%
	Cloudy fluid	1	0	100%
	No fluid	5	4/5=80%	20%
Feeding history parameters				
History of feeding wheat straw		9	7/9=77.78%	2/9=22.22%
History of not feeding wheat straw (except the 2m old)		5	2/5=40%	3/5=60%
Change in feed in last 30 days		3	2/3=66.67%	1/3=33.33%
History of diarrhea		3	1/3=33.33%	2/3=66.67%
De-worming history		8	6/8=75%	2/8=25%
Earlier history of colic		2	1/1=50%	1/1=50%
Surgical diagnosis				
Impaction		3	2/3=66.67%	1/3=33.33%
Fecalith		5	100%	0%
Foreign body		1	100%	0%
Volvulus		1	100%	0%
Strangulation		1	0%	100%
Sand colic		2	50%	50%
RDD of large colon		1	0%	100%
SI Ileus		1	0%	100%

Table 1: Continue...

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Days of passing feces after surgery			
Day 1 (7 out of 12=58.33%)	7	100%	0
Day 2 (2 out of 12=16.67%)	2	100%	0
Day 3 (1 out of 12=8.33%)	1	100%	0
Not passed (2 out of 12=16.67%)	2	0	100%
Blood cytology			
Shift to left	4	3/4=75%	1/4=25%
Mild to severe toxic neutrophils	8	5/8=62.50%	3/8=37.50%

Table 2: Per cent change in the clinical parameters pre (n=15) and postoperatively [2=12, day 3=11 or 10)].

General state	Pre-surgery	Day 1	Day 2	Day 3
Recumbent	2/15=13.33%	0/12=0%	0	0
Dull	11/15=73.33%	5/12=41.67%	3/12=25%	1/11=9.09%
Active	2/15=13.33%	7/12=58.33%	9/12=75%	10/11=90.90%
Mucous membrane				
Normal	2/15=13.33%	4/12=33.33%	11/12=91.67%	10/10=100%
Mild congested	2/15=13.33%	5/12=41.67%	1/12=8.33%	0
Congested	8/15=53.33%	3/12=25%	0	0
Injected	3/15=20%	0	0	0
CRT				
<2 sec	0	2/12=16.67%	6/12=50%	7/10=70%
2 sec	0	1/12=8.33%	1/12=8.33%	1/10=10%
>2 sec	5/15=33.33%	3/12=25%	4/12=33.33%	2/10=20%
3 sec	1/15=6.67%	4/12=33.33%	0	0
>3 sec	9/15=60%	1/12=8.33%	1/12=8.33%	0

than non-wheat straw fed, indicating that wheat straw predisposes to chronic impactive colic with favourable surgical prognosis. In contrary to literature, de-worming and change in diet was not found correlating with the onset of colic in the current study (Bihonegn and Bekele, 2018).

One horse with left ventral colon fecalith had history of diarrhoea and it survived the surgery. Two equines had the history of previous colic, of which one had passed fecalith 4 days back and recovered once, with diarrhea and re-occurrence of colic (SC strangulation, non-survivor), while the other was operated 8 months back for foreign body (this time sand colic, survivor). Diarrhoea is 10.8 times more likely to develop at initial examination as compared to horses with large colon impaction (Frederico *et al*., 2006).

Physical parameters (Table 1)

Auscultation for borborygmi and nasogastric intubation was not possible in 2 and 5 horses, respectively, due to severe pain. Pre-surgery absence of borborygmi was related to poor prognosis compared to hypomotile borborygmi (Southwood, 2013). One equine had nasogastric reflux of >5L (small intestine ileus) related to cranial GIT lesion (Cook and Hassel, 2014).

On abdominocentesis, the cloudy fluid was found associated with small colon strangulation (euthanized), serosanguinous with volvulus (survived) and small intestine ileus (euthanized), straw-coloured with fecalith or sand colic (all survived) and no fluid with fecalith or impaction (80% survival). As compared to serum, peritoneal fluid is better indicator of abdominal organs pathology (De Heer *et al*., 2002, Southwood, 2013; Shearer *et al*., 2017).

Rectal examination was possible in 6 equines with gas filled intestinal loops in 2, associated with fecalith and foreign body. Large colon impaction was felt per-rectally in one equine (Cook and Hassel, 2014).

Pre-surgery clinical parameters (Table 2 and 3)

There was no significant difference in the HR and rectal temperature of survivors and non-survivors and between those with strangulating or non-strangulating lesions. Tachycardia in non-survivors is indicative of deteriorating cardiovascular function and hypovolemia due to dehydration (Southwood 2013, Hackett *et al*., 2015). Rectal temperature had been reported to be normal in colicky horses unless if colic is acute or sand colic (Bihonegn and Bekele, 2018). Similarly, no significant difference was recorded in the average RR of survivors and non-survivors but, it was significantly high for equines with strangulating lesion compared to non-strangulating, which could be related to pain (Southwood, 2013).

All the non-survivors and those with strangulating colic had CRT more than 3 seconds. But, out of 10 survivors, in 4, the CRT was > 3 seconds (Stephan *et al.,* 2004; Krueger *et al.,* 2014). Most of the equines (n=8) had congested mucous membrane (5 survivors), followed by injected (n=3, strangulating

Table 3: Pre-surgical comparative values of clinical and hemato-biochemical parameters in all operated equines, survivors, non-survivors, strangulating and non-strangulating lesions.

Parameter	Reference range	Overall Mean±SD (range)	Survivor Mean±SD	Non-Survivor Mean±SD	Strangulating lesion (Mean±SD)	Non-Strangulating lesion (Mean±SD)
Clinical (n=15)						
HR (bpm)	28-40	71.20±21.71 (46-110)	65.80±18.98	82.00±24.90	70.67±29.14	71.33±21.10
RR/min	10-14	21.80±5.32 (10-28)	21.30±5.25	22.80±5.93	**25.67±2.08**	**20.83±5.49***
Temp (p F)	99-101	100.37±1.65 (98-104)	100.14±1.57	100.84±1.87	101.73±2.00	100.03±1.45
Hematological (n=14)						
Hb (g/dl)	10.1-16.1	12.08±2.74 (6.10-17.20)	11.62±2.66	13.25±2.98	**16.85±0.49**	**11.29±2.01****
TLC (cumm)	5.6-12.1×10^3	6817.14±3334.17 (400-15200)	7401.00±3284.97	5357.5±3441.28	11530.00±5190.16 (7860-15200)	6031.67±2446.03 (400-9130)
N%	52-70	71.86±18.80 (30-96)	76.20±15.39	61.00±24.52	**93.00±4.24**	**68.33±17.92****
PCV%	27-43	37.22±8.63 (18.0-52.0)	35.82±8.61	40.72±8.81	**51.10±1.27**	**34.91±6.86****
Platelets (X10^3/µL)	117-256	184.50±57.97 (99-289)	192.60±64.02	164.25±38.78	199.00±127.28	182.08±49.54
Serum biochemistry (n=14)						
Lactate (mmol/L)	<2	3.85±1.97 (1.4 to 7.6)	3.44±1.98	4.87±1.98	4.75±2.33	3.70±1.98
TP g/dl	5.6-7.6	6.00±0.75 (4.8-6.8)	6.00±0.75	6.00±0.85	6.40±0.56	5.93±0.77
CK (U/L)	60-330	558.57±357.10 (121-1288)	411.30±277.73	926.75±261.07$^{\$\$}$	826.00±653.37	514.00±311.02
AKP (U/L)	28-137	247.43±84.57 (155 to 512)	252.30±95.15	235.25±59.61	243.00±12.73	248.17±91.83
Na (mEq/L)	128-142	140.71±8.53 (126-155)	142.20±7.42	137.00±11.13	140.00±2.83	140.83±9.22
K (mEq/L)	2.9-4.6	3.53±0.21 (3.2-4.0)	3.53±0.24	3.52±0.15	3.40±0.28	3.55±0.20
Cl (mEq/L)	98-109	104.28±4.76 (99-116)	105.20±5.39	102.00±1.54	104.50±4.95	104.25±4.96
Ca (mg/dl)	10.2-13.4	11.03±0.64 (9.5-11.6)	11.15±0.54	10.73±0.85	11.40±0.28	10.97±0.67
Glu (mg/dl)	**62-134**	114.71±40.09 (62-176)	**95.60±29.24**	**162.50±11.70**$^{\$\$}$	**168.00±11.31**	**105.83±35.85***
Peritoneal biochemistry (n=14)						
Lactate (mmol/L)	<1	7.31±3.52 (2.6->12)	6.68±3.72	8.90±2.75	8.05±3.61	7.19±3.65
TP (g/dl)	<2.5	2.87±0.81 (1.2-3.8)	2.91±0.72	2.78±1.11	**1.50±0.42**	**3.10±0.59****
CK (U/L)	49-207	996.78±688.78 (<20 to >2000)	880.50±630.1	1287.50±840.85	1010.00±1400.07	994.58±618.43

(Normal reference values have been created Merck Manual 2016, Southwood, 2013, De Heer *et al.,* 2002 and Kilcoyne *et al.,* 2018).

$^{\$\$}$Significant difference between survivor and non-survivors at 1% (Within the row).

*Significant difference between strangulating and non-strangulating at 5% (Within the row).

**Significant difference between strangulating and non-strangulating at 1% (Within the row).

lesion, one survivor) (Stephan *et al*., 2004), mildly congested and normal (n=2 each, all survivors).

Pre-surgery haematological parameters (Table 3) (n=14), excluding the one presented in night for RDD and euthanized)

No statistically significant difference was found between the TLC and platelets values of survivors and non-survivors and those having strangulating and non-strangulating colic. Similarly, the Hb, neutrophil, lymphocyte count and PCV% values of survivors and non-survivors were non-significantly different; however, these were significantly higher in equines with strangulating compared to non-strangulating lesions. Dehydration associated haemo-concentration had been reported as a possible reason for increased hemoglobin level in non-survivors (Ihler *et al*., 2009). Increased PCV had been reported as poor prognostic indicator in large colon volvulus cases (Hackett *et al*., 2015) and small intestinal ileus (Southwood, 2013). Approximately, 30% equines operated for colic had shift to left indicating severe overwhelming inflammation, clinically signifying sepsis (Southwood, 2013).

Pre-surgical biochemistry (Table 2 and 3)

A. Serum biochemistry

There was non-significant difference in the serum lactate, total protein, AKP, sodium, potassium, chloride and calcium values of survivors and non-survivors and between the equines with strangulating and non-strangulating colic. Serum lactate was within the normal range *i.e*. <2 mmol/L in 3 equines (2 having fecalith and one with repeat surgery and having sand colic). Out of 4 equines with non-strangulating colic having marginal hypoprotenemia, 3 survived. Elevated serum lactate concentration >3 mmol/L was reported indicator of hypoperfusion and ischemia (Cook and Hassel, 2014) leading to shock and an elevation of >7 mmol/L as a strong negative prognostic indicator for colic (Southwood, 2013). Pre-surgery total protein assessment is considered important for assessing outcome (Sheats *et al*., 2010).

All 5 equines (with non-strangulating lesion) having creatine kinase within the normal range, survived. Mean creatine kinase of non-survivor equines was significantly high compared to survivors, which is an indicator of intestinal ischemia and poor prognosis (Krueger *et al*., 2014).

Mean glucose of non-survivors and with strangulating colic was significantly high as compared to survivors and non-strangulating colic. Serum glucose (r=-0.782**, p=0.001) and creatine kinase (r=-0.677**, p=0.008) had moderate negative but significant correlation with the survivability in colicky equine. A marked and persistent increase in serum glucose of colicky equines is a negative prognostic indicator suggesting insulin resistance due to possible sepsis leading to increased gluconeogenesis through epinephrine or cortisol release (Southwood, 2013).

B. Peritoneal biochemistry

There was non-significant difference in the peritoneal total protein concentration of survivors and non-survivors, while, it was significantly low in strangulating compared to non-strangulating lesions (De Heer *et al*., 2002).

The peritoneal fluid lactate and serum lactate ratios of >2.0 along with sero-sanguinous peritoneal fluid had been correlated with strangulating lesions (Shearer *et al*., 2018, Henderson, 2013). However, in the present study, 4 equines had ratio >2, of which 3 had non-strangulating lesion. There was non-significant difference in the peritoneal lactate and creatine kinase values of survivors and non-survivors and between the equines with strangulating and non-strangulating colic. However, elevated level of peritoneal CK is reported better indicator of strangulating lesions than peritoneal lactate (Kilcoyne *et al*., 2018).

Comparative pre-surgery and post surgery evaluation (n=12) (Table 2, 4)

1. Clinical parameters

No equine was recumbent after surgery and the activeness increased with follow up days except for the 2 equines which died on 2nd and 3rd day. Mucous membranes became normal within 3 days of surgery along with reduction in HR and RR (Southwood, 2013). Survivors showed reduced CRT on follow up days whereas in equines died or euthanized CRT remained >3 sec.

2. Hematological parameters

There was a non-significant reduction in haemoglobin and TLC count on the day 1 of surgery which could be due to fluid therapy and general anesthesia. But clinically these equines were normal and survived on long term also. Serial blood monitoring is reported to be of clinical significance to determine toxic changes in neutrophils, which are considered as poor prognostic indicators (Southwood, 2013). The PCV was seen to increase significantly with days of surgery in most of the equines.

3. Serum biochemistry

Pre-surgery serum lactate level was recorded reducing significantly with days of surgery. The one equine which was euthanized on day 3, had persistently elevated serum lactate. Every 1 mmol/L increase in post-operative serum lactate had been associated with a decrease in survivability by 29% (Henderson, 2013). A significant reduction in the serum total protein was recorded from pre-surgery to day 1. Hypoproteinaemia had been reported as a frequent complication in large colon volvulus postoperatively (Sheats *et al*., 2010).

Creatine kinase was recorded to be significantly increased on day 1 compared to pre-surgery which might be due to muscle trauma during surgery (Carvalho Filho *et al*., 2019). The serum AKP and potassium was seen to be increasing significantly with days of surgery; however, sodium and glucose were significantly decreasing. On day 1, the serum chloride showed a significant rise compared to pre-surgery (but mean still within the normal limits), but by day 3, it was within the normal range for all equines. Significant decrease in the serum calcium level as was

Table 4: Change in hematological and biochemical values in follow up days compared to pre-surgery (n=12 equines).

Clinical parameter	Normal ref range	Pre-surgery Mean±SD	Day 1'Mean	Day 2'Mean	Day 3'Mean
HR bpm	28-40	71.17±21.28	59.00±9.67$	53.42±7.44$$	48.89±5.95$
RR/min	10-14	21.75±5.15	20.67±4.72	19.58±2.87	18.40±2.06
Hematological parameter					
HB (g/dl)	10.1-16.1	11.62±2.51	11.49±3.42	11.63±3.64	11.66±2.85
TLC (cumm)	5.6-12.1×10^3	7265.00±3013.65	6716.67±3130.22	5774.25±2774.98	5207.00±1737.70
N%	52-70	73.83±14.98	65.50±19.75	63.33±15.64	66.10±13.12
PCV%	27-43	35.92±8.14	34.57±8.85	37.67±9.67**	37.54±8.25*
Platelets (X10^3/µL)	117-256	192.00±58.10	187.00±56.32	184.92±56.88	207.50±30.94
Serum biochemistry					
Lactate (mmol/L)	<2	3.6±1.79	1.96±1.61$$	1.88±1.98$	1.08±0.43$$
TP g/dl	5.6-7.6	5.8±0.74	5.52±0.73$	5.52±0.91	5.74±0.64
CK (U/L)	60-330	469.5±288.56	706.27±497.12$	773.10±629. 92	436.00±220.55
AKP (U/L)	28-137	242.83±90.52	272.10±53.64	310.00±106.92$	330.86±144.88$$
Na (mEq/L)	128-142	142.17±7.95	141.44±6.50	140.25±5.60	135.67±5.83$$**
K (mEq/L)	2.9-4.6	3.53±0.22	3.71±0.23$$	3.96±0.26$$**	4.13±0.16$$**##
Cl (mEq/L)	98-109	104.67±5.05	106.40±4.83$$	105.58±2.39	103.5±3.54
Ca (mg/dl)	10.2-13.4	10.98±0.68	10.62±0.71$$	10.69±0.92$	11.00±0.45
Glu (mg/dl)	62-134	105.83±35.85	98.18±31.96$	86.90±22.63$$	78.50±11.89$*
Peritoneal biochemistry					
Lactate (mmol/L)	<1	6.83±3.58	7.63±3.84	4.98±3.01$*	Not done
TP (g/dl)	<2.5	3.00±0.70	2.46±0.78	2.29±1.16$	
CK (U/L)	49-207	847.42±623.08	285.50±200.78$$	185.80±86.03$$*	

Normal reference values have been created Merck Manual 2016, Southwood, 2013, De Heer *et al.,* 2002 and Kilcoyne *et al.,* 2018. $$ Significant difference of pre-surgery with day 1, day 2 and 3 at 1% (Within the row); $ Significant difference of pre-surgery with day 1, day 2 and 3 at 5% (Within the row); ** Significant difference of day 1with day 2 and 3 at 1% (Within the row) *Significant difference of day 1 with day 2 and 3 at 5% (Within the row); ## Significant difference of day 2 and day 3 at 1% (Within the row).

recorded on day 1 and day 2 of surgery when compared to pre-surgery values.

4. Peritoneal biochemistry

On day 1 post-surgery, the peritoneal lactate was elevated, non-significantly, but later decreased on day 2, but was still more than the normal range. The peritoneal TP and CK were recorded to be significantly low on follow up days.

Ultrasonographic findings of equines operated for colic surgery

The pre-operative ultrasound was done in 4 equines (as rest were non-cooperative due to pain). Sand was seen as bright and hyperechoic in ventral large colon on USG (Fig 1). Free peritoneal fluid was seen in one equine (2 m old foal) with fecalith (Fig 2). Fluid filled dilated intestines were seen in all the equines but good peristaltic motility was seen in only foal of 2 month. In one equine with impaction, whirling motility was seen and it died 3 days after surgery. Sand accumulation had been reported to appear brighter and more hyperechoic in ventral region of large colon (Klohnen, 2012, Farooq *et al.*, 2020). FLASH ultrasonography had been reported as a quick and efficient tool to diagnose lesion in colic (Busoni *et al.*, 2011). But, in the present study, it was observed that ultrasonography cannot be applied as a prognostic

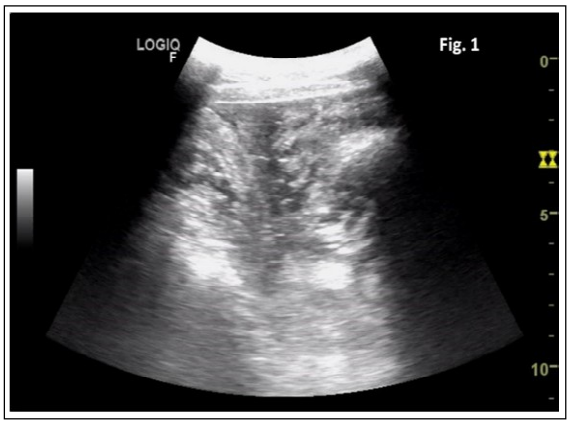


Fig 1: Ultrasonogram showing bright hyperechoic image in ventral large colon.

assessment aid as majority of the colicky equines are uncooperative due to acute pain.

Post-surgery, day 3 USG was done in 10 equines. The equine (with impaction) that died on day 3, had gas dilated cecum, whirling motility in intestines and lot of free fluid indicating obstruction to be still present. Another equine with small intestinal ileus and was euthanized on day 2, had no motility on day 2 USG, no free fluid in peritoneum and the loops

were still distended. All other survivors showed good intestinal peristaltic motility with minimal free fluid, except in one equine where the SI loops were distended with reduced motility.

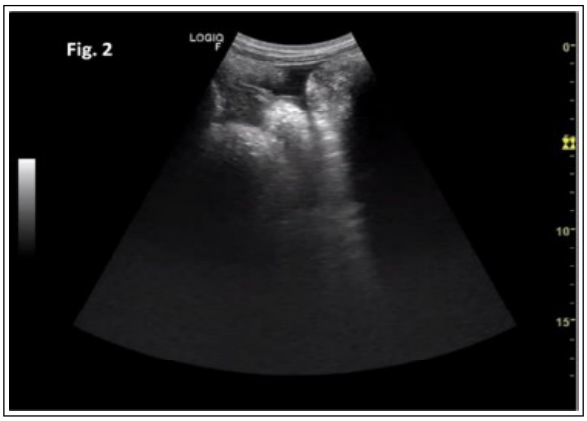


Fig 2: Ultrasonogram showing free fluid in abdomen.

Surgical findings as prognostic indicators (Table 1)

Pelvic flexure required drainage for emptying the contents or removal of fecalith / foreign body in 9 equines (9/15=60%). Caecum was distended and required drainage by incision in 4 cases (4/15=26.67%). Otherwise in all other cases, caecum was gas emptied using needle and suction. The reason for colic was diagnosed as impaction (n=3), fecalith (n=5, Fig 3), sand colic (2, one with ruptured intestines), foreign body (n=1, Fig 4), right dorsal displacement of large colon (n=1, Fig 5), large colon volvolus (n=1), small intestine ileus (n=1, Fig 6) and small colon strangulation (n=1).

All the equines which passed feces, recovered uneventfully. Two equines which did not pass feces and were dull on follow up days with one having gastric reflux of upto 10 liters (Ileus), died by day 2 and 3 (impaction) of surgery, respectively.

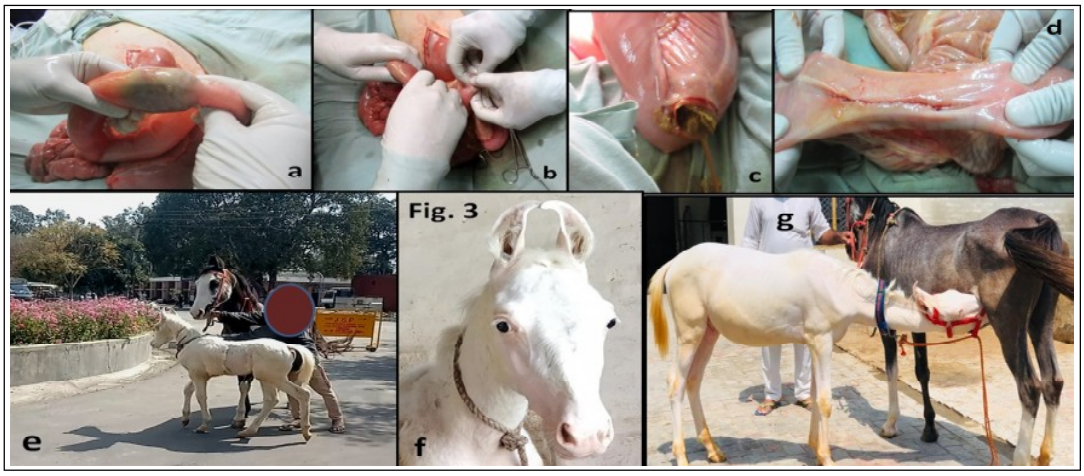


Fig 3: Photographs showing case study of a 2 m old Nukra foal with left ventral colon fecalith (a), Kneading of fecalith during surgery (b), Pelvic flexure drainage (c), Closure of pelvic flexure (d), 15 days follow up at suture removal (e), 4 month follow up at owner's place (f and g).

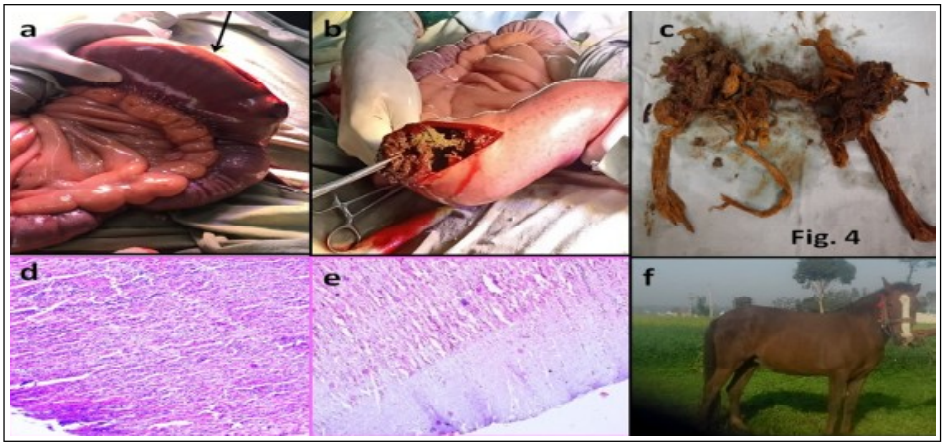


Fig 4: Photographs showing case study of a 2 yr old, 300 kg mule with small colon foreign body (a), Removing of foreign body (b), Ropes and polythene passed in feces also (c), Histopathology of small colon (H&E stain, 10x) showing severe necrosis along with acute inflammation (d, e), Long term follow up (f).



Fig 5: Photograph showing right dorsal displacement of large colon in a 13 yrs old thoroughbred mare with ischemic mesentery (euthanized during surgery).

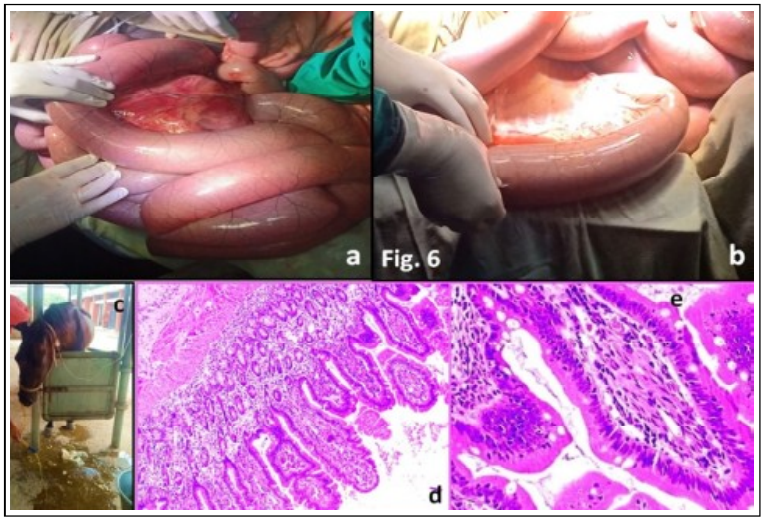


Fig 6: Photograph showing case study of a 7 yrs old thoroughbred mare with small intestine ileus (a), Small intestines enterotomy (b), Post-operative nasogastric reflux of 10L (c), Histopathology (H&E stain) showing chronic enteritis characterized by mild fibroplasia and mononuclear cell infiltration and congestion at 10x (d) and 40x (e).

Short and long term outcome of equine colic surgery (Table 1)

Out of 15, 12 recovered from anesthesia, while 3 were euthanized intra-operatively. However, in the due course of time of 2-3 days, one equine died and one was euthanized due to no improvement, thus making the short term survivability of 83.33% (10/12). The long term survivability was 100% (10/10), as all the equines discharged remained fit and healthy. Christophersen *et al.* (2014) reported surgical short term survival rate of 75%; 32% horses were euthanized pre-operatively while 27% were euthanized or died intra-operatively.

Peritoneal cytology and histological findings

Peritoneal fluid cytology was done in 9 equine and it was concluded that PMN cells alone or with lymphocytes is a better indicator of survivability. Histopathology was done in 8 equines with 10 tissue samples (pelvic flexure in 6, cecum in 2, small intestines and small colon in one each). Pelvic flexure biopsy showed variable degree of congestion in venules and inflammatory reaction in sub-mucosa and even total sloughing of mucosa and sub-mucosa, but still all these 6 equine were survivors. Equine with small intestinal ileus, recorded chronic acute inflammation with numerous PMN and some plasma cells and was euthanized on day 2. Small colon fecalith equine recorded necrosis and acute inflammation and survived the surgery. Pelvic flexure biopsy had been reported as a gold standard for intra-operative assessment of colon and short term survival (Sheats *et al.*, 2010). Necropsy was done on 2 out of 5 equines which died during hospital stay. One was of impaction which showed peritonitis and post-operative ileus. And the other was of small colon strangulation which showed endotoxemia due to necrosis of a large segment of small colon.

CONCLUSION

1. Wheat straw feeding is predisposing for non-strangulating colic in Marwari breed but had favorable surgical prognosis, while, Thoroughbred equines, not on wheat straw are commonly presented with strangulating lesion and need early referral for favorable surgical prognosis.

2. Prolonged CRT, injected mucous membranes, absent borborygymi, high serum CK and glucose are poor prognostic indicators for colic surgery.
3. Increase in hemoglobin, neutrophils, PCV, serum glucose and decreased peritoneal total protein are indicators of strangulating lesion in colicky equine.
4. In the early post-operative period, serial monitoring of HR, RR, PCV, serum biochemistry (lactate, TP, Ca, glucose, CK) and peritoneal fluid biochemistry (lactate, TP and CK) is recommended.
5. The colic surgery in equines bears very good short term and excellent long term outcome.

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