Serratospiculiasis in Captive Falcons in the Middle East: a Review

Jaime H. Samour MVZ, PhD, and Jesus Naldo DVM

From the Falcon Medical and Research Hospital, Fahad bin Sultan Falcon Center, P. O. Box 55, Riyadh 11322, Kingdom of Saudi Arabia.
Phone/fax: 00966-1-4567723. Email: falcon@shabakah.com
Abstract: Serratospiculiasis is a parasitic disease produced by filarial nematodes of the subfamily Dicheilonematinae of the genus *Serratospiculum*. This genus comprises at least 9 different species grouped according to the length of the spicules. In the Middle East, *S. seurati* has been the only species of this genus positively identified to date in captive falcons. *S. seurati* appears to have an indirect life cycle. In a previous study, the larval life cycle of *S. seurati* was replicated in five different species of beetles. More recently, two more invertebrate species, occurring naturally in the vicinity where falcons were maintained, have been added to this list. It is believed that the ingestion of infected beetles is the mode of transmission of *S. seurati* in captive falcons in the Middle East. Following ingestion of infected beetles, the L3 stage larvae are released from their capsule and penetrate the wall of the proventriculus and ventriculus. Histopathological evidence carried out recently suggests that the migration to the air sac system is direct. After reaching the air sacs, the L3 undergoes two further molts to produce the L5 or immature adult filarial worm. Adult parasites then breed and produce large quantities of embryonated ova, which are coughed out through the trachea to the mouth and then ingested and excreted in the feces. Histopathological findings in infected birds are normally associated with the presence of adult filarial worms, larvae and embryonated ova within the different tissues. In the periphery of the lungs, numerous parasitic stages have been found associated with mild focal hemorrhages and focal necrosis and mild to moderate macrophage infiltration. Adult filarial parasites of the genus *Serratospiculum* are commonly found on both sides of the collagen-muscle fibre layer immediately below the epithelial or mesothelial section of the air sacs. In several cases with severe infections, *S. seurati* have been found associated with pneumonia, air sacculitis and early lesions of aspergillosis. Ivermectin has been routinely used at the dose rate of 1 mg/kg SC repeated one or two weeks later without observing any abnormal side effects. Currently, the anthelmintic agent moxidectin is undergoing trials administered in tablet form for the control of *S. seurati* infections in captive falcons.

**Key words:** Serratospiculiasis, *Serratospiculum seurati*, falcons, Middle East, ivermectin, doramectin, moxidectin
Introduction

Serratospiculiasis is a parasitic disease produced by filarial nematodes of the subfamily Dicheilonematinae Wehr 1935 of the genus Serratospiculum Skrjabin 1916. This genus comprises at least 9 different species grouped according to the length of the spicules. Species with small spicules include Serratospiculum guttatum, S. chungi, S. congolensis, S. seurati, S. turkestanicum and S. kwangsiensis. Species with large spicules include S. tendo, S. thoracis and S. lii. An additional species, Serratospiculum amaculata, originally identified in North America from prairie falcons (Falco mexicanus) and peregrine falcons (Falco peregrinus anatum), is no longer a member of the genus Serratospiculum. This species has been re-classified as Serratospiculoides amaculata.

In the Middle East, S. seurati has been the only species of this genus positively identified to date in captive falcons. The identification was made through the use of scanning electronmicroscopy concentrating the examination on the cephalic structures (L. Gibbons, personal communication). In this species, the epaulettes are concave with regards to the dorso-ventral axis and are relatively narrower, unlike S. chungi, its closest relative, in which the epaulettes are rectilinear and slightly wider. Since many falcons are imported into the Middle East every year from many different parts of the world, the possibility exist that other Serratospiculum species may be prevalent in the area. Ongoing taxonomic studies carried out at this Hospital, may be able to identify additional species, such as S. tendo and S. chungi, in the near future.

Serratospiculiasis is the most widespread parasitic disease amongst falcons in the Middle East. For instance, in Qatar, up to 70% of the faecal samples examined from different falcon species were found positive to Serratospiculum sp. In a similar observation, made in the United Arab Emirates (UAE), up to 71% of the saker falcons (Falco cherrug) and up to 46% of the peregrine falcons (Falco peregrinus) examined were found positive to this parasite. In a parasitic survey, also carried out in the UAE, from 750 different falcons from six different species, 262 falcons (35%) were found positive to Serratospiculum sp. ova. In a similar study carried out in Bahrain, from 5360 different falcons examined, 1536 (25.29%) birds were positive to the presence of Serratospiculum sp. ova on fecal examinations. More recently studies carried out in the Kingdom of Saudi Arabia, from a total of 1910 falcon samples examined from four different falcons species, 850 (44.5%) have been found positive to the presence of Serratospiculum sp. ova (J. Samour, unpublished data).
Larval Life Cycle of *Serratospiculum seurati* within the Intermediate Host

*S. seurati* appears to have an indirect life cycle. In a previous study, the larval life cycle of *S. seurati* was replicated in five different species of beetles. In this study, 15 different invertebrate species were randomly allocated into naturalistic tanks and exposed to fecal samples containing 450-2000 ova of *S. seurati* per gram of feces. Invertebrate specimens were humanely destroyed and examined at 4, 6, 8, 10, 12, 14, 18, 22, 36, 44 and 70 days after exposure to the contaminated fecal samples. Microfilariae were observed surrounded by a thin and transparent capsule within the adipose tissue dissected from the central area of the body of the beetles (Figure 1). L1 microfilariae were observed as early as day 4, but most commonly these were found between day 4-6. L1 microfilariae measured 185.4 µm-566.5 µm in length and 15.4 µm-30.9 µm in width. L2 microfilariae were observed between day 6-10 and measured between 721 µm-1625 µm in length and 25 µm-50 µm in width. L3 microfilariae were observed after day 10 and measured between 2060 µm-3250 µm in length and 50 µm-75 µm in width. The results of this study suggested that the infective L3 larvae take a minimum of 10 days to mature within the intermediate host. The morphology and morphometrics of the L3 remained unchanged at day 70. In this study, it was not possible to replicate the life cycle of *S. seurati* in seven other different species of beetles, two species of grasshoppers and one species of cockroach. More recently, two more invertebrate species, occurring naturally in the vicinity where falcons were maintained, have been added to this list. Specimens from the two species were collected, humanely destroyed and examined under a dissecting binocular stereomicroscope. The examination revealed one or two L3 larvae within the body of 95% of the specimens collected. This observation confirms the hypothesis that certain naturally occurring invertebrate species may function as intermediate hosts for *S. seurati*. Specimens from the two species were collected and sent for identification to the Natural History Museum, London, UK. The specimens identified included a beetle from the Tenebrionidae family namely *Opatroides punctulatus* and an isopod or woodlouse from the Eubelidae family namely *Xeroniscus erythraeus* (P. Hillyard, personal communication).

Falcons are very often observed eating beetles roaming around their perch, particularly early morning or late in the afternoon when invertebrates are more active. These observations have been made on falcons weathering out in the open or on falcons maintained indoors and provided with sand as a substrate. It is believed that the ingestion of infected beetles is the mode of transmission of *S. seurati* in captive falcons in the Middle East.
Larval Life Cycle of *Serratospiculum seurati* within the Final Host

Following ingestion of infected beetles, the L3 stage larvae are released from their capsule and penetrate the wall of the proventriculus and ventriculus. Currently, it is unknown as to whether the larvae migrate directly to the air sac system or whether the migration takes place through the portal system. Histopathological evidence carried out recently, however, suggests that the migration to the air sac system is direct. After reaching the air sacs, the L3 undergoes two further molts to produce the L5 or immature adult filarial worm. Adult parasites then breed and produce large quantities of embryonated ova. Large quantities of these thin-shelled embryonated ova are coughed out through the trachea to the mouth and then ingested and excreted in the feces. Very often, immature and adult filarial parasites are coughed and cast out or conversely, these are swallowed and passed with fecal material. It is not known how long does it takes for the L3 to mature into an adult filarial parasite and begin reproducing. However, observations made at this hospital in newly imported birds into the Middle East from European countries suggests that the larval life cycle of *S. seurati* within the final host takes between two and three months.
Pathogenesis

Gross pathological changes observed at post-mortem examinations of infected birds include the presence of moderate to large number of adult filarial parasites within the thoracic and abdominal air sac walls. Embryonated ova and larvae, at different stages of development, are commonly observed in wet preparations obtained from the surface of the air sacs.

Histopathological findings in infected birds are normally associated with the presence of adult filarial worms, larvae and embryonated ova within the different tissues. In the periphery of the lungs, numerous parasitic stages have been found associated with mild focal hemorrhages and focal necrosis and mild to moderate macrophage infiltration. Adult filarial parasites of the genus *Serratospiculum* are commonly found on both sides of the collagen-muscle fibre layer immediately below the epithelial or mesothelial section of the air sacs. The abdominal air sacs walls appear to be the preferred site for adult *Serratospiculum* filarial parasites, but they can also be found on the walls of the thoracic air sacs (Figure 2).

Very often, large numbers of adult filarial parasites are present in the air sac system without producing any apparent pathological changes. When questioning owners of falcons carrying heavy parasitic burdens, they commonly report that the flight performance during training or hunting is not impaired.

There appears to be controversy in the literature as to whether parasites of this genus are pathogenic to the host. Early observations acknowledged that there was significant inflammatory reaction, including squamous metaplasia, on the air sacs of falcons harbouring *Serratospiculum* filarial worms, but despite this, it was not considered that these parasites could be pathogenic to its host. In North America, however, several authors concluded that the death of different birds of prey submitted for post-mortem examination was directly linked or greatly influenced by heavy parasitic burden with a close relative, the nematode filarial worm *Serratospiculoides amaculata*. Specimens examined included prairie falcons (*Falco mexicanus*), peregrine falcon and bald eagle (*Haliaeetus leucocephalus*). *S. amaculata* has also been incidentally observed and identified in a Cooper’s hawk (*Accipiter cooperii*) following euthanasia due to a compound fracture to its right femur.

In several cases with severe infections, however, *S. seurati* have been found associated with pneumonia, air sacculitis and early lesions of aspergillosis. In these cases, unilateral or bilateral focal congestion of the lungs was observed and a pale yellow to green fluid was seen covering large areas of the air sac system or in the form of focal deposits (Figure 3). On examination of this fluid, mixed growths of *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* were obtained on bacteriology cultures. *Aspergillus fumigatus*, *A. flavus* and *A. niger* have also been cultured in cases in which aspergillosis, as a disease, was already declared.
The gross pathological findings and histopathology changes observed during post-mortem examinations, suggest that severe infections with *S. seurati* could predispose falcons to pneumonia, air sacculitis and aspergillosis. In the Middle East, falcons are very often subjected to over exertion during the training period and prolonged periods of starvation during the training period or hunting trips. A falcon with a heavy *S. seurati* parasitic load, subjected to intensive exercise and with a low food intake, coupled with extreme weather conditions, could be predisposed to lower respiratory tract disorders.⁴⁵
Therapeutic Management

The therapeutic management of *S. seurati* infections has traditionally consisted in the administration of broad spectrum anthelmintics, such as mebendazole (Panacur, Hoechst UK Ltd, Milton Keynes, UK) at the dose rate of 20 mg/kg PO daily for 14 days, or fenbendazole (Telmin, Janssen Animal Health, High Wycombe, UK) at the dose rate of 20 mg/kg PO daily for 14 days. Although this therapeutic management has been used with certain degree of success, it is considered a difficult regimen to prescribe under general practice conditions in the Middle East. Other authors have favored the surgical removal of the adult filarial parasites using endoscopy, followed by treatment with 10 mg fenbendazole applied directly into the air sacs together with fenbendazole at the dose rate of 25 mg/kg PO daily for three days. The removal of adult filarial parasites without any previous anthelmintic treatment is a common practice in the Middle East. Although no side effects have been reported, this practice should be discouraged on the grounds of potential damage to the air sac system. Conversely, ivermectin (Ivomec or Panomec, MSD AGVET, Hoddesdon, UK) has been used at the traditional dose rate of 200 mcg/kg IM at the single dose followed by the removal of the adult filarial parasites three to five days after administration. This is normally followed by a similar second dose one or two weeks later. Such a low dose of ivermectin appears to be sufficient to stun the adult filarial parasites, which soon collect in the celomic cavity facilitating their removal by endoscopy (Figure 4). Ivermectin has been widely used percutaneously in the control of air sac mites (*Sternostoma tracheacolum*) in gouldian finches (*Chloebia gouldiae*) and canaries (*Serinus canaria*). Ivermectin is also very commonly used in the control of quill mites (*Dermoglyphus* sp., *Syringophilus* sp., *Picobia* sp., *Harpyhynchus* sp.) in passerines species and ostriches (*Struthio camelus*) and nematode infections in ostriches. In addition, ivermectin has been routinely used for the control of stomach worms (*Tetrameres americana*, *Diaspharynx nasuta*) and hairworms (*Capillaria* sp.) in domestic pigeons (*Columba livia*). Ivermectin at the dose rate of 3 mg/kg via the SC route has been suggested at a single dose for the control of nematodes, mites and lice in raptors. Recently, it was reported that ivermectin at the dose rate of 2 to 3 mg/kg IM was a safe anthelmintic for the control of serratospiculiasis in gyr falcon-peregrine falcon hybrids. Experience gathered at this Hospital, however, suggests that ivermectin at this high dose is effective at killing *S. seurati* filarial parasites followed by absorption, but it can produce deleterious side effects in some falcon species. In a comprehensive study carried out at this Hospital, ivermectin at the dose rate of 3 mg/kg IM was administered to 600 different falcons including saker falcons, peregrine falcons, lanner falcons (*Falco biarmicus*), gyr falcons (*Falco rusticolus*) and gyr-saker falcons and gyr-peregrine falcon hybrids. This trial was carried out during Sep 98-Mar 99. From this total, 27 (4.5%) falcons developed temporary bilateral blindness, anorexia, vomiting and ataxia that lasted for up to 48 hrs in some cases. Following this observation, a second trial was conducted at the dose rate of 2 mg/kg IM and it was administered to 340 different falcons from the same species. Similar, but milder clinical signs were observed in 12 (3.5%) falcons. This trial was carried out during Apr 99-Aug 99. Since Sep 99 to date, ivermectin has been routinely used at the dose rate of 1 mg/kg in 970 different falcons without observing any abnormal side effects (J. Samour, unpublished data). However, all falcons in this last trial were administered ivermectin SC since absorption appears to be more effective using this route. In the two
previous trials, it was observed that the results obtained using ivermectin administered via the IM route were not always reproducible. Falcons to which ivermectin has been administered at the dose rate of 1 mg/kg SC, stop shedding ova two or three days after treatment and by day 8-12 days are free from adult filarial parasites. Periodical fecal and endoscopy examinations conducted in 125 different falcons supported these observations (J. Samour, unpublished data). A second dose was normally administered one week later. Ivermectin at this dose rate seems to be effective not only in the control of adult filarial parasites, but also appears to have a larvicidal effect. Infected birds, kept under hospital conditions, remained free from *S. seurati* infections for up to a year after treatment. Also during this study, it was found that ivermectin at the same dose rate and using the same route was effective, at a single dose, in the control of *Capillaria* sp. infections. An additional trial was conducted using ivermectin orally at the dose rate of 3 mg/kg in 75 different falcons, but this route proved to be completely ineffective in the control of endoparasites, including *S. seurati* (J. Samour, unpublished data). Similar observations have been made in many other different avian species. For instance, in red-crested cardinals (*Cardinalis cardinalis*), ivermectin failed to control *Capillaria* sp. infections when used via the oral route (S. Gelis, personal communication).

Ivermectin is a member of the avermectin family, a group of potent and broad spectrum anthelmintic agents isolated from the fermentation of the fungus *Streptomyces avermitilis*, family Streptomycetaceae, order Actinomycetales. Commercially, ivermectin, in injectable form, is available diluted in propylene glycol and recommended for the SC route only. When given via the IM route, this preparation may cause temporal focal irritation and muscle necrosis. In addition, the pharmacokinetics might be altered when given via a different route, since the oily solution is intended as a depot for slow absorption. This may explain why many practitioners stop using ivermectin parenterally due to the variable results obtained (P. Redig, personal communication). A new generation of anthelmintic compounds have been produced such as doramectin (Dectomax, Pfizer Ltd, Sandwich, UK) from the avermectin family and moxidectin (Cydectin, Fort Dodge Animal Health, Southampton, UK), a second generation macrocyclic lactone of the milbemycin family. Doramectin is commercially available in injectable form diluted in sesame seed oil and it can be administered via the IM or SC route. To the knowledge of the authors, there have been no reports on the use of doramectin in falcons. However, this anthelmintic agent could prove useful in the control of parasitic infections in zoological medicine, including avian species, since it can be administered via the IM or SC routes. Conversely, moxidectin is available as an aqueous injectable solution and recommended for the SC only. However, moxidectin, since is water soluble, has been used successfully in the control of nematode infections in various birds of prey at the dose rate of 200 mcg/kg PO (A. Humphreys, personal communication). Avian species in this observation included sparrow hawks (*Accipiter nisus*), European kestrels (*Falco tinnunculus*), peregrine falcons, barn owls (*Tyto alba*), tawny owls (*Strix aluco*) and little owls (*Athene noctua*). In addition, moxidectin orally has been successfully used in the control of *Capillaria* sp. infections in red-crested cardinals (S. Gelis, personal communication). Currently, the anthelmintic agent moxidectin is undergoing trials at this facility administered in tablet form at different dose rates in the control of *S. seurati* infections in captive falcons.
During the molting season (March-September), falcons in the Middle East are commonly maintained tethered to a stand or in free-flying rooms provided with wall perches. Serratospiculiasis can be prevented during this time of the year by avoiding the use of sand as a substrate and making the rooms invertebrate proof. The use of artificial turf as substrate, placed immediately below the stand or perches within the room, could prove effective as a collateral measure in the control of serratospiculiasis. In addition, avoiding the use of sand as a substrate in molting rooms may also help to prevent other diseases such as aspergillosis and other respiratory and digestive tract infections.

It can be concluded, that ivermectin, doramectin and moxidectin can potentially be used in the control of *S. seurati* infections in captive falcons in the Middle East. In addition, these compounds could prove effective in the control of other species of filarial parasites such as *S. amaculata* and other endoparasites in different avian species. Other preventative measures, such as avoiding the use of sand as a substrate in molting rooms, could prove effective as a collateral step in the control of serratospiculiasis.

**Acknowledgements:** The authors would like to thank HRH Prince Fahad bin Sultan bin Abdulaziz Al Saud for his interest and continuing support to the clinical and research programme of the Falcon Medical and Research Hospital; to Mr. Basil Al Abbasi, Director General of the Fahad bin Sultan Falcon Centre, for his dedication and devotion to the Centre; to Mr. Shinto John, Mr. Nafeez Mohammed Jainudeen and Mr. Johnson Hillary Fernandez for providing technical assistance; to Mr. Alan Humphreys and Mr. Neil Forbes for helpful advice; to Mr. Paul Hillyard and the staff at the Department of Entomology, The Natural History Museum, (London, UK) for the identification of the arthropods; to Dr. Lynda M. Gibbons, formerly at the International Institute of Parasitology (St. Albans, UK) and currently at the Royal Veterinary College (London, UK), for the identification of *S. seurati* specimens.
References


Figure legends

Figure 1

Figure 1.- An L3 stage larva of Serratospiculum seurati surrounded by a thin, transparent capsule within the adipose tissue dissected from the mid portion of the body of a dung beetle (Scarabeus cristatus).

Figure 2.- A severe infection with large numbers of adult Serratospiculum seurati filarial nematodes harbouring the abdominal and thoracic air sac walls. Note that the majority of parasites are located within the walls of the abdominal air sacs producing severe air sacculitis.

Figure 3.- Very often adult Serratospiculum seurati filarial nematodes are observed associated with the presence of deposits of green-yellow fluid. On investigations of this fluid, mixed growths of Pseudomonas aeruginosa and Klebsiella pneumoniae have been obtained on bacteriology cultures.

Figure 4.- Following low doses of ivermectin, adult Serratospiculum seurati filarial nematodes collect in the celomic cavity facilitating their removal by endoscopy.