Reprinted from ANNALS OF INTERNAL MEDICINE Vol. 120; No. 5, 1 March 1994
Printed in U.S.A.

Human Enteric Infection with Canine Hookworms

John Croese, MB, BS; Alex Loukas, BSc (Hons); Joan Opdebeeck, PhD; Stephen Fairley, MB, BS; and Paul Prociv, PhD

■ *Objective:* To describe a zoonotic ancylostomiasis (canine), acquired from domestic pets by patients living in developed, urban communities.

■ *Design:* An 8-year, retrospective case study.

■ *Setting:* A clinical gastroenterologic practice in Townsville and a university parasitology department in Brisbane, Australia.

■ *Patients:* Nine patients, each with enteric hookworm infection diagnosed by finding a single organism in situ; five were treated by us, and the rest were referred to us for parasite identification.

■ *Measurements:* Clinical and demographic data, complete blood examinations, total serum immunoglobulin E assay, and serologic testing with enzyme-linked immunosorbent assay and Western blot using excretory-secretory antigens of *Ancylostoma caninum*. Gut biopsy specimens were examined histologically, and hookworms were identified using morphologic criteria.

■ *Results:* The infections in three of the patients were diagnosed during the initial 6 years and six in the last 2 years. All owned a dog and described activity potentially exposing them to infection with canine hookworm larvae. Three patients had a laparotomy for acute abdominal pain, and six had colonoscopies (five with pain and one without symptoms). Six of the nine had blood eosinophilia (mean, 0.97 × 10^9/L), and five of eight had elevated immunoglobulin E levels (mean level, 756 μg/L); six of eight had eosinophilic inflammation of the gut. In six patients, the worm was identified as *A. caninum*, whereas in three, damage to the specimen did not allow specific identification; however, they were unlikely to be human parasite species. Although all parasites were in the adult stage, none were sexually mature. Positive serologic findings in seven of the eight patients tested confirmed presence of antibody to the parasite.

■ *Conclusions:* Human enteric infections with *A. caninum* are being diagnosed more frequently in northeastern Australia. Although infection may be subclinical, the chief symptom is abdominal pain, sometimes sudden and severe. The pathologic finding is focal or diffuse eosinophilic inflammation caused by a type 1 hypersensitivity response to secreted antigens. Infection by sexually immature worms is scant and nonpatent, indicating poor adaptation to the human host. Serologic testing assists in identification of occult infection. Advanced hygiene and sanitation afford little protection because the parasite reservoir is a large and growing pool of infected domestic pets.

Ann Intern Med. 1994;120:369-374.

From the University of Queensland, Australia. For current author addresses, see end of text.

Since the 1920s, the common dog hookworm, *Ancylostoma caninum*, has been known to cause cutaneous disease in persons who have been exposed to infective larvae (1). Sporadic accounts of its occurrence as an adult worm in the human intestine have been reported from the Philippines (2), South America (3–5), and Israel (6); the occasional adult *A. caninum* was found among numerous human hookworm specimens (usually *Necator americanus*) recovered either after anthelmintic treatment or at autopsy. In no case was the parasite implicated in clinical disease or shown to be fully developed and producing eggs.

In 1988, a published series of 33 Australian patients with abdominal pain and blood eosinophilia included a patient with ileal obstruction caused by an eosinophilic phlegmon to which a hookworm was attached (7). Histologic sectioning precluded specific identification of the parasite. Because human hookworm infection, a persistent Third World problem, is not endemic in urban Australia and has virtually disappeared from the aboriginal communities of Queensland (8, 9), it was speculated that the cases had a common cause, possibly a dog hookworm. Shortly afterwards, two other cases of infection with a single adult *A. caninum* were reported, both detected at colonoscopy and one associated with eosinophilic ileitis (10, 11). We developed an enzyme-linked immunosorbent assay (ELISA) and Western blot (12, 13) that are helpful in the diagnosis of abdominal pain with blood eosinophilia and indicate that the parasite is a common cause of this syndrome in eastern Australia.

We describe six additional cases of human enteric infection with *A. caninum* and summarize pertinent features, including serologic findings, of all nine Australian cases so far identified.

Methods

From 1985 to 1992, five patients were diagnosed by us and four others were referred with single hookworm infections. They lived either in Townsville (latitude, 19 degrees S) or Brisbane (latitude, 27 degrees S). In each case, the medical records and biopsy tissue were provided by the attending clinician and pathologist. At least one serum sample collected within 4 weeks of diagnosis and the formalin- or alcohol-fixed worms were also available from all except one patient (patient 1).

Measurements

Clinical and demographic data were sought from the records and by interview. A complete blood examination, total serum IgE assay, and fecal microscopy were done in commercial or teaching hospital laboratories. Blood eosinophilia was ascribed to a count higher than 0.50 × 10^9/L, and the upper normal value for IgE was 288 μg/L. Tissue biopsy specimens were examined and reported by histopathologists not associated with the study. Hookworms were examined microscopically by

© 1994 American College of Physicians

Reprinted from ANNALS OF INTERNAL MEDICINE Vol. 120; No. 5, 1 March 1994
Printed in U.S.A.

Human Enteric Infection with Canine Hookworms

John Croese, MB, BS; Alex Loukas, BSc (Hons); Joan Opdebeeck, PhD; Stephen Fairley, MB, BS; and Paul Prociv, PhD

■ *Objective:* To describe a zoonotic ancylostomiasis (canine), acquired from domestic pets by patients living in developed, urban communities.

■ *Design:* An 8-year, retrospective case study.

■ *Setting:* A clinical gastroenterologic practice in Townsville and a university parasitology department in Brisbane, Australia.

■ *Patients:* Nine patients, each with enteric hookworm infection diagnosed by finding a single organism in situ; five were treated by us, and the rest were referred to us for parasite identification.

■ *Measurements:* Clinical and demographic data, complete blood examinations, total serum immunoglobulin E assay, and serologic testing with enzyme-linked immunosorbent assay and Western blot using excretory-secretory antigens of *Ancylostoma caninum*. Gut biopsy specimens were examined histologically, and hookworms were identified using morphologic criteria.

■ *Results:* The infections in three of the patients were diagnosed during the initial 6 years and six in the last 2 years. All owned a dog and described activity potentially exposing them to infection with canine hookworm larvae. Three patients had a laparotomy for acute abdominal pain, and six had colonoscopies (five with pain and one without symptoms). Six of the nine had blood eosinophilia (mean, 0.97 × 10^9/L), and five of eight had elevated immunoglobulin E levels (mean level, 756 μg/L); six of eight had eosinophilic inflammation of the gut. In six patients, the worm was identified as *A. caninum*, whereas in three, damage to the specimen did not allow specific identification; however, they were unlikely to be human parasite species. Although all parasites were in the adult stage, none were sexually mature. Positive serologic findings in seven of the eight patients tested confirmed presence of antibody to the parasite.

■ *Conclusions:* Human enteric infections with *A. caninum* are being diagnosed more frequently in northeastern Australia. Although infection may be subclinical, the chief symptom is abdominal pain, sometimes sudden and severe. The pathologic finding is focal or diffuse eosinophilic inflammation caused by a type 1 hypersensitivity response to secreted antigens. Infection by sexually immature worms is scant and nonpatent, indicating poor adaptation to the human host. Serologic testing assists in identification of occult infection. Advanced hygiene and sanitation afford little protection because the parasite reservoir is a large and growing pool of infected domestic pets.

Ann Intern Med. 1994;120:369-374.

From the University of Queensland, Australia. For current author addresses, see end of text.

Since the 1920s, the common dog hookworm, *Ancylostoma caninum*, has been known to cause cutaneous disease in persons who have been exposed to infective larvae (1). Sporadic accounts of its occurrence as an adult worm in the human intestine have been reported from the Philippines (2), South America (3–5), and Israel (6); the occasional adult *A. caninum* was found among numerous human hookworm specimens (usually *Necator americanus*) recovered either after anthelmintic treatment or at autopsy. In no case was the parasite implicated in clinical disease or shown to be fully developed and producing eggs.

In 1988, a published series of 33 Australian patients with abdominal pain and blood eosinophilia included a patient with ileal obstruction caused by an eosinophilic phlegmon to which a hookworm was attached (7). Histologic sectioning precluded specific identification of the parasite. Because human hookworm infection, a persistent Third World problem, is not endemic in urban Australia and has virtually disappeared from the aboriginal communities of Queensland (8, 9), it was speculated that the cases had a common cause, possibly a dog hookworm. Shortly afterwards, two other cases of infection with a single adult *A. caninum* were reported, both detected at colonoscopy and one associated with eosinophilic ileitis (10, 11). We developed an enzyme-linked immunosorbent assay (ELISA) and Western blot (12, 13) that are helpful in the diagnosis of abdominal pain with blood eosinophilia and indicate that the parasite is a common cause of this syndrome in eastern Australia.

We describe six additional cases of human enteric infection with *A. caninum* and summarize pertinent features, including serologic findings, of all nine Australian cases so far identified.

Methods

From 1985 to 1992, five patients were diagnosed by us and four others were referred with single hookworm infections. They lived either in Townsville (latitude, 19 degrees S) or Brisbane (latitude, 27 degrees S). In each case, the medical records and biopsy tissue were provided by the attending clinician and pathologist. At least one serum sample collected within 4 weeks of diagnosis and the formalin- or alcohol-fixed worms were also available from all except one patient (patient 1).

Measurements

Clinical and demographic data were sought from the records and by interview. A complete blood examination, total serum IgE assay, and fecal microscopy were done in commercial or teaching hospital laboratories. Blood eosinophilia was ascribed to a count higher than 0.50 ×10^9/L, and the upper normal value for IgE was 288 μg/L. Tissue biopsy specimens were examined and reported by histopathologists not associated with the study. Hookworms were examined microscopically by

© 1994 American College of Physicians

experienced parasitologists and were drawn and measured using standard techniques. Species identification was based on accepted criteria, which included overall length; esophageal length; body width; number of teeth in the buccal cavity; and, in male worms, length of spicules and structural details of the copulatory bursa (14, 15).

Sera were stored at −15 °C and tested, among numerous control sera, for IgG and IgE antibodies by one of the investigators who was unaware of the patient histories. The ELISAs incorporated excretory-secretory antigens from adult *A. caninum* (12). In the Western blots, these antigens were separated electrophoretically on polyacrylamide gels and transferred to nitrocellulose paper, which was then incubated with patient sera diluted 1:10 (13). Controls were sera from blood donors in the state of Tasmania, where *A. caninum* does not exist. The cut-off absorbance levels for positivity in IgG and IgE ELISAs were 0.147 and 0.155 optical density units, respectively. Both the IgG and IgE Western blots were reported as positive when a protein band (Ac68) with a molecular weight of 68 kd was recognized.

Results

All patients were white; six were men and three were women, with a mean age of 48 years (range, 30 to 61 years). Patients 1 to 3 were diagnosed from 1985 to 1990; the others were diagnosed from 1991 to 1993. Each patient lived in a freestanding house with lawns and garden and kept one or more dogs as pets. By gardening or walking outside barefooted, all patients had been potentially exposed to soil contaminated with canine feces. Except for patient 7, none had recently travelled to an area endemic for human hookworm. None had had atopic or immunologic diseases, and none reported cutaneous or respiratory symptoms that may occur with human or zoonotic ancylostomiasis (1). After removal of the worm, all patients recovered and have remained well (Table 1).

Patients 1 to 3

The clinical features of these patients have been published previously and are summarized in Table 1 (7, 10, and 11). A 61-year-old woman (patient 1) with a 4-week history of recurrent bowel obstructions had a laparotomy with resection of an inflamed ileal segment. A single hookworm was attached to the mucosa and was sectioned for histologic study, which precluded a species identification. Her case was reported to one of us several months after her recovery; serum had not been stored. A 50-year-old tradesman (patient 2) recurrent abdominal pain and a positive fecal occult blood test was diagnosed at colonoscopy. A feeding hookworm, species *A. caninum*, was removed from an inflamed and ulcerated terminal ileum. A 53-year-old male teacher (patient 3), having colonoscopy for vague abdominal pain and minor rectal bleeding thought to be caused by hemorrhoids, had a single feeding worm, species *A. caninum*, removed from his rectum. The colon and rectum appeared healthy.

Table 1. A Summary of Demographic, Laboratory, and Parasitologic Findings in Nine Patients Infected by Solitary Hookworms*

Variable	Patient Number								
	1	2	3	4	5	6	7	8	9
Year of diagnosis	1985	1989	1990	1991	1991	1991	1992	1992	1993
City	Townsville	Townsville	Brisbane	Townsville	Brisbane	Townsville	Brisbane	Townsville	Townsville
Age, *y*	61	50	53	41	45	30	51	50	54
Sex	F	M	M	F	M	F	M	M	M
Procedure	Laparotomy	Colonoscopy	Colonoscopy	Colonoscopy	Laparotomy	Colonoscopy	Laparotomy	Colonoscopy	Colonoscopy
Eosinophil count, $\times 10^9/L$	1.05	2.25	0.30	0.24	0.76	2.96	0.70	0.15	0.52
Total IgE, *μg/L*	NA	>2400	437	257	1320	430	48	1032	122
Inflammatory reaction	Eosinophilic	Eosinophilic	NA	Eosinophilic	Eosinophilic	Eosinophilic	Eosinophilic	Normal	Nonspecific
Worm									
Confirmed as *Ancylostoma caninum*	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Sex	NA	M	F	M	F	M	F	F	F
Length, *mm*	NA	8	11	8	8	10	8	7	10
ELISA absorbance values, *optical density units*									
IgG (cut-off: 0.147)	NA	0.621	0.324	0.062	0.096	0.120	0.087	0.310	0.284
IgE (cut-off: 0.155)	NA	0.434	0.388	0.131	0.153	0.089	0.128	0.171	0.168
Western blot†									
IgG	NA	Positive ++	Positive +++	Negative	Negative	Negative	Positive ++	Positive +++	Positive ++
IgE	NA	Positive +	Positive +	Positive ++	Positive ++	Negative	Negative	Positive +	Positive ++

* ELISA = enzyme-linked immunosorbent assay; NA = not assessed.
† Magnitude of reaction: +++ = strong; ++ = moderate; + = weak.

Figure 1. Feeding hookworm in ileum (patient 4). The worm, seen at colonoscopy, was feeding vigorously with blood present in and expelled from its gut. Localized hemorrhage into the mucosa appears at the point of attachment. The buccal capsule, necessary for morphologic identification, was damaged when extracted with biopsy forceps.

Patient 4

A 41-year-old woman from Townsville described three attacks during the preceding 5 weeks of mid-abdominal pain, which aroused her from sleep, lasted a few hours, and did not require urgent care. Her stools were loose and more frequent after each episode but she felt well between attacks. Results of a physical examination, abdominal ultrasonography, and upper gastrointestinal endoscopic examinations were normal. Colonoscopy, completed 20 cm into the ileum, showed two ulcers, 2 mm in diameter, in the cecum. A feeding nematode, 5 cm proximal to the ileocecal valve, was removed with biopsy forceps (Figure 1). Damage to the buccal cavity prevented specific identification of this 8-mm long, male hookworm, with spicules 750 and 785 μm long. Tissue obtained from near the worm and the cecal ulcers was excessively infiltrated with eosinophils and plasma cells.

Patient 5

A 45-year-old Brisbane man, with mild chronic dyspepsia that had not been investigated, was hospitalized after 24 hours of increasingly severe colic. He was afebrile and his abdomen was distended and tender; radiologic findings showed dilated loops of small bowel with fluid levels. A complete blood examination showed initial neutrophilia (10.25×10^9/L), with a normal eosinophil count of 0.37×10^9/L. After early improvement, the signs worsened; a laparotomy was done 36 hours later and showed increased serous peritoneal fluid and a 24-mm, inflamed ileal stricture, which was resected. An 8-mm long, female hookworm, without eggs, was attached to the lumen of the opened segment, but damage to the buccal capsule precluded its specific identification. Histologic findings showed intense eosinophilic ileitis. Mild blood eosinophilia (0.68×10^9/L and 0.76×10^9/L) was recorded 4 and 14 days after admission and resolved (0.15×10^9/L) by 4 weeks.

Patient 6

A 30-year-old Townsville woman complained of anorexia, abdominal pains, diarrhea, and a 6-kg weight loss during a period of 4 weeks. She described the pain as a persistent, dull ache with severe exacerbations lasting 5 minutes, often provoked by eating. Her normal bowel habit, three formed stools daily, had increased to 10 liquid movements, often at night; passing stool gave temporary pain relief. A clinical examination was normal, but the blood eosinophil count was 2.96×10^9/L. The results of a fecal culture and microscopic examination were normal. The colonoscope was passed approximately 20 cm into the ileum. The only abnormal finding was a hookworm feeding in the cecum; it was removed with biopsy forceps and identified as a 10-mm long, adult male *A. caninum*, with spicules 785 and 800 μm long (Figure 2). Random ileal and cecal biopsy samples showed intense eosinophilic inflammation. Three weeks later, her blood eosinophil count (0.26×10^9/L) was normal.

Patient 7

A 51-year-old Brisbane man had a laparotomy for suspected acute appendicitis. He had presented 3 days after developing generalized abdominal pain, which improved initially but became severe again just before

Figure 2. Scanning electronmicrograph (patient 6). Anterior extremity of formalin-fixed, 10-mm hookworm, clearly showing a pair of three ventral teeth in the buccal cavity; these plus spicule size clearly identify the specimen as *A. caninum* (original magnification, × 700).

assessment. Six weeks earlier, he had returned from a 3-week vacation in Vanuatu, in the South Pacific, where he had walked barefooted and had observed many freely roaming dogs and extensive environmental fouling with their feces. He bred and trained greyhound dogs professionally, treating his animals regularly with anthelminthic agents. A clinical examination showed maximum tenderness over the right iliac fossa, with absence of bowel sounds. The operative findings were peritonitis, with slightly turbid fluid (culture sterile; cells not identified) and an intensely inflamed ileal segment 60 cm proximal to the ileocecal junction, surrounding a 2-cm thickened area that at first appeared to be a tumor. The ileum was opened to show a small ulcer that, histologically, was intensely inflamed and infiltrated with eosinophils. An 8-mm long, female *A. caninum*, without eggs, was attached to the center of the ulcer.

Patient 8

A 50-year-old Townsville man with atherosclerosis was hospitalized with a 6-hour history of severe abdominal pain coming in waves lasting several seconds. He had noticed a mild increase in stool frequency during that day and had had bright rectal bleeding occasionally during the preceding 12 months. A clinical examination showed abdominal distension but little tenderness. Ascites, unexplained by liver, cardiac, or renal disease, was later confirmed by computed tomography, and abdominal radiography showed multiple fluid levels but no bowel dilation. A complete blood examination showed neutrophilia (19.1 × 10^9/L). His symptoms resolved completely within 12 hours, and he was discharged, feeling well, after 2 days. At colonoscopy 3 weeks later, a feeding hookworm was removed with biopsy forceps from the mid-transverse colon. The terminal ileal and colonic mucosa looked normal, except for 7- and 12-mm dysplastic polyps, which were removed from the sigmoid colon. Biopsy specimens from the feeding site showed normal histologic findings. The worm was a 7-mm long, female *A. caninum* without eggs. A repeat complete blood examination, including an eosinophil count of 0.16 × 10^9/L, was normal.

Patient 9

A 54-year-old Townsville man, asymptomatic except for anxiety about bowel cancer, had a colonoscopy. Sixteen days earlier, he had self-medicated with mebendazole, 200 mg daily for 3 days. His mother, assessed by one of us because of abdominal pain associated with blood eosinophilia, had responded to treatment with mebendazole and had advised her family to treat themselves regardless of symptoms. The colonoscopic findings were a few small ulcers in the terminal ileum, the largest being 5 mm in diameter, and a feeding hookworm 5 cm proximal to the ileocecal valve. The worm was a female *A. caninum*, measuring 10 mm; eggs were not seen. Ileal biopsy samples showed mild inflammatory change with 15 eosinophils per high-power field.

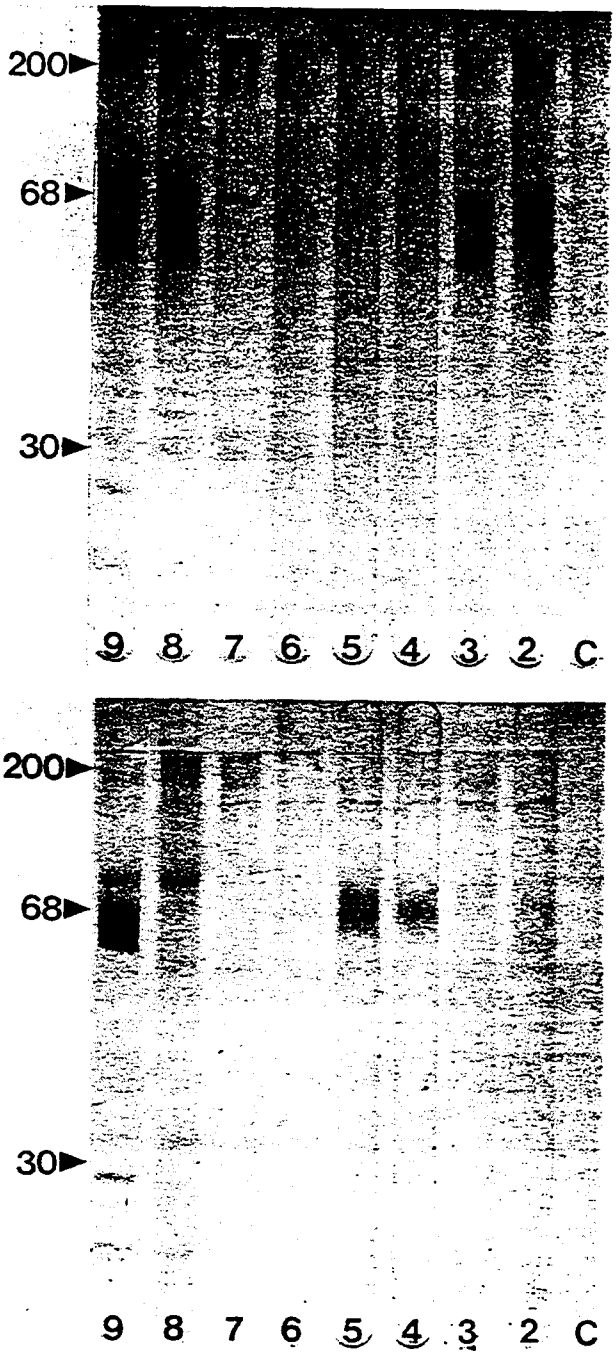

Figure 3. Immunoglobulin G and E Western blots comparing cases with controls. Molecular weight markers in the left lane. Numerals represent patient numbers. C = control (blood donor from Tasmania) serum. Reaction with a band at 68 kd signifies a positive reaction; other bands are ignored.

Serologic Findings

The serologic results from each patient are shown in Table 1. Both ELISAs were positive in four patients (patients 2, 3, 8, and 9), and four patients were negative by both tests. One or both Western blots tested positive in seven of eight patients (Figure 3). One patient (patient 6), who tested negative by both IgG and IgE Western blots, also had negative ELISA results. The negative IgE Western blots (patients 6 and 7) had faint 68Ac bands, but the intensity was insufficient to grade

other than borderline. The intensity of the Ac68 bands produced by IgG and IgE Western blots varied inconsistently within individuals.

Discussion

The major single morphologic feature distinguishing human from zoonotic hookworms is the tooth pattern. Three pairs of teeth, sometimes difficult to identify, characterize the two most common animal hookworm species in northeastern Australia, *A. caninum* of dogs and *A. tubaeforme* of cats (10), but are not found in human hookworm species. Although they were originally assumed to be the one species, they can be distinguished by careful morphologic studies (14, 15). Even if the damaged specimens from our patients were not *A. caninum*, the circumstantial evidence suggests they were not anthropophilic species, and the significance of our finding is not diminished. The patients originated from populations free of human hookworms; patent hookworm infections (where eggs are produced) are now rarely seen in either Brisbane or Townsville, and then only in travellers from overseas (unpublished observation). Living conditions are among the most sophisticated in the world, with highly developed and efficient water supply and sanitation facilities. It is clear that pets sharing our domestic environment are the reservoir of infection, and all our patients had been in contact with soil or grass potentially contaminated with dog feces. Detection of these nonpatent, zoonotic hookworm infections has been greatly facilitated by the eradication of previously endemic human ancylostomiasis, coupled with the increasing use of colonoscopy.

We have not been able to identify any feature of the worms retrieved from our patients or from local dog populations, to suggest a novel species. All worms were immature: they had not attained the full adult length (14 to 20 mm for females, 11 to 13 mm for males), and the females were not producing eggs (15). Further, these worms were all unusually low in the gastrointestinal tract, even in the patients who had surgery; in host-specific hookworm infections, the parasites aggregate in the jejunum (1). Failure to develop fully may reflect poor adaptation to the human host and premature expulsion from the bowel by the intense inflammatory response (along with the preparation for colonoscopy).

Infection probably caused illness. Although their symptoms ranged in severity, our patients had common clinical features including pain (sometimes associated with obstruction or peritonitis), diarrhea, abdominal distension, weight loss, and rectal bleeding. Blood eosinophilia was usual but not universal, and it resolved with symptoms. Along with the elevated IgE levels, these findings are consistent with other enteric parasitic infections, including the human-specific hookworms *A. duodenale* and *N. americanus* (16, 17). Subclinical infection, confirmed by serendipity in one patient (patient 9), may be common.

Hookworm detection, when infection is by a single, tiny organism, is difficult and approaches a chance finding. Despite our practice of routinely inspecting the ileum, the colonoscopic detection rate is likely to be low because the ileal segments found inflamed at laparotomy were 15 cm or more proximal to the ileocecal junction, beyond the reach of a conventional examination instrument. The clinical and laboratory features of the patients who had surgery, along with the operative findings of segmental inflammation with free intraperitoneal fluid, are virtually identical with those described in a series from Townsville and Brisbane, in which hookworms were not found but were suspected (18). Obscure abdominal pain, often associated with blood eosinophilia and responsive to treatment with mebendazole, is common in northeastern Queensland where we have investigated over 200 cases during the last 10 years (unpublished observation). We have linked this syndrome epidemiologically (7, 10) and serologically (12, 13) to occult infection by canine hookworms.

The histologic finding is identical with eosinophilic enteritis. This entity, often with gastric involvement, differs from our cases where inflammation was confined to the distal small bowel and colon. By convention, eosinophilic enteritis is idiopathic, specifically not caused by parasitic infection (19). Whereas classic enteric helminthiases associated with eosinophilic infiltration of the gut, such as ancylostomiasis, schistosomiasis, acute trichinelliasis, anisakiasis, capillariasis, angiostrongyliasis, and, sometimes, strongyloidiasis, can be readily diagnosed by fecal microscopy, routine endoscopy, or serologic tests, infection by *A. caninum* does not yet fit into this category. Fecal microscopy is likely to be negative, the worm is usually beyond the reach of endoscopy, and serologic tests are still being developed. This parasite is now implicated as the cause of the variant of eosinophilic enteritis commonly diagnosed in Queensland.

The heterogeneous clinical manifestations suggest a marked degree of host idiosyncrasy ranging from immunologic tolerance to a type 1 hypersensitive reaction, which even appears to vary within individuals. One patient (patient 8), presenting with acute obstruction and ascites, had been free of symptoms for 3 weeks before his colonoscopy. Presumably, the initial symptoms had resulted from localized bowel inflammation in response to worm secretions, either by the worm found at colonoscopy or, more likely, a predecessor, which had been expelled as a consequence of the immune reaction. The specific allergen might be secreted only by more advanced worms; this one (7 mm) was the smallest in the series. Alternatively, secretions of individual worms may differ qualitatively, so that not all induce an inflammatory reaction. Another possibility is that different parts of the gastrointestinal tract vary in their allergic reactivity.

The positive rate for the ELISA in this series was a surprisingly low 50%. In the Townsville population, 70% of patients with suspected *A. caninum* infection (presenting with obscure abdominal pain associated with blood eosinophilia) compared with 8% of healthy controls had positive ELISA values; we have observed a positive correlation with chronicity of symptoms and falling values during convalescence (unpublished observation). Patients with primary and acute symptoms have lower values, a situation that might be more representative of the persons with proven infection reported. Although the ELISA incorporates a wide range of antigens, only one of which has been found to be

diagnostic by Western blot (Ac68), it is specific for hookworm as opposed to other nematode infections, but it does not discriminate among different hookworm species (12). The positivity rate of the combined Western blots was 87.5% compared with 10% in Townsville patients with nonparasitic gastrointestinal diseases (unpublished observation), higher than the ELISA. The ELISA readings did not consistently correlate with band intensities on Western blots. Although IgG and IgE ELISA readings correlated within individuals, this association was less evident in the Western blots. It is not clear how these detectable antibodies relate to the gut inflammation and why a variation in the dominance of the different classes of immunoglobulin should exist among patients. In its current form, serologic testing has only limited diagnostic application.

Presumably, human exposure to infective larvae of *A. caninum* is related to its prevalence in local dog populations. In Brisbane, hookworm infection in impounded suburban dogs was 22% in winter and 38% in summer and in Townsville, the rates (around 50%) are higher (unpublished observation). These rates, however, are not exceptional; even in the more temperate climate of New Jersey, a 6-year survey found 24% of dogs to be infected (15). Perhaps the differences in canine infection rates are less clinically significant than human behavioral adaptations to climate in determining exposure to infection, such as contact with contaminated soil and grass. Nevertheless, as most of the world's people share their environment with *A. caninum*-infected dogs, canine hookworms could be encountered widely as a human enteric parasite (20).

Infection by *A. caninum*, proven and otherwise, undoubtedly explains some cases of ileal eosinophilic enteritis. As more clinicians and pathologists become aware of this phenomenon and its manifestations, enteric infections by hookworms acquired from pets will become recognized as a major zoonosis.

Acknowledgments: The authors thank Drs. Terrence Mulhearn and Neil Walker for referral of a patient and Associate Professor Rick Speare for assistance with identification and measurement of parasites (patients 4 and 8).

Grant Support: By the National Health and Medical Research Council of Australia, the University of Queensland, and the Wenkart Foundation.

Requests for Reprints: John Croese, MB, BS, 42 Ross River Road, Mundingburra, Townsville, Queensland, 4812 Australia.

Current Author Addresses: Dr. Croese: 42 Ross River Road, Mundingburra, Townsville, Queensland, 4812, Australia.

Mr. Loukas and Drs. Opdebeeck and Prociv: Department of Parasitology, The University of Queensland, QLD 4072, Australia.

Dr. Fairley: Townsville General Hospital, Townsville, QLD 4810, Australia.

References

1. **Beaver PC, Jung RC, Cupp EW.** Clinical Parasitology. 9th ed. Philadelphia: Lea & Febiger; 1984:276.
2. **Manalang C.** Studies on ancylostomiasis in the Philippines. Transactions of the 6th Congress of the Far Eastern Association of Tropical Medicine. Tokyo: Nanking; 1925:351-68.
3. **Deane MP.** Helminths eliminated from a group of Amazon residents after treatment with hexilresorcinol. Revista do Servico Especial de Saude Publica. 1950;3:443-64.
4. **Komma MD, Dos Santos MA, Da Silva AL, Jardim CD.** Collection of ancylostomes from, and their prevalence in, 14 natives of Goiania: a case infected by *Ancylostoma caninum*. Rev Goiana Med. 1969;15:169-74.
5. **Carrias VR, de Vargas PR.** Infection of the human intestine by *Ancylostoma caninum* Ercolani, 1859. Revista da Sociedade Brasileira de Medicina Tropical. 1985;18:57.
6. **Witenberg G.** Some unusual observations on helminthiasis in Israel. Harefuah. 1951;41:178-80.
7. **Croese TJ.** Eosinophilic enteritis—a recent North Queensland experience. Aust N Z J Med. 1988;18:848-53.
8. **Carroll SM, Walker JC.** Hookworm infection in Southeast Asia, Oceania and Australia. In: Schad GA, Warren KS; eds. Hookworm Disease: Current Status and New Directions. New York: Taylor and Francis; 1980:33-43.
9. **Prociv P, Luke R.** Observations on strongyloidiasis in Queensland aboriginal communities. Med J Aust. 1993;158:160-3.
10. **Prociv P, Croese J.** Human eosinophilic enteritis caused by dog hookworm *Ancylostoma caninum*. Lancet. 1990;335:1299-302.
11. **Sandford N, Prociv P.** Human infections with dog hookworms not restricted to tropical north [Letter]. Med J Aust. 1991;154:490.
12. **Loukas A, Croese J, Opdebeeck J, Prociv P.** Detection of antibodies to secretions of *Ancylostoma caninum* in human eosinophilic enteritis. Trans R Soc Trop Med Hyg. 1992;86:650-3.
13. **Loukas A, Opdebeeck J, Croese J, Prociv P.** Immunological confirmation of *A. caninum* as a human enteric pathogen. Am J Trop Med Hyg. 1994; [In press].
14. **Biocca E.** Recognition of the feline hookworm *Ancylostoma tubaeforme* (Zeder, 1800), and the differences compared with the canine species *Ancylostoma caninum* (Ercolani, 1859). Revista Parassitologia. 1954;15:267-78.
15. **Burrows RB.** Comparative morphology of *Ancylostoma tubaeforme* (Zeder, 1800) and *Ancylostoma caninum* (Ercolani, 1859). J Parasitol. 1962;48:715-8.
16. **Nawalinski TA, Schad GA.** Arrested development in *Ancylostoma duodenale*: course of a self-induced infection in man. Am J Trop Med Hyg. 1974;23:895-8.
17. **Maxwell C, Hussain R, Nutman TB, Poindexter RW, Little MD, Schad GA, et al.** The clinical and immunologic responses of normal human volunteers to low dose hookworm (*Necator americanus*) infection. Am J Trop Med Hyg. 1987;37:126-34.
18. **Croese J, Prociv P, Maguire E, Crawford AP.** Eosinophilic enteritis presenting as surgical emergencies: a report of six cases. Med J Aust. 1990;153:415-7.
19. **Talley NJ, Shorter RG, Phillips SF, Zinsmeister AR.** Eosinophilic gastroenteritis: a clinicopathological study of patients with disease of the mucosa, muscle layer, and subserosal tissues. Gut. 1990;31: 54-8.
20. **Kalkofen UP.** Hookworms of dogs and cats. Vet Clin North Am Small Anim Pract. 1987;17:1341-54.