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Haematological and Biochemical Changes in Nigerian Dogs with Short Bowel Syndrome

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ABSTRACT

The purpose of this study was to evaluate the haematological and biochemical changes in Nigerian dogs with short bowel syndrome. Thirty adult dogs each weighing approximately 12.4kg (range 7-18kg) were used in this study. The dogs were randomized into five groups of six dogs each. Group 1 is the control group. The dogs here were not placed on any treatment. Group 2 dogs were supplemented with glutamine. Group 3 dogs were supplemented with honey. Group 4 dogs were supplemented with ascorbic acid and group 5 dogs were supplemented with glutamine, honey and ascorbic acid combination. Haematological parameters, serum electrolytes (Sodium, potassium, bicarbonate and, chloride) and enzymes (alanine aminotransferase, aspartate aminotransferase and alkaline phosphatase) were also evaluated. There was no depletion in sodium, potassium, bicarbonate and chloride in all the animals as the value of these electrolytes had remained at normal range in all five groups. There was a significant decrease in the value of alkaline phosphatase in the five groups and non significant changes in the value of alanine aminotransferase in all the animals. It was therefore, concluded that patients with resection of proximal small intestinal tract have better chances of survival than patients with a resected distal small intestinal tract.

Keywords: Adaptation, Alanine aminotransferase, Electrolytes, Haematology, Alkaline phosphatase, Short bowel syndrome

INTRODUCTION

Patients with short bowel syndrome experience changes in physiological variables until the adaptation of the remnant small intestinal length takes place during which the digestive and absorptive capability of the residual bowel length improves (Ziegler et al., 2002; Cisler and Buchman., 2005; Efsen and Jeppesen., 2011; Rowland et al., 2012; Herath and Kulatunga, 2017).This happen in patients that have reason to undergo extensive small intestinal resection that will resects over 50% of the small intestine leaving the patient with less absorptive surface area that cannot support or meet the nutritional requirement of such patients (Sukhotnik et al., 2004; Gorman et al., 2006; Shaw et al., 2012). These patients experience nutritional malabsorption leading to malnutrition, diarrhea, steatorrhea, fluid and electrolyte imbalance and specific nutrient imbalance (Sundaram et al., 2002; Donohoe and Reynolds, 2010; Thompson et al., 2012; Cunha-melo and Costa, 2014). These patients therefore, require total parenteral nutrition (TPN) for survival (Messing et al., 2006; Joly et al., 2009; Han et al., 2015; Mayer and Kerner, 2017).

The severity of these signs depends on the remnant small bowel length, part or section of the intestine that was resected and the presence or absence of the colon and ileocecal valve (Sundaram et al., 2002; Storch, 2014). The amount of small intestinal absorptive surface area required for the survival of patients with short bowel syndrome varies between individuals (Liu et al., 2014; Tappendene, 2014). This study evaluates the nature and the types of physiological changesthat present themselves in Nigerian dogs with short bowel syndrome.

MATERIALS AND METHODS

Ethical Approval

This study was approved by the ethical committee of the college of veterinary medicine, university of Agriculture, makurdi, Nigeria with reference no.001.

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Experimental Animals

Thirty apparently healthy dogs with average age of 15 months (range 6-24 month) and approximate mean weight of 12.4kg (range 7-18kg) were used for this study. The dogs were bought from breeders and on arrival each dog was subjected to clinical evaluation where vital parameters (temperature, pulse and respiratory rates), blood and faecal samples were evaluated. They were dewormed and those with ectoparasites were treated. The dogs were stabilized for 4 weeks by being boarded in kennels within the veterinary teaching hospital. They were fed daily and water was provided *ad libitum*. Each animal was fasted for 12 hours prior to surgery. They were premedicated with Atropine sulphate (Jiangsu Huayang pharmaceutical, China) at a dose rate of 0.04mg/kg and xylazine hydrochloride (XYL-M2®, VMD, Belgium) at a dose rate of 1mg/kg body weight intramuscularly. Induction was done with thiopentone sodium (Rotexmedica, Germany) at a dose of 10mg/kg body weight intravenously.

Surgical procedure

Each animal was aseptically prepared and a ventral midline abdominal incision was made. The intestinal tract was exteriorized. A sterile drip infusion set with both end cut was used to measure the small intestinal length insitu. The measurement was done beginning from the duodenum, just at the distal end of the pancreas to the ileocolic junction. After each measurement, the drip set used was placed on a sterile calibrated ruler and the value of each measurement was determined in centimetres (cm) and recorded. Four measurements were done in each animal and the average intestinal length was determined for each animal. The crown-rump length of each dog was also measured and the average value for each determined. The average small intestinal length was divided by the average crown-rump length to get 3.4cm as the proportion. The crown-rump length value obtained was multiplied by 3.4 cm (mean of index of small intestinal length) and this gave the average total intact small intestinal length in each dog. This was then recorded. Seventy (70%) per cent of the small intestinal tract was resectioned from a point 7cm from the duoduno-jejunal flexure (treitz ligament). The residual intestinal tract was sutured using end to end anastomosis with polyglactin 910 (vicryl® Ethicon, USA) size "0" using horizontal mattress suture pattern. A full thickness biopsy sample of the small intestinal tract (Jejunum and ileum) were collected and fixed in 10% formalin (pretreatment sample). Two mls of normal saline was injected tangentially close to the anastomostic site to check for leakage and patency. Viability was assessed using arterial pulsations, peristalsis and colour. The anastomostic site was covered with omentum and then returned to the abdominal cavity. The abdominal incision was closed using a standard surgical technique (Fossum, 2014). Procain penicillin (Shuazhuang co ltd, China) (20,000 iu/kg) and Streptomycin (North China pharmaceutical co ltd, China) (10 mg/kg) was administered intramuscularly for five days post operation. Pentazocin (Bharat Parenterals ltd, India) was administered intramuscularly at the dose rate of 3mg/kg for seven days to relieve pain.

Blood samples were collected from the animals post-operatively on days 4, 6, 8, 10 and 12 for Complete Blood Count (CBC) and blood serum chemistry (AST, ALT, ALP, Na, K, Cl and HCO_3 ions) analysis using the haemocytometric and flame photometric methods respectively.

The dogs were given 5% dextrose infusion intravenously at 10mls/kg/hr on the second and third day post operation. They were fed bland diet gruel on the fourth post operation day and were then returned healthy to normal solid diet on day five post surgery.

Statistical analysis

Data were expressed as descriptive statistics. Differences among the groups were evaluated using one way analysis of variance (ANOVA) followed by a two tailed student's t-test. P values ≤ 0.05 were considered statistically significant.

RESULTS

In group 1 (control), the Red Blood Cells (RBC), Haemoglobin (Hg), White Blood Cells (WBC), Monocytes (MON), Granulocytes (GNC), Mean Corpuscular Volume (MCV), Red cell Distribution Width (RDW), Mean Platelet Volume (MPV), Platelet Distribution Width (PDW) all had shown (non-statistically) significant decrease while lymphocytes (LYM), Mean Corpuscular Haemoglobin (MCH), Mean Corpuscular Haemoglobin Concentration (MCHC), Platelet Crit (PCT) and Platelets (PLT) had also shown (non-statistically) significant increase from their base line values 12 days post surgery (Table 1).

In group 2, PCV, Hg, RBC all had shown a statistically significant decrease. WBC and GNC showed statistically significant increase. MCV, PCT and PDW all had shown anon statistically significant increase (Table 2). In group 3, RBC, MON, MCV, MCH, and RDW showed no statistically significant decrease. PCV, WBC, LYM and GNC showed statistically significant decrease. MCHC, PLT, MPV and PDW had shown no statistically significant increase (Table 3). In group 4, RBC, PCV, Hg, MON, GNC, MCV, MCH, RDW, MPV and PDW showed no statistically significant decrease while WBC, LYM, GNC, MCHC had shown (non-statistically) significant increase. PLT and PCT showed statistically significant increase (Table 4). In group 5, RBC, PCV, Hg, MCV, MCH, MPV and PDW had shown (non-

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significant) decrease. PLT and PCT showed significant increase while WBC, LYM, GNC, MCHC and RDW had shown an insignificant increase (Table 5).

There was no statistically significant difference in the values of sodium in group 1,2,3,4 and 5. The value of sodium in group 3 was significant. There was no statistically significant difference in the values of potassium in groups 1,2,3,4 and 5. There was no statistically significant difference in the values of chloride in groups 1, 3 and 5. The values in group 2 and 4 are significant. There was no statistically significant difference in the values of bicarbonate in groups 1 and 3 while the values in groups 2, 4 and 5 were significant.

There was no statistically significant difference in the values of Alkaline Phosphatase (ALP) in groups 1, 4 and 5. The values for groups 2 and 3 are significant. There was no statistically significant difference in the values of Aspartate Amino Transferase (AST) in groups 1, 3 and 4 while the values for groups 2 and 5 were significant. There was no statistically significant difference in the values of Alanine Aminotransferase (ALT) in groups 1, 2, 3, 4 and 5.

Table 1. Haematology of six dogs with post 70% small intestinal resection and anastomosis.

Parameter	Mean (Days)						Min-Max	Overall Mean ± SEM	P-value
	0	4	6	8	10	12			
RBC %	6.23	5.6	4.9	5.3	5.2	5.1	4.9-6.23	5.39±0.19	0.35
PCV (%)	44.48	40.5	33.4	37.3	36.1	34.8	33.4-44.48	37.76±1.67	0.27
HB (g / dl)	16.58	16.1	15.1	13.8	13.7	13.9	13.7-16.58	14.86±0.51	0.06
WBC (x 103/L)	16.85	21.3	17.9	15.0	13.6	14.7	13.6-21.3	16.56±1.14	0.53
LYM (x10^3)	3.35	6.5	29.7	4.5	3.5	4.4	3.35-29.7	8.66±4.23	0.33
MON (x10^3)	1.58	2.6	1.5	1.6	1.2	1.1	1.1-2.6	1.60±0.22	0.11
GNC (x10^3)	11.92	12.3	13.7	8.9	8.9	9.2	8.9-13.7	10.82±0.85	0.74
MCV (fl)	71.33	68.8	64.2	70.8	69.5	68.1	64.2-1.33	68.78±1.04	0.76
MCH (pg)	26.03	50.5	37.3	26.3	26.6	27.4	26.03-50.5	32.36±4.03	0.51
MCHC (g/dl)	36.50	42.3	87.8	37.1	38.7	40.1	36.50-87.8	47.08±8.19	0.46
RDW (%)	15.53	18.1	18.2	15.4	15.5	15.3	15.3-18.2	16.34±0.57	0.39
PLT (ml)	261.83	387.5	324.8	285.2	348	368	261.83-387.5	329.22±19.79	0.88
PCT (%)	0.22	0.4	0.4	0.3	0.3	0.3	0.22-0.4	0.32±0.03	0.66
MPV(fl)	8.12	9.2	8.0	8.2	8.5	8.3	8.12-9.2	8.39±0.18	0.52
PDW(gsd)	13.1	124.8	124.4	12.3	12.9	12.2	12.2-124.8	49.95±23.61	0.56

RBC: Red blood cell; PCV: Packed cell volume; HB: Haemoglobin; WBC: White blood cell count; LYM: Lymphocytes; MON: Monocytes; GNC: Granulocytes; MCV: Mean corpuscular volume; MCH: Mean corpuscular haemoglobin; MCHC: Mean corpuscular haemoglobin concentration; RDW: Red cell distribution width; PLT: Platelets PCT: Platelet crit; MPV: Mean platelet volume; PDW: Platelet distribution width

Table 2. Haematology of six dogs with post 70% small intestinal resection and anastomosis and treated with glutamine

Parameter	Mean (Days)						Min – Max	Overall Mean ± SEM	P-value
	0	4	6	8	10	12			
RBC	5.8	5.2	5.2	4.6	4.8	4.5	4.5-5.8	5.02±0.20	0.01
PCV (%)	40.2	38.9	34.6	32.1	35.3	34.7	32.1-40.2	35.97±1.23	0.02
HB (g / dl)	14.4	12.9	12.6	10.8	11.8	10.7	10.8-14.4	12.20±0.57	0.03
WBC (x 103/L)	10.4	18.7	14.0	14.5	14.1	11.6	10.4-18.7	13.88±1.17	0.01
LYM (x10^3)	4.6	3.2	3.4	2.9	2.3	2.5	2.3-4.6	3.15±0.34	0.07
MON (x10^3)	1.1	1.2	1.5	1.2	1.1	1.0	1.0-1.5	1.18±0.07	0.01
GNC(x10^3)	6.4	14.3	9.1	10.5	10.8	8.1	6.4-14.3	9.87±1.11	0.02
MCV(fl)	71.7	68	66.7	73.1	78.0	82.0	66.7-82.0	73.25±2.40	0.15
MCH(pg)	24.9	25.1	24	23.6	24.2	23.8	23.6-25.1	24.27±0.25	0.77
MCHC(g/dl)	35.7	38.3	36.4	33.7	33.2	31.3	31.3-38.3	34.77±1.03	0.21
RDW (%)	15.6	15.1	15.1	15.2	15.4	15.5	15.1-15.6	15.32±0.09	0.24
PLT(ml)	234	272.8	357.5	183.3	201	187.7	187.7-357.5	239.38±27.32	0.56
PCT (%)	0.2	0.22	0.21	0.17	0.26	0.22	0.17-0.26	0.21±0.01	0.81
MPV(fl)	9.1	9.2	9.6	9.6	10	8.9	8.9-10	9.4±0.17	0.70
PDW(gsd)	11.5	30.9	15.4	14.1	15.4	13.5	11.5-30.9	17.8±2.83	0.45

RBC: Red blood cell; PCV: Packed cell volume; HB: Haemoglobin; WBC: White blood cell count; LYM: Lymphocytes; MON: Monocytes; GNC: Granulocytes; MCV: Mean corpuscular volume; MCH: Mean corpuscular haemoglobin; MCHC:Mean corpuscular haemoglobin concentration; RDW: Red cell distribution width; PLT:Platelets; PCT: Platelet crit; MPV: Mean platelet volume; PDW: Platelet distribution width

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Table 3. Haematology of six dogs with post 70% small intestinal resection and anastomosis and treated with honey

Parameters	Mean (Days)						Min-Max	Overall Mean ± SEM	P-value
	0	4	6	8	10	12			
RBC %	6.9	5.6	5.5	5.4	5.2	5.6	5.2-6.9	5.70±0.25	0.47
PCV (%)	39.9	37.4	35.0	34.1	32.7	35.9	32.7-39.9	35.83±1.04	0.01
HB (g/dl)	13.9	13.6	13.4	12.8	12.4	13.2	12.4-13.9	13.22±0.22	0.55
WBC (x 10^3/L)	17.3	20.3	21.9	13.6	20.3	12.5	12.5-21.9	17.65±1.58	0.001
LYM (x$10^{3)}$	4.4	6.0	4.9	3.8	2.9	2.5	2.5-6.0	4.08±0.53	0.001
MON (x10^3)	1.8	1.6	1.6	0.9	1.0	0.7	0.7-1.8	1.27±0.19	0.65
GNC (x$10^{3)}$	11.1	12.7	15.4	8.9	7.9	9.3	7.9-15.4	10.88±1.14	0.00
MCV (fl)	67.7	66.8	63.4	63.2	62.4	64.3	62.4-67.7	64.63±0.87	0.17
MCH (pg)	23.7	24.2	24.2	23.3	23.7	23.5	23.3-24.2	23.77±0.15	0.92
MCHC (g/dl)	32.8	34.4	36.2	35.3	35.7	34.1	32.8-36.2	34.75±0.51	0.95
RDW (%)	16.0	15.8	15.8	16.2	15.8	15.7	15.7-16.2	15.88±0.08	0.96
PLT (ml)	258	384	316	275.7	270.8	267.7	258-384	295.37±19.5	0.51
PCT (%)	0.2	0.3	0.3	0.2	0.2	0.2	0.2-0.3	0.23±0.02	0.25
MPV(fl)	8.2	8.5	8.6	8.1	8.2	8.4	8.1-8.6	8.33±0.08	0.73
PDW (gsd)	12.1	11.8	12.9	12.7	12.6	13.4	12.1-13.4	12.58±0.23	0.79

RBC: Red blood cell; PCV: Packed cell volume; HB: Haemoglobin; WBC: White blood cell count; LYM: Lymphocytes; MON: Monocytes; GNC: Granulocytes; MCV: Mean corpuscular volume; MCH: Mean corpuscular haemoglobin; MCHC:Mean corpuscular haemoglobin concentration; RDW: Red cell distribution width; PLT: Platelets PCT: Platelet crit; MPV: Mean platelet volume; PDW: Platelet distribution width

Table 4. Haematology of six dogs with70% small intestinal resection and anastomosis and treated with ascorbic acid

Parameters	Mean (Days)						Min-Max	Overall Mean±SEM	P-value
	0	4	6	8	10	12			
RBC (%)	5.8	5.9	5.6	5.7	5.6	5.6	5.6-5.9	5.70±0.05	0.79
PCV (%)	38.0	40.1	38.5	36.3	35.5	35.8	35.5-40.1	37.37±0.74	0.51
HB (g/dl)	13.8	14.2	13.2	13.5	13.2	13.3	13.2-14.2	13.53±1.16	0.87
WBC (x103/L)	100.9	115.9	129.7	114.4	89.1	108.9	89.1-129.7	109.82±5.67	0.28
LYM (x103)	28.1	23.4	25.7	27.8	20.5	29.2	20.5-29.2	25.78±3.31	0.48
MON (x103)	1.6	1.3	1.4	1.2	4.1	1.2	1.2-4.1	1.80±0.45	0.08
GNC (x103)	10.6	14.2	15.9	13.3	9.9	12.1	9.9-15.9	12.67±0.92	0.17
MCV (fl)	89.9	66.7	68.5	64.3	65.1	65.2	64.3-89.9	69.95±4.04	0.88
MCH (pg)	23.9	23.8	23.6	23.7	23.6	23.9	23.6-23.9	23.75±0.06	0.88
MCHC (g/dl)	35.3	35.9	34.9	37.2	36.8	37.1	34.9-37.2	36.2±0.40	0.88
RDW (%)	17.6	17.4	17.2	17.6	17.2	17.1	17.1-17.6	17.35±0.09	0.99
PLT (ml)	204.8	294	377.2	442.7	421.5	402	204.8-442.7	357.03±37.0	0.00
PCT (%)	0.02	0.24	0.28	0.33	0.32	0.32	0.02-0.33	0.25±0.05	0.00
MPV (fl)	7.8	7.9	7.4	7.4	7.3	7.6	7.3-7.9	7.57±0.10	0.49
PDW (fl)	10.5	10.4	10.0	9.6	10.1	9.6	9.6-10.5	10.03±0.16	0.88

RBC: Red blood cell; PCV: Packed cell volume; HB: Haemoglobin; WBC: White blood cell count; LYM: Lymphocytes; MON: Monocytes; GNC: Granulocytes; MCV: Mean corpuscular volume; MCH: Mean corpuscular haemoglobin; MCHC:Mean corpuscular haemoglobin concentration; RDW: Red cell distribution width; PLT: Platelets PCT: Platelet crit; MPV: Mean platelet volume; PDW: Platelet distribution width

Table 5. Haematology of six dogs with post 70% small intestinal resection and anastomosis and treated with glutamine/ honey/ ascorbic acid

Parameter	Mean (Days)						Min – Max	Overall Mean ± SEM	P-value
	0	4	6	8	10	12			
RBC %	6.2	5.6	5.3	5.1	6.2	5.1	5.1-6.2	5.58±0.21	0.03
PCV (%)	39.2	34.8	33.1	32.3	33.2	33.7	32.3-39.2	34.38±1.02	0.13
HB (g / dl)	14.8	13.2	12.8	12.6	12.7	12.4	12.4-14.8	13.08±0.36	0.63
WBC (x 10^3/L)	14.8	19.4	15.1	14.4	14.3	12.7	12.7-19.4	15.12±0.92	0.03
LYM (x10^3)	3.2	4.2	3.3	2.9	1.9	2.3	1.9-4.2	2.97±0.33	0.04
MON (x10^3)	1.4	1.3	1.1	1.0	0.7	0.9	0.7-1.4	1.07±0.11	0.21
GNC(x10^3)	10.0	13.9	10.8	10.1	11.7	9.5	9.5-13.9	11.0±0.66	0.14
MCV(fl)	63.4	62	63.6	63.7	63.4	67.3	62-67.3	63.90±0.73	0.98
MCH(pg)	23.7	23.5	24.8	24.8	24.3	24.7	23.5-24.8	24.30±0.24	0.99
MCHC(g/dl)	37.6	37.6	38.5	38.8	38.0	36.6	36.6-38.8	37.85±0.32	0.86
RDW (%)	16.3	16.5	16.7	16.9	16.7	16.8	16.3-16.9	16.65±0.09	0.99
PLT(ml)	151.7	169.7	244.7	264.3	252.2	211.7	151.7-264.3	215.72±18.94	0.11
PCT (%)	0.12	0.14	0.20	0.22	0.21	0.18	0.12-0.22	0.18±0.02	0.15
MPV(fl)	8.1	8.0	8.2	8.4	8.2	9.7	8.0-9.7	8.43±0.26	0.33
PDW(fl)	12.4	121.7	13.4	125.6	12.7	125.8	12.4-125.8	68.60±24.95	0.02

RBC: Red blood cell; PCV: Packed cell volume; HB: Haemoglobin; WBC: White blood cell count; LYM: Lymphocytes; MON: Monocytes; GNC: Granulocytes; MCV: Mean corpuscular volume; MCH: Mean corpuscular haemoglobin; MCHC:Mean corpuscular haemoglobin concentration; RDW: Red cell distribution width; PLT: Platelets PCT: Platelet crit; MPV: Mean platelet volume; PDW: Platelet distribution width

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Table 6. Serum biochemistry values of dogs post 70% small intestinal resection and anastomosis

Substance	Days	Number of dogs (n = 6)						Mean ±SEM	P value
		1	2	3	4	5	6		
Sodium	0	138.6	140.0	140.0	133.0	132.2	142.0	137.63±1.66	0.33
	4	140.0	137.2	138.6	138.6	129.0	138.9	137.05±1.65	
	6	135.8	126.0	137.2	137.2	122.0	137.6	132.6±2.79	
	8	130.2	137.2	135.8	140.0	130.2	138.6	135.33±1.72	
	10	137.2	187.6	134.9	138.8	131.1	138.4	144.67±8.66	
	12	126.0	134.4	133.0	137.2	131.7	137.7	133.33±1.75	
Potassium	0	3.8	4.2	3.2	3.6	4.2	4.0	3.83±0.16	0.27
	4	4.3	4.1	3.1	3.4	4.0	3.8	3.78±0.19	
	6	4.3	2.3	3.0	3.3	3.6	3.8	3.38±0.28	
	8	4.2	4.6	3.0	2.7	3.8	4.0	3.72±0.30	
	10	4.8	4.4	3.0	3.0	4.0	4.2	3.90±0.30	
	12	2.3	2.8	3.0	3.0	4.0	3.8	3.15±0.26	
Chloride	0	100	88.5	100	100	102.4	103.2	99.02±2.18	0.30
	4	88.5	92.3	92.3	103.8	96.1	98.1	95.18±2.20	
	6	88.5	100	100	100	88.2	89.6	94.38±2.52	
	8	103.8	103.8	107.9	96.2	94.3	96.2	100.37±2.25	
	10	100	100	121.2	100	97.1	100	103.05±3.67	
	12	92.3	103.8	123.1	92.3	97.3	100	101.47±4.69	
Bicarbonate	0	21	25	24	25	25	24	24.00±0.63	0.18
	4	24	24	22	28	23	23	24.00±0.86	
	6	23	23	22	24	22	23	22.83±0.31	
	8	21	25	23	23	24	23	23.17±0.54	
	10	26	28	24	28	24	22	25.33±0.99	
	12	22	21	26	22	24	24	23.17±0.75	
ALP	0	23.1	24.1	36.1	36.2	37.1	32.3	31.48±2.59	0.31
	4	23.0	25.7	56.0	48.1	44.4	32.6	38.30±5.39	
	6	18.9	24.1	46.3	38.5	40.1	40.1	34.67±4.36	
	8	24.5	20.7	34.1	32.0	34.2	38.3	30.63±2.72	
	10	30.2	27.6	42.2	27.4	28.3	34.1	31.63±2.35	
	12	12.0	29.3	34.4	28.1	24.2	30.3	26.38±3.18	
AST	0	61	23	62	53	59	63	53.50±6.27	0.82
	4	39	35	32	81	36	48	45.17±7.51	
	6	28	41	99	16	64	45	48.83±12.02	
	8	93	38	74	19	62	40	54.33±11.05	
	10	15	29	98	38	49	36	44.17±11.70	
	12	19	44	255	29	48	58	75.50±36.35	
ALT	0	36	67	38	28	40	43	42.00±5.41	0.58
	4	18	48	48	41	38	40	38.83±4.50	
	6	47	48	35	27	38	38	38.83±3.20	
	8	51	42	45	10	45	41	39.00±5.97	
	10	52	29	45	39	48	50	43.83±3.50	
	12	48	58	45	43	48	48	48.33±2.11	

ALP: Alkaline phosphatase; AST: Aspartate aminotransferase; ALT: Alanine aminotransferase

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Table 7. Serum biochemistry values of dogs with post 70% small intestinal resection and anastomosis and supplemented with glutamine

Substance	Days	Number of dogs (n = 6)						Mean ±SEM	P value
		1	2	3	4	5	6		
Sodium	0	141.4	135.8	138.0	135.7	140.0	144.0	139.15±1.34	0.14
	4	140.0	182.0	137.6	148.9	138.6	142.6	148.28±6.94	
	6	138.6	190.4	138.2	157.3	133.7	141.2	149.90±8.75	
	8	133.0	135.8	136.0	135.7	135.9	135.6	135.33±0.47	
	10	135.8	131.6	138.0	131.5	137.1	138.4	135.40±1.27	
	12	137.0	144.2	136.0	144.1	139.1	139.6	140.0±1.42	
Potassium	0	4.3	3.8	4.2	3.9	4.0	4.2	4.07±0.08	0.18
	4	3.9	4.0	3.8	4.1	3.6	3.8	3.87±0.07	
	6	3.8	4.4	3.6	4.5	3.5	3.7	3.92±0.17	
	8	4.1	2.7	4.0	2.8	3.8	4.0	3.57±0.26	
	10	4.5	3.0	4.4	3.1	3.9	4.3	3.87±0.27	
	12	4.5	4.0	4.4	4.1	4.2	4.3	4.25±0.08	
Chloride	0	92.3	103.8	100	88.3	103.7	102.0	98.35±2.66	0.001
	4	92.3	84.6	100	88.1	84.5	83.4	88.82±2.60	
	6	107.7	96.2	115.2	105.2	95.3	94.3	102.32±3.44	
	8	76.9	92.3	88.2	78.6	91.4	93.3	86.78±2.95	
	10	96.2	107.7	98.1	98.3	106.6	103.1	101.67±1.97	
	12	106.4	96.1	107.3	108.6	97.2	98.2	102.30±2.33	
Bicarbonate	0	22	23	22	23	24	22	22.67±0.33	0.003
	4	24	23	24	23	23	22	23.17±0.31	
	6	23	26	23	25	26	23	24.33±0.61	
	8	23	24	23	24	24	23	23.50±0.22	
	10	26	20	24	22	24	23	23.33±0.84	
	12	26	26	24	26	26	26	25.67±0.33	
ALP	0	18.7	18.9	21.2	21.7	17.6	38.3	22.73±3.18	0.0001
	4	30.1	29.3	32.3	32.1	31.2	42.3	32.88±1.94	
	6	43.3	43.1	45.4	45.3	45.1	34.6	42.80±1.69	
	8	22.4	22.4	23.1	24.6	23.2	20.2	22.65±0.59	
	10	31.6	18.9	32.7	21.7	32.4	26.1	27.23±2.43	
	12	36.2	25.8	37.1	27.8	38.1	31.6	32.77±2.11	
AST	0	27	21	27	25	26	32	26.33±1.45	0.0001
	4	59	62	58	66	58	56	59.83±1.47	
	6	37	45	37	49	36	36	40.00±2.28	
	8	50	50	49	54	49	55	51.17±1.08	
	10	51	54	52	58	50	57	53.67±1.33	
	12	53	46	54	50	52	60	52.50±1.89	
ALT	0	42	44	45	46	41	48	44.33±1.05	0.15
	4	162	42	43	44	158	54	83.83±24.16	
	6	18	53	54	55	20	65	44.17±8.15	
	8	49	32	31	34	50	44	40.00±3.55	
	10	100	37	39	39	101	49	60.83±12.66	
	12	86	42	43	44	88	56	59.83±8.84	

ALP: Alkaline phosphatase; AST: Aspartate aminotransferase; ALT: Alanine aminotransferase

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Table 8. Serum biochemistry values of dogs with post 70% small intestinal resection and anastomosis and supplemented with honey

Substance	Days	Number of dogs (n = 6)						Mean ±SEM	P-value
		1	2	3	4	5	6		
Sodium	0	133.0	144.2	133.0	140.0	134.0	140.0	137.37±1.92	0.04
	4	133.0	137.2	133.0	138.0	136.2	137.0	135.80±0.93	
	6	130.2	140.0	138.6	138.0	138.0	134.0	136.47±1.50	
	8	140.0	131.6	133.0	136.0	138.0	138.0	136.10±1.32	
	10	135.8	126.0	134.4	137.0	139.0	137.8	135.00±1.91	
	12	186.2	140.0	196.0	138.2	134.0	140.2	155.77±11.28	
Potassium	0	4.2	3.7	3.8	3.8	4.2	4.3	4.00± 0.11	0.55
	4	4.8	3.7	4.5	4.0	4.6	4.1	4.28±0.17	
	6	4.3	4.5	4.8	3.8	4.3	3.8	4.25±0.16	
	8	4.3	4.4	3.0	3.7	4.3	4.0	3.95±0.22	
	10	4.6	3.0	4.8	4.0	4.4	4.2	4.17±0.26	
	12	4.2	4.4	4.8	4.2	4.3	4.2	4.35±0.10	
Chloride	0	88.5	111.5	88.5	100	111.2	98.1	99.63±4.18	0.35
	4	92.3	96.2	92.3	92.2	98.3	93.6	94.15±1.04	
	6	84.6	92.3	80.8	88.3	94.1	100.2	90.05±2.84	
	8	92.3	88.5	92.3	88.1	88.3	99.1	91.43±1.73	
	10	111.5	84.6	100	84.2	84.2	98.3	93.80±4.62	
	12	88.5	103.8	96.2	84.2	107.1	103.6	97.23±3.78	
Bicarbonate	0	24	22	23	23	24	23	23.17±0.31	0.06
	4	24	22	25	23	23	21	23.00±0.58	
	6	20	22	22	20	22	21	21.17±0.40	
	8	24	28	22	24	22	21	23.50±1.02	
	10	22	26	22	21	22	23	22.67±0.71	
	12	24	28	24	23	24	23	24.33±0.76	
ALP	0	38	34.1	45	38	46	36.2	39.55±1.98	0.0001
	4	41.7	43.5	36.6	43.8	40.1	45.4	41.85±1.29	
	6	31.6	21.2	32.0	33.5	36.2	29.6	30.68±2.10	
	8	13.8	18.9	18.9	15.4	32.1	26.7	20.97±2.87	
	10	15.5	13.8	25.9	17.4	18.3	26.4	19.55±2.18	
	12	17.2	13.8	50	17.8	38	27.2	27.33±5.79	
AST	0	26	95	32	28	34	62	46.17±11.14	0.75
	4	36	38	33	36	36	53	38.67±2.94	
	6	32	26	49	32	47	36	37.00±3.72	
	8	25	29	41	27	40	66	38.00±6.24	
	10	22	28	39	22	39	82	38.67±9.21	
	12	55	22	82	53	60	32	50.67±8.69	
ALT	0	38	165	41	41	42	44	61.83±20.65	0.68
	4	41	31	41	44	41	48	41.00±2.29	
	6	35	42	41	37	42	38	39.17±1.19	
	8	32	108	27	34	28	35	44.00±12.87	
	10	29	36	55	31	43	32	37.67±4.01	
	12	35	31	121	37	41	42	51.17±14.02	

ALP: Alkaline phosphatase; AST: Aspartate aminotransferase; ALT: Alanine aminotransferase

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Table 9. Serum biochemistry values of dogs with post 70% small intestinal resection and anastomosis and supplemented with ascorbic acid

Substance	Days	Number of dogs (n = 6)						Mean ±SEM	P-value
		1	2	3	4	5	6		
Sodium	0	133.0	144.2	133.0	140.0	134.0	140.0	146.90±9.96	0.79
	4	133.0	137.2	133.0	138.0	136.2	137.0	135.57±1.50	
	6	130.2	140.0	138.6	138.0	138.0	134.0	147.17±8.99	
	8	140.0	131.6	133.0	136.0	138.0	138.0	154.05±10.64	
	10	135.8	126.0	134.4	137.0	139.0	137.8	143.73±9.91	
	12	186.2	140.0	196.0	138.2	134.0	140.2	143.70±8.58	
Potassium	0	4.2	3.7	3.8	3.8	4.2	4.3	4.25±0.06	0.37
	4	4.8	3.7	4.5	4.0	4.6	4.1	3.93±0.25	
	6	4.3	4.5	4.8	3.8	4.3	3.8	3.57±0.23	
	8	4.3	4.4	3.0	3.7	4.3	4.0	4.07±0.12	
	10	4.6	3.0	4.8	4.0	4.4	4.2	3.63±0.37	
	12	4.2	4.4	4.8	4.2	4.3	4.2	3.93±0.30	
Chloride	0	88.5	111.5	88.5	100	111.2	98.1	93.78±3.04	0.02
	4	92.3	96.2	92.3	92.2	98.3	93.6	94.75±3.77	
	6	84.6	92.3	80.8	88.3	94.1	100.2	104.25±2.37	
	8	92.3	88.5	92.3	88.1	88.3	99.1	101.30±1.97	
	10	111.5	84.6	100	84.2	84.2	98.3	90.22±1.45	
	12	88.5	103.8	96.2	84.2	107.1	103.6	96.12±4.06	
Bicarbonate	0	24	22	23	23	24	23	24.17±0.40	0.006
	4	24	22	25	23	23	21	23.00±0.52	
	6	20	22	22	20	22	21	21.33±0.42	
	8	24	28	22	24	22	21	24.00±0.89	
	10	22	26	22	21	22	23	22.33±0.42	
	12	24	28	24	23	24	23	23.167±0.32	
ALP	0	38	34.1	45	38	46	36.2	32.22±4.31	0.76
	4	41.7	43.5	36.6	43.8	40.1	45.4	37.52±6.19	
	6	31.6	21.2	32.0	33.5	36.2	29.6	31.62±7.12	
	8	13.8	18.9	18.9	15.4	32.1	26.7	27.27±3.42	
	10	15.5	13.8	25.9	17.4	18.3	26.4	31.43±1.68	
	12	17.2	13.8	50	17.8	38	27.2	28.700±4.80	
AST	0	26	95	32	28	34	62	51.50±5.93	0.18
	4	36	38	33	36	36	53	40.50±2.99	
	6	32	26	49	32	47	36	34.00±3.27	
	8	25	29	41	27	40	66	39.67±6.08	
	10	22	28	39	22	39	82	38.00±9.51	
	12	55	22	82	53	60	32	31.17±1.47	
ALT	0	38	165	41	41	42	44	68.67±12.10	0.66
	4	41	31	41	44	41	48	61.83±7.76	
	6	35	42	41	37	42	38	64.67±5.52	
	8	32	108	27	34	28	35	54.83±2.59	
	10	29	36	55	31	43	32	53.67±2.84±	
	12	35	31	121	37	41	42	74.167±18.35	

ALP: Alkaline phosphatase; AST: Aspartate aminotransferase; ALT: Alanine aminotransferase

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Table 10. Serum biochemistry values of dogs with post 70% small intestinal resection and anastomosis and supplemented with glutamine/ honey/ ascorbic acid

Substance	Days	Number of dogs (n = 6)						Mean ±SEM	P-value
		1	2	3	4	5	6		
Sodium	0	116.2	134.4	182.0	136.0	145.4	140.0	142.33±8.89	0.82
	4	131.6	194.6	137.2	135.4	138.0	137.0	145.63±9.84	
	6	133.0	187.6	134.4	135.2	135.3	135.2	143.45±8.84	
	8	134.4	137.2	135.8	134.6	136.2	136.4	135.77±0.44	
	10	190.4	133.0	134.4	150.2	137.4	138.0	147.23±8.98	
	12	186.2	140.0	138.6	162.4	144.0	138.6	151.63±7.84	
Potassium	0	4.1	4.4	4.0	4.0	4.2	4.0	4.12±0.65	0.33
	4	4.1	4.2	2.1	3.8	3.6	3.8	3.60±0.31	
	6	4.2	4.2	2.8	3.8	3.6	3.9	3.75±0.21	
	8	4.2	2.4	4.0	3.9	3.9	3.9	3.72±0.27	
	10	4.2	2.9	2.8	4.0	4.0	4.0	3.65±0.26	
	12	4.0	4.2	4.2	4.1	4.2	4.2	4.15±0.03	
Chloride	0	84.6	103.8	96.2	97.2	100	102	97.30±2.79	0.92
	4	84.6	103.8	88.5	94.3	93.1	100	94.05±2.90	
	6	92.3	96.1	103.8	100.5	89.3	98	96.67±2.17	
	8	100	96.2	88.5	102.3	97.2	98	97.03±1.92	
	10	88.5	107.7	61.5	98.1	102.5	101.2	93.25±6.86	
	12	88.5	96.2	100	98.3	101.2	102	97.70±2.03	
Bicarbonate	0	22	22	22	23	22	23	22.33±0.21	0.01
	4	22	24	23	22	22	23	22.67±0.33	
	6	21	21	23	21	21	22	21.50±0.34	
	8	21	26	21	21	23	22	22.33±0.80	
	10	26	26	28	22	24	23	24.83±0.91	
	12	21	21	25	23	24	22	22.67±0.67	
ALP	0	58.6	22.4	50	45.2	52.5	59.7	48.07±5.59	0.75
	4	72.4	31.0	108.6	62.1	70.1	62.1	67.72±10.18	
	6	48.3	25.9	75.9	48.4	62.3	58.2	53.17±6.87	
	8	34.5	17.2	82.8	41.2	58.9	60.1	49.12±9.39	
	10	74.1	17.2	43.1	65.1	60.2	76.4	56.02±9.16	
	12	77.6	17.2	58.6	52.5	53.1	80.1	56.52±9.27	
AST	0	33	23	19	34	42	34	30.83±3.42	0.005
	4	47	31	36	40	55	48	42.83±3.59	
	6	36	30	73	36	50	38	43.83±6.42	
	8	34	29	32	35	41	36	34.50±1.65	
	10	52	34	24	49	36	54	41.50±4.88	
	12	97	23	85	70	40	98	68.83±12.70	
ALT	0	44	59	22	49	56	45	45.83±5.35	0,40
	4	188	73	35	51	70	64	80.17±22.31	
	6	88	57	79	65	54	53	66.00±5.91	
	8	80	49	78	62	50	47	61.00±6.09	
	10	112	55	69	57	49	57	66.50±9.48	
	12	179	51	140	52	52	52	87.67±23.27	

ALP: Alkaline phosphatase; AST: Aspartate aminotransferase; ALT: Alanine aminotransferase

DISCUSSION

In patients suffering from short bowel syndrome, the absorption of electrolytes is impaired due to loss of mucosal absorptive surface area and large amounts of these electrolytes are also lost in the ensuing diarrhea (Shaw et al., 2012; Winter and Shah, 2013; Walters, 2017; Gillard et al., 2017). Moreover, in this study, the predominant portion of the small intestine where absorption takes place (Jejunum) was completely lost with some portion of the ileum. It was therefore, expected that the amount of these electrolytes (Sodium, potassium, bicarbonates and chlorides) would fall below the normal values due to impaired absorption. But the result showed no impaired absorption as the electrolyte values were all within the normal ranges in all the animals including the control group. Though there were significant

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changes or differences in the values of some of these electrolytes in some groups such as group 2 (chloride and bicarbonate), group 3 (sodium only), group 4 (chloride and bicarbonate) and group 5 (bicarbonate only). However, these changes were still within the normal values of these electrolytes in dogs. This was due to the fact that significant fluid and electrolyte absorption also occurs in the colon which helps to compensate for small intestinal disease (German, 2005; Navarro et al., 2009; Vagholkar et al., 2016). The colon is particularly effective in absorbing sodium; therefore, sodium deficiency hardly occurs in short bowel syndrome patients with an intact colon (Vanderhoof, 2010; Cunha-Melo and Costa, 2014; Mayeur et al., 2016; Rodriguez-Montes et al., 2016). Those patients with their colon resected suffer from water and sodium deficiency and are susceptible to a number of disease conditions especially hypotension and kidney failure (Sundaram et al., 2002; Nightingale and Woodward, 2006; Sriram and Lonchyna, 2009; Matarese, 2013). Also when a significant portion of the jejunum is lost the remaining ileum can undergo morphological and structural adaptation to compensate for many of the jejuna functions including the absorption of electrolytes (German, 2005; Cunha-Melo and Costa, 2014).

The observed significant decrease in ALK value in glutamine and honey treated animals and non-significant changes in ALT in all the groups are an indication that there was no associated liver pathology in these animals. This is in agreement with the report of other researchers that placing patients with short bowel syndrome on enteral nutrition (oral feeding) reduces significantly the incidence of liver disease in such patients compared to its high incidence in patients placed on total parenteral nutrition (Le et al., 2010; Vipperia and O'keefe, 2014). The absence of thrombocytopenia- platelet count below normal gives further credence to the observation that there was no liver pathology.

Vagholkar et al. (2016) who had observed hypochromic microcytic anaemia and megaloblastic anaemia in human patients with short bowel syndrome but in this study, normocytic normochromic anaemia was observed as the PCV decreased from its baseline values in all animals in the five groups while the RBC, Hg, MCV and MCHC remained within the reference values. However, this decrease in the PCV is significant only in group 2 and 3 animals. This might be due to surgical haemorrhage during the surgery and hemodilution from intravenous fluid infusion during and after the surgery. This shows that iron absorption had not been impaired as anaemia due to iron deficiencies are microcytic hypochromic anaemia (Latimer, 2010; Thrall, 2012).This is because the duodenum where predominant absorption of iron takes place had not been resectioned (Seetharam and Rodrigues, 2011). The fact that the haemoglobin values had remained within the reference range is an indication that the animals did not become dehydrated since there was no depletion of fluids and electrolytes. The WBC count had increased in control and all the treated groups at day four post resection. These increases in white blood cell count were immune responses to inflammation that had followed bowel resection. The above findings had also been observed by Shaw et al. (2012).

CONCLUSION

Preservation of the colon in patients suffering from Short Bowel Syndrome improves the outcome and survival of these patients as the colon takes over the function of absorption of water, electrolytes and ensures that these patients attains enteral autonomy by reducing or eliminating the need for Total Parenteral Nutrition and its attendant consequences.

Competing interests

The authors have declared that no competing interest exists.

Author's contribution

AIK and JBA performed the surgery and writing of the manuscript. LMS analyzed the blood samples and reviewed the manuscript

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