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Normal and clinical haematology in the yak (*Bos grunniens*)

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Haematological examinations have been carried out on 21 clinically normal male and female adult yaks (*Bos grunniens*). Animals sedated with xylazine had significantly lower red cell counts, haemoglobin levels and packed cell volumes, fewer lymphocytes and higher monocyte counts than those bled while manually restrained. There were few significant sex differences. Several animals had eosinophilia associated with asymptomatic intestinal nematode infection. Haematological reference values were calculated for clinically normal, xylazine sedated and manually restrained yaks. These were used to identify haematological changes in 10 animals with various abnormal clinical signs. It was concluded that blood counts can provide valuable diagnostic information in this species.

ALTHOUGH clinical haematology is potentially a valuable diagnostic aid in the veterinary care of exotic animals, interpretation of results in sick animals is often difficult because reference values are not available for many species and information is lacking about the effects of physiological, environmental and induced variables on their blood. This paper reports the results of haematological studies on a group of yaks (*Bos grunniens*) maintained at Whipsnade Park by the Zoological Society of London. The group included both clinically normal and sick animals. The findings have been used to establish haematological reference values for adult yaks and to demonstrate that sedation with xylazine produces a marked effect on their blood count. On the basis of these observations, a preliminary analysis of changes in the blood count related to clinical diagnosis in sick yaks has been made.

Materials and methods

The yaks were kept as a group on permanent pasture with access to shelter. They shared the paddock with Bactrian camels (*Camelus bactrianus*). Meadow hay and a mixture of oats, wheat bran, flaked maize and dairy cubes were fed to the animals during the winter.

Blood counts were carried out on 29 individuals, many of which were tested on more than one occasion. All animals received a full clinical examination at the time of sampling. The group included both clinically normal and sick animals. Details of the animals studied and the number of tests carried out are given in the results section below. For collection of blood, all normal adult males and some adult females were sedated by intramuscular injection of xylazine (Rompun; Bayer, 0·5 to 1·5 mg/kg). Some normal adult females and most sick animals were manually restrained. Blood was obtained from a jugular vein using disposable needles and disposable plastic syringes and mixed with the dipotassium salt of ethylene diamine tetraacetic acid (EDTA), 1·75 mg/ml of blood. Haematological examinations were carried out as described by Dacie and Lewis (1975) and Hawkey et al (1982).

Statistical analysis

For comparison of results in the two groups, the *t* statistic for two means was calculated. Reference values are expressed as the mean and the range ± twice the standard deviation (SD).

Results

Comparison of findings in sedated and manually restrained adult female yaks

In a group of 12 clinically normal adult female yaks, 12 blood examinations were carried out on nine individuals under sedation with xylazine and 19 examinations on seven individuals restrained manually. Four individuals were tested under both circumstances. Comparison of the results from sedated animals with those from unsedated animals showed significantly lower red cell counts, haemoglobin levels, packed cell volume and lymphocyte values and higher monocyte counts in the sedated group (Table 1). Individuals tested both with and without sedation showed similar differences (Table 2).

TABLE 1: Significant differences in haematological findings in xylazine sedated and manually restrained adult female yaks

	Sedated				Manually restrained				
Test	Number of animals	Number of tests	Av	SD	Number of animals	Number of tests	Av	SD	P
Hb g/dl	9	12	11·0	1·1	7	19	13·7	1·7	0·05
RBC × 10^{12}/litre	9	12	5·3	0·6	7	19	6·4	0·9	<0·05
PCV litre/litre	9	12	0·30	0·03	7	19	0·38	0·04	<0·005
Lymphs × 10^{9}/litre	9	12	2·58	0·64	7	19	3·42	0·94	<0·1
Monos %	9	12	1·3		7	19	0·4		<0·1

Hb Haemoglobin
RBC Red blood cells
PCV Packed cell volume

TABLE 2: Differences in blood counts on individuals tested with and without sedation

		Sedation		No sedation	
Animal	Test	Number of counts	Result	Number of counts	Result
CW 184	Hb	2	10·4-11·2	1	14·5
	RBC	2	5·6-6·0	1	7·0
	PCV	2	0·30-0·32	1	0·38
CW 233	Hb	1	11·3	3	12·6-15·1
	RBC	1	6·0	3	6·1-7·1
	PCV	1	0·32	3	0·34-0·40
	Lymphs	1	2·91	3	4·02-4·94
CW 234	Hb	2	9·0-11·0	4	12·1-16·0
	RBC	2	4·5-5·1	4	6·0-6·7
	PCV	2	0·25-0·32	4	0·33-0·44
CW 116	Hb	2	12·0-12·9	1	16·0
	RBC	2	5·2-6·0	1	6·9
	PCV	2	0·31-0·35	1	0·43

Hb g/dl; RBC × 10^{12}/litre; PCV litre/litre; lymphocytes × 10^{9}/litre

Comparison of results in sedated adult male and female yaks

The results of 13 blood examinations on nine clinically normal adult male yaks sedated with xylazine were compared with those from the group of similarly sedated adult females described in the previous section. Males had a lower mean cell haemoglobin and erythrocyte sedimentation rate and fewer basophils than females (Table 2). No other significant differences were detected. These findings suggest that, when sedation effects are taken into account, there are few sex-related differences in the blood count of adult yaks.

Haematological reference values for sedated and manually restrained yaks

Reference values for adult yaks sedated with xylazine are given in Table 3. Where no significant sex difference was found, results on males and females have been combined. As already noted, these reference values are not valid for manually restrained animals. Reference values for manually restrained adult female yaks are shown in Table 4. Since few sex differences were found in sedated yaks, these are probably also valid for manually restrained males.

Clinical cases

Blood counts were carried out for diagnostic purposes on 10 yaks with signs of clinical disease. Details of these cases are given in Table 5. Most of the animals were in a weak state and were bled without sedation. In these cases, results from both adult males and females were assessed by comparison with the reference values for manually restrained adult females given in Table 4. For two adults sedated with xylazine, reference values given in Table 3 were used. No reference values were available for the two sick juvenile animals examined.

The most common clinical sign in the group was diarrhoea, which was present in six animals (cases 1 to 6). One of these was a juvenile (case 6) which may have had lymphocytosis. Neutrophilia was present in all five adult animals with diarrhoea; the neutrophils showed toxic granulation and Döhle bodies in one of

TABLE 3: Haematological reference values for adult yaks sedated with xylazine

Test	Group	Number	Av	SD	± 2 × SD (observed range)
Hb g/dl	M&F	18	10·9	0·9	9·0-13·1
RBC × 10^{12}/litre	M&F	18	5·4	0·66	4·1-6·5
PCV litre/litre	M&F	18	0·31	0·04	0·24-0·38
MCV fl	M&F	18	57·1	3·0	51·1-63·1
MCH pg	M	9	19·4*	1·7	16·0-22·8
	F	9	21·2*	1·6	18·0-24·4
MCHC g/dl	M&F	18	36·1	1·7	32·7-39·5
Retics % RBC	M&F	18	0·01		(0-0·1)
ESR mm in 1 hour	M	8	1·3**		(0-3)
	F	7	7·7**		(0-21)
WBC × 10^9/litre	M&F	18	5·8	1·6	2·6-9·1
Neutros %	M&F	18	45	9·6	26-65
Neutros × 10^9/litre		18	2·44	0·63	1·8-3·70
Lymphs %	M&F	18	41	8·4	24-58
Lymphs × 10^9/litre		18	2·13	0·54	1·05-3·21
Monos %	M&F	18	1·7		(0-3)
Monos × 10^9/litre		18	0·05		(0-0·15)
Eos %	M&F	18	13		(5-24)
Eos × 10^9/litre		18	0·76		(0·22-1·73)
Basos %	M	9	0·18*		(0-3)
	F	9	0·9*		(0-3)
Basos × 10^9/litre	M	9	0·04*		(0-0·14)
	F	9	0·06*		(0-0·19)
Platelets × 10^9/litre	M&F	14	250	57	136-364

* P<0·1; ** P<0·05
MCV Mean corpuscular volume
MCH Mean corpuscular haemoglobin
MCHC Mean corpuscular haemoglobin concentration

these cases and an increased number of immature forms (a left shift) in another. These findings are consistent with bacterial infection but direct evidence of this was not available in all cases (Table 5). The findings of transient lymphocytosis in case 4 may be significant since, like the juvenile with possible lymphocytosis, coronaviruses were isolated from the faeces. Eosinophils were absent or reduced in four animals, three of which had intestinal parasites. Slight monocytosis and abnormally high fibrinogen levels were found in two cases and two had marginally raised platelet counts. In one of these (case 4), the platelet count subsequently became subnormal, possibly reflecting low grade consumption coagulopathy. In three cases, evidence of microcytic anaemia was present.

TABLE 4: Haematological reference values for manually restrained adult female yaks

Test	Number	Av	SD	± 2 × SD (observed range)
Hb g/dl	7	13·7	1·7	10·3-17·1
RBC × 10^{12}/litre	7	6·4	0·9	4·6-8·2
PCV litre/litre	7	0·38	0·04	0·30-0·46
MCV fl	7	58·0	4·9	48·2-67·8
MCH pg	7	21·0	2·2	16·6-25·4
MCHC g/dl	7	36·3	1·5	33·3-39·3
Retics % RBC	7	0·05		(0-0·2)
ESR mm in 1 hour	6	0·4		(0-3)
WBC × 10^9/litre	7	6·6	1·2	4·2-9·0
Neutros %	7	42	12	18-66
Neutros × 10^9/litre		2·53	0·99	0·55-4·51
Lymphs %	7	46	10	18-66
Lymphs × 10^9/litre		3·42	0·94	1·54-5·30
Monos %	7	0·4		(0-2)
Monos × 10^9/litre		0·03		(0-0·15)
Eos %	7	10·7		(1-21)
Eos × 10^9/litre		0·78		(0·29-1·68)
Basos %	7	0·5		(0-3)
Basos × 10^9/litre		0·04		(0-0·23)
Platelets × 10^9/litre	6	251	47	157-345

Of the four remaining clinical cases (7 to 10) an adult female which died with ruminal stasis and metabolic acidosis of unknown origin (case 7) had white cell and platelet abnormalities indicative of bacterial infection although pathogenic organisms were not isolated. Another adult female (case 10) was studied on two occasions, once when it had metritis when no definite haematological abnormality was found and two years later when it had a bacterial infection of the vagina. On this occasion neutrophilia, a raised platelet count and high fibrinogen levels were consistent with the diagnosis. Eosinophilia, anaemia and a raised fibrinogen level were present in an adult male (case 9) with a heavy louse infestation in which polyuria and polydypsia were observed. A juvenile suffering from anorexia and weight loss of unknown aetiology apparently had neutropenia.

TABLE 5: Haematological abnormalities in sick yaks

Case number	Age/sex	Clinical signs	Haematological abnormalities (units as in Table 4)	Comments
1	Adult M	4.3.77: Diarrhoea 3 days (no sedation)	Neutros 4·70↑	
		8.3.77: Collapse (no sedation)	Neutros 5·10↑, left shift, no eos seen. PCV 0·29↓. Fibrinogen not measured	Euthanasia. Ulceration of fundic region of abomasum. *Sarcocystitis* sp and nematodes found
2	Adult M	Marked weight loss, chronic diarrhoea, unable to stand. Heavy *Damalina bovis* infestation. (No sedation)	WBC 12·3↑, neutros 8·12↑. No eos seen. Platelets 406↑, Fibrinogen 6·2↑	Euthanasia. Heavy infestation *Ostertagia ostertagi* in abomasum, intestine, caecum. Enterovirus isolated from faeces
3	Adult F	Diarrhoea 5 days. Very weak (no sedation). Long history of intermittent partial paraplegia and hind leg ataxia	WBC 13·8↑, neutros 10·63↑, toxic granulation. Döhle bodies. Monos 0·27↑, no eos seen. Fibrinogen not measured	Euthanasia. No neurological abnormalities detected. *Strongyloides* sp ova in faeces. No pathogenic bacteria
4	Adult F	19.6.78: Marked weight loss. Diarrhoea. Pregnant. (No sedation)	Platelets 365↑, neutros↑, MCV↓, MCH↓, compared with previous findings	*Strongyloides* sp and *Trichomonas* sp ova and coronavirus isolated from faeces
5	Adult F	New arrival. Diarrhoea. (No sedation)	WBC 15·0↑, neutros 9·90↑, monos 0·75↑	
6	2 months M	Weight loss. Diarrhoea. (No sedation)	No reference values available for age group. Lymphs 6·54, probably↑. Fibrinogen not measured	*Strongyloides* sp, *Trichuris* sp ova and coronavirus isolated from faeces
7	Adult F	Weight loss. Anorexia. Ruminal stasis. Nasal discharge. Alopecia. Pregnant. (No sedation)	WBC 14·7↑, neutros 10·73↑, left shift. Monos 0·44↑, platelets 368↑. Fibrinogen not measured	Died. Ruminal stasis and metabolic acidosis, cause unknown. No pathogenic bacteria isolated. Nematode ova in faeces
8	4 months F	Anorexia, weight loss. (No sedation)	No reference values available for age group. Neutros 0·50, probably↓	Euthanasia. Cause of debility not found
9	Adult M	Poor condition. Polyuria, polydypsia. Eye abnormality, probably congenital. (Sedated with xylazine)	Hb 9·5↓, PCV 0·26↓, eos 1·66↑. Fibrinogen 5·8↑	No protein, sugar or blood in urine. Heavy louse infestation. Euthanasia
10	3 year F	Calved 3 weeks ago. Metritis caused by retained placenta. (No sedation)	Fibrinogen↑compared with previous finding	Recovered on antibiotic treatment
	5 year F	Vaginal discharge. (Sedated with xylazine)	Hb 7·8↓, PCV 0·20↓, MCV 45·7↓, MCH 16·2↓, neutros 4·51↑, platelets 399↑, fibrinogen 8·0↑	

↑ Denotes increase above normal values; ↓ denotes lower than normal values

Discussion

The total number of yaks available for this study was small and, when subdivided according to age, sex, clinical state and conditions of sampling (ie, sedated or manually restrained) the number in each group was rarely large enough to permit valid statistical analysis of the results. This is a common problem with studies on exotic species and it is often necessary to make the best possible use of the few results which are available. Our calculated reference values for adult yaks are comparable with results from a single yak reported by Schalm et al (1975) and are in general agreement with those of domestic cattle and other related species (Table 6). Their validity is strongly supported by the finding of one or more haematological values falling outside the reference limits in all but one of the clinical cases examined. Unfortunately reference values are not yet available for juvenile yaks, but age related differences, as seen in domestic cattle (Schalm et al 1975) are predictable from the few juveniles so far studied but not reported in this paper. Until these are fully defined, haematological findings on juvenile yaks with abnormal clinical signs cannot be fully assessed.

The demonstration that erythrocytes, haemoglobin and packed cell volume values are higher in manually restrained than in xylazine sedated yaks is important although not unexpected since similar observations have been made in other species of Artiodactyla including domestic cattle (Goranov et al 1971), white-tailed deer (Presidente et al 1973), impala and eland

TABLE 6: Haematological values reported for various species of Bovini

Species	Yak (*Bos grunniens*)	Domestic cattle (*Bos taurus*)	Ankole cattle (*Bos taurus*)	Zebu cattle (*Bos indicus*)	Buffalo (*Bubalus bubalis*)	
Number	1	Collected results	30	40		
Age/sex	Adult M	Adult M&F	Adult M&F	Adult F	Adult	Adult
Sedation	?	?	No	No	?	?
Hb g/dl	12·8	11·0 (8·0-15·0)	7·7 ± 1·13	9·0 ± 1·5	10·3 ± 0·76	12·3 ± 1·1
RBC × 10^{12}/litre	6·2	7·0 (5·0-10·0)	5·1 ± 0·82	6·2 ± 0·94	5·13 ± 0·18	5·8 ± 1·1
PCV litre/litre	0·36	0·35 (0·24-0·46)	0·31 ± 0·05	0·33 ± 0·05	0·36 ± 0·02	0·32 ± 0·03
MCV fl	58·0	52 (40-60)	55·6 ± 8·9	53·2 ± 6·3	70·1*	55·1*
MCH pg	20·6	14 (11-17)	14·2 ± 2·05	14·6 ± 2·1	20·1*	21·2*
MCHC g/dl	35·6	32·5 (30·0-36·0)	25·3 ± 3·1	27·2 ± 1·8	28·6*	38·4*
ESR mm in 1 hour		0	–		98 ± 36†	26 ± 24
WBC × 10^9/litre	4·5	8·0 (4·0-12·0)	–	11·2 ± 2·4	11·3 ± 1·3	8·3 ± 1·8
Neutros %	67	29 (15-47)	–	31	33·0 ± 5·7	40·0 ± 7·4
Lymphs %	23	58 (45-57)	–	30	54·0 ± 9·3	51·0 ± 5·6
Monos %	3	4 (2-7)	–	6·0 ± 3·6	6·0 ± 2·2	1·0 ± 0·3
Eos %	7	9 (2·20)	–	13·0 ± 5·1	6·0 ± 2·8	8·5 ± 5·7
Basos %	0	0·5 (0·2)	–	rare	1·4 ± 0·8	0·3 ± 0·5
Reference	Schalm et al (1975)	Schalm et al (1975)	Smith (1959a)	Smith (1959b)	Sharma et al (1973)	Bokori (1974)

* Calculated from published findings
† Westergren method

(Drevemo and Karstad 1974), Bactrian camels (Custer et al 1977) and sheep (Hawkey et al 1980). These differences are thought to be due to the opposing effects of stress and sedation on the spleen and are predictable on all occasions when sedatives with adrenolytic properties are given to animals in which the spleen is an important storage organ for red cells. In conscious animals, catecholamines produced in response to stress situations, such as manual restraint, cause the spleen to contract and the red cells stored in it are released into the circulation, producing an increase in red cells, haemoglobin and packed cell volume values. Sedative drugs with adrenolytic properties, such as xylazine, reverse the effect of stress on the spleen, leading to its relaxation and re-uptake of red cells with a consequent fall in red cells, haemoglobin and packed cell volume. The impact that this reaction can have on the red cell count is illustrated by the fact that in sheep, for example, the spleen can hold as much as 25 per cent of the total circulating red cells (Turner and Hodgetts 1959). In these animals, therefore, red cell counts can vary between wide limits and it is essential to take account of the conditions under which blood samples are obtained when calculating reference values and when interpreting findings in sick individuals. If this had not been done with the present group of yaks, it might have been falsely concluded that adult males normally have lower red cell values than females and that anaemia was uncommon in sick animals.

Normal adult yaks had fewer lymphocytes than related species (Table 6) and the total white cell count was lower. Leucocytosis was found in five of the 10 clinical cases studied but on no occasion did the total white cell count exceed 15×10^9 per litre. It appears therefore that in yaks, as in domestic cattle, the white cell response to infection is not very great (Schalm et al 1975). Neutrophilia was recorded in seven cases. These included five out of six animals with diarrhoea and one female with a vaginal infection of bacterial origin, suggesting that neutrophilia is more reliable than leucocytosis as an indicator of infection. In domestic cattle, morphological changes in the neutrophils have been shown to provide useful diagnostic information (Schalm et al 1975) but in our series of yaks, neutrophil morphology varied in normal animals and was considered abnormal in only two of the clinical cases examined. The most signifi-

cant of these was the presence of toxic granulation and Döhle bodies in the neutrophils of case 3. A lymphocytic reaction to viral infections is suggested by the finding of lymphocytosis in an adult and possibly also a juvenile in which coronaviruses were isolated from the faeces.

It will be noted that eosinophilia was a common finding in many of the clinically normal animals examined. This is probably related to asymptomatic intestinal nematode infections which persisted in the group despite regular prophylactic treatment. This finding is apparently not unusual in bovine animals. In contrast, eosinophilia was rarely found in sick yaks; in four animals with diarrhoea, eosinophils were absent or reduced in number despite the proven presence of parasites in three of the cases. These animals had not been treated with corticosteroids or ACTH and their eosinopenia was probably induced by intrinsic corticosteroid production associated with infection (Schalm et al 1975). In cattle, this reaction prevails even when conditions causing eosinophilia are present (Morgan and Beeson 1971). Eosinopenia may therefore be a useful diagnostic sign in individuals from groups where chronic parasitic infections are evident.

There is much species variation in the erythrocyte sedimentation rate of normal bovine animals (Sharma et al 1973, Hawkey 1975) and the test is not generally thought to give useful diagnostic information in these animals. The different erythrocyte sedimentation rate values shown by sedated and unsedated yaks reported here probably reflect differences in packed cell volume. In only one clinical case was the erythrocyte sedimentation rate marginally raised. In many species, measurement of fibrinogen has been shown to be a useful alternative to the erythrocyte sedimentation rate (McSherry et al 1970, Schalm et al 1975, Campbell et al 1981, Hawkey et al 1982) and, although it has not been measured in all the animals in our series, the finding of higher than normal fibrinogen levels in three out of six clinical cases tested gives an indication of its potential diagnostic value in yaks.

Clearly, more information is required about effects of physiological, environmental and induced variables on the blood count of yaks. However, the findings reported in this paper illustrate the fact that useful reference values can be obtained from the study of a small number of animals providing that they are shown to be clinically normal at the time of sampling and providing that the effects of stress and sedation on the circulating blood are taken into account. In the case of yaks, availability of these reference values has allowed us to begin to define changes taking place in the blood in response to disease. Preliminary findings indicate that clinical haematology will prove to be a valuable diagnostic aid in this species.

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References

BOKORI, J. (1974) *Acta veterinaria Academiae-scientarum hungaricae* **24,** 73–76

CAMPBELL, M. D., BELLAMY, J. E. C. & SEARCY, G. P. (1981) *American Journal of Veterinary Research* **42,** 100–103

CUSTER, R., KRAMER, L., KENNEDY, S. & BUSH, M. (1977) *Journal of the American Veterinary Medical Association* **171,** 899–901

DACIE, J. V. & LEWIS, S. M. (1975) Practical Haematology, 5th edn. London, Churchill Livingstone

DREVEMO, S. & KARSTAD, L. (1974) *Journal of Wildlife Diseases* **10,** 377–383

GORANOV, S., NEJTSCHEV, O. & KOITSCHEV, K. (1971) *Deutsche tierärztliche Wochenschrift* **78,** 485–489

HAWKEY, C. M. (1975) Comparative Mammalian Haematology. London, William Heinemann

HAWKEY, C. M., FRANKEL, T., JONES, D. M., ASHTON, D. G., NEVILL, G. F., HART, M. G., ALDERSON, C. & BIRCHER, P. (1980) The Comparative Pathology of Zoo Animals. Eds R. J. Montali and G. Migaki. Washington, DC, Smithsonian Institution Press. pp 625–632

HAWKEY, C. M., HART, M. G. & JONES, D. M. (1982) *American Journal of Primatology.* In press

McSHERRY, B. J., HORNEY, F. D. & DE GROOT, J. J. (1970) *Canadian Journal of Comparative Medicine* **34,** 191–197

MORGAN, J. E. & BEESON, P. B. (1971) *British Journal of Experimental Pathology* **52,** 214–221

PRESIDENTE, P. J. A., LUMSDEN, J. H., PRESNELL, K. R., RAPLEY, W. A. & McGRAW, B. M. (1973) *Journal of Wildlife Diseases* **9,** 342–348

SCHALM, O. W., JAIN, N. C. & CARROLL, E. J. (1975) Veterinary Haematology, 3rd edn. Philadelphia, Lea & Febiger

SHARMA, D. P., MALIK, P. D. & SAPRA, K. L. (1973) *Indian Journal of Animal Science* **43,** 289–295

SMITH, I. M. (1959a) *British Veterinary Journal* **115,** 27–30

SMITH, I. M. (1959b) *British Veterinary Journal* **115,** 89–96

TURNER, A. W. & HODGETTS, V. E. (1959) *Australian Journal of Experimental Biology* **33,** 399–420