

Recurrent colic in the horse: Incidence and risk factors for recurrence in the general practice population

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Summary

Reasons for performing study: The frequency of recurrent colic in the UK equine general practice population is previously unreported. Elucidating risk factors for recurrent colic could provide a basis for clinical decision making and interventions.

Objectives: To determine the incidence rate of and risk factors for recurrent colic.

Hypotheses: Horse management, prophylactic health care and innate behaviour contribute to the risk of recurrent colic.

Methods: A cohort of 127 horses was enrolled at the point of a veterinary-diagnosed medical colic episode. Participating owners completed a baseline and 3 follow-up telephone questionnaires over one year. Clinical details of each colic episode were collected with data on management, behaviour and preventive healthcare. Incidence was calculated using time at risk data; non-time varying covariates were assessed for association with recurrent colic using multivariable logistic regression.

Results: The recurrence rate was 50 colic events/100 horse years at risk (HYAR). Including only veterinary attended recurrent colic episodes the incidence was 35 colic events per 100 HYAR. A multivariable logistic regression model was built to explore non-time varying risk factors for recurrence collected from baseline data. The model showed that horses that have a known dental problem (OR 5.5, 95% CI 1.3, 23.1) or crib-bite/windsuck (OR 12.1, 95% CI 1.4, 108.1) were at increased risk of recurrence during the year following a colic event.

Conclusions and potential relevance: The incidence of recurrence in horses following a medical episode of colic is high in this population and represents a welfare concern. The incidence rate can be used to compare intervention efficacy in similar populations. Identified risk factors could provide the basis for management interventions or highlight at risk individuals.

Introduction

Colic is an important cause of mortality in horses (Leblond *et al.* 1995; Egevall *et al.* 2006) and is a high priority health concern of owners (Mellor *et al.* 2001). Whilst many colic cases are isolated

episodes, recurrence is frequently reported and has been identified as a frustrating problem to manage (Beard and Freeman 1994; Hart and Southwood 2010). Although medical colic has been named as a frequent reason for veterinary attendance in practice (Traub-Dargatz and Salman 1991), there are no published reports of an incidence rate of recurrent colic and the occurrence within the UK leisure horse population is unknown.

A number of studies have shown that horses with a history of colic are more likely to suffer further episodes of both medical colic (Reeves *et al.* 1996; Tinker *et al.* 1997a; Hillyer *et al.* 2002) and/or particular types of surgical colic (Cohen *et al.* 1995, 1999; Cohen and Peloso 1996; Archer *et al.* 2008a,b). Furthermore, horses that have undergone exploratory laparotomy for colic are at increased risk of further colic episodes and post operative colic contributes negatively to post operative survival (French *et al.* 2002; Proudman *et al.* 2002; Mair and Smith 2005). However, there is a paucity of research investigating recurrent colic after nonsurgical episodes of colic. Cohort studies focused upon colic are few and, of those that report colic incidence, are representative of different horse populations including; horse farms in the USA (Tinker *et al.* 1997b; Traub-Dargatz *et al.* 2001), UK race yards (Hillyer *et al.* 2001) and army horses in Rio de Janeiro (Laranjeira *et al.* 2009). Almost a decade ago, Cohen (2003) noted that “*relatively little is known about these more common forms of colic* (referring to cases of colic managed in the field by equine practitioners in private practice) *including information about their incidence, predisposing factors, evaluation of treatments and responses, rates of recurrence and methods for prevention.*” Many of these questions still remain.

Only one study has identified risk factors specifically for recurrent or chronic intermittent colic. Cohen and Peloso (1996) reported risk factors in a population of Texas (USA) horses which included: age (>8 years), geldings, Arabian breed, recent change in diet, feeding of coastal grass hay, recent change in stabling, previous abdominal surgery, and farm density <0.5 horses/acre to be associated with recurrent or chronic intermittent colic. Exploration of risk factors for recurrent colic within the UK horse population is warranted.

The aims of this study were: 1) to determine the incidence of recurrent colic subsequent to an episode of medical colic among the veterinary-accessing general horse population in the UK; 2) to estimate the proportion of recurrent colic cases requiring surgery and deaths due to recurrent colic; and 3) to identify risk factors associated with recurrence. We hypothesised that management, the

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intrinsic behaviour of the horse and prophylactic health care may be factors influencing the risk of recurrent colic.

Materials and methods

Study design

A longitudinal cohort study was designed that enrolled horses subsequent to an episode of medical colic diagnosed and treated by a veterinary surgeon. Fifty-nine first opinion equine or mixed veterinary practices (identified from the 2006 RCVS register) in the northwest region of England were contacted to assist in recruitment.

All practices were sent a letter to introduce the study and then telephone contact was made in order to discuss participation and to identify veterinary surgeon and/or receptionist contacts. Each participating practice was sent a study stationery pack, containing material to advertise the study, prepaid reply postcards for owner consent and for the attending veterinary surgeon to record clinical details of the case. Informed consent was obtained prior to completion of a baseline questionnaire. To maintain continued participation in the study, fortnightly faxes were sent to each practice providing updates on case recruitment. In addition, the key contact within all participating practices was telephoned 4 times at intervals during the recruitment phase.

An estimated sample size was calculated using data from previous published reports of prevalence of recurrent colic (range 11–16% of horses having recurrent colic episode within one year, Kaneene *et al.* 1997; Tinker *et al.* 1997a; Hillyer *et al.* 2001; Traub-Dargatz *et al.* 2001) and data from the University of Liverpool first opinion equine practice. These sources suggested that approximately 20% of horses with colic would have a recurrence over the course of one year. Power calculations estimated that a cohort of 200 animals followed for 12 months, resulting in at least 40 cases of recurrence, would allow detection of an odds ratio of ≥ 2.5 for exposures of $\geq 20\%$ (with 80% power and 95% confidence). The aim was to recruit 250 horses to allow for loss to follow-up.

Participating practices were asked to identify any colic cases occurring between January and July 2008 that responded to medical therapy and did not require prolonged treatment including hospitalisation or surgery. Horses with a history of surgery for colic, those aged <6 months and mares with foals at foot were excluded from the study. Veterinary surgeons were requested to record their clinical examination findings for all recruited cases and rule out cases of false colic (e.g. laminitis).

The case definition of a recurrent colic episode was defined as an episode diagnosed by a veterinary surgeon or displaying behavioural signs of colic in the case of owner reported colic, on the proviso that the horse had been free from colic signs, eating a normal diet and passing normal faeces for a full 48 h since the end of the previous colic episode. This was a practical definition that owners could be asked to verify over the telephone. Where horses had a prolonged episode of colic with repeated visits from a veterinary surgeon on consecutive days this was classified as one episode of colic until the horse had fulfilled the above criteria.

Upon recruitment, owners completed an initial baseline telephone questionnaire and 3 follow-up telephone questionnaires at approximately 4 monthly intervals. Each horse was followed for 12 months from the date of recruitment. Participants were asked to notify the study team if their horse displayed any further colic signs

regardless of whether a veterinary surgeon attended. Clinical details of the recruitment episode and each subsequent colic episode were sought from any attending veterinary surgeon.

The baseline questionnaire collected data on the recruitment colic episode, case details and role/use of the horse, prophylactic medical care including vaccination, dentistry and anthelmintic schedule, diet, turnout and grazing, exercise routine and behaviour. Behaviour questions were similar to a previous study investigating risk factors for colic due to epiploic foramen entrapment (Archer *et al.* 2008a,b). Question formats included categorical choices with an 'other' option if required and Likert scales (where respondents were asked to select answers from a scale, e.g. never, rarely, sometimes, often, always, thereby producing ordinal [rank ordered] data). Open ended questions were kept to a minimum. The final questionnaire (available upon request from primary author) used in the study was designed using Teleform software to allow computer reading of completed questionnaires. The telephone questionnaire was piloted with horse owners within the faculty, including both vets and non-vets. Brief follow-up questionnaires captured change during the cohort study and whether there had been any further colic since the last telephone contact. A further questionnaire was completed whenever a participant reported a further episode of colic. This captured information about the colic episode, treatment and outcomes.

A horse was considered lost to follow-up if it was sold and the new owner did not wish to take part in the study or we were advised not to contact the new owner, or if the owners were not contactable (Table 1). In the case of surgery or death, details were obtained from the owner including the date and diagnosis. This was validated by obtaining clinical history from the referring veterinary practice or hospital.

Data analysis

Incidence rates were calculated by dividing all new episodes of colic in the cohort by the total contributed horse time at risk. The total horse time at risk was calculated by incorporating all the days from 2 days after enrolment (in accordance with our case definition) until the horse either had the event of interest (recurrence) or was censored (i.e. the horse had surgery for colic, died or was lost to follow-up). Horses that had a recurrent episode re-entered the population at risk 2 days after the conclusion of the recurrent colic episode.

Univariable and multivariable logistic regression analyses were conducted on all horses for which all 3 follow-up questionnaires were completed including those that had colic surgery or died during the cohort. Horses that were lost to follow-up were excluded

TABLE 1: Possible outcomes of horses on cohort

Possible outcome	Action
No further colic during study	Censored
Colic resolves without medication	Horse returns to population at risk 48 h after colic episode
Colic requires medical attention - clinical records obtained	Horse returns to population at risk 48 h after colic episode
Colic requires surgery	Surgical diagnosis and end of contribution to time at risk
Death/euthanasia after episode of colic	End of contribution to time at risk
Death from other causes	Censored
Drop out of cohort	Censored/loss to follow-up

from the analyses. The model explored non-time varying covariates and the risk of recurrence of colic episodes. All categorical items were tested using a Chi-squared test and confidence intervals for the odds ratios were computed. Where there were few observations a Fisher's exact test was used, or categories were combined if this made biological sense. Continuous variables were assessed for linearity using generalised additive models before incorporation into the model (Hastie and Tibshirani 1986).

To identify highly correlated variables, Spearman's correlation coefficients were used prior to building multivariable models. Multivariable logistic regression models were built using a backward elimination process including all variables $P < 0.2$ from univariable analysis. The final model was tested for goodness of fit using the Hosmer-Lemeshow test statistic and analysis of delta-betas for each of the covariates was performed and the model retested removing any outlying data points.

Results

Of the 59 practices approached, 42 were enrolled (71.2% response). Of these, 28 (66.7%) practices submitted colic cases to the study. A total of 147 colic episodes were notified of which 127 (86.4%) were recruited to the study. Table 2 shows the distribution of colic cases by month of recruitment. The median number of cases submitted per practice was 4 (range 1–15 cases). Four of the 28 practices (14.3%) submitted ≥ 10 colic cases to the study.

The 20 horses with colic excluded from the study were due to: death as a result of the initial colic episode ($n = 4$), previously undergone colic surgery ($n = 1$), the horse had gone on loan/been sold/moved away ($n = 3$), the owner was not contactable ($n = 3$), the owner did not wish to take part in the study ($n = 5$), the horse had not had colic ($n = 1$), other reasons ($n = 3$). From the initial 127 horse owners enrolled on the study, 112 (88.2%), 100 (78.7%) and 93 (73.2%) completed follow-up telephone questionnaires 1, 2 and 3, respectively (Fig 1).

Cohort demographics

Of the 127 horses in the cohort there were 64 (50.39%) mares, 60 (47.2%) geldings and 3 (2.4%) stallions. The median age was

TABLE 2: Distribution of month of recruitment of medical colic cases onto cohort

Month entered study (2008)	Number of horses recruited per month (% of 127)
January	27 (21.3)
February	42 (33.1)
March	24 (18.9)
April	16 (12.6)
May	10 (7.9)
June	4 (3.1)
July	4 (3.1)

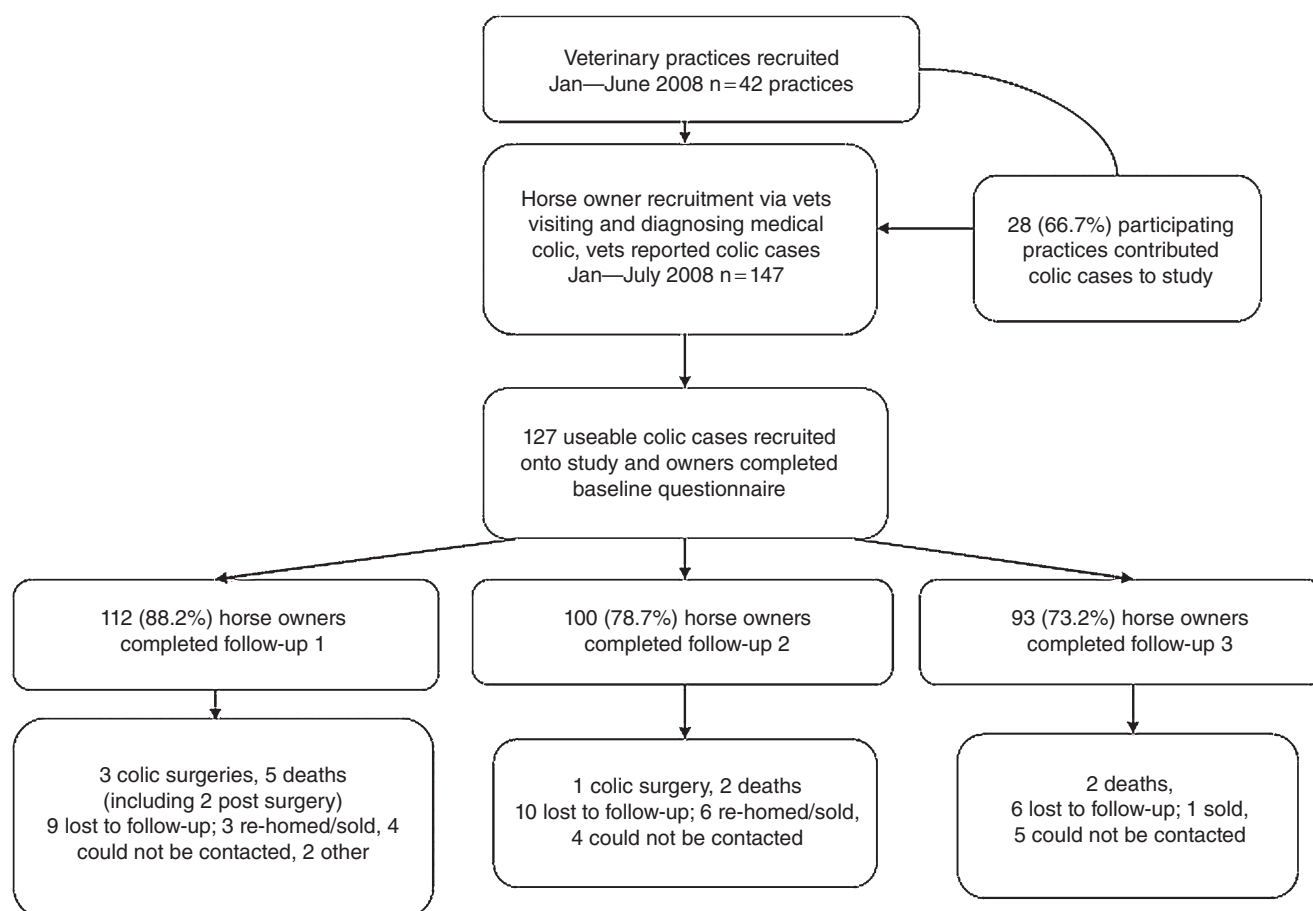


Fig 1: Flow chart of recruitment and retention within cohort.

11 years (range 0.75–41 years) and the median height of the population was 154.4 cm (range 40.6–175.8 cm). The median reported weight was 501 kg (range 95–900 kg); however, in many cases this was estimated (36.2% estimated, 12.6% weigh tape, 0.8% weigh bridge and 50.4% of respondents could not report weight). The person who owned the horse was also the main carer in 103 (81.1%) cases.

There were a variety of breeds within the cohort. Breeds were grouped into; Thoroughbred, Warmbloods (to include Trakehner, Hanoverian, Belgian and Oldenberg), Arabs, crossbred horses (Including Thoroughbred crosses and Warmblood crosses), Ponies, miniatures and crossbred ponies were grouped together (if <144 cm), cob (including purebred section D Welsh ponies >144 cm) and draught types (including pure Irish Draught) were grouped together, and an 'other' category was created (including Appaloosa and Knabstrupper).

Duration of ownership varied from one month to 25 years (median 3 years). Fifty-four (42.5%) horses were kept at the owners' home address. Of the remaining 73 horses, 40.9% were kept at livery, 0.8% racing yard, 1.6% stud, 11.8% other and 2.4% missing data. The number of horses kept on a premises ranged from 1–100 (median 11.5) with fewer horses tending to be kept on private premises and larger numbers at livery. Horse use spanned a wide range of equestrian disciplines; however the majority were pleasure horses used for leisure riding/hacking out (46.8%). Thirty-nine (31.4%) horses were classed as competition horses, which included national, regional and local competition, competition horses in training and amateur competition where they were used for competing most weekends and this was stated as the primary purpose of ownership. Other roles included breeding, young stock and competition horses not currently competing (e.g. injured) and 3 horses with no information on their use. Forty-four (34.6%) horses were insured at the start of the study.

Health and prophylaxis history

At the commencement of the cohort, 23 (18.1%) horses were being treated for a condition other than colic. This included arthritis (30.4%), current ligament injury (e.g. check ligament) and on box rest (17.4%), chronic musculoskeletal injury with ongoing care

(administration of nonsteroidal anti-inflammatory drugs and/or physiotherapy) (17.4%), recurrent airway obstruction (13.0%) chronic navicular syndrome (8.7%) and other miscellaneous conditions (13.0%). Thirty-four (26.8%) horses had a history of colic within the previous 12 months. One-hundred-and-twenty (94.5%) horses were reported to be up-to-date with vaccination, the majority being covered with both equine influenza and tetanus vaccinations (102, 80.3%). Of 110 (86.6%) horses having had their teeth checked, 60% were by an equine dentist and 40% by a veterinary surgeon. Teeth were reported to be examined by an equine dentist or veterinary surgeon more frequently than every 6 months (27.3%), every 6–12 months (31%), less frequently than every year (22.8%) and infrequently (>2 years) (7.3%) (11.6% missing data). Four owners reported that the teeth had only been checked once as they were new or young horses. Thirteen (10.2%) owners reported their horse had a known dental problem that their dentist or vet had alerted them to. Dental abnormalities included worn teeth interfering with the ability to chew food, one or more broken teeth, holes/gaps/diastemata, worn teeth from cribbing, overgrowth of molars/sharp hooks and conformational abnormalities, e.g. parrot mouth.

Description of recruitment colic episode

The most common colic signs observed by the owner were, getting up and down, lying down, rolling and flank watching (Table 3). Colic signs were reported to be constant (55.1%) or intermittent (42.5%) in nature. Owners considered the degree of pain to be mild (37.8% of cases), moderate (39.4%) or severe (21.3%) (1.5% missing).

In the 24 h prior to the colic episode, faeces were reportedly normal in 69.3% of cases, reduced in quantity (11%), firm (3.1%), absent (1.6%), diarrhoeic (4.7%) or unknown (10.2%). A change in management within the 24 h prior to the colic episode had been noted in 39.4% of cases. Owner reported changes ranged widely and included changes in diet such as a change in field, missed feeds (either owner forgot or horse was off feed), dietary indiscretions (e.g. eating sheep lick, holly hedge, wrong feed or spoiled feed given) and overgrazing leading to abdominal distension. Others reported a period of box rest or increased stabling, decreased water

TABLE 3: Frequency of colic signs in 127 horses reported by owners at recruitment colic episode and at recurrences (one or more colic signs may have been recorded)

Colic sign	At recruitment n (% of 127 horses)	Veterinary confirmed recurrence n (% of 42 horses)	Owner reported recurrence n (% of 17 horses)
Getting up and down	59 (46.5%)	7 (16.7%)	5 (29.4%)
Lying still	49 (38.6%)	15 (35.7%)	4 (23.5%)
Rolling	37 (29.1%)	8 (19.0%)	1 (5.9%)
Violent rolling (Chi-squared 0.037 but 2 expected counts <5)	0	6 (14.3%)	0
Flank watching	33 (26.0%)	11 (26.2%)	4 (23.5%)
Change in demeanour including quiet, not normal self, miserable and distressed	30 (23.6%)	6 (14.3%)	4 (23.5%)
Pawing	26 (20.5%)	11 (26.2%)	4 (23.5%)
Sweating	25 (19.7%)	3 (7.1%)	1 (5.9%)
Off food	23 (18.1%)	3 (7.1%)	1 (5.9%)
Kicking belly	16 (12.6%)	4 (9.5%)	4 (23.5%)
Box walking/pacing	10 (7.9%)	4 (9.5%)	2 (11.8%)
Vocalisation	9 (7.1%)	4 (9.5%)	0
Other including; rapid breathing, repeated stretching, irritable, flehmen/curling lip, not passing faeces, kicking, flatulence, rolling eyes.	58 (45.7%)	2 (4.8%)	1 (5.9%)

There was no significant difference when comparing recurrent colic episodes that had vs. those that had not been attended by a vet with respect to the colic signs they were showing.

TABLE 4: Veterinary reported clinical signs and treatment of recruitment colic episodes in 103 horses (24 cases where vet had submitted colic for study without clinical details)

Clinical sign	n (% of 103 horses)	Clinical sign	n (% of 103 horses)
Heart rate (beats/min)	Median 40 (range 28–80)	Rectal examination performed	63 (61.2%)
Respiratory rate (breaths/min)	Median 12 (range 8–40)	Normal	34 (33%)
Temperature (°C)	Mean 37.7 s.d. $\pm$ 0.4	Distended/gas filled colon	9 (8.7%)
Borborygmi	16 (15.5%)	Impaction	8 (7.8%)
Normal			
Increased	37 (35.9%)	Dry/firm faeces	6 (5.8%)
Absent	2 (1.9%)	Other (including palpable mass, displacement, taut taenial bands and pain)	6 (5.8%)
Reduced	17 (16.5%)	Nasogastric intubation	5 (4.9%)
Mixed	17 (16.5%)	Normal volume fluid	4 (3.9%)
Not reported	14 (13.6%)	Gaseous build up	1 (0.9%)
Medication		Clinical history 103 cases	
Buscopan		28 (27.2%)	
Nonsteroidal anti-inflammatory (NSAID) (phenylbutazone, flunixin, ketoprofen or meloxicam)		25 (24.3%)	
Buscopan plus NSAID combination		37 (35.9%)	
Buscopan plus combination of α_2 agonist, opioid and or NSAID		13 (12.6%)	
Fluids delivered via stomach tube		11 (10.7%)	
Liquid paraffin		2 (1.9%)	
Electrolytes		3 (2.9%)	
Combination of liquid paraffin, electrolytes and/or water		6 (5.8%)	

intake, change in faecal frequency or consistency, transportation, in season, change in bedding, increase in exercise or administering anthelmintics or noted the horse was not their normal self. A number of owners reported a sudden change in the weather as having preceded the colic, in particular cold conditions that led to frozen grazing ground and/or water troughs.

Veterinary assistance was sought in all the colic cases recruited at the start of the study and 126 (99.2%) were administered medical treatment (the exception being a mare in foal whose colic settled without medical management within one hour). Details of the clinical findings and treatment are in Table 4.

The majority of colic cases (48%) resolved within one hour of receiving treatment, 21.3% took >1 and ≤ 4 h, 7.9% >4 and ≤ 8 h, 8.7% >8 and ≤ 24 h, 6.3% >24 h to resolve and 7.8% showed continual colic signs with no period of resolution after initial treatment and therefore required a second veterinary visit. In total, it was necessary for a second veterinary visit (within 48 h) in 34 cases (26.8%). The reasons were: no response to medication (29.4%), initially responded but colic signs returned within 24 h (61.8%), return of colic signs between 24 and 48 h (5.9%) and worsening of colic signs (2.9%). Six cases (4.7%) required a third visit from a veterinary surgeon in order to achieve resolution.

Prevalence and incidence of colic

Of 104 horses that completed the cohort (i.e. owners completed all 3 follow-up questionnaires) there were a total of 54 recurrent colic episodes in 38 horses (36.5% prevalence) during the follow-up period (between January 2008 and July 31st 2009).

There were 43,291 contributing horse days (118.6 horse years) at risk in the entire cohort, with 59 episodes of recurrence occurring in 43 horses (individual horse contributing time: median 383 days, range 9–511 days). The incidence was 50 episodes of recurrence/100 horse years at risk (HYAR) or at horse level, 36 horses had at least one recurrence/100 HYAR. Figure 2 shows a Kaplan-Meier

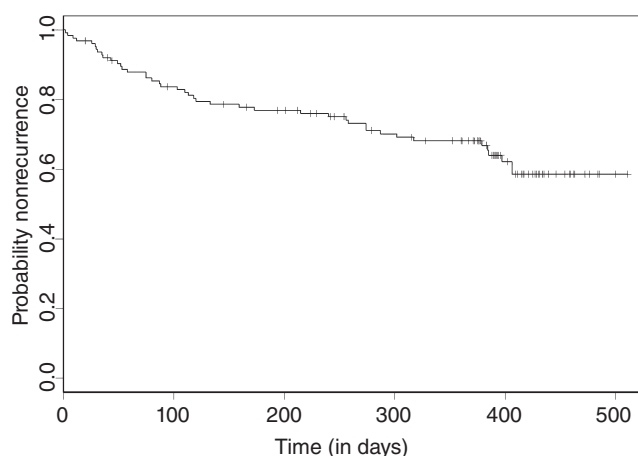


Fig 2: Kaplan-Meier plot of probability of recurrence of colic over time. Includes veterinary attended and owner reported colic.

(KM) survival plot of probability of time to first episode of recurrence.

Excluding owner reported colic episodes, there were 42 episodes of colic in 32 horses providing 43,325 horse days (118.7 horse years, individual horse contributing time median 383 days, range 9–511 days) at risk, giving an estimated incidence of 35 episodes of recurrence/100 HYAR or at horse level this is 27 horses with recurrence/100 HYAR.

Among the veterinary-visited colics, there were 4 (12.5%) horses that had surgery due to a recurrent episode of colic; these included 2 large colon torsions, 1 gastric impaction and 1 epiploic foramen entrapment colic, 2 of which resulted in euthanasia. All surgeries were therapeutic rather than elective procedures. A further 2 horses were subjected to euthanasia due to recurrent colic with no diagnosis obtained. Among all veterinary-visited and owner-reported recurrent colics, 10 (23.3%) horses had 2 or more episodes of recurrence during the cohort (including one horse with each of 3, 4 and 5 episodes).

Univariable and multivariable analysis

Univariable and multivariable analyses were conducted on 104 horses completing the cohort or where a known outcome (colic surgery or death) was recorded. These included 38 horses with at least one episode of recurrent colic. The outcome of interest was having at least one episode of recurrent colic during the cohort. A total of 16 variables had a P value < 0.2 and were used in multivariable model building (available in supplementary information). The final multivariable model is shown in Table 5. This showed that crib-biting/windsucking behaviour and having a known dental abnormality were associated with an increased risk of recurrence. The model showed satisfactory fit of the data and there were no correlated variables when tested using the Spearman-rho statistic or significant outliers identified within the delta-beta distribution.

Discussion

This study documents the high incidence of recurrent colic within the general equine population in the UK. Previously reported incidence rates for colic in general vary widely from 3.5–26 colic cases/100 HYAR (Uhlinger 1992; Kaneene *et al.* 1997; Tinker *et al.* 1997b; Hillyer *et al.* 2001; Traub-Dargatz *et al.* 2001). The majority of these estimates were from US horse populations with one study of UK racehorses in training (Hillyer *et al.* 2001) and as such may not represent the general UK horse population. The incidence for recurrent colic reported here is in the region of 5 times higher than those previously recorded for all colic episodes, and corroborates previously published evidence that has shown that horses with history of colic are at greater risk of further episodes of colic. Cohen *et al.* (1995, 1999) and Tinker *et al.* (1997a) reported that the risk of colic was 3.6–5.7 times higher in horses with a history of colic, estimates that are compatible with the findings of the current study. It is unknown whether some horses are prone to multiple recurrences and one potential bias was that veterinary surgeons would select horses they knew already suffered from recurrent colic. However, upon recruitment to this cohort, only a quarter of the horses had a history of colic in the past 12 months.

The KM plot of time to first recurrence showed a steeper decline around 380–400 days where there was a high frequency of recurrent episodes. As $> 50\%$ of horses (Table 2) were recruited during January and February this would correspond to the beginning of February 2009. Although no firm conclusions can be drawn about seasonality from this cohort as it was conducted over a one year cycle within each horse, this may suggest a seasonal component. Seasonality has been demonstrated in different types of colic including grass sickness, simple colonic obstruction and distension (SCOD) colic, and colic referrals to a veterinary teaching hospital (Archer *et al.* 2006). The pattern seen in this

study may have been due to particular types of colic although the aetiopathology of the majority of colic episodes within this cohort is unknown.

The proportion of recurrent colic episodes requiring surgery for colic (12.5%) was slightly higher than that reported by Proudman (1991), Hudson *et al.* (2001) and Mair (2004) who reported the prevalence of surgical lesions to be in the region of 7–9%. This may reflect the increased risk among the horses in this cohort that had previously had an episode of colic. The proportion of horses that died due to recurrent colic during the cohort (10.5%) is higher than reported by Hillyer *et al.* (2001) where, 5.9% of racehorses in training that were treated for medical colic had a fatal outcome. Kaneene *et al.* (1997) reported a higher fatality risk for nonsurgical colic of 10% among their cohort. However, in our study, it is difficult to conclude the exact cause of the colic signs leading to death as no *post mortem* examinations were carried out.

There is no standardised definition of recurrent colic and previous studies have defined recurrence categorised by time between episodes of colic. Cohen and Peloso (1996) distinguished 3 groups of chronic intermittent colic categorised by frequency of recurrence over defined time periods. Hillyer and Mair (1997) also divided cases into 3 groups by frequency in addition to duration of the recurrent colic episode. A study of colic among Thoroughbreds on training yards used a definition that horses must be free from behavioural signs of colic for 7 days before a further episode was distinguished and recorded as recurrence (Hillyer *et al.* 2001). Our case definition was designed to incorporate a set time period and behavioural indices, which we considered would be easily recognisable by owners but additionally, would potentially represent a return to normal physiological function of the gastrointestinal tract. We considered that normal faecal output and evidence of normal appetite for ≥ 48 h to be representative of this.

Multivariable modelling of risk factors for recurrence of colic suggests the presence of a known dental problem or crib-biting/windsucking were associated with an increased risk of recurrence. Although we have been able to detect risk factors with modest odds ratios, the confidence intervals are wide, which should be taken into consideration when interpreting these results. Additionally, the sample size may have resulted in some more subtle risk factors being omitted.

Horses that display crib-biting/windsucking behaviour were identified to be at increased risk of recurrent colic in the present study as reported in Table 5. The prevalence of this type of behaviour within the cohort (9.6%, $n = 10$) was greater than expected within the general population. McGreevy *et al.* (1995) reported a prevalence of cribbing of 6.3% in the general equine population and a cross-sectional study in America found that 4.4% of horses cribbed and the prevalence varied by breed (Albright *et al.* 2009). There is a growing body of evidence to suggest that horses that display crib-biting and windsucking behaviour are at

TABLE 5: Multivariable logistic regression model for recurrence of colic using data from 104 horses completing the cohort (including veterinary attended and owner reported recurrent colic) based on 90 observations

Variable	Category	No recurrence n (%)	Recurrence n (%)	Wald P value	Odds ratio	95% CI for odds ratio
Known dental problem	No	52 (65.8)	27 (34.2)	–	Ref	
	Yes	3 (27.3)	8 (72.7)	0.02	5.5	1.3–23.1
Crib-bites or windsucks	No	54 (65.1)	29 (34.9)	–	Ref	
	Yes	1 (14.3)	6 (85.7)	0.03	12.1	1.4–108.1

Hosmer-Lemeshow test statistic $P = 0.980$ -2 log likelihood = 107.05.

increased risk of developing specific types of colic (Hillyer *et al.* 2001; Archer *et al.* 2008a,b; Malamed *et al.* 2010). It has been hypothesised that this increase in risk may be due to underlying gastrointestinal dysfunction in these horses (Archer *et al.* 2008a,b). Alternatively, this behaviour may be a marker for management variables (such as diet and access to and time spent at pasture) and these, along with other time-varying covariates, are the subject of further analysis using the longitudinal data collected during this cohort.

The finding that a known dental problem could be associated with a risk of recurrent colic is consistent with other studies of colic including colic in donkeys (Cox *et al.* 2009; Du Toit *et al.* 2009) and SCOD colic in horses (Hillyer *et al.* 2002). Dental abnormalities that impair the normal mastication of a fibrous diet could lead to long fibre particles passing to distal portions of the gastrointestinal tract where they could predispose to impaction (Al Jassim and Andrews 2009). Alternatively, dietary imbalances resulting from inadequate mastication could, hypothetically, alter the nature of ingesta reaching the colon and may change the fermentation by colonic microbiota thereby encouraging overgrowth of particular microbial species leading to gaseous distention. Changes in microbiota and pH have previously been reported in response to a change in diet from hay to concentrate feed (Goodson *et al.* 1988; Shirazi-Beechey 2008) and could contribute to physiological alterations resulting in the development of some forms of colic.

We included owner-reported colic episodes in our incidence estimate and multivariable model and others have included operator-reported colic (Traub-Dargatz *et al.* 2001) after a period of training for recognising signs of colic. In the present study, this may have been a source of misclassification bias although this risk was minimised by requesting that behavioural signs of colic be reported in our questionnaire. There were 11 recurrences that the owners deemed did not require a veterinary visit (9 of these contributed to the data used to build the multivariable model). This may have been due to perceived familiarity with colic and hence an increased threshold until veterinary assistance was sought. The understanding of motivators to seek veterinary assistance, embark on clinical diagnostic investigation and owner adaptation of management factors among cases of recurrent colic are areas that require further research.

In common with other cohort studies of equine disease, the retention of horse owners on this study was good with only 13 (10.2%) participants lost for unknown reasons. Equine owners expressed a willingness and enthusiasm for taking part in colic research with many reporting that this was an issue of major concern to them. Telephone questionnaires were used to collect data and identify any nonreported colic episodes; direct contact with the researcher is thought to improve response rates compared with self-administered questionnaires (Siemiatycki 1979). Other studies involving long-term follow-up utilising telephone questionnaires to horse owners have reported similarly good retention (Proudman *et al.* 2002; Smith *et al.* 2007). The common denominator among these studies is that owners were recruited following a period of hospitalisation and surgery, hence participant involvement may be motivated by owners' understandable interest in the post operative recovery of their animal and the same incentives for participation are unlikely to be involved within our study. One nonhospital based study by Murray *et al.* (2006) contacted owners by post and then completed a questionnaire over the telephone with a response rate of 96.1%

response among case horses; this was achieved soon after the event of interest, which may influence the response rate.

The initial recruitment of horses via veterinary surgeons was slower than anticipated, resulting in a smaller sample size. Therefore, the time period for recruitment was extended within the capacities of the allotted study time and funding. Reported factors that hindered veterinary surgeons from recruiting cases included not wishing to introduce the topic of colic research whilst dealing with a colic case where the outcome was unknown, or owners were distressed, time pressures whilst in practice and the initial time of recruitment coinciding with a low occurrence of colic cases. Factors that encourage or deter equine veterinary practitioners involvement in research is an area that warrants further exploration in order to improve integration of clinical research and practice and beneficially utilise clinical data resources.

Conclusions

Recurrent colic is a high incidence condition among the UK general horse population and highlights a considerable welfare issue. Horses that display crib-biting/windsucking or have a known dental problem are at increased risk of recurrent colic. Knowledge of these factors is a first step towards understanding the mechanisms involved and the implementation of effective intervention strategies.

Conflicts of interest

No conflicts of interest have been declared.

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