Chronologic Growth Pattern of *Ascaris lumbricoides**

Byong-Seol Seo and Jong-Yil Chai

Department of Parasitology and Institute of Endemic Diseases,

College of Medicine, Seoul National University

INTRODUCTION

Jung(1954) stated that the most of the heavily infected cases with hundreds of *Ascaris* worms had single brood. However the cases with scores of worm had frequently been met in endemic areas from whom different sizes of worms were concomitantly collected. Because Cho(1977) proved that crowding effect did not affect weight of *Ascaris*, those cases with different size of worms should be interpreted as infected in continual pattern; that means further infection to already infected (=superinfection). Really superinfection pattern is one of the very important aspects in endemic areas where the "*Ascaris* environment" is seldomly changing.

To express the superinfection pattern numerically, it is necessary to discriminate the age of infection of collected *Ascaris*. In connection with aging of worms, Masuda(1963) was of opinion that, later than one month after the maturity, it was impossible to determine the age from length and weight of the worm, because female worms after maturity seemed to reveal variable weights due to extent of depletion of ovary. He actually analysed 53 adult *Ascaris* collected from 15 cases who had the known period of oviposition. Even though his observation was correct, it is hardly imaginable that the length

of worm is also variable with age or degree of ovary depletion. Cho(1977) observed a high correlation coefficient(0.957) between the length and weight of *A. lumbricoides* collected after chemotherapy with pyrantel pamoate. And he gave the detailed range of variations of weight in a given length of *Ascaris*. The length and weight of them were well correlated each other in logarithmic curve, $\text{Ln } Y \text{ (weight in gm)} = 3.032 \text{ Ln } X \text{ (length in cm)} - 8.2903$.

We thought that chronologic growth pattern could be figured out from the data of collected worms after various interval mass chemotherapies repeated on rural inhabitants with pyrantel pamoate. To confirm above idea on the chronologic growth of *Ascaris lumbricoides*, we analysed the measurement data of collected worms.

MATERIALS AND METHODS

1. Principle of study and collected worms

The subjected worms were those from the study of Seo *et al.* (1980). In their study, they applied different interval chemotherapy; 2-month, 4-month, 6-month and 12-month intervals, each to respective group of the inhabitants. Except for those from the first treatment, all of the collected worms in each interval group would fall into a limitation in terms of age, length and weight. Thus the largest worm from each treatment could be regarded as that of maximum growth during the interval of treat-

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Table 1. The sources of analysed cases to make growth curve of *Ascaris lumbricoides*

Treatment interval*	No. of target villages	Study period	No. of treatments**	Total No. of cases examined	No. of worm posit. cases	No.*** analysed
2-month	3	Jun. 1977-May 1980	9-17	1,553	87	53
4-month	2	Jan. 1979-May 1980	4	252	26	19
6-month	6	Apr. 1977-Sep. 1979	4	1,279	241	178
12-month	2	Apr. 1977-Apr. 1978	1	91	38	35
Total	11			3,175	392	285

* There were delays in terms of exact dating

** The first treatment was excluded

*** Excluded those cases who were not treated in former term

ments.

Inhabitants of 11 villages in Hwasung Gun, Kyunggi Do, Korea were treated with pyrantel pamoate during the period from April 1977 to May 1980. The number of repeated treatments is shown in Table 1. The subjected cases were treated without any preliminary information on the egg discharge.

After each treatment, whole-day stool specimens were collected for 2 days from each case. All of the worms expelled in stool were counted in each time, fixed in 10% formalin and measured by length and weight as well as the sex discrimination of the worms. The length of worms was measured by tracing whole length of worms with a soft lead line followed by spreading it on a rule, and the weight was read on a torsion balance after removing water drops on the surface.

2. Analysis of the data

The weight and length of collected worms plotted by sexes and by treatment intervals. And we observed the maximum size in each sex and interval.

In determining the maximum age in each treatment group, we considered both the delay of 5~10 days in repeated treatments and the migration time which is necessary for the infected larvae to reach at the intestine so as to be removed by pyrantel. The latter was calculated as 2 weeks in human *Ascaris* (Koino, 1922;

Fig. 1. A scheme of aging the collected *A. lumbricoides* by pyrantel with considerations of migration phase.

Ogata, 1922; Soulsby, 1965).

As shown in Fig. 1, in case of two-month interval for example, reinfected worms from '-2' to '0' week could not be expelled by the first treatment, but they would be detected at the second treatment on the '8th' week. Considering these two factors, 3 weeks were added to the interval between treatments in aging the *Ascaris*.

RESULTS

As presented in Table 1, among 3,175 cases examined, only 392 cases were worm-positive. Among them, 285 cases were subjected to the analysis because they were not dropped out in the previous treatments; in other words, they were infected within known period of time.

From 285 cases, a total of 497 worms was collected which consisted of 224 males and 273

Fig. 2. The distribution pattern of *Ascaris lumbricoides* by weight and length according to treatment interval. A: Males from 2-month interval, B: Females from 2-month interval, C: Males from 4-month interval, D: Females from 4-month interval, E: Males from 6-month interval, F: Females from 6-month interval, G: Males from 12-month interval, H: Females from 12-month interval.

Table 2. Sex ratio of the collected worms

Treatment interval	No. of cases analysed	No. of worms	Sex of worms		Sex ratio (M/F)
			Male	Female	
2-month	53	55	22	33	0.67
4-month	19	107	48	59	0.81
6-month	178	253	116	137	0.85
12-month	35	82	38	44	0.86
Total	285	497	224	273	0.82

females (sex ratio; male:female=0.82:1) (Table 2). The distribution pattern of length and weight of those worms in each treatment interval was as shown in Fig. 2. The worms in each treatment interval distributed in basically same pattern by weight and length following the equation; $\ln Y = 3.032 \ln X - 8.2903$ (when Y is weight in gm and X is length in cm). The only difference between each interval group was the maximal growth. And the maximum lengths of worms in 2, 4, 6 and 12-month groups were 12.5, 16.4, 19.2 and 22.8 cm in male and 14.2, 22.0, 26.2 and 30.8 cm in female respectively. Extraordinarily large worm was not found in all infection age of either sex. The corresponding weights were calculated from the above correlation equation; 0.53, 1.21, 1.95 and 3.29 gm in male and 0.78, 2.95, 5.01 and 8.18 gm in female, as

Table 3. Observed maximum length and weight of *Ascaris lumbricoides* according to the age

Age*	Maximum length(cm)		Maximum weight(gm)**	
	Male	Female	Male	Female
2 $\frac{3}{4}$ months	12.5	14.2	0.53	0.78
4 $\frac{3}{4}$ months	16.4	22.0	1.21	2.95
6 $\frac{3}{4}$ months	19.2	26.2	1.95	5.01
12 $\frac{3}{4}$ months	22.8	30.8	3.29	8.18

* Treatment interval+3 weeks (See text)

** Calculated weight from maximum length by correlation equation

presented in Table 3.

From the above data, the maximum growth curves of *A. lumbricoides* by treatment interval were made as Fig. 3 and 4. As already described, age determination was done by adding 3 weeks to each treatment interval. Because the maximum growth curve shows good correspondence with the age in month, the correlation equations were made. When the age in month is expressed by 'X' and length in cm by 'Y',

Fig. 3. The maximum growth curve of *Ascaris lumbricoides* revealed by the length.

Fig. 4. The maximum growth curve of *A. lumbricoides* revealed by the weight.

the equation was ' $Y=9.213 \ln (X+1)+0.025$ ' in male and ' $Y=11.953 \ln (X+1)+0.025$ ' in female respectively. The value '0.025' was a consideration of length of the second stage larvae that just hatched out from the eggs in duodenum (Seo, 1978).

From an overview of Figs. 3 and 4, the growth was more rapid in female than in male. Weight gain was more rapid than length growth in both sexes especially in female. The growth of length was more rapid during initial 2-3 months of infection while the weight gain was more rapid later than these period.

DISCUSSION

The growth curves of male and female *A. lumbricoides* were made by observing the length and weight of worms collected from different treatment intervals. In determining each chronologic growth, we used the length as a maximum growth indicator rather than the weight because there was a report that the weight of worms, especially in female is changeable due to the depletion of eggs and ovary (Masuda, 1963).

If the variation in weight in female are extreme enough, especially after maturity, thus the weight of worm has no correlation with the age of infection, the distribution pattern of weight would be superimposed exactly each other disregarding the treatment interval. However, our result was totally different. There was an apparent limitation of length and weight in the each treatment interval. Thus we could not accept the Masuda's opinion. And because the collected worms were challenged at different time during the allowed period of treatment interval, the most of the worm sizes were superimposed each other. However, there were always longer and heavier worms in next treatment interval terms.

As in other biological phenomenon, there

should be a variation in the growth of *Ascaris lumbricoides*. Probably because this worm is human parasitic, there have been surprisingly few reports on the size variation in known period of infection. Koino (1924) reported that 667 worms collected 50 days after self infection were in the range of 3-8 cm in length. Jung (1954) who observed the narrow range of size variation in heavily infected cases, concluded that those cases were infected with single brood. Anyway, the size variation of *Ascaris* of given period of infection should be rather narrow than previously considered.

Unless the meaning of the obtained growth curve is indiscriminately applied, it is expected that the problem of confusion in determining the age of worm would not arise. We should apply these curves by months unit rather than shorter interval, when superinfection pattern is analysed.

Still there remains another question on the growth curves. In obtaining the maximally grown worm in this study, there was a possibility of treatment failure, especially the smallest which was actually resided in intestine and escaped the drug action. If they are expelled by the next interval-treatment, the maximum-sized worm may be longer than the expected in that interval. In this respect, Cho (1977) observed that, by pyrantel pamoate, the fourth stage larvae of 1.2-1.9 cm long, still in moulting process were expelled with at least 90% of chance. Furthermore, this possibility can be neglected because most of the worms were collected by repeated treatments.

SUMMARY

The chronologic growth pattern of *Ascaris lumbricoides* was made by the maximum length of worms collected from inhabitants after mass chemotherapy with pyrantel pamoate by various

intervals; 2-month, 4-month, 6-month and 12-month.

The results obtained were summarized as follows:

1. When the collected 497 worms were plotted on weight/length chart by treatment interval, there was always size limitation in each group, permitting the idea of maximal growth in a given period of infection.

2. The maximum lengths in each interval treatment, 2, 4, 6 and 12-month were; 12.5, 16.4, 19.2 and 22.8cm in male and 14.2, 22.0, 26.2 and 30.8cm in female respectively.

3. The maximum growth curves were expressed by the equations; $Y=9.212 \ln(X+1)+0.025$ in male and $Y=11.953 \ln(X+1)+0.025$ in female when X is age in month and Y is length in cm.

4. It was revealed that female grew more rapidly than male. The growth of length was rapid in initial 2~3 months and weight gain was rapid in later than 2~3 months. The weight seems better than length as an indicator of aging.

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＝國文抄録＝

회충의 경시적 발육 양상

서울대학교 의과대학 기생충학교실 및 풍토병연구소

徐 丙 高・蔡 鍾 一

회충감염자를 치료하고 얻은 충체를 관찰하면 흔히 여러 크기의 회충이 섞여 감염되어 있음을 본다. 회충이 장 내에서 성장할 때에는 밀집효과(crowding effect)가 그 크기에 영향을 주지는 않으므로 시간경과에 따른 성장곡선을 크기에 적용할 수 있을 것으로 추정된다. 만약 개략적일지라도 경시적 회충 성장양상을 알 수 있다면 충체수집을 통하여 회충疫學에 있어서의 중요한 문제 하나를 해결할 수 있다. 즉 개개인에서 년간 추가되는 감염(super-infection)의 빈도를 계산할 수 있다.

과거의 개념으로는 회충의 무게는 특히 암놈에서 자궁안 충란의 抱卵정도 및 난소의 발육정도가 때에 따라 달라지기 때문에 회충 무게에 의한 감염기간 추정은 불가능하다는 것이었다.

이 연구에서는 지난 3년간 각종 치료 간격을 두고 감염회충을 얻어 비교적 명확한 나이를 알 수 있는 회충을 수

집하고 그 길이와 무게를 측정하였다. 여기에서 경시적 성장곡선을 얻을 수 있었다. 그 결과를 요약하면 다음과 같다.

1. 最長 장내 감염기간이 명백하였던 감염자에게서 얻은 회충 497마리에 있어서 性比(암놈 : 숫놈)은 1 : 0.82이었다.

2. 腸內감염기간에 體內移行期間(migrating phase) 2주일 및 각 치료간격의 지연 1주일, 모두 3주일을 더하여 각각 2 $\frac{1}{4}$, 4 $\frac{1}{4}$, 6 $\frac{1}{4}$ 및 12 $\frac{1}{4}$ 개월 동안의 감염기간을 가진 회충에 있어서 제일 긴 회충은 숫놈에서 각각 12.5cm, 16.4cm, 19.2cm 및 22.8cm이었고 암놈에서는 각각 14.2cm, 22.0cm, 26.2cm 및 30.8cm이었다.

3. 총체의 감염기간과 最長 길이와의 관계는 숫놈에 있어 $y=9.213 \ln(x+1)+0.025$ 의 상관공식으로 표시되고 암놈에서는 $y=11.953 \ln(x+1)+0.025$ 의 상관곡선의 식을 따르는 것으로 나타났다(x : 감염월수 : y : 길이 cm).

4. 성장곡선의 概型은 암놈이 숫놈보다 더 빨리, 더 길게 자라고, 또한 무게가 길이보다 더 뚜렷하게 증가하고 있음을 보이고 있다. 길이의 성장은 감염후 2~3개월에 가장 빠르고 무게의 증가는 그 이후에 나타남을 보이고 있다.