MOLECULAR CLONING OF AN IMMUNODOMINANT ANTIGEN OF ONCHOCERCA VOLVULUS

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Onchocerciasis, or “river blindness,” is caused by the filarial nematode Onchocerca volvulus, which infects an estimated 18 million people in Africa and Latin America (1). It is one of the leading causes of blindness in sub-Saharan Africa today. However, few biochemical and immunological studies have been conducted on O. volvulus because humans and chimpanzees are its only known mammalian hosts (2). Since the parasite cannot be maintained in the laboratory, there is a severe shortage of parasite antigen material for the development of immunodiagnostic tests and the assessment of immunoprophylactic potential. As a first step to overcome this problem, we describe here the cloning and characterization of the gene for an immunodominant antigen of this parasite.

Materials and Methods

Immunochemistry. Female worms isolated from nodules by collagenase digestion (3) were solubilized in sample buffer (63 mM Tris-HCl, pH 6.8, 10% [vol/vol] glycerol, 3% [wt/vol] SDS, 5% [vol/vol] β-mercaptoethanol) containing 1 mM each of ε-amino-n-caproic acid, EDTA, benzamidine, and PMSF. The sample was sonicated at 500 W for 2 min and boiled for 2 min. Electrophoresis of the supernatants was in 10–14.5% gradient polyacrylamide gels followed by transfer to nitrocellulose (4). The filters were saturated with 3% BSA, serially reacted with the primary antibodies and horseradish peroxidase-conjugated antibodies against mouse IgG or human IgG, and developed using 4-chloro-l-naphthol as substrate. Frozen sections of female worms of 4 μm thickness were fixed with acetone on glass slides for 2 min and serially reacted with mAb 4A7 and anti-mouse IgG antibodies conjugated with FITC.

DNA Manipulations. DNA sequence determinations (5) and Northern and Southern blots (6) were conducted as described.

Results and Discussion

In previous studies we identified and characterized an immunodominant antigen of O. volvulus that is potentially an important diagnostic reagent (7, 8). Immunoblots demonstrated that this antigen is specific for Onchocerca since it is recognized by sera of 96% of onchocerciasis patients but not by sera from patients infected with other filarial parasites. mAb 4A7 directed against this antigen binds to components

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of Mr 33,000 and 21,000 in adult parasite extracts (Fig. 1A, lane 2). The 21,000 Mr component is probably a proteolytic fragment of the 33,000 Mr component since it is much more prominent in extracts of dead worms than live worms (not shown). A polyvalent mouse serum generated by immunization with mAb 4A7-purified antigen also binds to these two bands on immunoblots (Fig. 1A, lane 4). In extracts of infective larvae obtained from the black fly vector, the target epitope of mAb 4A7 is located on a Mr 133,000 band that has not been characterized further because of a shortage of larvae material (8). The epitope recognized by the mAb is not present in extracts of microfilariae isolated from skin snips. Examination of frozen sections of adult worms with mAb 4A7 by immunofluorescence assay reveals that the antigen is present in the reproductive organs and muscles but not in the cuticle (Fig. 1B). The lack of this antigen on the surface of adult worms and its absence from microfilariae in the skin suggests that the host immune response to it is induced by release of the antigen from the adult.

The polyvalent serum directed against the 33,000 Mr antigen (Fig 1A, lane 4) was used to immunoscreen 650,000 phage of an unamplified λgt11 cDNA library prepared from poly(A)^+ RNA of adult O. volvulus collected from patients in Kumba,
FIGURE 2. The nucleotide sequence of the Ov33-3 cDNA and deduced amino acid sequence. Restriction fragment termini labeled for the sequence determination were generated by HpaII, NdeI, Sca I, and Eco RI. The indicated reading frame is in phase with the β-galactosidase gene of Xgtll.

Cameroon, West Africa (9). Four recombinant phage clones gave a positive signal. Their different-sized cDNAs crosshybridized under high stringency conditions, indicating that they all encode the same sequence. Clone Ov33-3, which contained the largest Eco RI cDNA insert, produces a recombinant fusion protein that is also recognized by both mAb 4A7 and human patient sera (Fig. 1 C). This 1.0-kb cDNA was subcloned into pUC12 and its sequence was determined (Fig. 2). An open reading frame encoding 239 amino acids is in phase with the reading frame of the β-galactosidase gene of λgt11, followed by a 3' nontranslated region of 254 nucleotides that is missing the 3' poly(A) tail. Comparison of the sequence with the nucleotide and amino acid sequences in GenBank did not reveal any significant similarities.

To estimate the abundance of the corresponding mRNA in adult parasites, 16 x

FIGURE 3. Radioactive Ov33-3 cDNA was used to probe (A) a Northern blot of 2 μg of total RNA from O. voloulus collected from patients in the villages of Kumba (K) and Touboro (T) in Cameroon, and from patients in Mali (M) and Guatemala (G), and (B) a Southern blot containing Hind III digests of 5 μg of genomic DNA from the same organisms. Hind III fragments of λDNA were used as standards (st). The probe hybridizes to a 1.2-kb RNA and a 14-kb Hind III restriction fragment in organisms from all four locations.
10^3 recombinants of the unamplified cDNA library were screened with Ov33-3 cDNA. It hybridized to the phage DNA in 48 plaques, indicating that its mRNA constitutes 0.3% of the total poly(A)^+ RNA in the adult worms. The cDNA was also used to probe blots of RNA and genomic DNA from adult O. volvulus collected at four widely spaced locales, two savanna regions in Africa (near Touboro, Cameroon and Bamako, Mali), a forest region in Africa (Kumba, Cameroon), and in Central America (near Guatemala City, Guatemala). O. volvulus causes blindness much more frequently in savanna regions than in the forest, an observation that has been attributed to different genetic forms of the parasite in the two habitats (10). The Northern blot (Fig. 3 A) indicates that a 1.2-kb mRNA for this antigen is present in parasites from all four places and suggests that the Ov33-3 cDNA lacks only ~200 nucleotides of the mature message. In a Southern blot (Fig. 3 B), the cDNA hybridizes to the same 14-kb Hind III fragment in all four genomes. This result, as well as those obtained with other restriction enzymes, indicates that there is little or no heterogeneity in this genomic region among O. volvulus from the four different locations.

To determine whether the Ov33-3 gene is also present in filarial parasites of other genera, we examined the extent of its crosshybridization with other DNAs. Fig. 4 (left) shows that in a Southern blot washed under low stringency conditions, the cDNA hybridizes to a single Hind III fragment of a different size in the DNAs of O. volvulus, Brugia malayi (a human lymphatic filarial parasite) and Dirofilaria immitis (the dog heartworm). However, with moderate stringency it does not hybridize to B. malayi DNA (Fig. 4, middle) while in high stringency it does not hybridize to either B. malayi or D. immitis DNA (right). Thus, the gene is different in the three parasites although the corresponding D. immitis sequence is more similar to the O. volvulus gene than is the B. malayi sequence. These nucleotide differences most likely cause amino acid changes in the corresponding protein that form the basis for the specificity of mAb 4A7 for Onchocerca. The similarities in the gene, on the other hand, are confined to parasitic nematodes since, even under very low stringency, the cDNA probe does not bind to DNA from Caenorhabditis elegans, a free living nematode (not shown).

This paper presents the first characterization of a gene in O. volvulus. The three...
previous reports on the DNA of this important parasite described the identification of noncoding repetitive DNA segments that may be useful for epidemiologic and diagnostic studies (10-12). Here we describe a protein and its gene that may also contribute to these kinds of studies. Furthermore, it could have major immunological significance. Studies on murine schistosomiasis show that, in addition to surface components such as the \( M_r 28,000 \) antigen of \textit{Schistosoma mansoni} (13), proteins like paramyosin and glutathione-S-transferase also induce partial protective immunity against challenge infections (14, 15). An assessment of the immunoprophylactic potential of the \( 33,000 \) \( M_r \) antigen, and all other \textit{O. volvulus} antigens, will be difficult because of the high degree of host specificity of the parasite. However, further characterization of the Ov33-3 protein product should provide more information about its immunological significance and its potential as an immunodiagnostic reagent and vaccine component.

Summary

We have cloned and characterized the gene for an immunodominant antigen of \textit{O. volvulus} that is recognized by the sera of 96% of patients with onchocerciasis. Its 1.2-kb mRNA constitutes 0.3% of adult worm poly(A)* RNA and its cDNA sequence reveals that it is not a highly conserved structural protein such as actin or tubulin. Similar but not identical genes occur in the genomes of related filaria, \textit{Brugia malayi} and \textit{Dirofilaria immitis}. The recombinant antigen has both immunodiagnostic and immunoprophylactic significance.

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References

1. World Health Organization. 1987. Third report of the expert committee on Onchocerciasis. Technical Report Series No. 752. World Health Organization, Geneva.
2. Duke, B. O. L. 1980. Observations on \textit{Onchocerca volvulus} in experimentally infected chimpanzees. \textit{Tropenmed. Parasitol.} 31:41.
3. Schulz-Key, H., E. J. Albiez, and D. W. Büttner. 1977. Isolation of living adult \textit{O. volvulus} from nodules. \textit{Tropenmed. Parasitol.} 28:428.
4. Burnette, W. N. 1981. "Western" blotting: electrophoretic transfer of proteins from SDS-polyacrylamide gels to unmodified nitrocellulose and radiographic detection with antibody and radio-iodinated protein A. \textit{Anal. Biochem.} 112:195.
5. Maxam, A., and W. Gilbert. 1977. Sequencing end-labeled DNA with base-specific chemical cleavages. \textit{Methods Enzymol.} 65:499.
6. Thomas, P. S. 1980. Hybridization of denatured RNA and small DNA fragments transferred to nitrocellulose. \textit{Proc. Natl. Acad. Sci. USA.} 77:5201.
7. Lucius, R., D. W. Büttner, C. Kirsten, and H. J. Diesfeld. 1986. A study on antigen recognition by onchocerciasis patients with different clinical forms of disease. \textit{Parasitology} 92:569.
8. Lucius, R., H. Schulz-Key, D. W. Büttner, A. Kern, B. Kaltmann, J. Prod'hom, F. Seeber, R. D. Walter, K. C. Saxena, and H.-J. Diesfeld. 1988. Characterization of an im-
munodominant. *O. volvulus* antigen with patient sera and monoclonal antibody. *J. Exp. Med.* 167:1505.

9. Donelson, J. E., B. O. L. Duke, D. Moser, W. Zeng, N. E. Erondu, R. Lucius, A. Renz, M. Karam, and G. Z. Flores. 1988. Construction of *O. volvulus* cDNA libraries and partial characterization of the cDNA for a major antigen. *Mol. Biochem. Parasitol.* In press.

10. Erttmann, K. D., T. R. Unnasch, B. M. Greene, E. J. Albiez, J. Boateng, A. M. Benke, J. J. Ferraroni, M. Karam, H. Schultz-Key, and P. N. Williams. 1987. A DNA sequence specific for forest form *O. volvulus*. *Nature (Lond.)*. 327:415.

11. Perler, F. B., and M. Karam. 1986. Cloning and characterization of two *O. volvulus* repeated DNA sequences. *Mol. Biochem. Parasitol.* 21:171.

12. Shah, J. S., M. Karam, W. Piessens, and D. F. Wirth. 1987. Characterization of an Onchocerca-specific DNA clone from *O. volvulus*. *Am. J. Trop. Med. Hyg.* 37:376.

13. Balloul, J. M., P. Sondermeyer, D. Dreyer, M. Capron, J. M. Grzych, R. J. Pierce, D. Carvallo, J. P. Lecocq, and A. Capron. 1987. Molecular cloning of a protective antigen of schistosomes. *Nature (Lond.)*. 326:149.

14. Lanar, D. E., E. J. Pearce, S. L. James, and A. Sher. 1986. Identification of paramyosin as schistosome antigen recognized by intradermally vaccinated mice. *Science (Wash. DC).* 234:593.

15. Smith, D. B., K. M. Davern, P. G. Board, W. U. Tiu, E. G. Garcia, and G. F. Mitchell. 1986. M. 26,000 antigen of *Schistosoma japonicum* recognized by resistant WEHI 129/J mice is a parasite glutathione S-transferase. *Proc. Natl. Acad. Sci. USA.* 83:8703.