It is quite evident, after twenty years' experience of natives and their stock in East Africa, that the only way to obtain adequate return for the money spent in veterinary research is by applying the best methods of education in live stock matters to our primitive native stockowner and actual demonstration of animal husbandry, which gives better results than his own, is evidently the way to achieve this result.

A Central Native Training Centre serves as the educational centre for native live stock education in the Colony, and is, I hope, only the beginning of an organization which will develop into a Native Veterinary College on the lines of the Lahore Veterinary College in the Punjab which trains the Indian native in veterinary matters and turns out the Indian veterinary assistants employed in Eastern Africa.

Such an institution is strongly indicated in Kenya to serve Eastern Africa. It would embrace every side of animal husbandry suitable for native requirements, and would maintain small herds of native and improved stock which would not only afford the necessary material for teaching modern methods of management, such as proper milking and calf rearing, but would also be able to obtain results valuable from a nutrition and breeding research point of view.

1. The readiness of the African to absorb improved methods when suitably demonstrated.

2. The material for demonstration and advantages of training pupils in an atmosphere of improved stock and stock management in the settled areas where they could get experience in preventive inoculations.

3. And, finally, the enormously increased return from expenditure on research by allowing of the wider application of results, all support this view.

An institute such as I have in view would be supplementary to local education by districts. Selected pupils would be received for secondary education and graduate. The benefits to the live stock industry by having a supply of men trained in this way to work amongst native-owned live stock of Eastern Africa under European officers cannot, in my opinion, be overestimated.

Paper No. 41.

THE SPLEEN IN RUMINANTS AND EQUINES.

MAINLY A REVIEW ON THE SEQUELAE OF SPLENECTOMY.

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THE object of this paper is to review, briefly, the various observations made at Onderstepoort in the case of domesticated animals on which splenectomy had been performed. The literature on splenectomy, especially regarding the lower animals, has been reviewed by De Kock and Quinlan (1927), De Kock (1928), De Kock (1929 A), De Kock (1929 B), and only some of the salient points will be referred to here. Splenectomy has been very successfully performed on man, dog, the

various laboratory animals (rabbits, mice, rats, guinea-pigs), monkeys, equines, bovines and ovines. The literature contains full descriptions of the various methods of operation. At Onderstepoort it soon became evident that the results to be expected from splenectomy depended on the fact as to whether the animal was the *carrier* or not of certain blood parasites. De Kock and Quinlan (1926) showed that the course of *ovine anaplasmosis* in South Africa was of such a mild nature that it was not identified for a long time. It was only in 1924, when *carriers* of *ovine anaplasma* were splenectomized, that relapses of acute anaplasmosis followed, which in some instances actually proved fatal. In the same way, splenectomy in equines, the carriers of *Nuttallia equi*, was followed by fatal relapses of Nuttalliosis. In bovines, relapses of *anaplasmosis* alone, or combined with *piroplasmosis* and *gonderiosis*, followed.

According to Ziemann (1924), human patients without a spleen show malaria relapses, in some instances ending fatally. Dealing with splenectomy in apes, Gonder and Rodenwalt (1910) maintain that *Plasmodium kochi* usually disappears quickly from the blood, whereas after splenectomy the parasites remain for months in the blood in large numbers. Lauda (1925) showed that the extirpation of the spleen in rats was followed by a severe anaemia. His work was confirmed by Mayer and co-workers (1927), who noted that the corpuscles of splenectomized rats, affected with this severe anaemia, contained small bacilliform bodies resembling *Bartonella bacilliformis*. Regendanz and Kikuth (1928) showed that splenectomy in marsupial rats was followed by the appearance in the blood of a new piroplasm (*Uuttallia brasiliensis*). Kikuth (1928) found that dogs infected with *Piroplasm canis* and *Bartonella canis*, when splenectomized, showed fatal relapses in eight cases out of nine. From the above it would, therefore, seem that the spleen has a distinct bearing on the course of immunity of some protozoal and becterial diseases in man and animals.

In order to review the most important observations made at Onderstepoort, it is advisable to consider the results of splenectomy under the following headings:—

(*a*) Animals *not* the carriers of any disease-producing entity, e.g. anaplasma, piroplasma, nuttallia, gonderia, etc.

(*b*) Animals which are *carriers* of blood parasites.

(1) *Splenectomy in non-carriers* will be considered in the equine, bovine, and ovine. In a normal horse, splenectomy was followed by a leucocytosis, at times reaching 55,000 per c.mm. In the first instance it was a neutrophilia, and, later, a monocytosis with slight erythrophagocytosis. There was a slight reduction in the number of erythrocytes, e.g. from 11 millions to 8 millions, but this might have been due to the fact that the animal was brought from the veld to stable conditions. Unfortunately, the writer did not have an opportunity of studying the results of splenectomy in a bovine not the carrier of blood parasites. Splenectomy on about 22 susceptible sheep was followed by a temporary polyglobuli and neutrophilia. Four sheep died as a result of the operation. In one case, death occurred 18 hours afterwards, whereas one survived as long as seven days. At post-mortem these cases revealed no specific changes, nor was the seat of operation complicated by suppurative inflammation.

These cases afforded sufficient material for observing the effect of splenectomy on the blood-forming organs of sheep not the carriers of any blood parasite. Besides slight degenerative and circulatory disturbances, no characteristic lesions were observed in any of the organs. De Kock and Quilan (1927) maintain that the operation of splenectomy in susceptible (non-carriers) equines, bovines, caprines, and ovines can be carried out practically without any mortality: De Kock (1928) states that it would appear that the reticulo-endothelial apparatus of the sheep is so developed that it can adapt itself, after removal of the spleen, to deal with normal blood destruction, without revealing specific changes in any of the haemopoietic organs.

As the *distribution of the R.E. cells* varies greatly in different species, it follows that different organs are chiefly concerned. Thus in man, dog, and ovine species the spleen seems to be the most important organ dealing with the disposal of worn-out erythrocytes, but less so in rabbits and guinea-pigs, whereas in birds the liver is the chief agent. However, it may be said that the fate of the erythrocytes in animals with or without a spleen is by no means settled, and in any case it will be found to be considerably modified in different species. The intermediate steps of disposition of the products of red-cell destruction are even less certain.

(2) *Splenectomy in animals which are carriers of parasites.*—In the case of equines (De Kock and Quilan, 1927), splenectomy of carriers of *Nuttallia* sp. showed fatal "*relapses.*" A recurrence of the parasites in the blood occurred in three to four days, together with a neutrophilia. The latter was followed by a monocytosis associated with erythrophagocytosis and "vacuole" formation. Symptoms and post-mortem changes were those of a peracute form of nuttalliosis. In the case of bovines, it would appear that all animals at Onderstepoort are not necessarily the carriers of the three parasites, viz., *P. bigeminum*, *G. mutans* and *Anaplasma marginale*. Some animals only showed mild reactions of anaplasmosis when splenectomized, whereas, when subsequently infected with blood containing *P. bigeminum*, they showed acute reactions of redwater. Carriers of the three parasites, when splenectomized, showed the presence of *Gonderia* in great numbers without any apparent clinical manifestations. *P. bigeminum* was mainly responsible for the acute symptoms of oligocythemia when it made its appearance after splenectomy. In all bovines without a spleen the course of the disease was of a chronic nature, especially as regards the blood changes. According to De Kock (1929) it would definitely appear that the spleen plays a part in the acquisition and maintenance of *immunity* in some of the protozoal diseases of man and animals. With reference to this immunity very little exact information is available about the precise function of the spleen. Some authorities are definitely of opinion that the spleen is the *only* organ capable of setting up an immunity, and that it plays the sole part in the formation of antibodies. In would appear that these antibodies are continually being liberated in the spleen by virtue of a *labile* or *latent* infection, maintained in the spleen, probably in virtue of its involved system of blood sinuses.

In the case of splenectomy in piroplasmosis, a relapse takes place as a result of the multiplication of the parasites present in the circulation. The antibodies still circulating in the system will determine whether the parasites will predominate and so cause the death of the animal, or whether the animal will recover from such a relapse. The

recovered animal may remain immune for some time by virtue of the antibodies still present in the circulation. Due to the absence of the spleen, however, no further antibodies are manufactured, and in this way the animal again becomes susceptible. From the acute nature of redwater following reinfection, which took place in bovines in 1928, splenectomized in 1925, it would appear that these animals had completely lost their immunity. In fact, they seemed to have become far more susceptible than ordinary locally bred animals to which class they belonged. In all instances, the majority of the erythrocytes in the blood revealed the presence of parasites. How soon after splenectomy an animal loses its immunity has not yet been determined. On the other hand, non-splenectomized locally bred cattle acquire a good lasting immunity against the local strain. Splenectomy of the locally bred animal in some way or other interferes with the natural inherited resistance, because locally bred animals naturally immunize for more readily than imported cattle. When such locally bred splenectomized susceptible animals are exposed to natural infection, they die of peracute redwater, their susceptibility resembling that of imported cattle. In fact it appears enhanced.

Ovine anaplasmosis was for the first time described by De Kock and Quinlan (1924). It was found that a certain percentage of sheep kept locally become carriers of *Anaplasma*. The course of the disease is of such a very mild nature that, as a rule, no clinical symptoms are manifested. When, however, *carriers* of ovine anaplasma are set up, which in some instances actually prove fatal. In those animals which did not die, the course of the disease was protracted. For instance, sheep 8439 splenectomized in September, 1924, is still (July, 1929) showing the presence of Anaplasma in the blood. The parasites vary from rare to frequent. This animal has never recovered the red-cell quota registered before splenectomy, i.e. 10 million per c.mm. The number of erythrocytes per c.mm. has varied from 3 to 8 millions, and sometimes distinct morphological changes of the blood have been observed.

The blood-changes in the splenectomized infected sheep were associated with a marked *oligocythemia*. With reference to the white blood cells, first a *neutrophilia* was noted, then a monocytosis with erythrophagocytosis, followed by a lymphocytosis (De Kock and Quinlan). It would appear that the neutrophilia is associated with the operation of splenectomy, the monocytosis with the removal from the circulation of degenerated or worn-out erythrocytes, and the lymphocytosis seems to have some relation with the return to normal of the erythrocytes. More or less the same course was encountered either in " carriers " splenectomized, or in susceptible splenectomized sheep subsequently injected with infected blood.

Regarding the *pathology of anaplasmosis in splenectomized sheep*, De Kock (1928) maintains that the most characteristic lesions were encountered in the *liver*, and that these were characterized by extensive erythrophagocytosis and desquamation of the " stern " cells of Kupffer. In these " stern " cells phagocyted erythrocytes were found in all stages of digestion, i.e. from recently phagocyted erythrocytes to haemosiderin pigment granules and vacuoles. In some instances the accumulated desquamated " stern " cells were responsible for a good deal of atrophy of the liver parenchyma. Desquamated histiocytes (?) with well-marked erythrophagocytosis and haemosiderosis were also prominently associated with the capillaries of the alveolar

walls of the lung. It was not clear whether they were histiocytes derived from the lung tissue, or whether they had drifted to the lung with the blood from elsewhere. As regards the *fate* of these cells with engulfed erythrocytes, De Kock (1928) is inclined to believe that the phagocytes are capable of carrying an intracellular pigment metabolism. Part of the metabolized pigment is extruded into the blood and excreted, whereas the residue forms the granules so conspicuous in those cells, known as the monocytes. The cells pass on from the lung and reach the circulation, where they constitute the monocytosis referred to above.

Recently De Kock (1929) described interesting *changes in the livers* of a number of ruminants that had died or were killed about *three* years after splenectomy. All these animals, without exception, showed the presence of *multiple nodules* in the liver. At first it was thought that they were of the nature of a neoplasm, but microscopical examination and the regular occurrence of these nodules after splenectomy, substantiated the fact that they were *new tissue* formations, i.e. probably of the nature of a metaplasia. In some instances they resembled very closely the structure of haemolymph glands and, provisionally, they have been designated *haemolymphoid-like nodules*. These nodules were completely circumscribed. They were usually multiple and varied from ½ inch to 1½ inch in diameter. In the case of sheep these nodules revealed well-formed follicles, with so-called "germinal centres," and even the organ smears from these nodules had a very close resemblance to similar smears prepared from haemolymph glands.

It would appear that *haemolymphoid-like* or *spleen-like* nodules have been observed to occur in the abdominal cavity of man after splenectomy. In all recorded cases in man and animals, with the exception of Schmidt's observations, none of these nodules made their appearance in the liver substance. According to Schmidt, these nodules in the livers of white mice, after splenectomy, morphologically resembled splenic palpa. The morphological studies in connection with these nodules in ruminants are continuing.

It may be of interest to know that part of the tissue in these nodules is actually associated with a *haemosiderosis*, i.e. these nodules undoubtedly possess reticulo-endothelial tissue dealing with the breaking-down process of degenerated or worn-out erythrocytes. At the present moment it is not yet known for what purpose and why these haemolymphoid-like nodules make their appearance in the liver so late after splenectomy. It was pointed out above that susceptible ruminants, after splenectomy, are able to adapt themselves to normal pigment metabolism without showing any morphological tissue changes in the haemopoietic organs of the body. In other words, the reticulo-endothelial system left over in the body and removal of the spleen is capable of dealing with worn-out erythrocytes without showing an increase or otherwise in the reticulo-endothelial tissue. At the present moment it is not known how soon after splenectomy this new tissue makes its appearance in the body. In ruminants it is certainly a period well over eighteen months.

One is not inclined to believe that their occurrence has any bearing on the chronic course of anaplasmosis and gonderiosis, referred to by De Kock (1929) in sheep and goats. Goat 8304, splenectomized 30.5.24, showed no parasites when killed on 19.7.28, whereas sheep 8428, splenectomized on 3.7.24, still revealed a mild gonderiosis when

killed on 19.7.28. At post-mortem both animals showed the presence of identical haemolymphoid-like nodules in the liver. Experiments are, however, being undertaken to ascertain whether such nodules will develop in splenectomized sheep which have never shown any parasitic infection.

Another point of interest is the fact that this new tissue does not seem to be able to function for splenic tissue in respect of *immunity* against piroplasmosis and anaplasmosis. It was shown above that immunized bovines which revealed these nodules at post-mortem had become almost " hypersusceptible " to reinfection some time after removal of the spleen. This new tissue in the liver was, therefore, not on a par with splenic tissue, and not able to manufacture the antibodies supposed to be formed in the spleen.

Enlargement of the spleen in ruminants and equines in South Africa is certainly of some significance in acute infectious diseases, and in those diseases in which there is excessive blood destruction or haemolysis. The rôle played by the spleen under these conditions is not understood at the present moment. When these diseases of ruminants and equines are, however, compared with those met with in the human being, one at once realizes that ruminants and equines in South Africa are practically free from those gross chronic splenic enlargements so frequently encountered in man, e.g. haemolytic jaundice, myelogenous leucaemia, splenic anaemia (Banti's disease), pernicious anaemia, chronic infections of the spleen as a result of malaria, bilharzia, syphilis, etc., various forms of splenomegaly associated with lipoid manifestations as encountered in Gaucher's disease, Niemann's disease, etc. Even the common splenic injuries of man, such as torsion and rupture, are extremely rare.

In acute cases of *infectious anaemia of equines*, De Kock (1923) referred to the extraordinary extensive erythrophagocytosis in the reticulo-endothelial cells of the liver, whereas the much enlarged spleen revealed a decided pigment poverty, i.e. a decreased pigment metabolism. It is not yet known why the spleen in this disease of equines shows this abnormality, why it is not capable of dealing with this slight surplus of damaged erythrocytes, and why the liver partially functions for the spleen in this particular respect.

At the present moment there are no known diseases in rumninants and equines in South Africa where the *erythropoietic* and *myelogoietic* functions of the red pulp of the spleen has been resumed under pathological conditions. *Hyperplasia of lymphoid tissue* in the spleen occurs in East Coast fever and snotsiekte, but it would appear that these changes do not subsequently lead to any chronic enlargements of the spleen.

Apart from its *experimental significance*, splenectomy in domestic animals has not formed a place in *therapeutics*. This drastic form of intervention in human medicine has of late years been assigned an indefinite rôle. According to Thursfield (1929) there has undoubtedly been an advance in knowledge on surgical technique, but physiology and pathology remain largely subjects for conjecture and hypothesis. In human medicine splenectomy has become the routine practice for at least three diseases, viz., splenic anaemia (Banti's disease), haemolytic jaundice and essential thrombopenia, whereas the value of its application in many other diseases becomes extremely doubtful. In pernicious anaemia of man, for instance, splenectomy seems to be undesirable since more effective medical treatment is now available.

There are still many interesting problems to be studied in splenectomized ruminants, e.g. what rôle the spleen plays in health and disease in regulating *the volume of blood* in the body. Barcroft and others, for instance, maintain that during exercise the spleen may expel more than half its volume of blood. *The increased resistance of erythrocytes* to haemolytic agents after splenectomy has been referred to by several investigators. When studying the effect of splenectomy in equines, De Kock (1927) was inclined to believe that the erythrocytes had developed such a resistance. The influence of splenectomy on the *thrombocytes* of the blood has repeatedly been referred to, although the exact mechanism is not yet fully understood. Experiments on dogs and monkeys have led various investigators to believe that the anaemia which follows removal of the normal spleen seems to be due to the loss with the spleen of a *substance* that has a stimulating effect on erythropoiesis, a concept strengthened by the fact that splenic extract is more potent than any other in raising the red blood-cell count when marrow is still functioning normally. This has recently been made the basis of a new therapy for certain forms of anaemia. Here a means may be found in treating the anaemia in such diseases where anaemia is brought about by blood-destroying agencies, such as piroplasms, anaplasms, trypanosomes, etc.

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