MALARIA ON THE CHINA BURMA HIGHWAY[1]

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A number of epidemics were reported along the China-Burma Highway in the southwest portion of Yunnan Province during the rainy season (summer) of 1939. As the diseases were making disastrous inroads on the hundreds of thousands of Chinese employed as laborers to maintain the road and as drivers to bring in war supplies, the Chinese Government requested the assistance of the United States Government. The Surgeon General, Dr. Parran, sent me with Dr. Bruce Mayne and Surgeon H. J. Bush to coöperate with the Chinese National Health Administration, Wei Sheng Shu. We were expected to determine the nature of the epidemics, to suggest methods for their control, and to train a group of Chinese doctors in such methods. As it was believed that pernicious malaria was the chief cause of deaths, equipment for establishing a laboratory for diagnosis and instruction was hurriedly assembled and we sailed for China.

On reaching Hong Kong we found that flying over the Japanese lines from there to Kunming was precluded by the cost of carrying our supplies and equipment (the estimate being 10,000 Hong Kong dollars). So we went via Haiphong and Hanoi in French Indo-China. Shipments for China overwhelmed the freight capacity of the narrow gauge railroad so our coolies fought our 24 boxes on board the train as excess baggage and a guardian sat on them for three days while we crawled the 760 miles to Kunming, the capital of Yunnan Province. After discussions with the authorities of the Province and the National Health Administration, we found that though plague had not been reported in southwest China for 40 years, it had been present recently just over the border in Burma. A brief investigation

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revealed that during the summer of 1938 there had been an epidemic at Namhkam (50 miles away in Burma). Under Dr. Seagrave (Director of the Baptist Mission Hospital) it was quickly controlled through wholesale inoculation. A small outbreak (principally an epizootic among rats) occurred at Hsenwi (75 miles west in Burma) during September, 1939. An anti-rat campaign controlled this one. During our stay, plague appeared again in Bahmo (head of navigation on the Irrawady) but did not spread into China. In upper Burma, plague has consistently followed food (grain) routes. The grain routes from Burma into China have not been overland. Unless they become so, there is little danger from plague.

To date cholera has played no great rôle in the building of the road, though some cases occurred last year. There have been minor reports of dysentery and some smallpox, but the attention of all is focused on malaria, which is severe. Control of this disease is the greatest problem confronting the Chinese. Therefore, we suggested that a group of young Chinese doctors accompany us on the trip, so that they might learn to make malaria surveys, mosquito surveys, and how to control the disease. As our party of 21 left Kunming in four trucks we made surveys as we traveled west.

CHINA-BURMA HIGHWAY

We headed toward the Burma border over an amazing highway, 625 miles long cutting across the loops of an ancient caravan route, traversing numerous high mountains, transformed by hand labor in nine months into a passable road without the aid of modern equipment. The road was laid out and engineering supervision provided by the Central Government, but labor was supplied by local officials. On this project hand-work literally meant hand-work. More than half of the coolies had no tools of any description. They grubbed up rocks and handfuls of earth and carried them in their bare hands to the fill and dropped them. Mile after mile was cut, angling steeply up across the face of almost sheer cliffs, cut by hand through clay or rock on slopes so abrupt that a few feet sliced into the mountain com-

pelled a vertical cut of hundreds of feet. When these deep hill-side cuts were first made they were vertical as it was impossible to slope them without road machinery. There were no steam shovels, no tractors and trucks, and there were very few picks and shovels. Hand labor necessary for sloping was beyond the means of supply, even in China. It was easier to wait for the rains of the next season to indicate which parts of the slopes were stable and which would slide to determine which sections of fill had settled and which would wash out. Labor could be kept at strategic points to clear the landslides and refill the washouts. This was the original system and is the maintenance method in effect at present.

After the road via Nanning to Indo-China was cut and when the railroad from Indo-China was bombed, the road to Burma became increasingly important to the Chinese. It was imperative that it be kept open. Greater gangs of laborers were employed so that wash-outs and landslides would not block the road for more than 24 hours at a time. In addition many small groups were placed at dangerous points to clear the road after accidents, which were all too frequent. The road is narrowest where it is steepest and most difficult to cut. Here and there it widens for a turnout where descending trucks await the climbers. Sometimes the speed is too great for a stop at the turnout. The usual result is one car across the road, and the other one from a few feet to a few thousand feet down the mountain. The labor gangs can live fairly well on the road only if they are kept free of malaria.

HISTORY OF MALARIA IN YUNNAN

In ancient days southwest Yunnan was feared as the home of a disease deadly to strangers and travelers, which was called chang-ch'i. Old rock inscriptions in Kweichow Province refer to this infection, indicating that it was probably known as early as the third century B.C. Old Chinese manuscripts advise the traveler going into the southwest to make arrangements for the remarriage of his widow, as few men ever returned. The disease was described as a late summer and autumn fever, often with

coma. Members of the native population often recovered but later showed chronic manifestations with jaundice and enlargement of the abdomen, followed by cachexia and death within one or two years. Such a description is familiar to those acquainted with malaria, especially when accompanied by tales from prehistoric times that the disease was either caused by the deadly gases of decaying animal or vegetable material, or, and most usually, by the vapor rising from damp ground in the high valleys of this subtropical section. One is not surprised, therefore, to find out that chang-ch'i is made up of words meaning "malicious air." In 1935 Yao, Ling, and Lin, proved (1) that chang-ch'i was none other than malignant tertian malaria. As the authors pointed out in another report (2) the natives had noticed that the top of a mountain was usually free of the disease but that at lower elevations the infection was heavy. It is now thought that malaria is responsible for more deaths than all the other infectious diseases in the province and that hundreds of thousands of young adult lives are damaged annually.

Dr. H. Y. Yao, the provincial health administrator (one of those accompanying us) informed us that the disease was hyperendemic in the three districts which constituted the southern and southwest border of the province. During a trip in 1935 he had found the death rate very high and had observed a considerable economic loss. Based on this survey he and Dr. Yen, Director of the National Health Service, had suggested a comprehensive five year program for the control of malaria, which had just been adopted by the local officials. However, it had not as yet been put into operation.

INHABITANTS

The people of southwest Yunnan are not Chinese. Between one and two hundred miles before the border is reached the Chinese commence to give way principally to the Shans. As Burma is approached the Chinese disappear almost completely to be replaced by Shans and aboriginal tribes, the second largest being Katchins. Dotted here and there principally in the mountains are found smaller and smaller groups of Lolos, Miaos and Lisos.

Each of these races has its own language. Fortunately, our colleagues were English speaking Chinese who could converse with an occasional Chinese speaking Shan, who in turn interpreted our questions to the local inhabitants.

The life of these people is primitive. The better houses are of sun-dried mud brick, but the average is mud-plastered bamboo with thatched roof. The local ruler, the Sawbwa, and members of his family, may live on a higher scale if his ancestors had imported teak from Burma, and had brought in Chinese carpenters to build their Yamens (large compounds), an architectural mixture of the Burman, Shan, and Chinese. The Sawbwa holds office by inheritance and his domination is complete. He makes and administers all the laws just as he is the owner of all the land and the people in his district. These rulers are invariably the ones chosen by the Central Government as local magistrates, for it is obvious they are the only ones who can exert any authority.

Most of the Shans inhabit the valleys at elevations between 2,000 and 5,000 feet, which are on or close to the Tropic of Cancer and, therefore, have a climate favorable to malaria. Malaria rates are high. Through the centuries these valley dwellers have become accustomed to malaria and have learned to live with it, but they have hardly learned to work with it. The ground is so fertile, however, that living is easy and no destitution is apparent.

The Lolos and Katchins seem to prefer the higher mountain sides where it is very much colder and where opportunities for mosquito breeding are much restricted. As a consequence malaria is absent for the most part and is seldom found over 2 to 4 per cent. Many of these people come into the valleys in the late autumn and plant winter crops. A number put in a late spring planting, then they retreat to the mountains for the duration of the malaria season, taking a few daylight trips on market days, but not spending the night in the valley until the commencement of the dry season in November. They then gather what crop has survived the summer. Thus they have avoided malaria through the centuries. They, of course, make good laborers but, if concentrated in labor camps in the low ground in the rainy season, when they are most needed, malaria quickly becomes

epidemic. Cerebral cases soon appear, deaths follow, and the healthy disappear into the hills.

MALARIA PREVALENCE ON THE ROAD

As was expected, the first (eastern) part of the road did not give any evidence that malaria was prevalent. Although it is estimated that there are over 500,000 cases each year in the province, the rate is less than 2 per cent in the city of Kunming, which is at an elevation of approximately 6500 feet above sea level.

At Hsiang Yun, a few miles west of Kunming, elevation 6800 feet, in the hospital for railroad workers, the records showed that 40 per cent of the patients had malaria, both benign tertian and malignant tertian. However, they were imported from lower elevations to the west. Of the 17 local children between 1 and 12 years of age who were present, all had spleens of normal size. In an examination of 94 school children at Hsia Kwan still farther west, elevation 6,000 feet, we found a spleen index of 4.25 per cent and parasite index of 2.1 per cent (thick blood films). These were all benign tertian. Malaria is minimal on the high plateaus and in the valleys between Kunming and Hsia Kwan, a distance of 265 miles and at elevations averaging 6,000 feet. It is all benign tertian and we found infection rates not over 2 per cent. It is light endemic benign tertian from Hsia Kwan west 160 miles to Pao Shan (elevation 4,800 feet), with rates up to 6 per cent. Between here and Lungling, 105 miles west, and at approximately the same elevation (4,700 feet), the incidence was perceptibly greater, 16 per cent, and malignant tertian was present. As we moved yet farther west to the Burma border (about 100 miles) the rates rose even more sharply as elevations fell (see table 1). This is the hyper-endemic area.

The highest rates found on our survey were in Chefang during the month of January, which is the time of lowest infection rates. (See chart 1.) So we established our headquarters and laboratory at this point. During the rains of June to October it seems certain that these rates must equal 100 per cent. From Lungling to Wanting (the border) and on into Burma comprises the hyper-endemic area.

The survey at Chefang included the largest single group of children between four and twelve years of age examined at any one place. The distribution of plasmodial species and the relation between positive blood films and spleen index is well illustrated in this group. Of the 237 children examined there were 144 or 60.8 per cent with enlarged spleens, all hard and varying in size between the umbilicus and half way from this point to the costal margin. Thick film examination revealed 124 positive cases or

TABLE 1

SEASON	PLACE	ELEVATION ABOVE SEA LEVEL	NUMBER EXAMINED	SPLEEN INDEX	PARASITE INDEX
		feet		*per cent*	*per cent*
Summer	Kunming	6,500			2.0 (estimate)
December	Hsia Kwan	6,000	94	4.2	2.1 (thick blood film)
December	Yung Ping	6,200	60	6.6	3.3 (thick blood film)
December	Pao Shan	4,800	55	9.1	5.4 (thick blood film)
March	Lungling	4,750	100	15.0	16.0 (thick blood film)
December	Manghsih	2,800	31	25.4	45.2 (thick blood film)
January	Chefang	2,500	237	60.7	52.3 (thick blood film)
April	Wanting (adults)	3,500	54	52.0*	24.0 (thick blood film)
April	Loogan vi page	3,500	20	95.0	25.0 (thick blood film)
January	children				
	Loiwing Chinese	2,500			
	(newcomers)				
	Adults		577		18.4 (thick blood film)
	Children		122	5.7	14.7 (thick blood film)
February	Loiwing	2,500			
	Shan children		27	63.0	33.3 (thick blood film)

* Adults.

52.3 per cent. Of those with normal sized spleens, 12 per cent were blood positive. The true midwinter rate is, therefore, 72.8 per cent. Of the 144 blood positive cases, 30 per cent were *P. vivax* and 67 per cent *P. falciparum*; 3 per cent were mixed.

It is evident that malignant tertian malaria has been moving slowly east, farther into China, since the opening of the road. How far it will travel is problematical. In this connection the history of some of the cities is interesting. The eastern-most point where malignant tertian was found was Lungling, elevation 4,750

feet, which is the first place (traveling from Kunming) with an elevation below 5,000 feet. It is only 22 miles east of Manghsih which is only 2,800 feet above sea level. The Manghsih rate was 45 per cent, yet that at Lungling only 16 per cent. However, still farther east at Pao Shan, at approximately the same elevation, 4,800 feet, there is no malignant tertian and the parasite

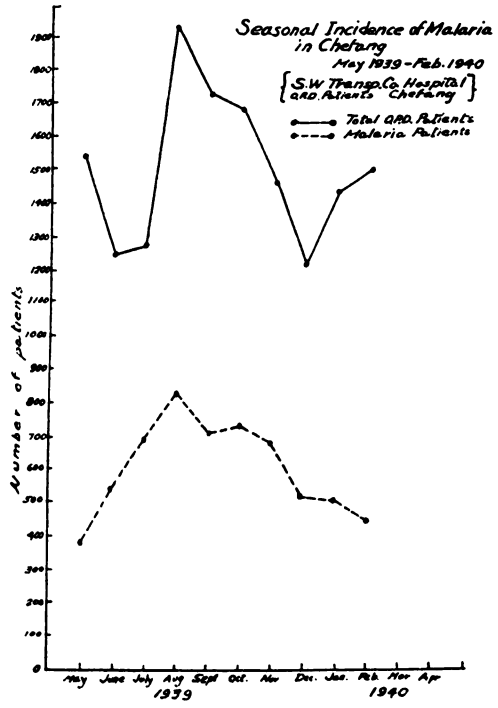

CHART 1

rate is only 5.5 per cent. Until the road was opened malaria had not been noticeable at Lungling and none had been reported for 30 years. The rate of 16 per cent has developed between commencement of work on the road in 1938 and its opening in 1939. It was not difficult for malignant tertian to jump the 25 miles from Manghsih to Lungling for traffic was heavy over the one mountain. It will hardly make a quick jump of the 105 miles to Pao Shan and then another 170 miles to Hsia Kwan,

for now it must not only cross a number of very high mountains and pass the Salween gorge and the Mekong gorge, but must also adapt itself to a much higher altitude. In this road division most of the traffic is freight; the drivers do not go "through," each sticking to his own section. During the season of our visit (December) no mosquitoes were observed at any point east of Pao Shan and it is doubtful if *Anopheles* production is at all high even in the summer. Even if malignant tertian appears its control should be relatively simple.

MALARIA AND THE LOCAL ANOPHELES

During our surveys between December 1939 and May 1940 we identified 11 species of anopheles, as follows: *A. aitkeni, A. barbirostris, A. hyrcanus var. sinensis, A. gigas var. baileyi, A. minimus, A. jeyporiensis var. candidiensis, A. annularis, A. maculatus, A. splendidus, A. stephensi, A. tessellatus.*

Dr. R. C. Robertson (3) made a survey at Manghsih during the rainy season of 1939. He did not find all of these but did find five additional ones which we did not see: *A. lindesaii, A. culicifacies, A. vagus, A. kochi, A. karwari.*

He noted, as we did, that next after *A. hyrcanus*, the anopheline present in greatest density was *A. minimus*. Also, it was the species most heavily infected. Although he found infection in five other species it seemed evident to us that *A. minimus* was the principal and perhaps the only local vector. All but one of his infected species breeds along with *A. minimus* and can be grouped with it. This is not true of the other, *A. hyrcanus*, in which he found infection (3.5 per cent in 242 dissections). However, knowing that *hyrcanus* is a vector of no importance in other areas, and is infected only when a better vector species maintains a high malaria rate, we believed the same would hold true in Yunnan.

Of course, if our deductions proved erroneous and *hyrcanus* was capable of continuing the high local malaria rate, then additional measures would be necessary if any control of the disease was to be secured. In preparation for such a contingency an extra supply of Paris green was secured and a fish hatchery was

dug for propagation of top minnows. It was manifestly impossible to apply a larvicide to all of the rice fields which might supply *hyrcanus* to a village. Rice fields extend from one end of the valley to the other. It should not be difficult to stock such rice fields with top minnows. Although they would not control all *Anopheles* production, they could be expected to reduce their numbers sufficiently so that the density of adult mosquitoes would no longer be excessive. Having utilized minnows to reduce production in the larger area, Paris green could be dusted at weekly intervals on nearby fields, thus controlling production almost wholly from those within an eighth of a mile of town. These two measures should so reduce the density of such a poor vector as *hyrcanus* as to assure malaria control in the absence of a better vector.

By good fortune the Rockefeller Foundation was seeking a location for their research laboratory. They utilized facilities of the laboratory we equipped at Chefang and chose that as their headquarters. The director, Dr. W. C. Sweet, decided that his primary study should be a determination of the natural infection rate (if any) in *A. hyrcanus var. sinensis* in the absence of *A. minimus*. Chefang was ideal for this because it is part of the hyperendemic area and we had already commenced to control the production of *A. minimus*. Our Chinese colleagues agreed to continue this control.[2]

We began malaria control at Chefang and supervised it at the airplane factory at Loiwing, not only for the purpose of controlling malaria at the two worst places, but also for demonstrating the methods and feasibility of control. We utilized sections of locally grown bamboo as sub-soil tile; demonstrated the technique of distributing oil and pyrethrum emulsion as anopheline larvicides, and various methods of diluting Paris green and distributing it. We commenced a nursery for the propagation of shade bushes and stocked our hatchery with the American top minnow *Gambusia affinis*, which has now circled the globe. We even taught them screen door making.

[2] In a recent communication Dr. Sweet states that to September no infected *hyrcanus* have been found.

At our suggestion most of the Chinese physicians trained by us have been appointed by Wei Sheng Shu as their first malaria control unit for the China-Burma Highway. Headquarters of this unit have been established at our laboratory at Chefang. Dr. Sweet and his assistants are remaining at the laboratory, thereby assuring the continued benefits of advice and aid from them. In addition the Chinese have established their own research station at Manghsih under the direction of Dr. Y. T. Yao.

The anti-malaria unit is equipped to finance and direct control work at the border station of Wanting, as well as at the important headquarters and transfer points of Chefang and Manghsih. This unit will supervise the locally financed project at Loiwing and is prepared to supervise projects at Lungling and Yung Ping. We arranged through Dr. Yen that the Minister of Finance (Dr. Kung) give to this unit the authority to select camp sites where malaria could be controlled easily.

It is felt that these measures, namely, protection of the labor camps and protection of the headquarters towns, will solve the principal health problems which militated against the building of the road and which have slowed up the carrying in of war supplies. It is hoped that this unit will be a center, not only for the dissemination of knowledge of malaria, but a force which will stimulate malaria control in the cities.

REFERENCES

(1) YAO, Y. T., LING, L. C., AND LIU, K. B.: Studies on the so-called chang-ch'i. Chinese Med. Jour., 1936, **50**, 726–748.

(2) LING, L. C., LUI, K. B., AND YAO, Y. T.: Studies on the so-called chang-ch'i. Chinese Med. Jour., 1936, **50**, 1815–1828.

(3) ROBERTSON, R. C.: Malaria in Western Yunnan with reference to the China-Burma Highway. Chinese Med. Jour., 1940, **57**, 57–73.