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The haematological values of European badgers (*Meles meles*) in health and in the course of tuberculosis infection

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SUMMARY

Captive, healthy, adult badgers have blood containing haemoglobin at 13·3 g/dl, and $8{\cdot}4 \times 10^{12}$/l red cells with an MCV of 46·2 fl and an MCH of 15·6 pg. They have $5{\cdot}1 \times 10^{9}$ white cells/l of which $3{\cdot}29 \times 10^{9}$ are polymorphs, $1{\cdot}49 \times 10^{9}$ are lymphocytes, $0{\cdot}26 \times 10^{9}$ are monocytes, $0{\cdot}07 \times 10^{9}$ are eosinophils and $0{\cdot}01 \times 10^{9}$ are basophils. These values are somewhat less in adult animals just trapped from the wild, and are lower still in wild cubs.

Changes associated with tuberculosis are a rise, and then a fall in red blood count and white blood count, an increase in the proportion of polymorphs and monocytes and a fall in lymphocytes late in the disease. This picture is similar to that seen in widespread, disseminated, tuberculin negative, tuberculosis in humans, a type of disease similar to that occurring in many badgers.

BCG vaccination of badgers did not produce any measurable change in the blood picture.

INTRODUCTION

No detailed account has been published previously of the haematological values of the European badger (*Meles meles*), although data is available for the family Mustelidae (Hawkey, 1975). There has been a recent increase in interest in the badger in relation to its possible role in the transmission of bovine tuberculosis in Great Britain and the particular aspects of the disease that it manifests.

We describe here the haematological values in apparently healthy (non-tuberculous) wild adult and cub badgers as well as for those held in captivity for 3–12 months before experimental infection with virulent bovine tubercle bacilli or vaccination with BCG.

MATERIALS AND METHODS

Two different groups of wild badgers were live-trapped in Staffordshire and East-Sussex where tuberculosis has existed in both cattle and badgers for many

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years (Mahmood *et al.* 1987*a*). These animals were examined clinically and bacteriologically, bled for haematological and immunological examinations, killed and subjected to detailed post-mortem examination as described by Pritchard *et al.* (1986).

Captive badgers were live-trapped in areas of southern England where cattle had been free from tuberculosis for many years, and there was no evidence of tuberculosis in badgers submitted by the public (MAFF, 1986). Under Ketamine anaesthesia, all animals were examined clinically, blood was taken for haematological and immunological examination, and samples were obtained for bacteriological culture and guinea-pig inoculation. This was carried out soon after capture and at intervals during their captivity before and after BCG vaccination or challenge with bovine tubercle bacilli.

Eight non-vaccinated badgers were challenged either intradermally or intratracheally with bovine tubercle bacilli. The latter route failed to lead to disease (Pritchard *et al.* 1987; Mahmood *et al.* 1987*b*).

The measurement of white cells (WBC, $\times 10^9$/l), red cells (RBC, $\times 10^9$/l) haemoglobin (Hb, g/dl), packed cell volume or haematocrit (Hct), mean cell volume (MCV, fl) mean corpuscular haemoglobin (MCH, pg/cell), mean corpuscutar haemoglobin concentration (MCHC, g/dl), and platelets (PLT, $\times 10^9$/l) were carried out in a Coulter counter (S plus IV, Coulter Electronics, USA). Conventional wedge peripheral blood smears were stained by the Romanowsky method and examined for differential white cell count and appearances according to Dacie & Lewis (1986). Student's t test was used to analyse the results throughout the study.

RESULTS

Results obtained for 26 healthy, wild, adult animals are shown in Table 1. The RBC, Hb and Hct values in boars are significantly higher than in sows ($P < 0{\cdot}025$, $< 0{\cdot}01$, and $< 0{\cdot}01$, respectively). The results for nine cubs are shown in Table 2; amongst them the RBC, Hb and Hct are all higher in the females. There is a distinct tendency for all the haematological values to be higher in the adults than in the cubs.

Table 3 shows the results obtained in 26 captive adults. There are no significant differences between sows and boars, and all the results are similar to those obtained from healthy wild adult male badgers (Table 1).

The effects of BCG vaccination

No significant differences were found between the 10 vaccinated and 7 control animals throughout the experiment. However, during its progress, small seasonal variations occurred in MCV with compensatory RBC changes (data not shown).

The effects of tuberculosis

In wild badgers there is a slight, but not statistically significant, tendency for the tuberculous adults and cubs to show a reduction in both red and white cell counts and in Hb, without change in MHC (Table 1 and 2). The reduction in WBC does not appear to be due to a fall in any particular cell type.

After experimental intradermal infection the four animals had haematological

Table 1. *The results of haematological examination of blood obtained from wild badgers*

	Healthy						Tuberculous Both sexes Total ($n = 9$)	
	Males ($n = 9$)		Females ($n = 17$)		Total ($n = 26$)			
Criteria	Mean	Range	Mean	Range	Mean	Range	Mean	Range
WBC ($\times 10^9$/l)	5·8	4–8·5	7·0	4–15·1	6·6	4–15·1	5·3	3·8–7
RBC ($\times 10^{12}$/l)	7·8	6·3–9·1	6·7	4·7–8·8	7·1	4·7–9·1	6·5	4·6–7·1
Hb(g/dl)	12·4	10·3–14·7	10·6	7·2–13·5	11·2	7·2–14·7	10·3	7·1–13·3
Hct(ratio)	0·356	0·283–0·417	0·304	0·210–0·386	0·322	0·210–0·417	0·295	0·209–0·383
MCV (fl)	46·1	44·7–48	46·6	44–57·8	46·4	44–57·8	45·5	45–47
MCH (pg)	15·9	15·1–16·6	16	14·9–20·6	16	14·9–20·6	15·8	15·1–16·4
MCHC(g/dl)	34·9	33·2–36·5	34·7	33–36·9	34·8	33–36·9	34·7	33·1–35·9
PLT ($\times 10^9$/l)	N.D.	—	463	292–580	—	—	432	394–473
Polys	4·1	2·5–7·1	5·2	2·67–13·7	4·8	2·5–13·7	3·77	2·92–5
Lymphs	1·29	0·51–2·24	1·22	0·23–3·84	1·24	0·23–3·84	1·01	0·34–2·27
Monos	0·39	0·03–1·96	0·34	0·08–0·83	0·37	0·03–1·96	0·26	0·06–0·46
Eos	0·07	0–0·42	0·11	0–0·54	0·09	0–0·54	0·05	00·12
Basos	0	—	0	—	0	—	0	—

Table 2. *The results of haematological examination of blood from wild badger cubs*

	Healthy						Tuberculous Both sexes Total ($n = 2$)	
	Males ($n = 5$)		Females ($n = 4$)		Total ($n = 9$)			
Criteria	Mean	Range	Mean	Range	Mean	Range	Mean	Range
WBC ($\times 10^9$/l)	5·6	4·6–6·5	4·7	2·6–5·5	5·2	2·6–6·5	4·8	4·7–4·8
RBC ($\times 10^{12}$/l)	4·6	4·3–6·7	6·7	5·4–7·7	5·9	4·3–7·7	4·7	4·6–4·7
Hb (g/dl)	8·4	6·7–11·3	10·2	8·5–11·4	9·2	6·7–11·4	7·4	7·2–7·5
Hct (ratio)	0·235	0·190–0·298	0·296	0·234–0·334	0·262	0·190–0·334	0·213	0·212–0·213
MCV (fl)	45·4	44·5–46·3	44·3	43–45	44·9	43–46·4	45·7	45·5–45·9
MCH (pg)	16	15·7–16·6	15·1	14·6–15·9	15·6	14·6–16·6	15·9	15·6–16·1
MCHC (g/dl)	35·4	34·1–37·7	34·3	33·9–34·9	34·9	33·9–37·7	34·6	33·9–35·3
PLT ($\times 10^9$/l)	432	381–484	—	—	—	—	328·5	312–345
Polys	3·65	3·13–3·97	3·18	1·95–4·24	3·44	1·95–4·24	3·34	3·31–3·38
Lymphs	1·56	1·06–2·08	1·16	0·57–1·73	1·39	0·57–2·08	1·02	0·94–1·1
Monos	0·25	0·11–0·41	0·10	0·08–0·31	0·21	0·08–0·41	0·41	0·38–0·43
Eos	0·06	0–0·26	0·20	0·0·43	0·10	0–0·43	0	—
Basos	0·03	0–0·14	0	—	0·02	0–014	0	—

Table 3. *The results of haematological examination of blood taken from healthy captive badgers*

	Healthy captive adults ($n = 26$)					
	Males ($n = 13$)		Females ($n = 13$)		Total ($n = 26$)	
Criteria	Mean	Range	Mean	Range	Mean	Range
WBC ($\times 10^9$/l)	5·2	3·2–7·8	5·05	3·3–8·7	5·1	3·2–8·7
RBC ($\times 10^{12}$/l)	8·4	7·1–10	8·5	7·10	8·4	7·10
Hb (g/dl)	13·3	11–15·3	13·3	11·3–16	13·3	11–16
Hct (ratio)	0·385	0·323–0·442	0·394	0·339–0·569	0·390	0·323–0·569
MCV (fl)	46·4	42–49	46	44–47	46·2	42–49
MCH (pg)	15·8	15–16·5	15·3	12·2–16·7	15·6	12·2–16·7
MCHC (g/dl)	34·5	32·5–35·8	33·9	28–35·8	34·2	28–35·8
PLT ($\times 10^9$/l)	468	255–657	400	210–800	431	210–800
Polys	3·31	1·38–6·16	3·27	2·28–6·35	3·29	1·38–6·35
Lymphs	1·51	0·38–3·02	1·38	0·52–3·11	1·49	0·38–3·11
Monos	0·21	0·03–0·48	0·31	0·08–1·04	0·26	0·03–1·04
Eos	0·06	0–0·47	0·08	0–0·20	0·07	0–0·47
Basos	0·01	0–0·06	0·01	0–0·07	0·01	00·07

values within the normal range for healthy captive adults at the time of challenge (Table 4). With the exception of a fall in RBC with accompanying reduction in Hb and Hct in the three animals surviving to 21 months (the final reading), the values all remained within the normal ranges for each parameter. Nevertheless, when compared with their own initial values, the four animals showed an increase in the WBC, 12 and 15 months after challenge due to polymorphs and monocytes and 2 of the 3 surviving animals had a lymphocytopenia at month 21.

A fall in RBC, Hb and Hct occurred in months 18 and 21, although there was a small compensatory increase in MCH. No changes were observed in the four animals challenged intratracheally and in which no disease developed.

DISCUSSION

As expected, adult healthy badgers held for several months in captivity had slightly different haematological parameters than did healthy (ie non-tuberculous) adult animals just trapped from the wild. Notably they had lower white cell counts due to a reduced number of polymorphs, and the haematological differences between the sexes disappeared. On detailed analysis the sex difference in the freshly trapped animals was found to be largely due to four female badgers presumably suffering from some unrecognized bacterial infection with high WBC (mean of $12{\cdot}6 \times 10^9$/l) due to an increase in polymorphs. There is no obvious explanation for the anaemia found in all five wild male cubs. Since it was true for all of them, partially clotted blood samples does not offer a likely explanation.

Examination of the blood films did not disclose any special features of badger blood to differentiate it from that of most other mammals, and the values obtained were within the ranges expected for members of the Mustelidae

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Table 4. *The haematology results of the badgers I.D. challenged with virulent bovine tubercle bacilli. Data for four animals until month 15, and three animals thereafter*

	Months after intradermal challenge													
	0		6		9		12		15		18		21	
Criteria	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
WBC ($\times 10^9$/l)	4·3	3·5–4·6	4·1	3·3–4·8	3·9	3·3–5·3	5·8*	5·1–7·3	5·6**	5·4–5·8	4·8	4·3–5·3	4·3	3·1–5·6
RBC ($\times 10^{12}$/l)	8·6	7·9–9·2	8·1	7·5–9·2	8·7	7·5–9·9	9·5	8·6–10·7	8·2	7·6–8·9	7·3*	6·6–8·0	6·1*	5·1–7·2
Hb (g/dl)	13·2	11·3–14·5	12·9	11·2–15	13·6	11·9–15·7	15·7*	13·7–18	15·4	12·5–17·6	11·5	10·3–12·8	10·1*	8·6–11·9
Hct (ratio)	0·391	0·399–0·442	0·369	0·332–0·416	0·374	0·332–0·428	0·421	0·440–0·453	0·362	0·349–·375	0·330*	0·299–0·356	0·284*	0·222–0·339
MCV (fl)	46	43–49	45·8	45·3–46·3	44·3	42–45	46·2	45·8–46·6	46·3	46–47	45·6	44·7–46·6	46·3	44–48
MCH (pg)	15·3	14·2–16·1	15·9	15·5–16·3	15·6	15·2–15·8	16·4	16–16·9	16·4	15·8–17	15·9	15·7–16·1	16·3	15·6–17
MCHC (g/dl)	33·9	32·9–35·8	34·8	33·5–36	36·4	35·6–37·3	35·5	34·3–36·4	37	36·8–37·1	34·8	33·9–35·9	35·8	33·6–37·7
PLT ($\times 10^9$/l)	261	220–290	415**	351–469	—	—	361*	289–434	—	—	391	S.R.	219	155–282
Polys	2·70	2·1–3·36	2·39	2·21–2·74	2·28	2·01–2·48	3·94*	3·21–5·33	3·77*	3·1–4·57	3·25	3·12–3·4	3·14	2·45–3·58
Lymphs	1·32	0·87–1·89	1·46	0·30–2·21	1·30	0·53–2·7	1·34	1·2–1·41	1·33	0·61–2·26	1·23	0·65–1·64	0·74	0·27–1·57
Monos	0·20	0·50–0·35	0·39	0·14–0·98	0·31	0·1–0·48	0·41*	0·26–0·66	0·38	0·12–0·9	0·31	0·26–0·37	0·32	0·23–0·45
Eos	0·07	0 0·14	0·05	0–0·14	0·01	0–0·04	0·07	0–0·22	0·11	0–0·22	0·02	0–0·05	0	—
Basos	0	—	0·04	0–0·14	0	—	0	—	0	—	0	—	0	—

*Significant at $P < 0·05·01$; **Significant at $P < 0·005$; S.R., single reading.

(Hawkey, 1975). The very varied picture of changing haematological values during the course of tuberculosis makes it unlikely that these parameters could be of diagnostic value in anything but extreme terminal disease.

Interestingly, the final results resemble those described for man in extreme disseminated or milliary disease associated with a negative tuberculin reaction. Such severe disease has been associated with monocytosis, basophilia, leukocytosis, leukopenia, normochromic normocytic anaemia, leuco-erythroblastic anaemia with bone marrow fibrosis, and pancytopenia (Cameron, 1974; Fountain, 1954; Glasser, Walker & Herion, 1970; Paully, 1954). This parallel provides further evidence that tuberculosis in the badger is within the spectrum of the disease seen in other mammalian species.

REFERENCES

Cameron, S. J. (1974). Tuberculosis and the blood-a special relationship? *Tubercle* **55**, 55–72.

Dacie, J. V. & Lewis, S. M. (1986). *Practical Haematology*, 6th edition. Edinburgh, London, New York: Churchill Livingstone.

Fountain, J. R. (1954). Blood changes associated with disseminated tuberculosis. Report of four fatal cases and a review. *British Medical Journal* **2**, 76–79.

Glasser, R. M., Walker, R. I. & Herion, J. C. (1970). The significance of hematologic abnormalities in patients with tuberculosis. *Achives of Internal Medicine* **125**, 691–695.

Hawkey, C. M. (1975). *Comparative Mammalian Haematology: Cellular Components and Blood Coagulation of Captive Wild Animals*. London: Heinemann Medical Books.

Ministry of Agriculture Fisheries and Food (1986). *Bovine Tuberculosis in Badgers*, 10th report by the Ministry of Agriculture, Fisheries and Food.

Mahmood, K. H., Stanford, J. L., Rook, G. A. W., Stuart, F. A., Pritchard, D. G. & Brewer, J. I. (1987*a*). The immune response in two populations of wild badgers naturally infected with bovine tubercle bacilli. *Tubercle* **68**, 119–125.

Mahmood, K. H., Rook, G. A. W., Stanford, J. L., Stuart, F. A. & Pritchard, D. G. (1987*b*).The immunological consequences of challenge with bovine tubercle bacilli in badgers (*Meles meles*). *Epidemiology and Infection* **98**, 155–163.

Paulley, J. W. (1954). Blood changes associated with disseminated tuberculosis. *British Medical Journal* **2**, 411–412.

Pritchard, D. G., Stuart, F. A., Wilesmith, J. W., Cheeseman, C. L., Bode, R. & Sayers, P. (1986). Tuberculosis in East Sussex. III: Comparison of post mortem and clinical methods for the diagnosis of tuberculosis in badgers. *Journal of Hygiene* **97**, 27–35.

Pritchard, D. G., Stuart, F. A., Brewer, J. I. & Mahmood, K. H. (1987). Experimental infection of badgers (*Meles meles*) with *Mycobacterium bovis*. *Epidemiology and Infection* **98**, 145–154.