Mortality Rates and Associated Factors in Equine Colic Operations — A Retrospective Study of 341 Operations

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SUMMARY

A retrospective survey of 300 surgical treatments for colic involving 341 interventions was carried out to determine mortality rates and associated factors. These horses had been referred to the Ontario Veterinary College over the period September 1974 to February 1980. Data from the case records was collected and stored on a computer and statistical analysis was carried out using χ^2 tests.

Fifty percent (150/300) of the horses survived to be discharged from the hospital. Fifty-two horses were euthanized during the operation and another ten horses should have been; if these cases are excluded the overall survival rate is 64.7% (150/232). A wide range of breeds were involved but the breed did not significantly affect survival. There was a significantly greater occurrence of serious colic in the two week to two month and one to two year age groups and significantly less in the two to four year age groups when compared with the total number of horses admitted over the same period. There was an even distribution of male and female horses but males showed a significantly lower mortality rate (57% of the males survived compared with 43% of the females). The size of the animal did not affect survival significantly. There was no seasonal variation when compared with the total number of equine patients.

Survival was significantly influenced by the lesion, the preoperative packed cell volume and total plasma protein and by the length of the surgical procedure.

RÉSUMÉ

Une étude rétrospective du taux de mortalité et des facteurs associés à des cas de coliques équines qui nécessitèrent 341 interventions chirurgicales

Cet article présente une étude rétrospective de 300 traitements chirurgicaux de coliques, qui impliquait 341 interventions chirurgicales et qui visait à déterminer le taux de mortalité et les divers facteurs associés à ces cas de coliques. Les chevaux impliqués représentent des cas référés au Collège vétérinaire de l'Ontario, au cours de la période de septembre 1974 à février 1980. On recueillit les renseignements enregistrés dans les dossiers et on les emmagasina dans un ordinateur, afin de procéder à une analyse statistique en utilisant les texts χ^2.

La moitié de ces 300 chevaux survécurent et reçurent leur congé de l'hôpital; il fallut cependant en sacrifier 52, au cours de l'intervention chirurgicale et il aurait également mieux valu d'en sacrifier dix autres. L'exclusion de ces 62 cas aurait donné un taux de survie de 64,7%. Plusieurs races chevalines étaient représentées, mais la race comme telle ne sembla pas influencer de façon significative le taux de survie. Une analyse du nombre total des chevaux hospitalisés au cours d'une même période révéla que les cas de coliques les plus graves s'avérèrent plus nombreux chez les poulains âgés de deux semaines à deux mois et d'un à deux ans que chez les sujets âgés de deux à quatre ans. La condition frappa un nombre égal de mâles et de femelles, mais les premiers affichèrent un taux de mortalité sensiblement moins élevé; en effet, 57% d'entre eux survécurent, comparativement à seulement 43% des femelles. La taille ne sembla pas exercer d'influence sur le taux de survie. L'analyse du nombre total des patients ne révéla pas de variations saisonnières.

Les lésions, l'hématocrite et les protéines plasmatiques totales préopératoires, ainsi que la durée de l'intervention chirurgicale, influencèrent de façon significative le taux de survie.

INTRODUCTION

Surgical exploration of the equine abdomen was, for many years, approached with faint hope of success. In the last 15 years many of the myths have been dispelled and at teaching institutions and in some practices equine celiotomies are performed routinely.

Equine anesthesia has advanced considerably over the same period and there are several excellent reviews of this subject (1,2,3,4,5,6). Improved technology has played a prominent part in the ability of the anesthetist to manage the patient more effectively, e.g. the availability of safer anesthetic agents and accurate methods of administration, of effective ventilators, blood gas machines and blood pressure monitoring equipment. However, there is very little data relating preoperative findings to the anesthetic regimen used and the intraoperative and postoperative progress of the surgical intervention in the equine colic case (3,7,8).

A summary of previous reviews of survival rates for equine colic surgery are shown in Table I. In several instances overall mortality was very high, but when the horses with inoperable lesions were excluded more realistic survival rates are evident. Direct comparison between the reports could be misleading due to the incidence or prevalence of different conditions. For instance, grass sickness is not found in North America or most of Europe, but accounts for a number of the horses

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TABLE I
A REVIEW OF OTHER REPORTS INVOLVING A SERIES OF SURGICAL COLIC HORSES

Years Covered by Survey	No. of Surgical Cases	Total Survival Rate (%)	Survival Rate Excluding Horses Euthanised at Surgery (%)	Remarks	Reference
1849-1934	15	20	—	Literature review may	(1)
1934-1963	127	78	—	reflect the tendency to report successful cases only	(1)
NS	55	36.4	74	Many of the cases dying intraoperatively died of irreversible shock	(9)
NS	43	48.8	—	Standing laparotomies	(10)
1962-1967	24	25.0	26.1		(11)
1958-1968	95	—	46.5		(12)
1969-1971	36	—	61.2		(12)
1965-1973	41	36.3			(13)
1965-1972	190	35	49.6		(14)
NS	74	62.2	69.7	Mainly standing laparotomies	(15)
NS	42	23.8	68	Many of the horses euthanised had inoperable verminous arteritis lesions	(16)
1966-1974	181	—	57		(17)
1974-1978	61	45.9	57.1		(18)
1975-1977	50	45.9	51		(7)
1977-1979	49	65	89		(8)
1979	223	78	85.3		(19)
1980	40	60	69		(20)

NS = Not specified

with inoperable lesions in the United Kingdom reports (16).

The purpose of the present study was to provide further information on mortality rates and associated factors from a retrospective survey of a large number of surgical treatments for equine colic at one institution. Particular attention was paid to the information recorded during the perioperative period especially with regard to anesthetic management.

MATERIALS AND METHODS

A retrospective study of 341 surgical interventions for colic in 300 horses was carried out. This sample represented all the equine celiotomies requiring a general anesthetic which were treated at the Ontario Veterinary College (OVC) from September 1974 to February 1980. Thirty-one horses had two operations and five horses had three interventions. In 12 instances horses were discharged from the clinic and readmitted some time later prior to their second or third surgery. There were 23 records which contained insufficient information for complete analysis and data from these horses was only utilized in the patient age, sex, breed and mortality statistics. For comparison purposes similar data, where available, was obtained from the total equine case load over the same time period.

The breeds involved were as follows: 93 Standardbreds, 92 Thoroughbreds, 28 Quarter horses, 18 Arabians, 6 Appaloosas, 5 Pintos, 5 Belgians, 4 each of American Saddle horses, Clydesdales and Hackneys, 3 ponies, 2 Trakehners, 1 Percheron, 1 Morgan and 1 donkey. The remaining 33 horses are of mixed breed or were classed as grade horses. Because of the small numbers of breeds other than Thoroughbreds and Standardbreds, the other breeds were pooled for comparative purposes. Of the 157 male horses, 71 were entire males, 66 were geldings and there were 20 other males whose status was not specified in the records. One hundred and forty-two females were submitted for surgery and the sex of one Thoroughbred was not recorded. The general details of the fluids used, the methods of administration and the anesthetic techniques have recently been published (6). Dehydrated horses were given preoperative intravenous fluid therapy except where the violence of their behaviour precluded this treatment. In this retrospective series of surgeries variations in premedication, induction regimes and supportive therapy arose from the perceived clinical status of the horse and the personal preferences of the anesthetist and surgeon involved. Surgery was carried out with the horse in dorsal recumbency using a midline abdominal incision through the linea alba. Where necessary a lateral or inguinal approach was also used. The survival figures were taken at the time of discharge from the hospital, usually seven to ten days after surgery.

For the purpose of this study specific details on patient history, patient signalment, anesthetic regime and response, biochemical laboratory data, fluids used, operative time, personnel, surgical lesion and eventual outcome were recorded. The large amount of data thus generated was stored on a computer for subsequent analysis. Information needed for this protocol, when not present in the records, was entered as "unknown". Thus in the results section care has been taken to define the data base for each criterion.

The duration of colic prior to admission, taking into account that many owners were unsure of the exact time of onset of colic, was recorded as "acute" or "chronic". Chronic was defined as anything lasting for 36 hours or more, and acute was anything shorter than this. The preoperative packed cell colume (PCV), plasma protein and base excess were entered if they had been taken within one hour prior to the induction of anesthesia. When rapid rehydration was taking place, only blood samples collected within 15 minutes of induction of anesthesia were included. Anesthetic regimes and volumes of fluid used until the end of the surgery were recorded. The lesions were not classified individually but were divided into seven categories: (a) primarily small bowel, (b) primarily large bowel, (c) mixed large and small bowel, (d) gas distension and ileus only, (e) no visible lesion, (f) nonenteric lesions and (g) unable to classify. The presence or

TABLE II
SURVIVAL AND MORTALITY DATA IN 300 HORSES UNDERGOING GENERAL ANESTHESIA AND SURGERY FOR COLIC AT THE ONTARIO VETERINARY COLLEGE

Category	No. of Horses
1. Discharged from hospital after one surgery	139
2. Discharged from hospital after more than one surgery	11
3. Euthanised during surgery	52
4. Died on induction of anesthesia	2
5. Died during anesthesia/surgery	4
6. Died in the first 24 hours with lesions that were severe enough to have justified euthanasia during operation	10
7. Died in the first 24 hours due to obvious operative mistake	2
8. Died in the first 24 hours due to anesthetic and/or surgical complications (including shock)	35
9. Died or euthanised after 24 hours postoperatively	27
10. Died or euthanised subsequent to a second anesthetic	15
11. Died or euthanised subsequent to a third anesthetic	3

absence of devitalized bowel was also recorded and this was assessed on the basis of the surgeon's notes evaluating the presence of cyanotic bowel with no return to normal colour during surgery. Intraoperative and postoperative complications were recorded and an arbitrary classification was made regarding the occurrence of hypoventilation and hypoxemia. If the P_aCO_2 rose above 65 torr it was regarded as hypoventilation. If the P_aO_2 fell below 80 torr with the animal on 100% oxygen it was classified as hypoxemia. These values were obtained from heparinized arterial samples collected anaerobically, usually from the submandibular artery. Blood gas and acid base analyses were carried out immediately, using standard methods and equipment, assuming a body temperature of 38.2°C.

The mortality data was arranged into 11 categories (Table II). One of the authors (P.J. Pascoe) made the mortality classification for each horse based on a comprehensive study of the individual case record including the postmortem report. It is recognized that categories six to eight require a subjective assessment but it was felt that this was important to the present study. Animals were included in category six if there was extensive contamination of the abdomen during surgery, if the underlying cause of the colic was not corrected at surgery or if there had been a failure to remove devitalized bowel.

The results were analysed using Chi-squared tests applying Yates' continuity correction for two by two tables but not for tables larger than this. In some instances the horses were divided into four equal size groups over the range of values in ascending order. Each of these groups is referred to as a quartile. The values expressed in the paper above and below the mean are standard deviations.

RESULTS

In this series of surgical treatments for colic 150/300 (50%) of the horses survived and were discharged from the hospital (Table II). The survival rate of horses that went into the recovery stall was 62% (150/242). If one also excludes those animals that retrospectively should have been euthanised at surgery, the overall survival rate was 64.7% (150/232).

There was no statistically significant difference in survival rates for animals treated by different surgeons or anesthetists.

Breed/Age/Sex/Weight

No significant difference ($P < 0.05$) was found between the breed distribution of colic as compared to that of all horses admitted to the clinic. Breed did not affect survival rates, which were 48.9% (45/92), 50.5% (47/93) and 48.7% (56/115) for Thoroughbreds, Standardbreds and other breeds respectively.

There was a tendency towards a poorer prognosis for the younger and older age groups with only seven (33.3%) of the horses surviving that were between five days and four months old and only ten (30.3%) of the horses that were over ten years old surviving. However these differences were not statistically significant ($P < 0.05$).

The gender of the horse affected survival significantly ($P < 0.025$): with 56.7% (89/157) of males surviving compared with 43% (61/142) of the females.

There was no statistically significant change in rate of survival ($P < 0.05$) with increasing weight, although out of nine animals that weighed more than 600 kg only one survived.

History

The histogram (Figure 1) shows that there were relatively fewer colics in winter than in summer, however the total hospital case load showed a similar trend. There was no statistical difference between the colic patients and the total admissions for any individual month or between the numbers operated on for the six monthly periods October to March and April to September.

At admittance to the hospital 70/312 (22.4%) horses were recorded as having a previous history of colic prior to the current episode. Thirteen horses had had surgery for colic at some other time and only one had been done elsewhere. Twenty-seven horses had a history of a previous surgery on the same stay and two of these horses had a previous history of two surgeries on the same stay. Five of these horses underwent two surgeries on the same day.

The duration of colic was recorded for 285 horses where no previous surgery was carried out during that hospital stay. Of these 225 were classified as "acute" and 60 were "chronic", and there was no significant difference in overall survival between these groups. Intraoperative euthanasia was carried out in 15.6% (35/225) of the "acute" colics and in 16.7% (10/60) of the "chronic" cases.

Type of Lesion

This analysis was carried out for all of the 312 surgeries where there was no previous surgery on the same hospital stay (Table III). The 25 animals classed as having nonenteric lesions, included some with vascular lesions due to *Strongylus vulgaris,* a mesenteric hematoma, several involving adhesions to other organs and also strangulations by lipomata.

Horses with devitalized bowel comprised 18/23 (78.3%) of the animals with small intestine lesions which were

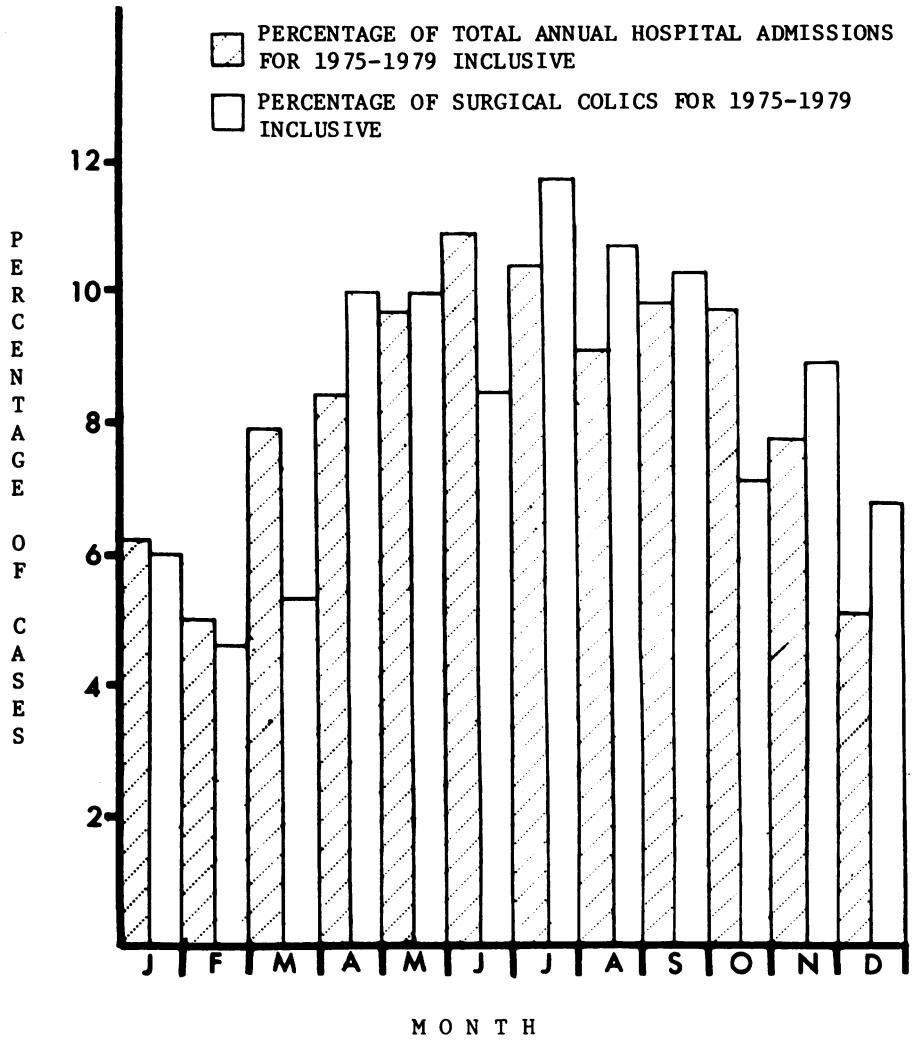

FIGURE 1. Monthly variation in total hospital equine admissions and surgical colic cases for 1975-1979 inclusive.

euthanised at surgery. There was a significantly lower survival for animals with small bowel lesions ($P < 0.025$) versus large bowel lesions, devitalized small bowel ($P < 0.005$) versus nondevitalized small bowel and devitalized large bowel ($P < 0.005$) versus nondevitalized large bowel.

The incidence of large bowel and small bowel lesions was compared over the five complete years and there was no significant change in the lesion incidence over this period ($P < 0.05$). There was also no significant change in the survival of large bowel or small bowel cases for different years or for different months of the year ($P < 0.05$).

Preinduction Packed Cell Volume, Plasma Protein and Base Excess

Case records with insufficient data and horses with a prior surgery on the same hospital stay were excluded from this assessment. The preinduction PCV was recorded in 157 cases. The mean value was 0.45 ± 0.087 litres/L with a range of 0.25 to 0.73 litres/L. These values were divided into quartiles and compared with survival (Table IV). There was a significantly higher mortality rate ($P < 0.01$) in those horses with high packed cell volumes at the time of induction but the relationship between PCV and survival rate was not linear.

The opposite effect was seen with plasma protein levels, which were recorded preoperatively in 143 cases. The mean plasma protein concentration was 6.1 ± 1.2 g/dL with a range of 3.2 to 8.9 g/dL. Significantly higher mortality ($P < 0.025$) was seen with horses which had a low plasma protein value at the time of induction (Table IV) and the relationship between plasma protein levels and survival rate was linear.

The base excess was recorded in 135 cases prior to induction and the mean value was -1.9 + 4.7 mmol/L with a range of -16 to +12 mmol/L. When these values were split into quartiles there was no significant difference for

TABLE III
SURVIVAL RATES FOR 312 SURGERIES WITH RESPECT TO THE LESION FOUND AT SURGERY

Type of Lesion	Overall Number of Survivors	% Survival	Survival Rate Excluding Inoperable Cases	% Survival	Presence of Devitalized bowel	Survival Rate of Cases with Operable Devitalized Bowel	% Survival
Small bowel	48/122	39.3	48/98	49	72/122	20/54	37.0
Large bowel	85/150	56.7	85/116	73.3	27/150	1/7	14.3
Mixed large bowel/ Small bowel	6/12	50.0	6/8	75	5/12	3/4	75
Gas distension and ileus only	7/12	58.3	7/12	58.3	—	—	—
No visible lesion	3/4	75	3/4	75	—	—	—
Nonenteric Lesion	14/25[a]		14/19	73.7	3/25	1/1	100
Unable to classify	0/1	0	0/1	0	0	—	—

[a]14 of these horses were placed in more than one lesion category (e.g. where a lipoma caused a small bowel strangulation)

survival ($P > 0.05$) although there did appear to be a trend towards a poorer survival with greater negative values of base excess (Table IV).

Anesthetic Premedication and Induction

Meperidine[1] was the most popular premedicant drug, excluding cases with insufficient records and animals which had been operated on twice on the same day. It was used in 194 horses; five of these animals also received other sedative drugs (e.g. xylazine[2] or acepromazine[3]). Ten animals were given acepromazine only, while nine horses were given xylazine only. No premedication was used in 89 cases and there were seven records where the premedication was not recorded. Five horses received some other drug as a premedicant. No analysis was carried out with respect to dosage or survival since it was felt that there was too much personnel bias.

Induction of anesthesia was achieved with a combination of glyceryl guaiacolate ether[4] and thiamylal sodium[5] in 156 animals, thiamylal sodium and a casting dose of succinylcholine[6] in 68 animals and with thiamylal alone in 39 animals. There were 28 animals which were masked with halothane[7] and 16 horses were cast with glyceryl guaiacolate only. Other agents were used in 12 cases and the induction regime was not recorded in the remaining 22 cases.

The means and standard deviations of the recorded doses for the common induction regimes were; glyceryl guaiacolate 100.5 ± 22.7 mg/kg and thiamylal 3.3 ± 0.9 mg/kg (145 animals), thiamylal 4.9 ± 1.2 mg/kg and succinylcholine 0.1 ± 0.05 mg/kg (61 animals) and thiamylal 5.11 ± 1.17 mg/kg (37 animals).

The survival rate of horses anesthetized with the five main induction regimes were compared and there was no significant difference ($P < 0.05$). Two horses died on induction (Table I). One horse went into ventricular fibrillation immediately after induction with glyceryl guaiacolate and thiamylal. At postmortem it was found to have 4.5 meters of small bowel herniated through the epiploic foramen. The induction regime was not recorded for the other horse which died at this point. At postmortem a ruptured cecum was found and it was apparent that this had occurred prior to induction.

Maintenance of Anesthesia

All the anesthesias were maintained with halothane and oxygen. Nitrous oxide was used in seven horses and various injectable agents were used during the anesthetic period, according to the personal preference of the anesthetist and the perceived clinical requirement. The main agents used are shown in Table IV.

Four horses died during anesthesia. A seven year old Belgian gelding weighing 912 kg with a gravel impaction of the ileum went into ventricular fibrillation one and one-half hours after induction with glyceryl guaiacolate and thiamylal. Another horse of mixed breeding weighing 676 kg died as small intestine was being released from herniation through the epiploic foramen. The third horse, a six year old Standardbred had ruptured some bowel preoperatively and there was necrosis of some jejunum and an area at the base of the cecum. It went into cardiac arrest, was resuscitated and then arrested again. The fourth horse went into asystole about five minutes after induction. This horse had ruptured bowel preoperatively as a result of a rope enterolith.

There were 314 case records suitable for the analysis of data with respect to ventilation. One hundred and ninety-two horses were left to ventilate spontaneously throughout the operation, 87 horses were ventilated (intermittent positive pressure ventilation, IPPV) at some point during the surgery and 35 horses were ventilated throughout the operation.

Hypoventilation occurred in 108 animals with a mean peak $PaCO_2$ value of 78.8 ± 17 torr, ranging from 66 to 184 torr. Hypoxemia occurred in 41 animals with a mean lowest PaO_2 value of 67.2 ± 9.4 torr, ranging from 39 to 80 torr. Twenty of these animals showed both hypoxemia and hypoventilation. Table VI shows the frequency of hypoxemia and hypoventilation during spontaneous ventilation and IPPV in those cases where sufficient information was available. It should be recognized that hypoxemia

TABLE IV
RELATIONSHIP BETWEEN SURVIVAL RATES IN COLIC HORSES AND PREOPERATIVE PACKED CELL VOLUME, TOTAL PROTEIN AND BASE EXCESS VALUES

Range	Number of Animals	Survival Rates	% Survival
P.C.V. (litres/L)	157		
0.25 to 0.38		28/40	70.0
0.38 to 0.44		24/39	61.5
0.44 to 0.50		14/39	35.9
0.50 to 0.73		16/39	41.0
Protein (g/dL)	143		
3.2 to 5.4		10/35	28.6
5.4 to 6.1		18/36	50.0
6.1 to 6.9		20/36	55.5
6.9 to 8.9		23/36	63.9
Base Excess (mmol/L)	135		
- 16 to - 5		10/33	30.3
- 5 to - 2		19/34	55.9
- 2 to + 1		18/34	52.9
+ 1 to + 12		16/34	47.1

[1]Demerol, Allen and Hanbury, Toronto, Ontario.
[2]Rompun, Haver Lockhart, Mississauga, Ontario.
[3]Atravet, Ayerst Laboratories, Montreal, Quebec.
[4]Gecolate, British Drug House, Toronto, Ontario.
[5]Biotal, M.T.C. Pharmaceuticals, Hamilton, Ontario.
[6]Anectine, Burroughs Wellcome, Kirkland, Quebec.
[7]Fluothane, Ayerst Laboratories, Montreal, Quebec.

TABLE V
ANESTHETIC AND SUPPORTIVE DRUGS USED DURING THE INTRAOPERATIVE PERIOD (IN ADDITION TO HALOTHANE)

Drug	Number of Patients	Average dose mg/kg	Average No. of Times Used/ Anesthetic
Glyceryl Guaiacolate	36	30.95	1.58
Sodium thiamylal	6	1.09	1.17
Morphine[b]	14	0.22	1.07
Succinylcholine	39	0.142[a]	1.6[a]
Pancuronium[c]	3	0.073	2.0

[a]Average dose and number of times for 35 patients
[b]Morphine, Ingram and Bell, Don Mills, Ontario
[c]Pavulon, Organon, Toronto, Ontario

TABLE VI
FREQUENCY OF HYPOXEMIA AND/OR HYPOVENTILATION IN ANESTHETISED HORSES UNDERGOING CELIOTOMY DURING SPONTANEOUS VENTILATION AND/OR INTERMITTENT POSITIVE PRESSURE VENTILATION

Ventilation	Hypoventilation[a]	Hypoxemia[b]	Hypoxemia and Hypoventilation
Spontaneous ventilation throughout the operation	50/131[c]	18/124	11/124
IPPV at some point during the operation	43/77	12/75	4/75
IPPV throughout the operation	9/31	8/30	3/30

[a]Hypoventilation is defined as $PaCO_2 > 65$ torr
[b]Hypoxemia is defined as $PaO_2 < 80$ torr
[c]Numbers represent those with recorded values

and/or hypoventilation probably occurred prior to the use of IPPV where animals were only ventilated for part of the operation.

Forty-three horses were recorded as moving during the surgery which led to a delay in surgical progress, or made it necessary to administer further intravenous agents in order to keep the horse still. Fifteen animals had cardiac arrhythmias of various types, four horses had a respiratory arrest that responded to IPPV and one animal had a cardiac arrest, was resuscitated and then arrested again.

Anesthesia and Surgery Times

Cases which were euthanised intraoperatively and those for which the duration of anesthesia was not accompanied by a figure for the duration of surgery were excluded from this assessment. The mean duration of anesthesia and surgery in the remaining 237 instances was 2.22 ± 0.75 hours and 1.91 ± 0.73 hours respectively. The range for anesthesia times was from 50 minutes to four and one-half hours. There was a significantly higher survival rate with the shorter anesthetic periods ($P < 0.005$) (Table VII).

TABLE VII
SURVIVAL RATE WITH RESPECT TO DURATION OF ANESTHESIA IN 237 HORSES

Time (H)	Survival Rate	% Survived
0.83 - 1.58	48/59	81.4
1.6 - 2.08	38/59	64.4
2.08 - 25	36/59	61.1
2.75 - 4.5	26/60	43.3

(χ^2 value is 18.491 so $P \leq 0.005$)

Preoperative Fluid Administration

Of the 289 cases with sufficient records that had no previous surgery on the same hospital admittance, 133 horses received fluids preoperatively, 113 did not and in 43 cases it was not recorded.

By the end of the operation there were only 11 horses from the above 289 which had not received any fluids. The total preoperative and intraoperative volume of lactated ringers was recorded in 197 cases and a mean volume of 48.09 ± 1.99 mL/kg was used ranging from 2.25 to 194.94 mL/kg. There were 220 cases where the quantity of sodium bicarbonate was recorded. The mean quantity used was 3.15 ± 1.6 mmol/kg ranging from 0.33 to 16.77 mmol/kg. Plasma was used in 27 cases and a mean volume of 5.07 ± 2.92 mL/kg was given ranging from 1.46 to 14.9 mL/kg. Dextrans were also used (mostly 75,000 and 40,000 molecular weight compounds) in 30 cases with a mean volume of 2.82 ± 2.41 mL/kg and a range of 0.23 to 10.34 mL/kg. Whole blood was given in four cases.

Chi-squared tests were performed on the survival rates for the volumes of lactated Ringers and the quantities of bicarbonate split into quartiles and there was no significant difference between the four groups for either fluid.

The volumes of lactated Ringers given were also ascertained with regard to the type of lesion. For the results see Table VIII. Table IX gives the results of the quantities of sodium bicarbonate that these animals were given. Thus for the mean values applied to a 450 kg horse, 13.5 to 27 litres of lactated Ringers was used and 900 to 1350 mmol of sodium bicarbonate was used (1.5 to 2.25 litres of 5% sodium bicarbonate) for any type of case. In order to compare these volumes for different lesions, some two by two tables were constructed using median values as a dividing

TABLE VIII
RECORDED VOLUMES OF LACTATED RINGERS GIVEN TO HORSES WITH COLIC

Lesion	No. of Cases	Mean Value mL/kg	Std. Dev.	Range
Small bowel with no devitalization	33	33.35	± 27.95	0-112.5
Large bowel with no devitalization	97	38.04	± 29.53	0-147.89
Small bowel with devitalization	51	57.97	± 37.94	0-170.53
Large bowel with devitalization	17	30.93	± 29.74	0-170.53

TABLE IX
RECORDED QUANTITIES OF SODIUM BICARBONATE GIVEN TO HORSES WITH COLIC

Lesion	No. of Animals	Mean Dose mmol/kg	Std. Dev.	Range
Small bowel with no devitalization	49	2.06	1.89	0-6.9
Large bowel with no devitalization	22	2.05	1.71	0-7.04
Small bowel with devitalization	64	3.06	2.98	0-14.67
Large bowel with devitalization	22	2.50	2.18	0-7.20

point. Healthy small bowel was compared with healthy large bowel by using the median value for all horses with healthy bowel as the dividing number. A Chi-squared test was then applied. This procedure was repeated for devitalized small bowel versus devitalized large bowel, healthy small bowel versus devitalized small bowel and healthy large bowel versus devitalized large bowel. This was done for both lactated ringers and sodium bicarbonate. Using this test the only significant difference found was between the volumes of lactated ringers used for healthy small bowel versus devitalized small bowel ($P < 0.01$) (greater volumes being used for cases with devitalized bowel).

Corticosteroids

The two corticosteroids used in this series were dexamethasone[8] and prednisolone.[9] Twenty-seven animals were given prednisolone only, 19 horses were given dexamethasone only and 48 animals were given both intraoperatively (after excluding animals with a previous surgery on this admittance). Out of the 70 instances where dexamethasone was given and the dose recorded, the mean dose was 0.67 mg/kg ± 0.37 ranging from 0.14 to 2.2 mg/kg. The dose of prednisolone was recorded in 74 cases and the mean dose was 0.98 mg/kg ± 0.58 ranging from 0.34 to 3.4 mg/kg. The survival of animals receiving steroids was consistently poor, 9/27 (33.3%) of the prednisolone only group survived, 7/19 (36.8%) of the dexamethasone only group survived and 18/48 (37.5%) of the horses treated with both steroids survived. There was no significant difference between the groups.

The dose of steroids was then split into quartiles and survival data extracted for these four groups. There was a significantly higher mortality in the higher dexamethasone dosage groups ($P < 0.05$).

Survival and mortality data was then extracted for healthy or devitalized bowel. Those that were treated with corticosteroids were then compared with those that were not. Chi-squared tests performed on these figures revealed no significantly better (or worse) survival for any of the treated versus non-treated groups.

Postoperative Complications

Three horses had a very prolonged anesthetic recovery (< 3 hours) and in 13 cases where there was an inability to stand postoperatively. Fractured long bones occurred in three horses; one fractured its tibia, one fractured its femoral neck with avulsion of the greater trochanter and one fractured its femur on one side and the acetabulum on the other side when its hind legs became severely abducted in the recovery stall. The remaining animals placed in this category died or were euthanised in the recovery stall. Pancuronium had been used on one of these horses and it had to be ventilated (due to an inability to reverse the muscle relaxant) until it died several hours later. At postmortem it was found to have had a massive abdominal hemorrhage but the cause of this was not determined. Myositis was a very uncommon postoperative feature in this series of horses. One horse had unilateral myositis as a result of being tilted to one side while performing a colostomy. Three horses had bilateral myositis and of these one horse had myositis or paralysis in the obturator region as well as myositis in the left foreleg, one had a slight myositis over the gluteals which manifested itself as a partial posterior paresis, the third case was a very sick mare which had myositis in the hindlimbs after one operation and then had to be reanesthetised within a few hours because of an omental hernia from the wound. This horse did not recover from the second anesthetic.

Fourteen horses were recorded as having a recurrence of colic in the immediate post operative period. Seven of them survived and the importance of the occurrence of this event is difficult to assess.

DISCUSSION

The cases described in this survey were sent as referrals to the OVC. The results may reflect this situation in that some horses had to be transported for some distance before being seen at the clinic, and this not only prolongs the course of the condition but also stresses the animal still further (3,6). It is of interest that the best survival rate published to date is from a general practice situation where a large percentage of the operative population would be local (19).

Comparison of the patient data to the total hospital population does not represent a true control group. There is insufficient information regarding the horse population in Ontario and also no comparable figures are available for the incidence of nonsurgical colic in this population.

The survival rate for the horses in this series is comparable with most other published studies except for the most recent studies (Table I). The rather poor overall survival rate of 50% is partially a reflection of the fact that, during this development period for colic surgery at OVC, corrective surgery was almost always attempted regardless of the gravity of the prognosis.

Over the time period involved there was no change in survival rate, indicating that no major improvements in patient management had been made during this time. From an examination of Table II it is evident that there

[8]Azium, Schering Canada Inc., Pointe Claire, Quebec.
[9]Solu Delta-cortef, Tuco Products, Orangeville, Ontario.

are two areas where improvements could be made. The first is in the diagnosis of the condition. If the preoperative diagnosis was more accurate it might help to eliminate some of the animals that were euthanised intraoperatively (this does not take into account those cases where surgery was requested despite a very poor prognosis). Secondly, the mortality of horses in the first 24 hours after surgery where there were (potentially) preventable or treatable complications (Category 8, Table II) was rather high with 35 of 300 animals (11.7%) dying. Gastric rupture was seen in a number of these cases (despite the use of nonfenestrated nasogastric tubes in some instances) and some deaths were due to continuing shock. In another recent report, on surgery of the equine ileum, 37% (10/27) of their cases could have been placed in this category (21). It is obvious that the postoperative period is critical for any animal, but this is especially true in the postoperative colic case due to the severe physiological insult that many of these horses have sustained. More intensive monitoring and treatment in this period might help to resolve some of these problems (19).

The measurement of preoperative PCV, plasma protein and base excess has been shown to have some prognostic value. The values measured may have followed vigorous therapy and do not necessarily reflect the values at the time of admission. Despite this, the finding that a higher PCV gives a poor prognosis agrees with previous studies (7,14,22,23). In this series, horses with high PCVs at the time of induction were mostly cases that were too violent to enable fluid administration. The poorer survival with low total protein values has not been reported before, although it has been surmised that this would be the case (24,25). With loss of protein into an inflamed abdominal cavity coupled with fluid therapy a pronounced fall in the intravascular total plasma protein will occur. This will be associated with loss of colloid osmotic pressure with a consequent further loss of fluid from the intravascular space. Horses with total protein values of less than 4.5 g/dL at the time of induction should probably receive some form of colloidal solution as part of the required fluid therapy. The failure to show a significant difference with the base excess is slightly surprising but is possibly a reflection of the relative ease with which a severe intravascular acidosis can be promptly corrected with sodium bicarbonate without correction of the underlying cause or even the intracellular acidosis. There was a trend towards a poorer prognosis for a more severe negative base excess. Since these samples were taken at the time of induction it would suggest that an attempt should be made to correct a severe negative base excess before the animal is anesthetised.

With respect to the failure to show any difference in survival in relation to the duration of colic, there are several explanations. The first is that the time chosen to differentiate acute and chronic may have been too broad and a second is that the lesions were not classified to the extent necessary to analyse this further. Horses that had been colicky for more than 36 hours are unlikely to have a complete strangulation lesion due to the rapid onset of shock in this situation (26). In Sembrat's article (17) the lesions are subdivided into smaller categories and comparisons for the time course of the condition were made. A strangulating obstruction had a very poor prognosis if the surgery was performed by any time greater than 24 hours after the onset of the colic. In other studies the preoperative duration of colic was longer in the survivors than the nonsurvivors (7,14), but the lesions were classified in a similar manner to this study so no more detailed analysis was possible.

Fluid therapy was used in most of the cases in this study to counteract the shock induced by the colic. Crystalloid solutions were used for most of this volume replacement except where the horse's protein fell to a very low level or where the blood pressure could not be restored by this method alone. The lack of a statistical difference in survival over the range of volumes of fluid employed could be interpreted in one of three ways: 1) That this fluid therapy was totally inappropriate so that the fluids did not contribute to the rate of survival, 2) that the fluid therapy was necessry but that the volumes used were incorrect since the total survival rate was only 50%; or 3) that the fluid therapy was appropriate for the clinical condition but that there were many other factors which contributed to the survival or death of the patient.

Since many of these horses were in a state of shock at the time of presentation, fluid therapy was judged to be necessary as it is the single most effective treatment for most states of shock (27,28,29). The second and third interpretations are both valid as in some cases the volumes used were probably incorrect (e.g. when animals died due to shock in the first 24 hours), however in most instances the fluid therapy was probably appropriate and given in adequate amounts.

In the same way the use of corticosteroids was restricted to those cases where it was felt that there was a high risk of endotoxic shock and this was usually only evaluated at the time of surgery. This fact probably explains the poor survival rates for horses treated with corticosteroids. Even when the type of lesion was taken into account in comparing survival rates, it is evident that the corticosteroid treated cases were clinically more severely affected than the untreated horses. Nevertheless, even when high doses of steroids were used in experimental equine endotoxic shock (1 mg/kg dexamethasone or 30 mg/kg prednisolone) there is little change in the clinical or clinicopathological picture (30). Nonsteroidal antiinflammatory agents, which inhibit arachidonic acid metabolism, attenuate the experimental endotoxic response but unfortunately had not been used in sufficient cases in this study to evaluate their clinical efficacy. In a limited experimental trial using *Escherichia coli* endotoxin, phenylbutazone attenuated the pyrexia, hemoconcentration and peripheral circulatory effects but did not alter the rate of survival significantly (31).

The anesthetic induction and maintenance techniques used in these horses appears to have been relatively successful. The six fatalities that occurred either at induction or during maintenance were mainly related to the severity of the underlying disease process although the addition of anesthetic agents which are potent cardiopulmonary depressants undoubtedly contributed to their demise. Of the six anesthetic deaths, three animals had ruptured bowel and two had large

areas of devitalized small bowel associated with herniation through the epiploic foramen. These horses presumably had a very significant component of endotoxic shock in their pathophysiology. The remaining anesthetic death occurred in a 912 kg Belgian during a long operation.

Recently a xylazine/ketamine combination for induction has been examined and has been shown to produce less cardiopulmonary depression than most other inductions regimes in normal horses (32). In the series of 49 cases published by Short and colleagues (8) there were no fatalities during induction or during maintenance where xylazine/ketamine was used at induction.

None of the injectable agents used during maintenance of anesthesia (Table IV) have proven to be entirely satisfactory in our clinical experience. Usually these drugs were used to stop movement or supplement analgesia. A notable example of this was glyceryl guaiacolate which produced a dramatic hypotension in some animals, when given during the maintenance period. The use of nondepolarising muscle relaxants probably should not be undertaken unless the electrolyte balance of the animal is known. Calcium gluconate was used for its positive intropic effects in 26 animals but it did not give consistent results. Care was taken when injecting potassium penicillin due to the cardiotoxicity of the potassium.

The possible causes of hypoxemia and hypoventilation seen in these cases has been discussed (6,33,34) and it is undoubtedly related to a reduced lung volume, right-to-left intrapulmonary shunting of blood and altered ventilation/perfusion relationships within the lung. These problems will be compounded by endotoxin release and/or a low cardiac output. It is recognized that the values used to define hypoxemia and hypoventilation are somewhat arbitrary, but the authors believe these values represent significant derangement of the normal physiological state. During general anesthesia the body temperature usually falls which implies that the degree of hypoxemia was underestimated in the present study (a PaO_2 of 80 torr read at the standard temperature of 38.2°C represents a PaO_2 of 60 torr in an animal with a body temperature of 35°C), while the hypercapnia was overestimated (a $PaCO_2$ of 65 torr at 38.2°C would be 52 torr at 35°C). It would have been preferable to correct all the blood gas values to body temperature, but this was not possible as body temperature was not monitored in most instances.

Intermittent positive pressure ventilation gives a greater depression of cardiac output than spontaneous ventilation in the anesthetised horse (35). In many of these patients the preexisting cardiovascular instability would have been exacerbated by the addition of positive intrathoracic pressure and so 61% of the horses were left to ventilate spontaneously. In the rest ventilation was used either because of a progressive hypoxemia, a progressive hypercapnia or in instances where the degree of abdominal tympany indicated that the anesthetised animal would have considerable difficulty with spontaneous ventilation. This study provides informatioin on the effects of this policy but there is insufficient data to determine the efficacy of this approach in the individual animal. In a similar study (8) an "assisted" pattern of ventilation was used on all horses.

The incidence of myositis in the recovery stall was surprisingly low (36). The horses had usually been severely stressed prior to surgery, they were often relatively hypotensive, some became significantly hypoxemic during the surgery and they were often anesthetised for long periods. If these same conditions applied to a similar group of horses placed in lateral recumbency for surgery the occurrence of myositis and the inability to stand may have increased considerably. Nevertheless, the fact that any animals die in this manner should be regarded as unacceptable and every effort made to prevent the occurrence of such complications.

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BOOK REVIEW

The Mechanics of the Horse. J.R. Rooney. Krieger Publishing Company, Huntington, New York. 1981. 104 pages. Price $12.50.

The forces, spatial and temporal relationships, and control mechanisms of equine locomotion are discussed. The book is intended for the inquisitive horseperson. Anatomical and physiological terms are used throughout. The author is attempting to "present a reasonably broad yet complete introduction to a most complex area of study". The topic of mechanics requires mathematical treatment but the precision of the subject is limited to "approximations, generally true for a generalized horse". Dr. Rooney suggests the level of knowledge of mechanics developed here should be basic for veterinarians working with horses.

This is a hard bound book of excellent paper quality. There is an abundance of pleasant, handdrawn illustrations. Confusion results in several instances where diagnoses are incorrectly labelled or labelling is omitted.

The first chapter introduces mechanics and discusses some of the fundamental laws of mechanics, simple geometry and algebra. This chapter is designed to familiarize the reader with mechanisms which will be used in the remaining chapters. The second chapter describes how the horse's back acts to support weight, the centre of mass and its effect on loading the back and limbs. A discussion on lateral bending of the back leads to a dissertation on the forces acting on a horse in a turn and the contribution of banking to the horse's stability in the turn. Chapter three deals with gait. Mathematics are used to explain the angular and linear displacement of the limbs resulting from forces generated by muscle contraction and the changing position of the centre of mass. The next two chapters discuss the forces involved in the dynamic and static loading of the fore and hind limbs. In chapter six, the final section of the book, the relationship of the nervous system to movement is based on anatomical principles and the author's observation. Having no mathematical proofs, this is the most readable chapter in the text.

The first four chapters are difficult to read because of the mathematics. The concept of applying trigonometry and geometry to the horse's movement is made more difficult to grasp by numerous typographical and mathematical errors. The text has been poorly edited. Readers should be made aware of the hypothetical nature of much of the discussion in the first five chapters. The author admits to presenting hypothesis in the work pertaining to the nervous system in the final chapter. Reference numbers have been left out of the text, and at least one reference does not discuss the work it is credited with in the text.

A preface statement that "this material cannot be grasped in a single quick reading", foreshadows the task ahead for the reader. This book cannot be read in a logical, methodical manner as a result of editing and mathematical errors. Rooney's descriptive analyses and hypotheses of functional physiology and anatomy are more readable than his mathematical treatment of equine mechanics. The frustrating persistence required to read this book outweigh the intellectual rewards gained.

W. Crawford.