ACTA UNIVERSITATIS AGRICULTURAE SUECIAE

VETERINARIA 19

# Chronic Suppurative and Pyogranulomatous Disease ("Stövarsjuka") in Hunting Dogs

## Pathogenesis, diagnostics and treatment

Jan Frendin

SWEDISH UNIVERSITY OF AGRICULTURAL SCIENCES

**Chronic suppurative and pyogranulomatous disease ("Stövarsjuka") in hunting dogs. Pathogenesis, diagnostics and treatment**

**Jan Frendin**

Akademisk avhandling som för vinnande av veterinärmedicine doktorsexamen kommer att offentligen försvaras i Ettans föreläsningssal, Klinikcentrum, Ultuna, fredagen den 29 augusti 1997 kl. 09.15.

**Abstract**

Three conditions - thoracic/abdominal wall swellings, pleuritis with empyema and sublumbar lesions - were studied in a total of 39 adult, large-breed hunting dogs. Previously they were considered to be different diseases with poor prognosis. The aetiology and pathogenesis was obscure but filamentous microorganisms found on histopathological examination of tissue and exudate were identified as *Nocardia asteroides* by morphological criteria. Prodromal signs in the dogs of the present work included lethargy, low grade fever and respiratory signs. The dogs were subjected to as radical surgery as possible supported by chemotherapy. In the sublumbar cases the inflammatory lesions were located by imaging techniques including radiography, ultrasound, scintigraphy and magnetic resonance imaging. In the cases of pleuritis with empyema, pleural drainage was established by a special technique. The macroscopic appearance of the tissue changes in the three syndromes were uniform, showing new tissue masses of the pyogranulomatous type and varying amounts of viscous reddish-brown exudate, occasionally accompanied by white or yellowish granules. A "homogenous" type of non-specific, mixed infection, composed of anaerobic bacteria including *Actinomyces sp* was found. *Nocardia asteroides* was not retrieved in any of the cases. In the majority, if not in all, of the cases, foreign bodies of grass origin were found in the inflammatory lesions in all three syndromes. It is proposed that aspiration of very small plant parts is the common denominator of the three conditions. According to this theory, the plant parts are aspirated, penetrate the lungs and are forced between the pleural layers in a caudal direction. The foreign bodies may remain in the pleural cavity or become trapped at the peripheral attachment of the diaphragm, and migrate further from this point into the intercostal, abdominal or sublumbar musculature, in the immediate vicinity, where local inflammatory changes occur. It is reasonable to believe that the infection arises from mucous membrane commensals, which seemingly colonise the plant parts as they penetrate the mucous membranes of the respiratory tract. The prognosis after treatment by the proposed regime seems to be good as 34 of the 38 dogs treated returned to normal health.

*Keywords*: hunting dogs, pyogranulomatous inflammation, thoracic/abdominal wall swellings, sublumbar lesions, pleuritis, anaerobes, migrating plant parts, aspiration

Distribution:
Swedish University of Agricultural Sciences
Department of Small Animal Clinical Sciences
S-750 07 Uppsala, Sweden

Uppsala 1997
ISSN
ISBN 91-576-5408-5

# Chronic Suppurative and Pyogranulomatous Disease ("Stövarsjuka") in Hunting Dogs

**Pathogenesis, diagnostics and treatment**

Jan Frendin
*Department of Small Animal Clinical Sciences*
*Uppsala*

**Doctoral thesis**
**Swedish University of Agricultural Sciences**
**Uppsala 1997**

**Acta Universitatis Agriculturae Sueciae**
Veterinaria 19

ISSN 1401-6257
ISBN 91-576-5408-5

*"When empyemata are opened by the cautery or knife and the pus flows pure and white, the patient survives. But if it be muddy, red, or foul smelling, he will die"*

Hippocrates of Cos (460 - 367 BC)

To my family

# Abstract

Frendin, J. 1997. *Chronic suppurative and pyogranulomatous disease ("Stövarsjuka") in hunting dogs. Pathogenesis, diagnostics and treatment.* Doctoral dissertation.
ISSN 1401-6257, ISBN 91-576-5408-5

Three conditions - thoracic/abdominal wall swellings, pleuritis and sublumbar lesions - were studied in a total of 39 adult, large-breed hunting dogs. Previously these were considered to be different diseases, as they did not appear at the same time. The prognosis was poor. The aetiology and pathogenesis were obscure, but filamentous microorganisms found on histopathological examination of tissues and exudate were identified as *Nocardia asteroides* by morphological criteria.

Prodromal signs in the dogs of the present investigation included lethargy, low grade fever and respiratory signs. The dogs with thoracic/abdominal wall swellings underwent radical surgery supported by chemotherapy. In the sublumbar cases, localisation of the lesions was based on diagnostic imaging techniques including radiography, ultrasound, scintigraphy and magnetic resonance imaging. In these cases a lateral muscle-splitting longitudinal incision was used to gain access to the inflammatory lesions. In the cases of pleuritis with empyema, pleural drainage was established by a technique developed at the clinic for controlled and virtually atraumatic and painless insertion of small size Teflon catheters.

The macroscopic appearances of the tissue changes in the three syndromes were similar, with new masses of diffusely confined, gelatinous, reddish-brown tissue with a glistening section surface. In the cases of pleuritis there were vast adhesions between the lung and the chest wall. Varying amounts of viscous reddish-brown exudate, in the cases of pleuritis in the form of empyema, were seen, occasionally accompanied by white or yellowish granules or flakes. The histological picture was one of mixed chronic and acute inflammation of the pyogranulomatous type.

In spite of the different locations of the lesions, the bacteriological examination revealed a "homogeneous" type of non-specific, mixed infection, composed of anaerobic bacteria including *Actinomyces sp. Nocardia asteroides* was not retrieved in any of the cases.

In the majority, if not in all, of the cases, foreign bodies of plant origin were found in the inflammatory lesions in all three syndromes.

It is proposed that aspiration of very small plant parts is the common denominator of the three conditions. According to this theory, the plant parts are aspirated and penetrate the lungs into the pleural cavity and by respiratory movements are forced between the pleural layers in a caudal direction. The foreign bodies finally become trapped at the peripheral attachment of the diaphragm, or migrate further from this point into the intercostal, abdominal or sublumbar musculature, in the immediate vicinity, where local inflammatory changes occur. The productive inflammation in the pleural cavity, with empyema of the type described in this study, may result from aspirated plant parts that became trapped in the thoracic cavity. It is reasonable to believe that the infection arises from mucous membrane commensals of the type found, which seemingly colonise the plant parts as they penetrate the mucous membranes of the respiratory tract. This theory is supported by the histological findings.

The prognosis after treatment by the proposed regime seems to be good, as 34 of the 38 treated dogs were restored to normal health.

*Author's address*: Department of Small Animal Clinical Sciences, Swedish University of Agricultural Sciences, SLU, Box 7037, 750 07 UPPSALA, Sweden.

This thesis is based on the following four papers, which will be referred to by their Roman numerals.

I. Frendin, J., Greko, C., Hellmén, E., Iwarsson, M., Gunnarsson, A. & Chryssantou, E. 1994. Thoracic and abdominal wall swellings in dogs caused by foreign bodies. Journal of Small Animal Practice, 35: 499-508

II. Frendin, J., Funkquist, B., Hansson, K., Lönnemark, M. & Carlsten, J. 1997. Diffuse back pain in the dog caused by migrating plant parts. Submitted.

III. Frendin, J. 1997. Pyogranulomatous pleuritis with empyema in hunting dogs. Journal of Veterinary Medicine A, 44: 167-178

IV. Frendin, J. & Obel, N. 1997. Catheter drainage of pleural fluid collections and pneumothorax. Journal of Small Animal Practice, 38: 237-242

# CONTENTS

# Introduction

## A brief historical review

For several decades, hunters in Sweden, and particularly on the island of Gotland, have recognised a condition in their hounds and gun dogs (stövare, English pointers, setters and German pointers) referred to as "Stövar disease" and characterised by a local, productive inflammatory reaction with a diffuse margin against the surrounding muscular tissue on either the thoracic or the abdominal wall, or both (Fig. 1). The gross appearance on preliminary studies of the lesions was characteristic. In the central part of the lesion, masses of gelatinous, reddish-brown tissue were seen, with a bulging and glistening section surface, showing varying amounts of viscous reddish-brown exudate, occasionally accompanied by white or yellowish granules or flakes. Incision and drainage combined with chemotherapy resulted in only transient resolution of the lesions, and the disease either followed a lethal course or led to euthanasia because of recurrent infections. On the other hand, radical surgery with total removal of the new tissue mass usually resulted in total recovery (Frendin and Persson 1987).

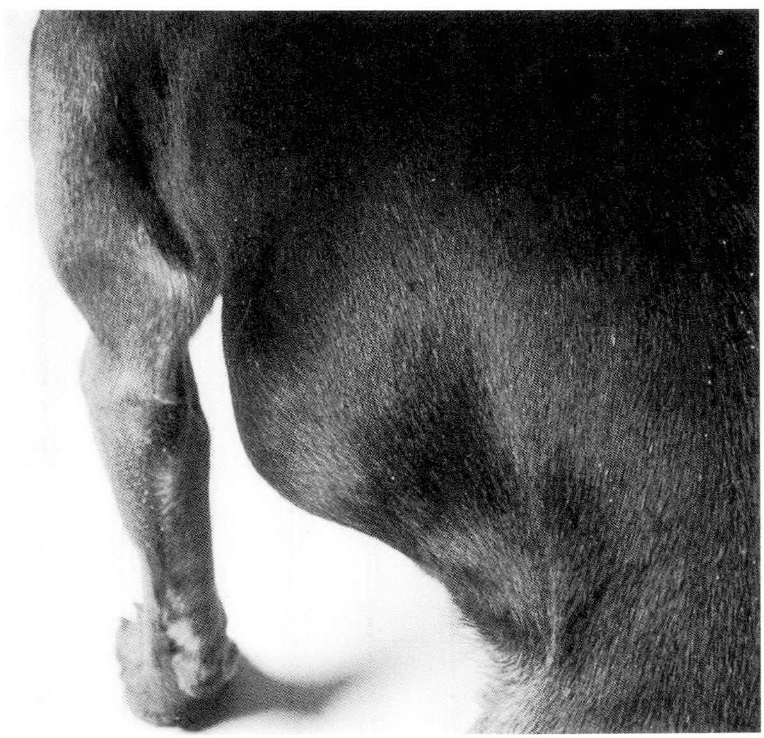

Fig. 1. Swelling on the caudal thoracic wall and the cranial abdominal wall of a Schillerstövare with productive inflammation. (Photo M. Gerentz)

During the same period of time, idiopathic pleuritis was observed in hunting dogs of the type mentioned above. Preliminary post-mortem examination of these dogs showed chronic proliferative inflammation in the pleural cavity of the same type as described above on the thoracic/abdominal wall, including reddish-brown exudate accompanied by varying amounts of granules or flakes. Pleural drainage combined with chemotherapy in these cases occasionally led to total recovery, but in many cases the dogs were destroyed because of complications related to the placement of the pleural catheters. Seemingly, this was attributable to the profuse adhesions between the pleural layers observed in severe cases of the disease.

Previous observations indicated that in spite of the fact that the exudate and the microbial findings in these two conditions were similar, they did not appear at the same time in the individual dogs, for which reason they were considered to be two separate entities. Amongst dog owners, the theories concerning the aetiology of these two conditions have been numerous. High-performing hunting dogs seemed to be overrepresented among dogs with lesions of this kind and it was believed that the dogs became infected at the end of the hunting season when they were tired and more susceptible to infections, and that signs of disease did not show until spring. Others believed that the disease derived from malnutrition, or from alimentary infection due to ingestion of carcases of myxomatosis-infested rabbits, or to ingestion of sheep droppings. A congenital deficiency of the anti-bacterial systems of the animals was also proposed, as well as the possibility of infections resulting from skin wounds caused by thorns whilst rushing through dense undergrowth.

In the spheres of veterinary and human medicine, the pathogenic microorganisms that have been found in these kinds of lesions have been subjected to several reclassifications and have been named differently from one time to another (e.g. Rippon 1988). In a report from Sweden by Cedervall (1954), covering the results of post-mortem examinations in 24 hunting dogs and 12 cats within the period 1926 - 1951, lesions of the described type were classified as streptotrichosis or pseudo-actinomycosis, based on findings of *Streptothrix canis* on bacteriological examination. Fourteen cases exhibited subcutaneous inflammation with abscess formation, in seven cases affecting the musculature of the thoracic or abdominal wall, and in 25 cases there was an exudative-productive pleuritis. In seven of these cases there were lesions in both the subcutis and pleura. The author suggested that the infection with *Streptothrix canis* takes place through skin wounds or through the respiratory tract. As examples of the latter route of infection the author mentions two dogs that had aspirated twigs and contracted a secondary pleuritis. During the following three decades, filamentous microorganisms were found on histopathological examination of tissue and exudate in both syndromes and were identified as *Nocardia asteroides* on the basis of morphological criteria.

It is evident from the above discussion that there has been considerable confusion in the taxonomy of filamentous microorganisms found in chronic suppurative lesions in man and animals. In a literature review, McGaughey (1952) mentions that several terms for actinomycosis in the dog and cat have been used in textbooks on veterinary pathology, e.g. "streptotrichosis", "nocardiosis", "pseudo-actinomycosis", "oosporosis" and "mycetoma", since the first case of actinomycosis in the dog was reported by Vachetta in 1882. The bacteriological and histological descriptions of *Streptothrix canis* in Cedervall's report fits well with the infective agent that is referred to today as *Actinomyces sp.* The term "actinomycosis" however, has been used for diseases caused by both *Nocardia asteroides* and *Actinomyces sp*, and additional confusion has resulted from the fact that the term "nocardiosis" has been used in cases when *Actinomyces sp.* was apparently responsible for the disease (Swerczek et al. 1968a). Currently there seems to be agreement in the veterinary literature that a distinction should be made between actinomycosis and nocardiosis as being two separate diseases in the dog. A description of the principal characteristics of the infective agents involved in these two diseases may be of interest, as they are closely linked to the conditions which are the subjects of the present study.

## Nocardiosis versus actinomycosis

*Nocardia* and *Actinomyces* are of the order Actinomycetales, allied to the coryneform group of bacteria (Bergey's manual 1984). They are non-motile, non-spore-forming, gram-positive rods. *Nocardia* usually occur as branching filaments, whereas *Actinomyces* are variably filamentous and branching. *Nocardia* are aerobic and irregularly acid-fast, whereas *Actinomyces* vary in their relation to oxygen and are non-acid-fast. *Nocardia* grow on unenriched media and on blood and Sabouraud agar, at 25° or 37°. The colonies are irregularly folded, raised, and smooth or granular. Their colour varies from white through yellow to deep orange (Carter and Chengappa 1991). These microorganisms are soil-borne and occur as saprophytes in moulding organic material. *Actinomyces* grow on blood and brain heart infusion agar at 37°. *A. viscosus* colonies have a dense centre with a filamentous fringe, and are opaque, cream to white in colour, and soft, mucoid to viscous in consistency (Rippon 1988). *Actinomyces* are commensal organisms of the mucous membranes of the oropharyngeal tract, intestine and vagina in man and animals.

Clinical differentiation between nocardiosis and actinomycosis is difficult, but the age of the animal and the presence or absence of granules in exudate or tissue may be helpful (Swerczek et al. 1968a and 1968b). Nocardiosis usually affects dogs less than a year old (Grain et al. 1978, Elias et al. 1980, Ackerman et al. 1982, Buchanan et al. 1983, Sato and Mochizuki 1986), whereas actinomycosis appears to be a disease of older dogs (e.g. Swerczek et al. 1968a and 1968b). Case reports on canine actinomycosis occur more commonly than those on canine nocardiosis. Attemps to culture the organisms may be unrewarding and in such cases the diagnosis should be based on the histopathological changes and staining characteristics of the organisms in tissues. The filaments of *Nocardia asteroides*, the species commonly found in the dog, do not form granules in tissue. The filaments are diffusely scattered throughout the lesions, especially in focal areas of necrosis, and the granulomas are not encapsulated. *Actinomyces sp* produces a suppurative granuloma characterized by abscess formation and marked fibrosis, and in tissue will form granules in which densely packed clusters of fine, branching, filaments can be seen. It is important though, to distinguish actinomycotic granulomas from actinobacillosis and staphylococcal granulomas, both of which contain granules (Swerczek et al. 1968a).

In man, *nocardiosis* primarily is a pulmonary disease of respiratory origin and is believed to result from inhalation of the microbes. The condition is primarily seen as an opportunistic infection in individuals debilitated by other diseases, e.g. as a complication of the acquired immunodeficiency syndrome (AIDS), or of treatment with antileukaemic drugs, cytotoxins, immune depressants and corticosteroids (Rippon 1988). In animals, *N. asteroides* occurs as an opportunistic pathogen and has been associated with diseases in cattle, dogs, cats, pigs, fish and wild animals. *N. asteroides* causes a systemic disease in dogs which has a predilection for the thoracic cavity and subcutaneous tissue. Sinus openings in the skin may drain a thick red-brown exudate (e.g. Ackerman et al. 1982). In some cases a disseminated disease develops, with granulomatous lesions not only in the thoracic or abdominal visceral organs and regional lymph nodes, but also in the central nervous system (Swerczek et al. 1968b, Sato and Mochzuki 1986) and joints (Buchanan et al. 1983). The pathogenesis of the disease is obscure. As previously mentioned, the disease is primarily seen in young individuals up to the age of one year. The route of infection is usually not known, but post-mortem findings described in case reports (e.g. Grain et al. 1978, Elias et al. 1980, Ackerman et al. 1982, Buchanan et al. 1983, Sato and Mochizuki 1986) suggest a pulmonary origin of the disease. Distemper and long-term corticosteroid therapy have been reported to be predisposing factors in nocardiosis (Fawi et al. 1971, Ackerman et al. 1982, Sato and Mochizuki 1986).

In a historical perspective, *actinomycosis* in both cattle and humans was thought to develop after chewing on straw or other plant material that caused abrasions to the mucosa and planted the organism in tissue. Sanford and Voelker in 1925 stated that the public generally should be warned of the danger of chewing straws, weeds and grain, as a possible means of infection with actinomycosis. However, the theory that plant material may harbour *Actinomyces sp* is now rejected. It is now well established (Rippon 1988) that the aetiological agents are normal flora of the buccal, gingival and intestinal mucosa. However, the route of entry of the microorganisms in lesions referred to as actinomycosis is obscure in both man and animals. In man, cervico-facial actinomycosis is associated with trauma to the mucous membrane of the mouth or the pharynx, by way of carious teeth and tooth extraction or infection through the tonsils. Thoracic actinomycosis is believed to result from contiguous extension of the disease from the oropharyngeal region, from extension of abdominal or hepatic infection through the diaphragm, or as a primary infection from aspiration of the organism through the mouth (Flynn and Felson 1970). It is proposed that abdominal actinomycosis might result from perforation of the intestinal wall by such objects as fish and chicken bones, from knife, gunshot and bite wounds, from intrauterine devices or at surgery, but most frequently the primary source suggested is the diseased appendix. Immunosuppression has been proposed as a predisposing factor in human actinomycosis (Rippon 1988). It is proposed that extension to the spinal column might result in vertebral osteomyelitis, usually in the lumbar region (e.g.Young 1960, Kannangara et al. 1981). In animals, actinomycosis was first described in the jaw of cattle ("lumpy jaw") (Harz 1877). Actinomycosis has also been reported in sheep, goats, horses, dogs, cats and wild life animals. The sites most frequently affected in dogs, as in humans, are the cervico-facial, thoracic and abdominal regions (e.g. Swerzcek et al. 1968a, Collins et al. 1968, Chastain et al. 1976, Staman et al. 1978, Kirpensteijn and Fingland 1992). Subcutaneous lesions are characterised by suppuration, chronic pyogranuloma and abscess formation and the development of draining sinus tracts and marked fibrosis (Swerczek et al. 1968a, Kirpensteijn and Fingland 1992). The sinus openings may drain a reddish-brown exudate containing granules. The thoracic and abdominal forms are characterised by pyogranulomatous masses with varying degrees of reddish-brown exudate and granules (Swerzcek et al. 1968a, Collins et al. 1968, Chastain et al. 1976). Suggested routes of entry of the microorganisms include bite wounds (Swerczek et al. 1968a), gun shot wounds (Davenport et al. 1974), inhalation through the mouth (Collins et al. 1968) or via aspirated foreign bodies (Turner and Breznock 1988). Chronic draining tracts in the interdigital web infected with *Actinomyces* are often associated with penetrating foreign bodies, particularly grass awns (e.g. Hur 1974, Brennan and Ihrke 1983).

The *purpose of the present studies* was to make a thorough analysis of the pathogenesis of the above described characteristic productive inflammatory lesions with the typical exudate recognised in the thoracic/abdominal wall and in the pleural cavity in certain types of hunting dogs, and to find a possible common aetiological denominator. During the period in which these dogs were investigated, we observed hunting dogs with diffuse signs of back pain which displayed inflammatory tissue changes and bacteriological conditions corresponding to those described above, but in these cases located in the sublumbar muscles. This prompted us to include dogs with such diffuse signs of pain in the thoraco-lumbar region in the studies.

# Aims of the investigation

The overall aims of this investigation were:

1. to investigate the aetiology and pathogenesis of productive inflammatory lesions in the thoracic/abdominal wall, in the pleural cavity and in the sublumbar muscles in the dog;

2. to evaluate a new technique for drainage of the pleural cavity in the dog;

3. to evaluate the therapeutic results and to propose guidelines for treatment on the basis of points 1 and 2.

# Materials and methods

## Dogs

Studies I - III comprised a total of 39 dogs. These dogs were presented at the university clinic within the period 1986 - 1994 and were selected on the basis of local thoracic/abdominal wall swelling (I), diffuse signs of back pain (II) or signs of pleural effusion (III) of unknown cause. Twenty-four of the dogs in study I, two in study II and one in study III were native of the island of Gotland in the Baltic sea. These were referred by local practitioners or were admitted to the clinic after direct telephone contact with the dog owners. As a rule the dogs were transported from Gotland to the university clinic by air and the histories of the dogs were obtained by telephone interviews. In a retrospective study (IV) covering 39 dogs (including two dogs in study I and eight dogs in study III) and two cats in a 10-year period (1984 through 1993), the results of pleural drainage by a modified Seldinger technique, undertaken by reason of various underlying disorders, were evaluated. The cases were selected for pleural drainage on the basis of thoracic radiographic examination.

## Methods of examination and treatment

*Clinical examination (studies I - III)*

Careful histories were obtained from the dog owners. The dogs were subjected to thorough clinical examination. Routine haematological examination, including concentrations of haemoglobin, leucocytes, urea and glucose and activities of alanine transferase and alkaline phosphatase, was performed in the dogs in study II.

*Radiological examination (studies I - III)*

Standard radiographs of the thorax were obtained in 19 dogs in study I and in all dogs in studies II and III at presentation. In studies I and II, radiographic left lateral and ventro-dorsal views of the abdomen were obtained, and in study II, also of the lumbar spine.

*Ultrasonography (study II)*

In five dogs in study II, the radiographic examination of the lumbar region was supplemented with ultrasonography (at presentation in four cases, after 9 weeks in one case). The technique is described in detail in paper II.

*Scintigraphy (study II)*

Four dogs in study II were subjected to scintigraphy of the lumbar region within one week after presentation. Both skeletal and soft tissue scintigraphy were performed in three dogs and skeletal scintigraphy alone in one dog. The technique is described in detail in paper II.

*Magnetic resonance imaging (study II)*

In four of the dogs in study II magnetic resonance imaging (MRI) of the lumbar region was performed within one week (3 cases) or 9 weeks (1 case) after presentation. The technique is described in detail in paper II.

*Surgery (studies I - III)*

All of the dogs in studies I (except one case) and II and two of the dogs in study III underwent surgery of the thoracic/abdominal wall or the sublumbar muscles. The surgical intervention was performed as radically as possible and was supported by chemotherapy. Anaesthesia was induced with pentothal sodium (Abbot Laboratories) and maintained with halothane or isoflurane vapourised in oxygen (ISC/Triplus). The surgical techniques are described in detail in papers I and II. Preoperative chemotherapy was excluded, so as not to compromise the bacteriological examination of excised tissue and exudate. In most dogs (study I), the wide extent of the lesions made it necessary to remove parts of the abdominal and/or thoracic muscles, in some cases including partial costectomy. In seven dogs (study I) thoracotomy was necessary in order to gain access to all affected tissue. In study II, a muscle-splitting lateral longitudinal incision with extraperitoneal dissection was used to reach the inflammatory lesions in the sublumbar muscles. However, the view in the surgical wound was limited by bleeding and because of the descent of the intervertebral nerves in this region. This impeded radical surgery of the lesions. Drainage was established in all dogs.

*Drainage of the pleural cavity (studies III - IV)*

In paper IV a pleural catheter drainage technique for dogs and cats is described. Thirty-nine dogs (including 2 dogs in study I and 8 dogs in study III) and two cats were treated by this method. Conventional chest-tube drainage of pleural fluid or air with insertion of the large-bore, blunt-tipped trocar catheters may require substantial force and is often traumatic and painful in spite of local anaesthetic administration. At the university clinic for small animals, the trocar catheter technique has been restricted for these reasons to cases of acute life-threatening pneumothorax. For drainage of pleural effusions and for evacuation of air in cases of non-life-threatening pneumothorax in the dog and the cat, a technique for controlled and virtually atraumatic and painless insertion of pleural catheters has been developed and used during the last decades. The technique is a modification of the Seldinger guide technique (1953) for percutaneous introduction of catheters in human arteriography. Briefly, the Seldinger technique consists in the use of a guide that is introduced into the vessel through a puncture needle, which is then removed. The catheter is threaded over the guide, after which the guide is removed. The tip of the catheter is fitted to the diameter of the guide (Odman 1959) so that the catheter will slide easily through the tissue without hooking to the wall of the vessel when the catheter is threaded over the guide. This technique has been modified for insertion of chest catheters in the dog and cat. Thus, the puncture needle is equipped with a special balloon indicator (Forsell 1948) which indicates when the tip of the needle perforates the pleural cavity. The small size catheters (ID 1.93 mm x W 0.3 mm) are equipped with side holes and are made of Teflon, a material which causes very little local tissue reaction and is resistant to compression.

*Morphological examination (studies I - III)*
Tissue excised from the affected areas at surgery or at post-mortem examination (studies I - III) was thoroughly dissected by cutting it into 1 to 2 mm thick slices. For histological examination two to 20 samples (mean 4.8) were collected from different parts of the lesions in 23 dogs in study I, in four dogs in study II and in four dogs in study III. The samples were fixed in 4 per cent buffered formalin, paraffin-embedded, cut into 4 µm thick sections and stained with haematoxylin and eosin and periodic acid-Schiff.

*Bacteriological examination (studies I - III)*
Samples from affected tissue and exudate were collected aseptically during surgery or pleural drainage for bacteriological examination. Three cases in study I were excluded from bacteriological examination because of presurgical chemotherapy. The samples were transported to the laboratory in tightly capped sterile tubes and were processed within 1 to 2 hours. Tissue samples and exudate (sometimes containing granules) were homogenised before culture. Samples were plated onto blood agar (horse blood 7 per cent v/v) and Fastidious Anaerobe Agar (Lab m, Salford) with 10% horse blood for aerobic and anaerobic incubation at 37°C, respectively, and on Sabouraud dextrose agar for incubation at room temperature. The plates were examined for bacterial growth every second or third day for a minimum of 2 weeks. Morphologically differing colony types were subcultured. For identification, standard procedures were used (Carter and Cole 1990).

*Immunohistochemical examination (study I)*
Formalin-fixed, paraffin-embedded sections of specimens from 22 of the 27 dogs in study I were examined for the presence of *Actinomyces viscosus* and *Nocardia asteroides* (nine sections each), by a modified indirect immunofluorescence test (Schaal and Pulverer 1973, Schaal and Gatzer 1985).

*Foreign body analysis (studies I - III)*
Foreign bodies detected at surgery were stored in diluted alcohol (70 per cent) and subjected to thorough examination under a stereo microscope and compared with archive specimens.

*Follow-up study (studies I - III)*
Long terms results of the treatment in studies I - III were evaluated by questionnaires sent to the owners or by telephone interviews. The mean

follow-up periods after treatment were 3.3 years (range, 0.6 - 6.5 years), 4.1 years (range, 1.3 - 7.8 years) and 5.3 years (range, 3.5 - 9 years), respectively, in studies I, II and III.

# Results

## Lesions in the thoracic and/or abdominal wall (study I)

Study I comprised 27 dogs. Without selection of breed, these were exclusively large hunting dogs (7 Schillerstövare, 7 Hamiltonstövare, 4 mixed breeds, 3 German pointers, 2 Finnish stövare, 2 English pointers, 1 English setter and 1 Dunker hound). There were 13 males and 14 females and the mean age was 4.2 years (range 2 - 10 years). The dogs were well trained and mostly considered excellent hunters. Prodromal signs (Table 1) in seven of the dogs (study I) included distinct respiratory signs such as respiratory distress, coughing and/or hawking. Three of these dogs had previously been treated for suspected pneumonia. Twenty-two dogs had had periods of lethargy and reduced performance lasting from some weeks to some months before a characteristic firm, sometimes tender, local swelling developed on the thoracic wall and/or the abdominall wall (Fig. 2). The swellings varied in size, measuring 5 to 15 x 5 to 15 cm. In the 26 dogs which underwent surgery, the centre of the lesion consisted of masses of gelatinous, reddish-brown tissue with a bulging and glistening section surface (Fig. 3), showing varying amounts of thick, flocculent reddish-brown exudate, occasionally accompanied by white or yellowish flakes or granules. On the periphery, bands of affected tissue deeply infiltrated the muscle layers of the thoracic wall, including the intercostal musculature and/or sublumbar and abdominal muscle.

Table 1. Prodromal signs in the dogs of studies I - III.

| Study | Total no. of dogs | Lethargy/ reduced performance | Low grade fever | Inappetence/ weight loss | Respiratory signs |
|---|---|---|---|---|---|
| I | 27 | 22 | 5 | 6 | 7 |
| II | 6[1)] | 6 | 1 | 2 | 3 |
| III | 9[2)] | 9 | 6 | 6 | 9 |

1) including one of the dogs in study I
2) including two of the dogs in study I

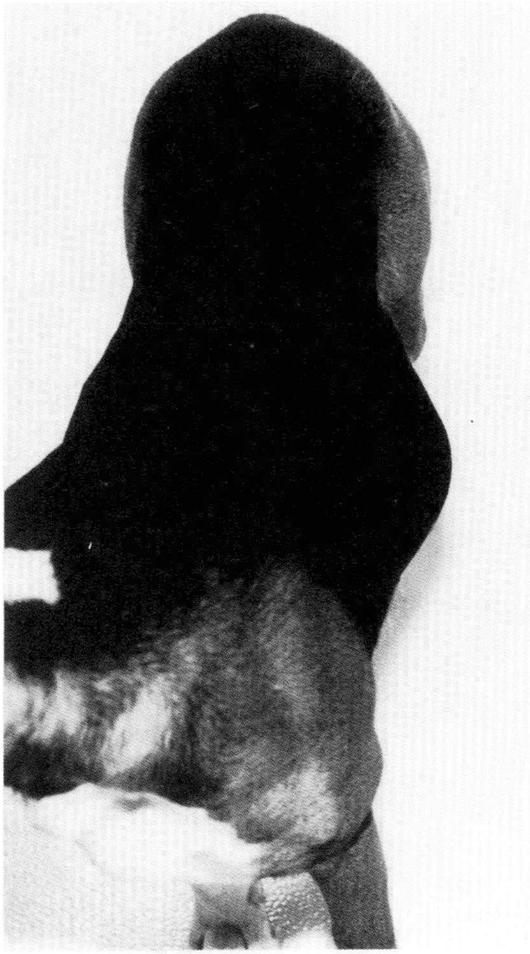

Fig.2 Swelling on the caudal thoracic wall and the cranial abdominal wall of a Hamiltonstövare with productive inflammation. (Photo M. Gerentz)

In 14 dogs foreign bodies of plant origin (of sizes ranging from 0.8 x 4.6 mm to 3.4 x 35.7 mm) were found in the inflammatory tissue. The foreign bodies were usually located in the intercostal muscle, in the cranial part of the lesion, along to the line of pleural reflection, i.e. the peripheral attachment of the diaphragm (Fig. 4). In seven cases distinct fibrotic cords spanning the distance between the foreign body and the pleura at the peripheral attachment of the diaphragm were seen (Fig. 5). In these dogs, the foreign body was found in the region where the cord fused with the new tissue masses on the thoracic wall. Thorough examination of the foreign bodies under a stereo microscope showed that with one exception the plant parts derived from different wild grasses (paper I, Table 2).

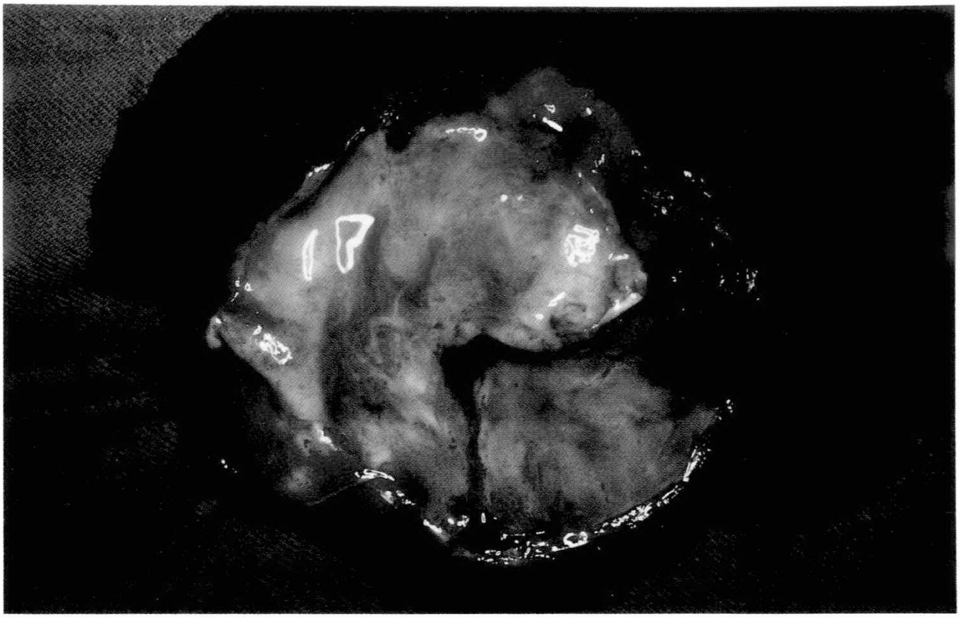

Fig. 3 Productive inflammatory tissue, with a bulging and glistening section surface, excised from the thoracic wall of a dog.

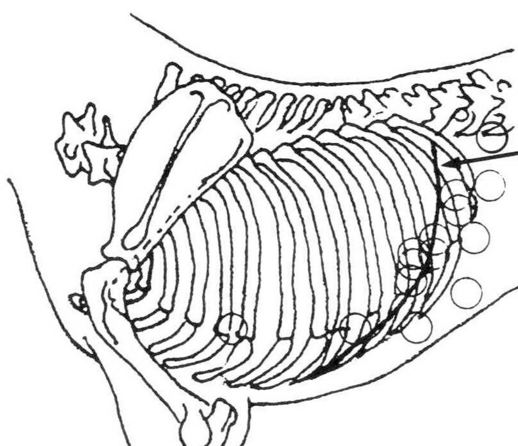

Fig. 4. The locations (circles) of 14 plant part foreign bodies on either the left or right thoracic or abdominal wall in 13 dogs. The outline of the peripheral attachment of the diaphragm is indicated by a continuous line (arrow). (Illustration A-M. Lövgren)

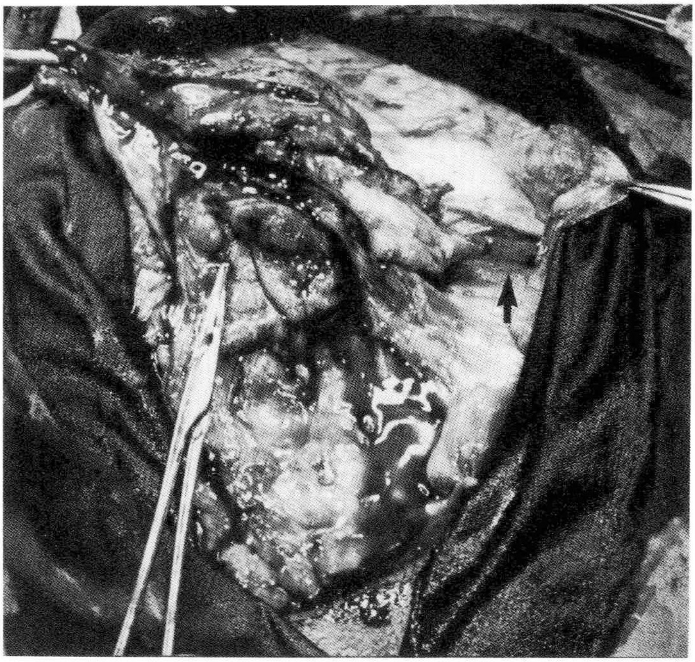

Fig. 5. An intraoperative photograph of productive inflammatory lesions over the 8th to 11th intercostal (IC) spaces. A floret of *Brachypodium silvaticum* was found in the inflammatory tissue over the 10th IC space (tip of forceps). A cord of altered tissue (arrow) connected the inflammatory area to the parietal pleura at the level of the 7th rib.
(Photo A-M. Lövgren)

Histologically the new tissue masses were classified as pyogranulomatous inflammation showing the presence of profuse neutrophilic granulocytes and macrophages. The stroma was sparse. Bacteriological examination of the excised tissue and the exudate revealed polymicrobial infections composed of anaerobes (e.g. *Bacteroides*, *Fusobacterium* and *Peptostreptococcus*) and facultative anaerobes (*Pasteurella* and *Actinomyces*) (Table 2). The single most prevalent species was *Fusobacterium*. The mean number of isolated species per positive sample was 3.5, out of which 2.7 were anaerobes. The presence of *A. viscosus* was shown by indirect immuno-fluorescence in one case. *Nocardia asteroides* could not be found, either bacteriologically or by indirect immunofluorescence. The surgical wounds healed uneventfully, in three dogs after a second or third operation necessitated by recurrences. There were no signs of disease during an observation period of 3.3 years (range, 0.6 - 6.5), except in one dog (case 11), which was successfully treated for pleuritis 3 months after surgery. The normal hunting capability of the dogs was restored after treatment.
A summary of some clinical details is given in Table 3.

Table 2. Bacteriological findings and the occurrence of bacteria in single* or mixed infections in the individual studies (I, II and III).

| Cultured microorganisms | The distribution of bacterial findings in studies I - III by species Study I (22 cases) | Study II (6 cases) | Study III (9 cases) |
|---|---|---|---|
| Facultative anaerobes: | | | |
| *Pasteurella multocida* | 8 | 1 | - |
| *Pasteurella dagmatis* | - | 1 | - |
| *Pasteurella* species | - | 1 | 1 |
| *Actinomyces viscosus* | 3 | - | 2 |
| *Actinomyces* species | 4 | 4 | 2 |
| Other genera | 3 | - | - |
| Anaerobes: | | | |
| *Fusobacterium nucleatum* | 8 | 1* | 1 |
| *Fusobacterium* species | 7 | 1 | 3 |
| *Bacteroides buccae* | - | - | 1* |
| *Bacteroides* species | 12 | 3 | 2 |
| Other gram-negatives or not identified | 9 | - | 1 |
| *Eubacterium* species | 3 | - | 2 |
| *Peptostreptococcus* species | 7 | - | 2 |
| *Propionibacterium* species | - | 1 | - |
| Other gram-positives or not identified | 11 | - | 1 |

Table 3. Summary of some clinical details in 39 dogs (studies I - III).

| Study | No. of cases with pathological thoracic x-ray findings [rate] | No. of cases with single or mixed anaerobic infections [rate] | No. of cases with detected plant parts as foreign bodies [rate] |
|---|---|---|---|
| I | 14 (19) [74 %] | 20 (22) [91%] | 14 (26) [54 %] |
| II | 3 (6) [50 %] | 6 (6) [100 %] | 5[1)] (6) [83 %] |
| III | 9 (9) [100 %] | 8 (9) [89 %] | 2[1)] (5) [40 %] |

1) One dog is also included in study I. Numbers in brackets ( ) are the total numbers of cases examined.

## Lesions in the lumbar region (study II)

In one of the dogs in study I (case 6), which had back pain and a local swelling in the cranio-dorsal lumbar region with a discharging sinus in the flank, surgery revealed a fistulous tract that led to a minuscular plant part (0.8 x 4.6 mm) situated in the sublumbar muscle ventral to the second lumbar vertebra. During the period in which the "Stövar disease" was being investigated, five dogs of the same type of hunting breed with diffuse signs of back pain were presented at the clinic. In the first of these dogs (case 2, study II), the exterior was unaffected and despite thorough clinical and radiographic examination of the spine, including myelography, the source of the pain could not be determined. By reason of our experience from the case in study I mentioned above, this dog and the following four were subjected to special examination of the lumbar region with ultrasonography, scintigraphy and/or MRI. The anatomy of the lumbar region in the transverse plane in shown in Fig. 6. The results of the ultrasound and MR examinations performed 9 weeks after presentation in case 2 are shown in Figs. 7A and 7B.

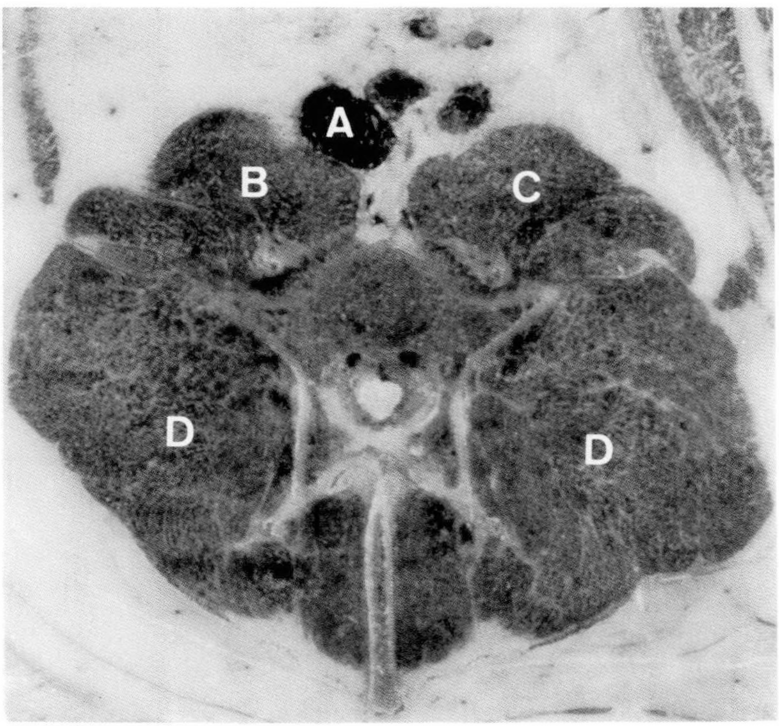


Fig. 6. The anatomy of the lumbar region in a healthy dog. Transverse section, ventral recumbency. A = aorta, B = left sublumbar muscles, C = right sublumbar muscles, D = epaxial muscles.

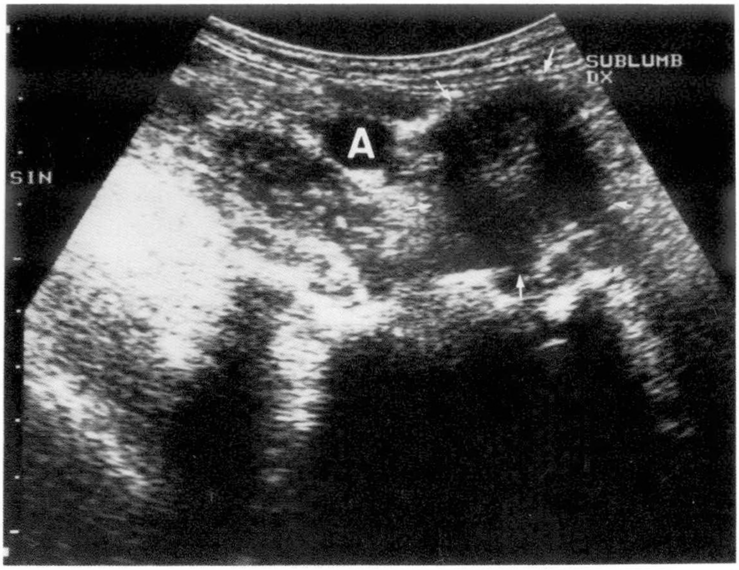


Fig. 7A. Ultrasound in case 2, study II. Transverse plane with the ultrasound beam directed dorsally towards the lumbar spine. The image shows normal striated sublumbar muscles on the left side and enlarged hypoechoic and anechoic sublumbar muscles on the right side (arrows). A = aorta. (Photo K. Hansson)

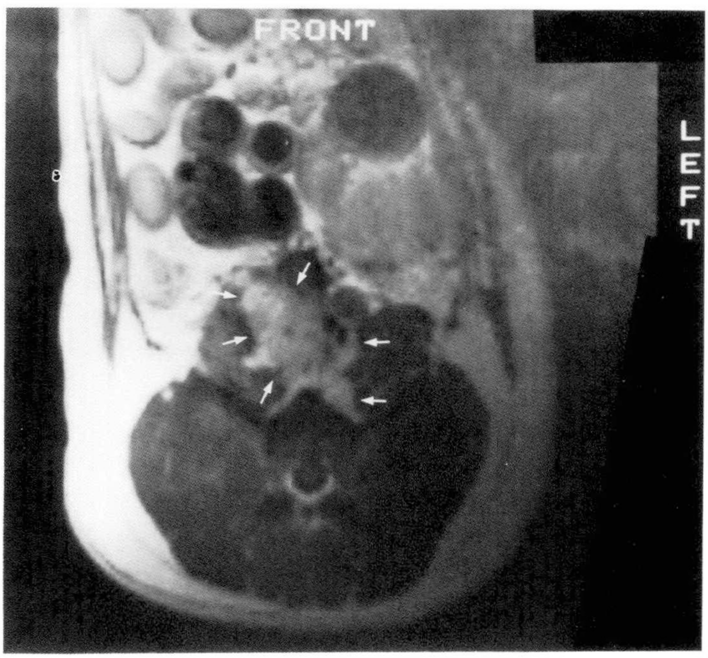


Fig. 7B. A T1-weighted transverse MR image in case 2, study II, after administration of contrast medium. Bilateral lesions (arrows) in the sublumbar muscle compartment show higher signal intensity than normal muscle. (Photo B-M. Bolinder)

A total of six dogs with diffuse signs of back pain (including case 6 of study I) were investigated in study II. The dogs were exclusively of large hunting breeds (3 German pointers, 1 Hamiltonstövare, 1 Schillerstövare and 1 mixed breed). One was male and five were female and the mean age was 4.2 years (range, 2 - 8 years). The dogs were well trained and mostly considered excellent hunters. They all had a history of diffuse signs of back pain or "body" pain, including an arched back, lethargy, reduced performance and inappetence. Three of the dogs had had cough for periods of 2 weeks to 2 months prior to presentation and before the signs of back pain appeared (Table 1). A firm swelling had developed in the cranio-dorsal lumbar region in two dogs and in the caudo-dorsal lumbar region in another two. The exterior was unaffected in two dogs. At routine haematological examination the leucocyte count was elevated in two dogs but was within the normal range in four dogs. A summary of some clinical details is given in Table 3.

The results of examinations with three of the four imaging modalities used are shown in paper II, Table 2. Initial radiographs of the lumbar region were abnormal in four out of six cases, showing periosteal new bone formation (four cases) and diffusely outlined and enlarged sublumbar muscles (two cases). Soft tissue scintigraphic findings were inconclusive in the early diagnosis of lesions in the lumbar region, whereas skeletal scintigraphy (Fig. 8) was useful in detecting inflammatory lesions in this region in two out of four cases. Ultrasound revealed pathological changes (e.g. increased diameter, abnormal echogenicity) in sublumbar soft tissue in all four cases examined on admission (Fig. 7A), in three of which the radiographs were normal. The ultrasound results also indicate that imaging by this technique may visualize foreign bodies of plant origin within an abscess, as seen in case 3, but they also emphasize that very small foreign bodies may be overdiagnosed or may not be discernible, if, for example, they are obscured by bony structures or by dense connective tissue that may occur in a fistulous tract. MRI clearly demonstrated a pathological process and its extension in the paralumbar soft tissue in all examined cases (Fig. 9). A comparison between MRI and ultrasound regarding diagnostic capacity indicates that MRI currently seems to be the most reliable basis for surgical intervention. However, ultrasound is more realistic than MRI in terms of economy and availability.

At surgery, foreign bodies in the form of very small plant parts (sizes between 0.3 x 2.4 and 0.5 x 39 mm) were found in the inflammatory tissue in the sublumbar muscles in five of the six dogs (paper II, Table 1). Histological examination of excised tissue in four cases showed mixed chronic and pyogranulomatous inflammation. Bacterial examination of excised tissue and exudate yielded mixed cultures with anaerobic and facultative anaerobic bacteria (Table 3). No *Nocardia sp* were found bacteriologically. The surgical wounds healed uneventfully in four dogs and after a second and third operation, respectively, in two cases. There have been no signs of disease during an observation period of 4.1 years (range 1.3 - 7.8 years). The dogs returned to their normal hunting activity after treatment.

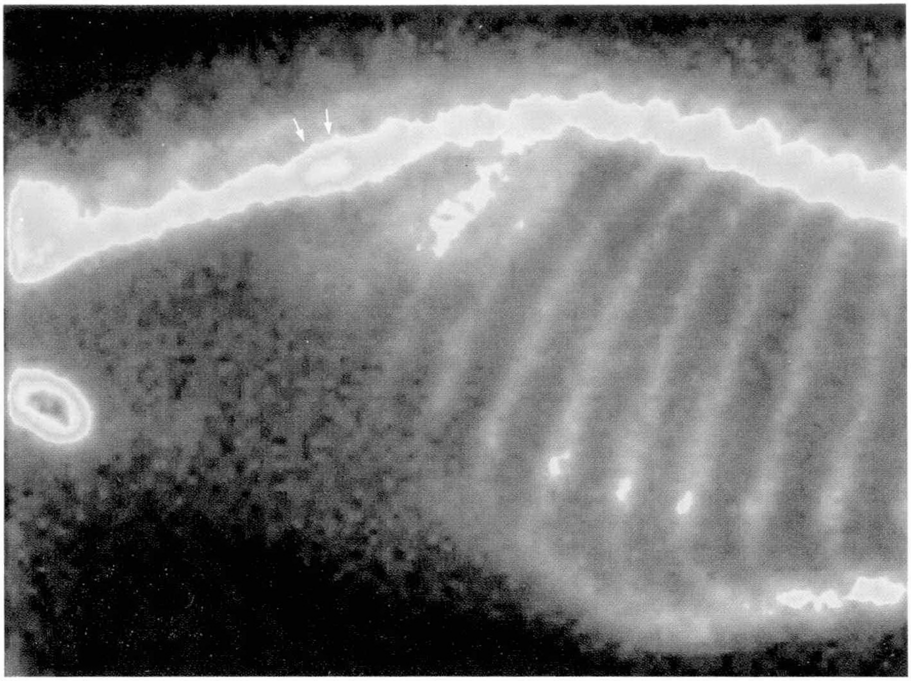

Fig. 8. Skeletal scintigraphy with HDP and $^{99m}Tc$ in cases 3, study II. Right lateral view. There is increased uptake in lumbar vertebra 3 (arrows). (Photo P. Eksell)

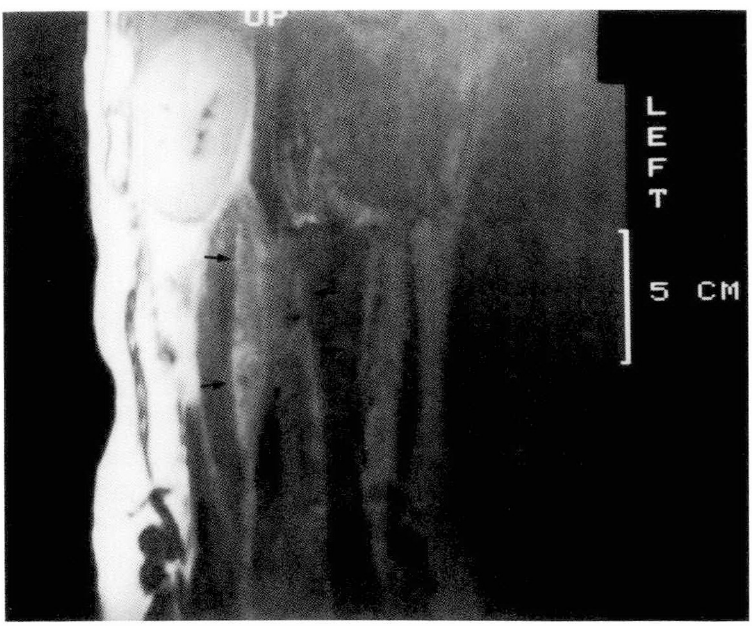


Fig. 9. T1-weighted frontal MR image in case 2, study II, after administration of contrast medium. Bilateral lesions in the sublumbar muscle compartment (arrows), more pronounced on the right side, show higher signal intensity than normal muscle.

## Lesions in the pleural cavity (study III )

Study III comprised nine dogs (including two dogs of study I) with thoracic empyema of unknown underlying cause. Without selection of breed, these were all medium or large size hunting dogs (2 Hamiltonstövare, 3 English pointers, 1 Drever, 1 Springer spaniel, 1 Irish setter and 1 Schillerstövare). There were 3 males and 6 females and the mean age was 3.3 years (range 2 - 5 years). The dogs were well trained and mostly considered excellent hunters. The prodromal signs are shown in Table 1.

In one dog an unsuccessful attempt was made to place a conventional trocar catheter and the dog was destroyed without any further treatment. The other eight were treated by pleural drainage and antibiotics according to the technique described in paper IV. The average amount of fluid removed from each patient in the first 24 hours was 530 ml (range 140 -1,100 ml). The pleural exudate in all cases was yellowish-red to reddish-brown in colour and usually accompanied by white or yellowish flakes or granules (about 1 mm in cross-section). One dog was operated on prior to and one dog was operated on after pleural drainage because of thoracic wall swellings. One dog with severe dyspnoea on admission was destroyed in an early phase of treatment because of complications related to placement of one of the catheters and a poor prognosis as judged by the radiographs. The other seven dogs recovered within 2-3 weeks after termination of drainage. In two of these dogs, however, the pleural infection recurred. One of these dogs died at home after two relapses 1.3 years after primary treatment and the other dog was destroyed 3.5 months after primary pleural drainage because of an inoperable intrathoracic mass. In five dogs there have been no signs of disease during the observation period (mean 5.3 years, range 3.5 to 9 years).

Post-mortem examination of the four dogs that were destroyed or died showed severe productive pleuritis. There were massive adhesions between the pleural layers (Fig. 10). The pleural cavity contained reddish-brown exudate (100 - 1,200 ml). The pleural surfaces in three cases were covered by large amounts of gelatinous reddish-brown tissue, forming vast new local tissue masses that infiltrated the lung parenchyma spotwise, while the intrathoracic lesions in one case seemed to be more confined and thus of a more chronic character.

Histopathologically the inflammatory tissue from the intrathoracic lesions and the thoracic wall was classified as pyogranulomatous, as the main findings were the presence of profuse neutrophilic granulocytes and macrophages. As a rule the stroma was sparse. The results of bacteriological examination of exudate and tissue samples are summarized in Table 2. The mean number of isolated species per positive sample was 2.6, of which 2.0 were anaerobes. The most common bacteria in one sample were *Fusobacterium sp.* and *Actinomyces sp.* No *Nocardia sp* were found bacteriologically.

In two dogs foreign bodies of plant origin were found intrathoracically during surgery for thoracic wall swellings. In case 5, a fragment of a stem from a grass of undetermined origin, measuring 0.7 x 27.8 mm, was found in

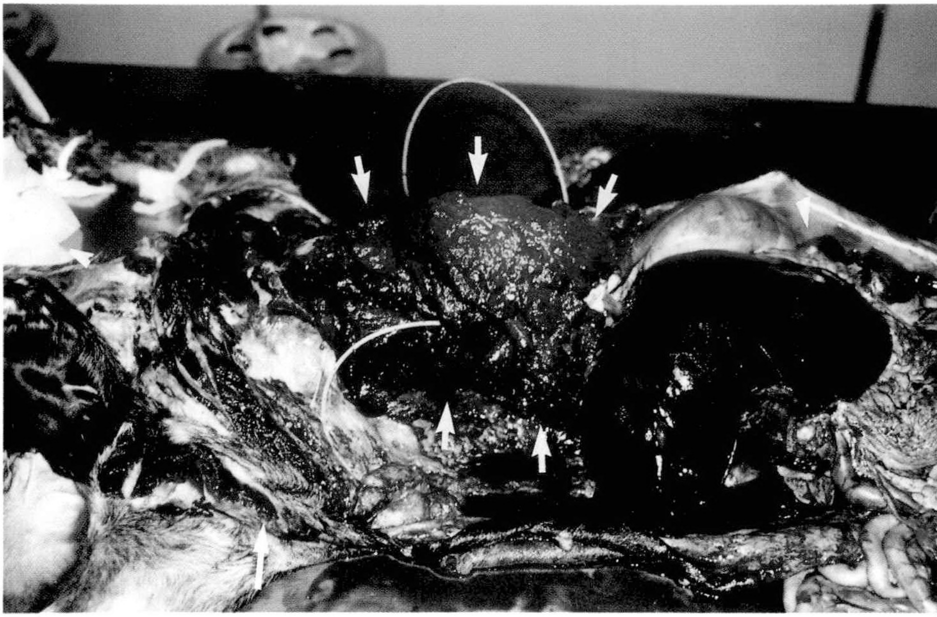

Fig.10. Pyogranulomatous pleuritis with empyema in case 9, study III. The pleural surfaces are thickened and covered by masses of gelatinous reddish-brown tissue, spotwise infiltrating the lung. There are massive adhesions between the pleural layers. The location of the heart and the lungs is indicated by the arrows.

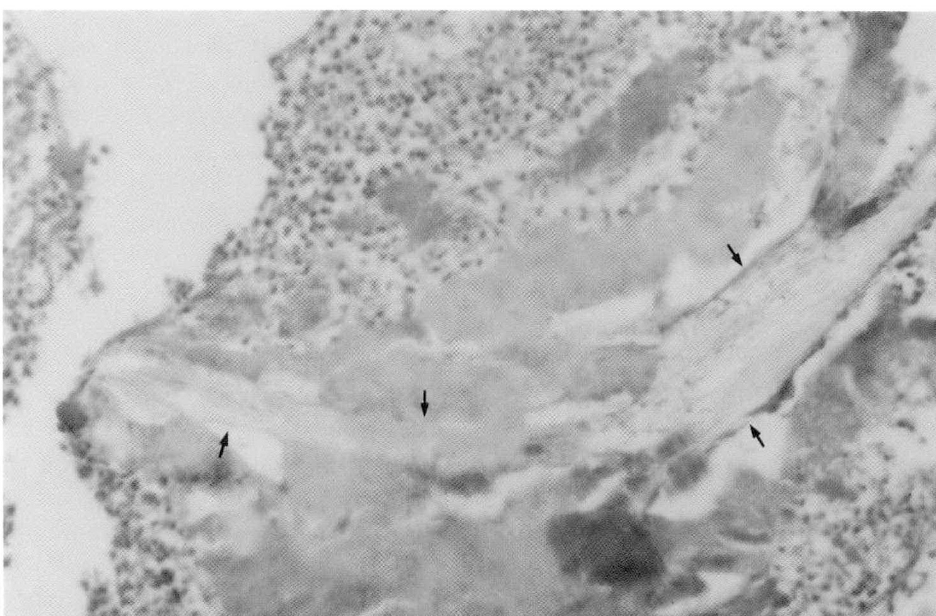

Fig. 11. Pyogranulomatous inflammation in the pleural cavity in case 8, study III, showing clusters of microorganisms centered around a foreign body of plant origin (arrows). Haematoxilin and Eosin X 20. (Photo E. Hellmén)

the 12th intercostal muscle, partly situated in the pleural space. In case 8, lodging in a tissue mass within the pleural cavity, a grain with a base of palea from the grass *Brachypodium silvaticum*, measuring 1.7 x 10 mm, was found (paper III, Fig.2). Histological sections from one out of five tissue samples obtained from the same region revealed further foreign bodies of plant origin in the tissue mass. These were surrounded by clusters of microorganisms (Fig. 11). Bacteriological examination of excised tissue from this region yielded growth of *Actinomyces viscosus, Fusobacterium sp* and unidentified anaerobic gram-negatives.
Some clinical details are summarized in Table 3.

During the ten-year period of investigation, only one further case of suppurative pleuritis was diagnosed at the university clinic. As the aetiology and pathogenesis in this case are known, it was not included in the study. This dog developed thoracic empyema after intrathoracic cardiac massage due to cardiac arrest during general anaesthesia. However, this case showed a clear discrepancy regarding the bacteriological findings and the appearance of the pleural exudate. The dog was treated using pleural drainage by the described modified Seldinger technique (paper IV). A viscous, yellowish pus was drained from the pleural space. Bacteriological examination yielded *Escherichia coli.* The pleural drainage was combined with intrathoracic deposition of metronidazole (Flagyl, Rhone-Poulenc Rorer). The dog was restored to normal health and there have been no signs of disease during an observation period of 2.5 years.

## The catheter pleural drainage technique (study IV)

The results of pleural drainage by the modified Seldinger technique in 39 dogs and two cats with various underlying disorders (pyothorax, hydrothorax, chylothorax, haemothorax, haemothorax/pneumothorax or pneumothorax) are shown in paper IV, Table 1. The pleural drainage arrangement was well tolerated by the animals (Fig. 12) and the drainage was efficient even in cases of viscous, purulent pleural fluid. Nineteen patients died or were destroyed because of the underlying disorder in spite of efficient drainage. One of the eight dogs in study III treated by this method, with empyema and suspected productive pleuritis and adhesions (according to radiological examination), was destroyed because of recurrence of pneumothorax after each suction due to misplacement of one of the pleural catheters. Further treatment was considered unlikely to succeed, as thoracic radiographs showed generalised irregular outlining of the lung lobes and pleural fissure lines, indicating profuse pleural adhesions. Twenty-one surviving animals were accessible for follow-up. The mean observation period was 3.6 years (range 0.5 to 9 years). Except for the case mentioned above, there were no complications that could be related to the catheter drainage technique. The results of this study showed that the described technique allowed controlled and virtually atraumatic and virtually painless introduction of chest catheters into the pleural cavity, even in cases of suspected pleural adhesions. Without impairing the drainage capacity, the guide technique and the Teflon material made it possible to use catheters with smaller diameters than are used in conventional techniques.

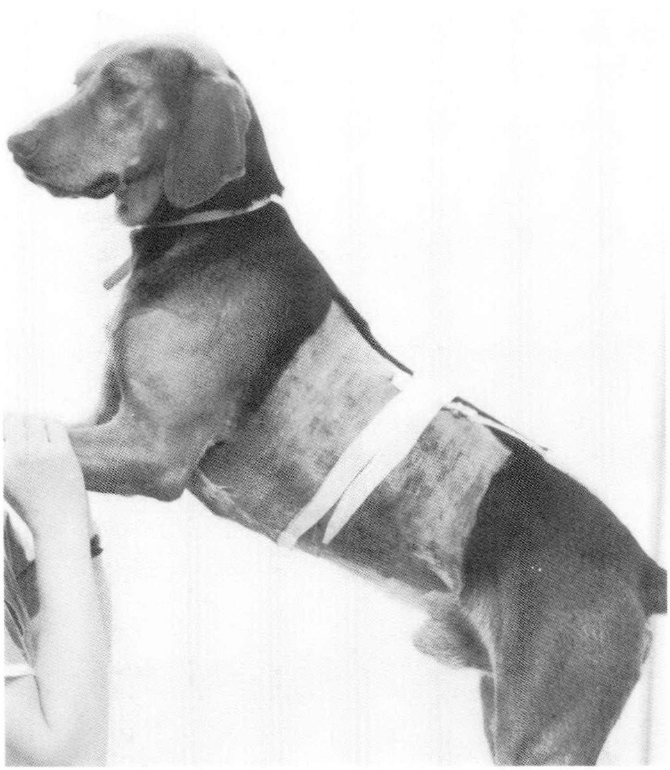

Fig. 12. Catheter drainage of thoracic empyema in a dog. Maximum evacuation is achieved by shifting the dog stepwise into lateral and dorsal recumbency and by elevating the front or the hind of the dog. The pleural drainage arrangement is well tolerated by the dogs.

## Analysis of the foreign bodies (studies I - III)

Plant parts as foreign bodies were found in 19 dogs in studies I - III. Fifteen foreign bodies were confirmed as deriving from grasses. The grass parts in 11 cases consisted of florets or parts of florets (Fig. 13), in one case the culm, in one case a rhachis with four complete spikelets, in one case fragments of a leaf and in one case a part of a lemma (Fig. 14), from different wild grasses. It should be pointed out that the detected plant parts sometimes only constituted a part of a floret. The anatomy of the grass inflorescence is seen in Fig. 15. In one case two clustered pine-needles were found (Fig. 16) and in one case parts of a twig. In the remaining two cases minuscular plant fragments which were not identifiable were detected. Most of the foreign bodies found in the dogs included in this work were hardly visible to the naked eye, as they were very small and were covered by organic tissue and soaked in serosanguineous liquids.

Fig. 13. Grass florets found in dogs subjected to radical excision of thoracic/-abdominal wall swellings. X 15 (Photo M. Iwarsson)

Fig. 13 (*cont.*). Grass florets found in dogs subjected to radical excision of thoracic/-abdominal wall swellings. X 15 (Photo M. Iwarsson)

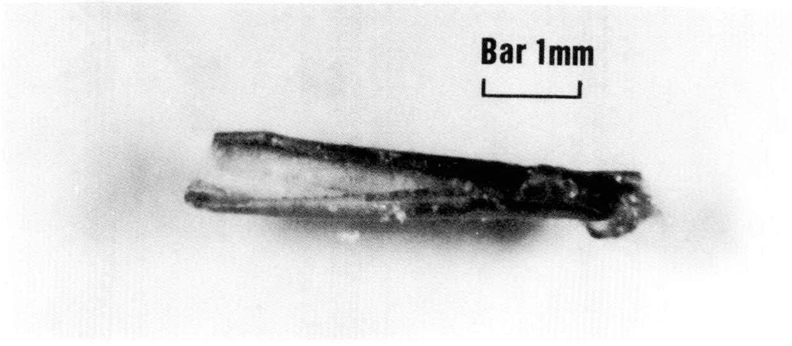


Fig. 14. Part of a lemma from a grass floret (*Poaceae* family), measuring 0.8 x 4.6 mm, found in the sublumbar muscle tissue immediately ventral to the transverse process of L3 on the affected side in case 1, study II. X 13.5 (Photo M. Iwarsson)

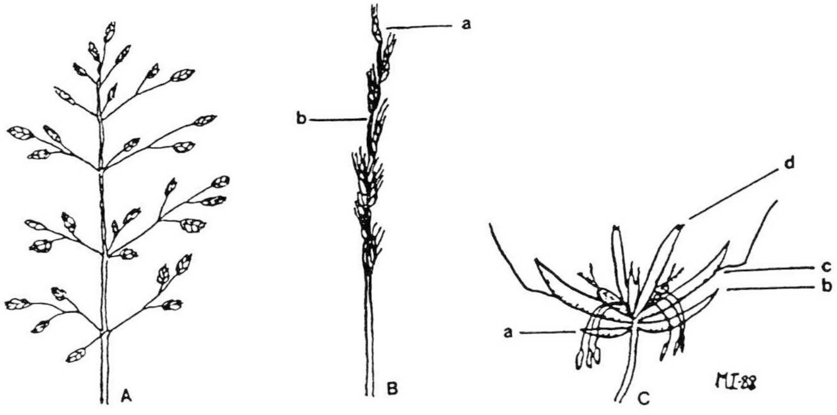


Fig. 15. Survey of the grass inflorescence. Two types of grass inflorescences occur. A. Stalked spikelets in a panicle. B. Unstalked spikelets in a spike. a: spikelet*, b: rhachis. C. Spikelet with two florets*. a: lower glume, b: upper glume, c: lemma with an awn, d: palea. **often referred to as an awn in the veterinary literature*
(Illustration M. Iwarsson)

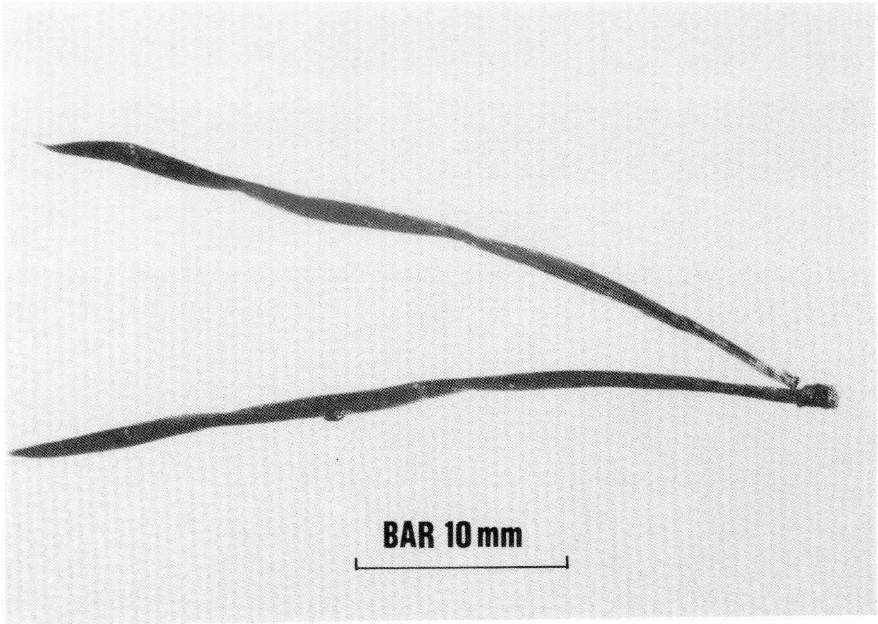


Fig. 16. Two clustered pine-needles, measuring 38 and 39 mm, respectively, found in the sublumbar muscle tissue, in the mid-line at the caudo-ventral margin of the body of the L2 vertebra in case 3, study II. X 2.8 (Photo M. Iwarsson)

# DISCUSSION

## Pathogenesis

A summary of the results from the studies of the three investigated syndromes - thoracic/abdominal wall swellings, pleuritis and sublumbar lesions - yields the following picture. Without selection of breed or type of dog, all patients were large-breed hunting dogs (e.g. Stövare, English pointers, Setters, German pointers). The macroscopic appearances of the tissue changes in the three syndromes were similar (Fig. 17), and the histological picture was one of mixed acute and chronic inflammation of the pyogranulomatous type.

Fig. 17. Specimen of masses of gelatinous reddish-brown new tissue covering the pleural surfaces and partly infiltrating the diaphragm (arrow) and the lung in a dog with pyogranulomatous pleuritis with empyema.

A survey of the results from the bacteriological examinations summarized in Table 2 shows a "homogeneous" type of non-specific, mixed infection in spite of the different locations of the lesions. These anaerobic and facultative anaerobic bacterial species are commensals of the mucous membranes of the oropharyngeal and respiratory tracts. *Actinomyces* did occur, but was an inconstant finding. *Nocardia*, however, was not retrieved in any of the cases. In the majority, if not all, of the cases, foreign bodies of grass origin were found in the inflammatory lesions in all three syndromes. These small plant particles (Fig. 18) were sometimes accidentally found within the voluminous inflammatory lesions or after thorough dissection of the excised tissue by cutting it into 1 to 2 mm thick slices. It is thus reasonable to assume that in many cases plant material may have remained undetected, as was in fact discovered in the dogs with relapse. To find such a small particle within, for

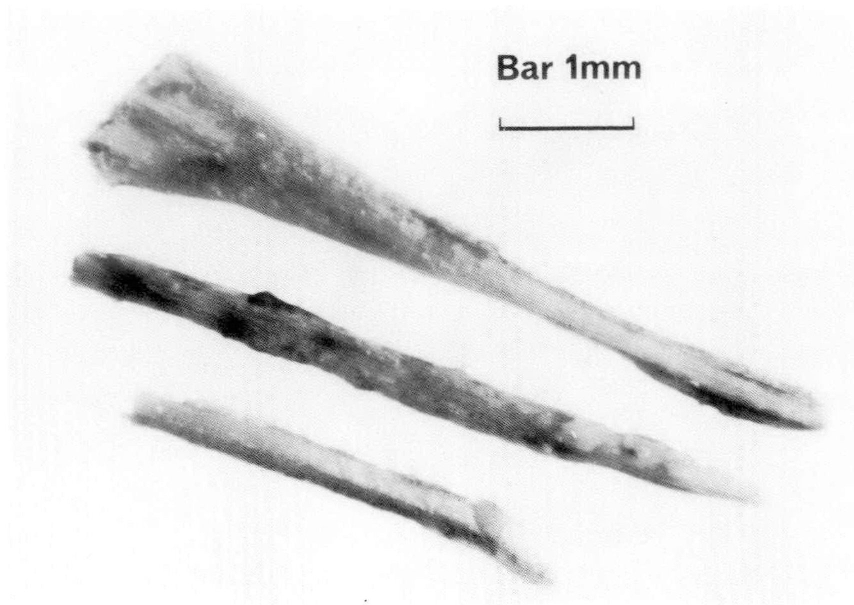


Fig. 18. Minuscular plant parts, measuring 0.3 x 3.5 mm, 0.5 x 5.5 mm and 1.0 x 6.0 mm, respectively, found in the sublumbar muscle tissue, immediately ventral to the transverse process of L3 on the affected side in case 2, study II.
(Photo M. Iwarsson)

example, the pleural space, when this is filled with new tissue masses and purulent exudate, must be considered to be extremely fortuitous.

Nevertheless, grass parts, measuring 0.7 x 27.8 mm and 1.7 x 10 mm, were found within the pleural space in two cases, respectively. In one of these cases, another plant particle was found on histological sections after complete dissection of the excised tissue. When looking at the locations in which the foreign bodies in the three disorders were discovered (apart from one of the cases with pleuritis), a regularity is seen which may give a clue to the pathogenesis of the different syndromes (Fig. 4). The grass particles that were found in the thoracic/abdominal wall lesions were located in the wall musculature along the line of peripheral attachment of the diaphragm to the chest. The foreign bodies found in the sublumbar muscles also followed this anatomical pattern. This musculature is an extension of the dorsal attachment of the diaphragm (Fig. 19). When the prodromal respiratory signs noted in the histories of the dogs with the three syndromes (i.e. coughing, suspected pneumonia or pleuritis) are added to the findings described above, the assumption that aspiration of foreign bodies is the common denominator of the three conditions would seem reasonable. According to this theory the plant parts are aspirated and penetrate the lungs into the pleural cavity and by respiratory movements are forced between the pleural layers in a caudal direction. The foreign bodies finally become trapped at the peripheral

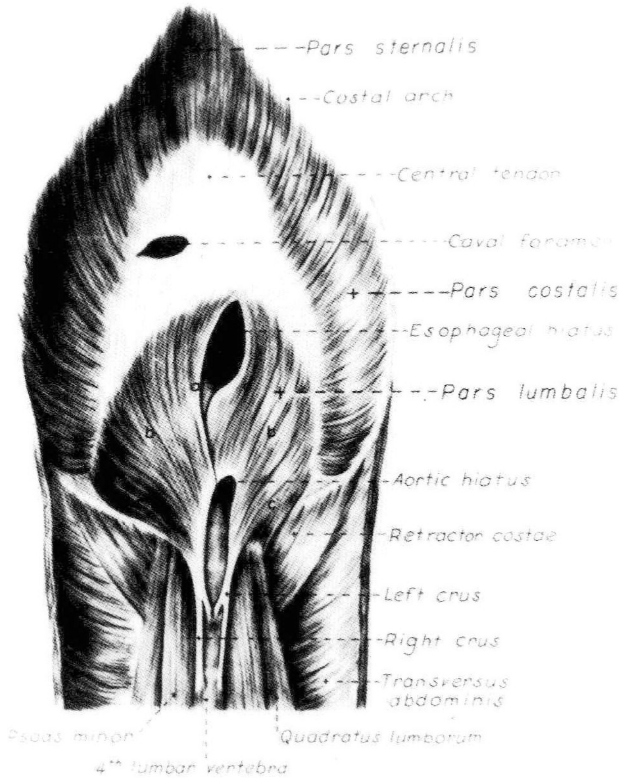


Fig. 19. The diaphragm and sublumbar muscles, abdominal surface. (Reprinted with permission from Evans, H.E. In: Miller´s Anatomy of the dog. 3rd ed., W.B. Saunders Co., Philadelphia, 1993.)

attachment of the diaphragm, or migrate further from this point into the immediately adjacent intercostal, abdominal or sublumbar musclature, where local inflammatory changes occur. The productive inflammation in the pleural cavity, with empyema of the type described in this study, may result from aspirated plant parts that were trapped in the thoracic cavity. The fact that the bacteria that were cultured from these lesions are commensals of the mucous membranes of the oropharyngeal and respiratory tracts, further fortifies the aspiration theory. It is reasonable to believe that the infection arises from bacteria which seemingly colonise the plant parts as they penetrate the mucous membranes of the respiratory tract. The strong pathogenicity of these organisms when they gain entrance to tissues beyond their usual habitat as a result of penetration by foreign bodies was demonstrated in preliminary studies in which sterile plant parts, soaked in saliva from the dog, were placed subcutaneously. These produced severe inflammatory lesions with peracute abscess formation.

Thus, in the light of the above discussion, it is hard to consider penetration of these grass parts through the skin. Hygroscopic movement or torsion is a physical property of the spikelets of some grasses (Murbach 1900) that may promote skin and/or mucous membrane penetration. In Australia, New Zealand and the former Soviet Union this dispersal promoting mechanism in barley grass (*Hordeum murinum*) is the cause of great suffering amongst sheep and lambs, as the spikelets become trapped in the coat and steadily work their way through the skin and deep into the flesh. The economic losses due to reduced slaughter weight and rejection of carcasses and skins are substantial (Loughnan 1964, Bashkatov 1969, Jacobs 1988). In the present studies there were no signs indicating such penetration of foreign bodies through the skin. Not in one single case did careful examination reveal skin wounds. The observed sinus openings, discharging purulent exudate, occurred after the swellings had developed. Further support for the aspiration theory, and contradicting the idea of skin penetration, are the fistulous tracts (fibrotic cords) that were found in seven cases during surgery. The origin and end of these tracts and the location of the foreign body within the fistulous tract suggest that the tracts developed during the migration of the plant part from the wall musculature towards the subcutis. The distinct fibrotic cords were found, namely, to span the distance between the inflammatory tissue and the pleura at the peripheral attachment of the diaphragm. The foreign body was discovered in the outer part of the fibrotic cord, where it fused with the inflammatory tissue on the thoracic wall (Fig. 5).

The fact that the described syndromes were seen exclusively in hunting dogs may be explained by looking closer at the types of dogs involved and their area of activity. These are dogs that are used for field or forest hunting. At maximum speed and breathing with open mouth they rush through the dense grass undergrowth where the game hides (Fig. 20). It is in this type of vegetation that we find the kinds of grasses that are the source of such particles as we have found in the inflammatory lesions. About three quarters of the dogs in this study, referred to the university clinic, came from the island of Gotland in the Baltic sea. This region of Sweden is known for its maritime climate with long dry summers, mild winters and low annual precipitation. Sparse pine forests and extended seashore meadows, both with profuse grass undergrowth, are the dominating types of vegetation in the hunting areas. Under these conditions, parts of the mature, sun-dried grass inflorescence easily become separated from the erect stem (culm). The aspiration theory fits well with these conditions. The general opinion of hunters in Gotland is that a hunting season with low precipitation is followed by a high incidence of "Stövar disease" amongst their hunting dogs.

As both bacteria and plant material are involved in the syndromes of the present studies, the question arises as to whether both are required for the typical productive inflammatory tissue, which was characterised histologically as pyogranulomatous (studies I and III). The gelatinous appearance of the affected tissue, with a bulging and glistening section surface, could be ascribed

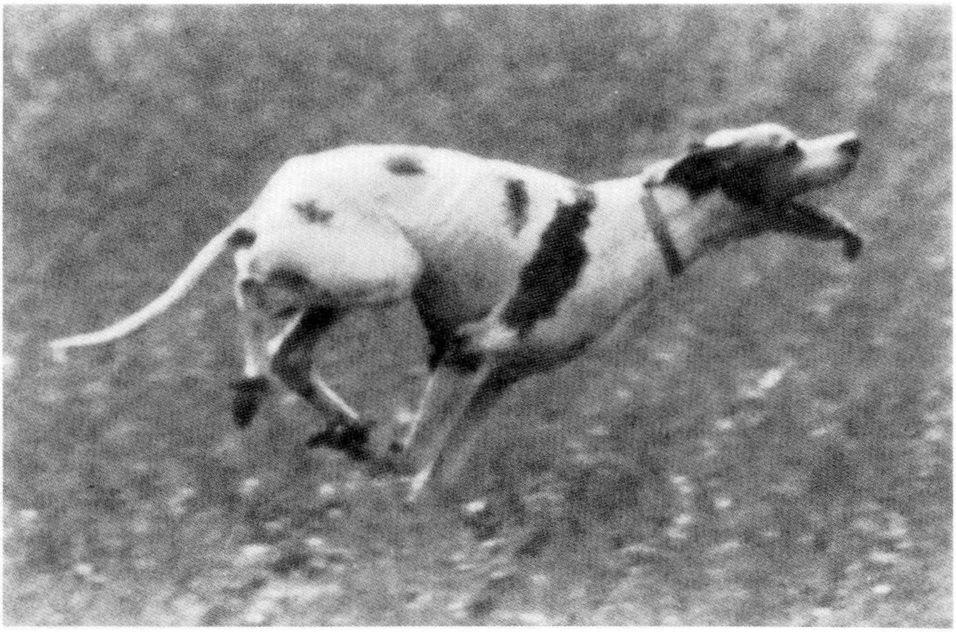

Fig. 20. At maximum speed and breathing with open mouth, the hunting dogs rush through the dense grass undergrowth and may easily aspirate parts of the mature, sun-dried grass inflorescence. (Photo Å. Wintzell)

to the accumulation of large numbers of neutrophilic granulocytes and macrophages that made up a large part of the lesions, together with only sparsely occurring stroma. For these reasons, the lesions studied were designated as pyogranulomatous inflammation according to the definition given by Cheville (1988). An interesting observation was that the hallmarks of ordinary granulomatous inflammation, typical of the tissue response elicited by indigestible substances, i.e. nodular collections of epithelioid and giant cells, were not seen in the tissue surrounding the foreign bodies. The absence of granulomatous inflammation might be explained by the actual migration of the plant material, making it impossible for the host´s cellular response to confine the process. The productivity and the typical gelatinous appearance of the affected tissue seen at gross examination in the present study are not observed in cases of foreign bodies of non-grass origin in dogs. Foreign bodies that remain in tissue after pharyngeal or skin-penetration injuries by wood (twigs) often lead to localised abscesses with encapsulation of the foreign body and sinus tract formation. The productivity of the inflammatory tissue seen in the cases presented in this study could have been due not only to the migration and possible chemical irritants within the plant material, but also to colonisation of the foreign body with bacteria of mucous membrane origin. Even if the foreign bodies are aspirated without touching the walls of the oropharyngeal tract, they may become contaminated by bacteria from this region. In previous studies of the normal flora of the trachea and lungs in the dog (Lindsey and Pierce 1978, McKiernan et al. 1984) and of bacterial pathogens of the lower respiratory tract in humans (Bartlett 1981), it has been shown that oropharyngeal bacteria are frequently aspirated and may be present for an unknown period of time in the normal tracheo-bronchial tree and lung. Colonisation of foreign bodies of plant origin by bacteria is illustrated in Fig. 11, which shows the findings on histological sections from tissue excised from the thoracic cavity of case 8, study III. This figure indicates that minuscular foreign bodies of plant origin can be colonised by bacteria and may serve as vehicles and reservoirs for the infection. Bacteria colonise inert surfaces in the form of glycocalyx-enclosed microcolonies, referred to as biofilms. The chronic character of the lesions could be due to such biofilms consisting of microcolonies embedded in a polysaccharide matrix produced by the bacteria. Adherence of bacteria to and subsequent biofilm formation on synthetic surfaces such as surfaces of industrial or medical material are well known in human medicine (Jansen and Kohnen 1995). The tissue damage in chronic bacterial infections caused by biofilm-producing bacteria is dominated by a persistent immune complex-mediated inflammation and infiltration by neutrophilic granulocytes (Høiby et al. 1994). This phenomenon is likely to have occurred arround the foreign bodies within the lesions in the cases of this study. It has been shown that bacteria in biofilms are protected from, and partly refractory to antibiotics as well as to the antibacterial systems of the host (Cheng et al. 1981, Costerton and Lapin-Scott 1989).

*Plant parts as foreign bodies in the dog*

The anatomy of the grass inflorescence is seen in Fig. 14. In the inflorescence, spikelets are parted into florets (often incorrectly referred to as "awns" in veterinary literature), which constitute a unit, a diaspore, which spreads the grass species in nature. Murbach (1900) described *hygroscopic movement* or *torsion* of the spikelets of some grasses, in that the glumes spread out as they dry. This mechanism spreads the diaspores from the mother plant and presses them into the soil (van der Pijl 1982). Further, in some species the lemma has an awn (bristle) which is spirally twisted by this mechanism when drying. When the awn is moistened it unfolds and becomes straight, causing a rotating movement of the floret (Fig. 21). In the Swedish flora this phenomenon holds for the false oat species (*Arrhenaterum sp.*) and feather grass (*Stipa joannis* ). In grasses, epidermal cells shaped like angled barbs, prickle hairs, with a sharp edge, are also common. Along the veins of the leaf, along the culm and profusely in the inflorescence, prickles are arranged in rows (Fig. 22). It is reasonable to believe that these prickle hairs may promote forward migration but prevent retrograde movement as they hook onto the tissue. The mixed chronic and pyogranulomatous inflammation seen in some of the cases may be due to intermittent migration of the plant parts, promoted by muscular activity and the prickle hairs.

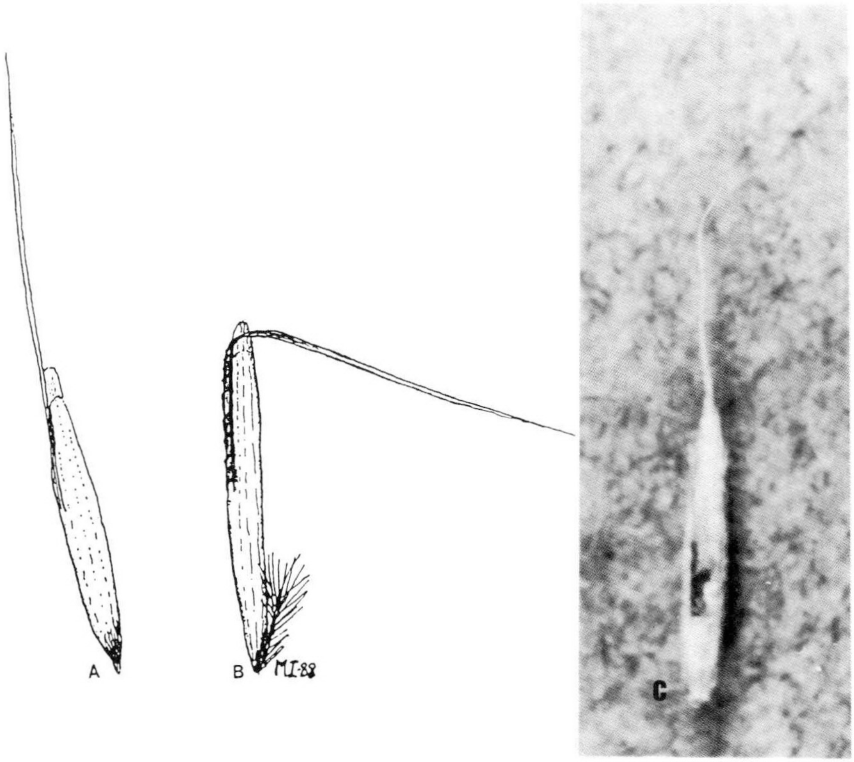


Fig. 21. Hygroscopic movement. Two lemmas with awns from florets of *Arrhenatherum pubescence*. A. the lemma is moistened - the awn is straightened out. B. the lemma is dry - the awn is spirally twisted. C. A floret of *Elymus caninus*, measuring 1.3 x 15.9 mm, found in case 21, study I. The lemma is moistened and the awn is straightened out. X 3.15

(Illustration and photo M. Iwarsson)

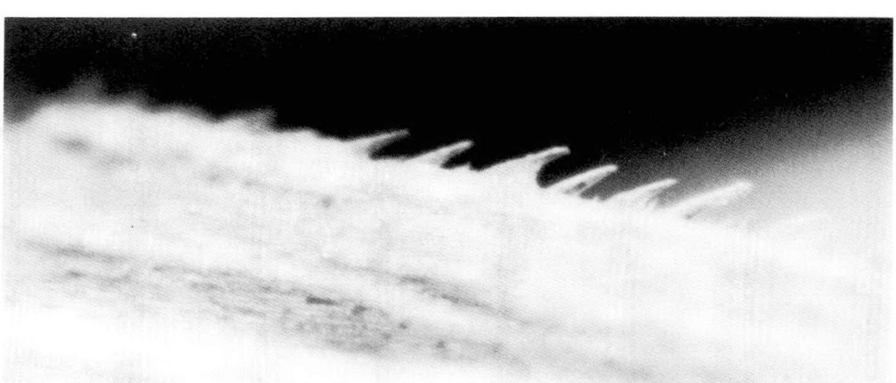

Fig. 22. Epidermal cells shaped like angled barbs, prickle hairs, occur commonly in grasses. Along the vein of the leaf, along the culm and profusely in the inflorescence, these are arranged in rows. (Photo M. Iwarsson)

In the particular flora of Gotland there are numerous grass species with sharp, barbed and/or hygroscopic plant parts that are potentially dangerous to the dog. Some of them are presented in Table 4.

Table 4. Some grass and sedge species in the flora of Gotland with sharp, barbed and/or hygroscopic* plant parts that are potentially dangerous to the dog.

| **Poaceae** Grass species | Vernacular name | Potentially dangerous plant part(s) |
|---|---|---|
| *Ammophila arenaria* | Marram Grass | leaf apex, stem, spikelike |
| panicle*Ammophila arenaria x* | | |
| *Calamagrostis epigeios* | hybrid | stem, panicle |
| *Arrhenaterum elatius* | Oat-grass | spikelets, bristles long* |
| *Arrhenaterum pratense* | Meadow Oat | spikelets, bristles long* |
| *Arrhenaterum pubenscens* | Hairy Oat | spikelets, bristles long* |
| *Avena fatua* | Wild Oat | spikelets, bristles long* |
| *Avena sativa* | Oat | spikelets, bristles long* |
| *Elymus caninus* | Bearded Couch-grass | spikelets scrabid |
| *Elymus farctus* | Sand Couch-grass | spikelets scrabid |
| *Elymus farctus x repens* | hybrid | spikelets scrabid |
| *Elymus repens* | Coutch-grass | spikelets scrabid |
| *Hordelymus europaeus* | Wood Barley | bristles long* |
| *Hordeum distichon* | Two-rowed Barley | bristles long* |
| *Hordeum jubatum* | Squirreltail Barley | bristles long* |
| *Hordeum murinum* | Wall Barley | brisles long* |
| *Hordeum vulgare* | Six-rowed Barley | brisles long* |
| *Leymus arenarius* | Lyme-grass | leaf, stem, spikelets |
| *Phragmites australis* | Reed | leaf, stem scrabid |
| *Secale cereale* | Rye | spikelets, bristles long* |
| *Triticum sp.* | Wheat | spikelets scrabid |
| **Cyperaceae** Sedge species | | |
| *Cladium mariscus* | Sedge | leaves, stem, inflorescence |

Soft tissue foreign bodies may be a challenging clinical problem in veterinary practice. During the past thirty years there have been many reports on cases in the dog with suppuration, pain, swelling and/or the formation of draining sinus tracts secondary to invasion of plant parts as foreign bodies. Although abscesses and draining fistulas secondary to penetrative injuries in the orbit or pharynx caused by wooden twigs are occasionally reported (e.g. Peeters 1992), the overwhelming majority of the reported cases have comprised lesions caused by migrating grass parts. These injuries have occasionally been observed in Australia and Europe, but the majority of the cases derive from the western and south-eastern United States. In these regions migrating grasses are reported to be a serious problem in hunting and sporting breeds. A review of reports in the veterinary literature (1962-1990) describing grass floret migration in the dog is presented in Table 5. In a survey of the volume and distribution of surgical cases in 78 small animal practices in California during a two-month period (Vasseur et al. 1981), the removal of "foxtail" grass awn foreign bodies was listed as the sixth most common surgical procedure. Grass florets ("awns") or spikelets have been found in almost every region or part of the dog and the suggested routes and mechanisms by which they gain entrance to the body are numerous (Table 5). Grass floret migration through every possible body orifice, i.e. penetration into or through the nasal sinuses, the ear canals, the orbit, the mouth, the salivary ducts, the oesophagus, the gastro-intestinal canal, the lungs and the urethra, have been suggested in the dog (Table 5). Brennan and Ihrke (1983) reported on grass awns in the external ear canal, the interdigital web, the conjunctiva and the nictitating membrane, the nasal passages, the oral cavity, the perineum and the lumbar and flank regions. These authors suggested that the location of the grass awns in the dogs mainly depends on the size and shape of the dominating grass species in that particular part of the country and that the ability to penetrate the skin is likely to rely upon the physical properties of the offending awn. According to Brennan and Ihrke (1983), passive acquisition of grass awn, with trapping of the awn in the animal's coat and subsequent migration through the skin, is more common when the offending awn has a *large size* (20-50 mm), such as *H jubatum*, commonly called "foxtail". Accordingly, in the western United States injuries secondary to migration through the skin are the most common type of lesions. Nicholson and Horne (1973) and Horne (1981) described lesions associated with migrating grass florets or awns in the cervico-facial region, the interdigital web and the flank and costo-chondral region. According to these authors facial abscesses, lodging grass awns of the genus *Stipa* (10-12 mm), are the most common clinical features in the south-eastern United States.

The presence of plant particles in the thoracic/abdominal wall, the sublumbar muscles and the pleural cavity have thus been reported previously in the veterinary literature, but usually without any closer study of the pathogenesis. Different routes of entry of the foreign bodies have been suggested (percutaneously, via the alimentary or digestive tract or the respiratory tract) (Table 5). However, the pathogenesis proposed in these reports has not been verified consistently either at surgery or post-mortem examination. The most comprehensive description supporting the aspiration theory was given by Head et al. (1975), who reported a case in which a grass floret had partially perforated the pleura and protruded into the pleural cavity and had caused a granulomatous type of bronchopneumonia. However, Head et al. only describe the lesions in the lung and do not mention anything about the presence of a concurrent pleuritis.

Table 5. Review of reported cases of grass floret (awn) migration the dog with special reference to localization, suggested route of entry and associated signs.

| Grass floret (awn) localization | Suggested route of entry | Associated signs | References |
|---|---|---|---|
| Nasal sinus | nasal passages | sneezing, nasal discharge, epistaxis | Brennan and Ihrke (1983) Norris and Laing (1985) Hargis et al. (1986) |
| External ear canal | ear canal | ruptured tympanic membrane | Brennan and Ihrke (1983) |
| Vertebral canal (atlas bone) | ear-foramen magnum, atlanto-occipital joint | severe pain when moving head | Trees (1970) |
| Face, head and neck | oral mucosa or conjunctiva | periorbital, retrobulbar or periapical abscess | Nicholson and Horne (1973), Horne (1981), Brennan and Ihrke (1983) |
| Conjunctiva or nictitating membrane | oral mucosa or conjunctiva | conjunctivitis | Brennan and Ihrke (1983) |
| Nasal lacrimal duct | upper lacrimal puncta | ocular discharge | North (1977) |
| Oral mucosa | mouth | gingivitis, glossitis, gingival hyperplasia, halithosis, increased salivation | Brown (1985), McKeever and Klausner (1986) |
| Tonsillar crypt | mouth | tonsillitis | Herbert (1977) |
| Parotid duct | buccal opening, p. duct | facial swelling, purulent saliva | Bell (1978) |
| Bronchia | airways | cough, respiratory distress | Deguelle and Lenihouannen (1977), Jones and Roudebush (1984), Brownlie (1986), Suter and Lord (1984), Dobbie et al. (1986) Lotti and Niebauer (1992) |
| Thoracic cavity | oesophagus | cough, pneumonia | Hur (1974) |
| Heart | oesophagus | respiratory distress, dullness Post-mortem: pericarditis, punctured right auricle | Bowman et al. (1982) |
| Pericardium | oesophagus or trachea | | Aronson and Gregory (1995) |
| Costochondral area | lower airways, paralumbar and flank region | swelling and/or discharging sinus in the caudal ribcage area, paralumbar or cranial flank region | Nicholson and Horne (1981), Horne (1983), Robertson et al. (1983) |
| Intercostal muscle | airways | longstanding signs of pulmonary disease | Schmitt (1962) |
| Lumbar and flank | lower airways, skin alimentary canal | recurrent posterior paresis, discharging sinus flank, vertebral osteomyelitis with sublumbar abscess | Johnston and Summers (1971), Parker (1980), Brennan and Ihrke (1983), Robertson et al. (1983), Johnston and Christie (1985) |
| Abdominal cavity | not mentioned | not mentioned | Brennan and Ihrke (1983) |
| Scrotum | skin | scrotal abscess | Hur (1974), Brennan and Ihrke (1983) |
| Penis | urethra | dysuria | Herbert (1977) |
| Prepuce | prepuce opening | purulent discharge | Herbert (1977) |
| Bladder | urethra | hematuria, grass awn centered in a struvite urolith | Brennan and Ihrke (1983) Van Noppen (1987) |
| Perineal region | skin | | Brennan and Ihrke (1983) |
| Anal sacs | anal sac excretory duct | swelling, anal sac abscess | Bergeaud (1994) |
| Interdigital web | skin | draining fistulous tract | Hur (1974), Horne (1981), Brennan and Ihrke (1983), Dean and Kraus (1986) |

## Actinomycosis versus foreign body-related diseases in the dog

As previously mentioned, in a historical perspective, the source of infection in human actinomycosis has been shown to be endogenous (mucous membranes) rather than exogenous. However, the fundamental mechanisms that allow the agents of actinomycosis to establish an infection in humans are not known (Rippon 1988). As suggested by Holm (1950, 1951) actinomycosis in man appears to be a co-operative disease of *Actinomyces* and a mixed flora of other bacteria, predominantly facultative anaerobes and anaerobes. According to Holm, these bacteria exert synergistic activity in the pathogenesis of actinomycosis. Furthermore, *Actinomyces sp* alone seldom succeed in producing disease, as confirmed by laboratory tests (Jordan and Kelly 1983, Jordan et al. 1984). The abscence of these "other" bacteria in bacterial cultures where *Actinomyces sp* is recovered may be due to inadequate bacteriology. For instance, the role of anaerobes in infections is often underestimated for the reason that anaerobic cultures are frequently not requested or the sample is improperly handled for anaerobes (Finegold et al. 1975, Dow et al. 1986, Dow and Jones 1987). In cases of thoracic empyema, *Actinomyces sp* may be difficult to grow on bacterial cultures from pleural exudate, although the microorganism may be found in granules on direct smears of pleural exudate (e.g. Horne 1981).

*Nocardia sp*, previously incriminated as the aetiological agent in "Stövar disease", could not be found in any of the three syndromes studied in this work. The identification of *Nocardia asteroides* in previous cases of "Stövar disease" in the dog was based on morphological characteristics of granules in tissue. However, it was suggested by Swerczek et al. (1968a) that the finding that the actinomycotic granules that form in dog tissues lack the prominent characteristic peripheral clubs seen in bovine actinomycosis may have tempted some workers to call the organism in dogs *Nocardia asteroides*, especially when cultural identification was not attempted. According to Swerczek et al. (1968a and 1968b), *Nocardia asteroides* in dogs does not produce granules in tissue and the irregularly acid-fast organisms are diffusely scattered throughout the inflammatory tissue.

*Actinomyces sp* was cultured from 36 per cent of the cases in studies I - III. Although nearly one hundred reports of cutaneous, subcutaneous, thoracic, abdominal and vertebral actinomycosis in the dog, or reports dealing with lesions in the dog where the diagnosis is compatible with modern criteria for actinomycosis, have been published during the last century, the pathogenesis of the disease is still not known. If the syndromes in dogs associated with migrating grass parts in the flank or costo-chondral region ( e.g. Schmitt 1962, Nicholson and Horne 1973, Horne 1981, Brennan and Ihrke 1983) are compared with reports of subcutaneous and/or cutaneous actinomycosis in the dog (e.g. Schnelle 1929, Fethers 1934, McGaughey 1952, Swerczek et al. 1968a, Davenport et al. 1974, Wachowitz and Weber 1987, Kirpensteijn and Fingland 1992), striking similarities are found concerning the location and the macroscopic and microscopic appearances of the lesions. Whereas Nicholson and Horne (1973) and Horne (1981) described these lesions secondary to grass floret or awn migration, Kirpensteijn and Fingland (1992) reported similar lesions in the thoracic and abdominal wall in a review article based on medical records of 48 dogs from four universities in the United States but designated them as actinomycosis. In the lesions described by Horne, in which grass parts were found as foreign bodies, "nocardia-like" organisms were sometimes seen, but usually the culture was negative. Kirpensteijn and Fingland suggested that skin wounds are likely to be the site of entry of *Actinomyces* and *Nocardia* in cutaneous infections, although few of the dogs had a history of trauma. *Actinomyces sp* was isolated from 60 per cent of the cases examined and a mixed bacterial population was evident in 69 per cent. Horne (1981) suggested different routes of entry of the foreign bodies, e.g. aspiration of the grass parts and penetration through the pleura with subsequent migration towards the subcutaneous tissue, or penetration through the gastrointestinal wall and migration through the peritoneum to the costochondral area after swallowing, but gave no pathophysiological details and did not describe the appearance of the altered tissue. The importance of radical surgery to avoid recurrence of the lesions is stressed in the report by Horne and that by Kirpensteijn and Fingland, although the authors of theses two reports base their opinions on different conclusions regarding the pathogenesis of the syndromes in question.

The same pattern of similarities concerning the location of the lesions and the macroscopic and microscopic findings is found when osteomyelitis of the lumbar vertebrae that is reported to be secondary to plant part migration (Johnston and Summers 1971, Head et al. 1975, Parker 1980, Johnston and Christie 1985 and 1990) is compared with osteomyelitis in the same region that is suspected to be a primary bacterial infection caused by *Corynebacterium sp* (LaCroix 1973), *Actinomyces sp* (Dunbar and Vulgamott 1981, Edwards et al. 1988) or *Nocardia sp* (Mitten 1974, Stead 1984, Bradney 1985). It was considered that these microorganisms might have reached the affected areas haematogenously. It is interesting to note, however, that Johnston and Christie (1990) distinguish between sublumbar lesions caused by plant parts and those caused by primary actinomycotic infections. In study II of the present work, bacteriological examination showed growth of *Actinomyces sp* in mixed infections in three out of five cases in which plant parts were found in the sublumbar region. In case 2, the foreign bodies consisted of three minuscular plant parts, measuring 0.3 x 3.5 mm, 0.5 x 5.5 mm and 1.0 x 6.0 mm, respectively. The presence of these very small foreign bodies is interesting, as they may be the "missing link" in the pathogenesis in many cases of vertebral osteomyelitis in the dog. In textbooks on veterinary medicine or in occasional case reports without any further documentation of cases, Morgan (1972), Head et al. (1975) and Parker (1980) briefly mention the theory that foreign bodies may seek their way out of the lung and through the diaphragm into their final location near the lumbar insertion of the crura of the diaphragm, where they cause an osteomyelitis. Head et al. (1975)

described a case in which a grass awn was found in a fibrous tract spanning the distance between the diaphragm and the perirenal area. The foreign body was found at the level of the second lumbar vertebra. Johnston and Summers (1971) and Beischer and Robbins (1993) suspected that the plant parts or wooden sticks found had reached the lumbar region after swallowing, and had subsequently penetrated the intestinal wall at the caudal duodenal flexure and had ascended in the mesoduodenum to the lumbar vertebrae. However, in 1985 and 1990 Johnston and Christie reported findings of grass awns in six cases (including the three described by Johnston and Summers 1971), the end of a pine branch in one case and pieces of wood in one case, all in the sublumbar region, and now suggested a different route, namely that the plant parts had penetrated at the turn of the terminal oesophagus, had moved past the left crus of the diaphragm and had come to rest ventral to the vertebral bodies.

It is interesting to note that the cases of purulent pleuritis presented at the university clinic during the past ten-year period (study III), in which the cause of infection has been obscure, belong without exceptions to the type described. The macroscopic and microscopic appearance of the lesions and the bacteriological findings in these cases correspond by and large to reports of thoracic empyema, referred to as thoracic actinomycosis (e.g. Bahr 1902, McGaughey 1952, Swerzcek et al. 1968a, Collins et al. 1968, Davenport et al. 1974, Hardie and Barsanti 1982, Edwards et al. 1988), or as thoracic empyema in which foreign bodies (Robertson et al. 1983) or aspirated grass parts (Turner and Breznock 1988) were suspected of having caused the disease. When surveying the literature on the subject of the aetiology and pathogenesis of thoracic empyema, it is apparent that the route by which the pleural space becomes infected is generally not known (study III, Table 1). In veterinary textbooks many suggestions as to how the pleural cavity becomes infected have been put forward, e.g. by penetrating thoracic wounds (bite or foreign body wounds), penetrating wounds of the thoracic oesophagus (foreign bodies), penetrating wounds of the airways, extension from bacterial pneumonia, pulmonary abscess, bronchopleural fistula, bronchiectasis, migrating foreign bodies, extension of cervical, lumbar or mediastinal infections, extension from discospondylitis or septic processes affecting the vertebrae, haematogenous spread, postoperative infection and aspirated pleural foreign bodies (grass florets) (Suter and Zinkl 1983, Orton 1985, Bauer 1989). In case reports Collins et al. (1968a) and Turner and Breznock (1988) suggested a pulmonary origin of the disease with subsequent extension to the pleural membrane. Robertson et al. (1983) precluded access of the infection via the respiratory tract because of the absence of associated lung disease. Nevertheless, at a closer study of the detailed histories presented in the cases reported by these authors, one finds prodromal signs of the same type as are described in the present study which if anything may be regarded as support for the aspiration theory. Infection secondary to inhalation of grass florets is the most common suspected aetiology in the western and south-eastern United

States (Horne 1981, Brennan and Ihrke 1983, Turner and Breznock 1988). The proposed aetiology, however, has not been documented consistently either at surgery or at post-mortem examination. To my knowledge, there is only on case report on thoracic empyema in which intrathoracic foreign bodies of plant origin have been found, apart from the two cases described in study III of the present report. Hur (1974) described one case in an English pointer in which two grass florets were found near the base of the diaphragm. The macroscopic tissue changes were similar to those described in the cases of study III, in which the pleural surfaces were thickened and covered by large amounts of gelatinous reddish-brown tissue, forming vast local tissue masses that infiltrated the lung parenchyma spotwise. In the case described by Hur, the history included coughing. However, the author suggested thoracic penetration via the oesophagus without presenting any specific findings supporting his theory. In this context it should be mentioned that Aronson and Gregory (1995) reported infectious pericardial effusions in five dogs. In two dogs a grass floret was detected in the pericardium. The authors speculated that the grass florets might have migrated to the heart via the oesophagus or trachea.

We consider that in a majority of the dogs presented in this work (studies I - III), the lesions in the thoracic and abdominal wall, the sublumbar region and the pleural cavity in all respects fulfil the criteria for lesions generally referred to as classical actinomycosis. In view of the fact that foreign bodies in the form of plant material were found in 54, 83 and 40 per cent of the dogs subjected to surgery or post-mortem examination in studies I, II and III, respectively (Table 1) and that *Actinomyces sp* was cultured from tissue or exudate or was observed on direct smears of exudate in 15, 50 and 100 per cent of these cases, respectively, it is tempting to suggest that synergism may occur between plant material and endogenous bacteria in the pathogenesis of actinomycosis. The presence of small plant parts, often invisible to the naked eye, that not only may cause abrasions of the mucosa, but readily may migrate into the tissue, and that serve as vehicles and reservoirs for the aetiological agents, has not to date been documented consistently in the pathogenesis of the disease. The present study would seem to give rise to the question as to whether lesions in which *Actinomyces sp* are recovered should be regarded as specific *Actinomyces* infections or whether the syndrome should be considered to be due to non-specific mixed infections that arise from commensal microorganisms of the mucous membranes of the oropharyngeal tract. These could be carried to the lesion site by inhaled fragments of plant material that penetrate through the lower respiratory tract and serve as vehicles and reservoirs for the infection due to biofilm formation, leading to the ensuing chronic condition and resistance to treatment.

*Comparative aspects of human and canine actinomycosis*

As previously mentioned, actinomycosis is also seen in other mammals, including man. Flynn and Felson (1970) mention that the past mortality rate of 90 per cent in human actinomycosis has been reversed with modern treatment and a 90 per cent cure rate is now possible. The similarities between man and the dog concerning the location of the lesions and the insidious and chronic course of the disease are surprising. In man, cervico-facial, abdominal and thoracic forms most commonly occur; cervico-facial lesions are most frequently reported, but practically any part of the body, including the vertebrae, may be attacked by this disease (Sanford and Voelker 1925). Sanford and Voelker give a comprehensive account of 670 cases in man. About half of the patients lived in a rural environment and/or were farmers, many of whom had the habit of chewing on straw, weeds, or grain. The other half of the patients included craftsmen and labourers, for example. The post-mortem findings in the human thoracic cases, sometimes including chest wall abscesses, are similar to those in study III. Findings of foreign bodies are not reported in any of these cases, but in view of our experience of the difficulties in detecting the very small foreign bodies that seemingly cause the lesions, it is not unlikely that the source of infection may be the same in man. Nevertheless, aspiration of foreign bodies in the form of grass parts with ensuing lobar pneumonia and subsequent lung lobe resection are not unusual in man, particularly in children less than three years of age (eg. Carter et al. 1948, Jackson 1952, Wooley 1955, Clery et al. 1959, Merriam et al. 1964). However, in these reports bacteriological examination of the affected lung was not accounted for. Merriam et al. (1964) mention that spikes of grasses with soft spikelets, such as those of Timothy grass, remain lodged within the bronchus, whereas grass spikes with firm spikelets, such as those of Barley grass, have a tendency to be moved toward the periphery of the lung, occasionally to the point of extrusion through the chest wall, causing empyema or pyopneumothorax.

In human medicine there are also reported cases of diffuse signs of back or abdominal pain in which *Actinomyces sp* were found in the sublumbar muscles and the lumbar vertebrae at surgery (Axelrod et al. 1982) or at post-mortem examination (Flynn and Gillies 1938). The source of infection could not be determined in these cases, but a contiguous spread from the lung was suspected in the case reported by Flynn and Gillies (1938). Cope (1951) reported 15 cases of actinomycosis of the vertebral column, some of them including swelling on the thoracic wall or in the lumbar region and sometimes accompanied by sinus openings to the skin. On the basis of our experience from the cases in study II, it is tempting to suggest that the basic cause of the disease in the human cases may have been small, undetected foreign bodies of plant origin acting as reservoirs for a mixed infection due to biofilm formation leading to the chronic course of the disease.

## Suggestions for treatment based on the results from studies I - IV

Having learned about the small size of the plant particles that cause the extensive productive inflammatory lesions, it is not to be wondered at that radical removal has proven to be preferable to incision and drainage (alone or in combination with chemotherapy) in disorders of this kind. Naturally, the more inflammatory tissue that is removed, the greater the chance of removing any conceivable foreign body. Hence, to avoid relapses, one has to consider costectomy in cases of thoracic/abdominal wall swellings in order to gain access to all inflammatory tissue that may be located in the intercostal muscles or in the pleural membrane medial to the ribs, and in which plant parts may be embedded. The results of the retrospective studies by Frendin and Persson (1987) and by Kirpensteijn and Fingland (1992) and the report by Nicholson and Horne (1981) support this conclusion. Previously, preoperative chemotherapy was used to reduce the swelling and thus the amount of tissue to be removed at surgery (Frendin and Persson 1987). However, many of these dogs had relapses. Thus, in order to improve the chances of removing the foreign body, preoperative chemotherapy should probably be excluded.

Whereas the disorders in the thoracic/abdominal wall and in the pleural cavity meet with fewer diagnostic problems, the diagnostic difficulties in cases with diffuse signs of back pain are considerable. Clinically, there are usually no features indicating an infectious process, such as fever and/or leucocytosis, and primary radiographs and scintigrams of the lumbar region may be inconclusive. These facts indicate that the inflammation in the sublumbar muscles is of low grade. The primary aim of the diagnostic measures in these cases is to determine the extent of the lesions, thus providing a basis for surgical intervention, rather than to localize a possible plant part. The benefit of locating a foreign body by ultrasound is in our experience of secondary importance, because of the bleeding and the limited space in the surgical field, which means that even if a foreign body has been located ultrasonically, the surgical intervention nevertheless has to be done blindly. For anatomical reasons the affected tissue cannot be radically excised, and hence the chances of removing the foreign body are reduced. For these reasons it is important to determine the extent of the area in which a search for a foreign body can be made. A comparison between MRI and ultrasound regarding diagnostic capacity, based on the results from study II, indicates that MRI currently seems to be the most reliable basis for surgical intervention. However, irrespective of whether a foreign body can be detected with certainty, ultrasound is useful in finding pathological changes in the sublumbar soft tissue that may indicate the presence of a foreign body. Further, ultrasound is more realistic than MRI in terms of economy and availability. Regarding treatment of lesions in the lumbar region, a more radical approach than is described in paper II, including incision of some intervertebral nerves, would probably not interfere with the muscle function in such a way that the gallop action would be impaired. If the infection has been spread to the vertebral column, curettage of the lesions in the affected vertebrae should be performed to prevent any compression of the spinal cord.

The treatment chosen for lesions in the pleural cavity should include complete drainage of pleural exudate and long-term penicillin. Oral antibiotics alone or in combination with intermittent thoracocentesis may have an uncertain effect, as indicated by the results in cases 3, 7 and 9 in study III, in which this treatment only temporarily improved the dog's condition. The introduction of pleural catheters, however, is hazardous in view of the common occurrence of extensive adhesions between the chest wall and the lung in this type of pleuritis. As shown by the results from study III, puncture of the lung can be avoided in most cases by using the method described in study IV, which includes a puncture technique with an indicator balloon and a Seldinger technique for introduction of a flexible guide. The pulmonary trauma after accidental perforation using this technique with a small-diameter catheter is much less severe, and more reparable, than perforation by a large-diameter conventional catheter with an internal trocar. Radical surgery may also be of benefit in cases of productive pleuritis in which there is a localised intrathoracic new tissue mass that may be connected to a swelling on the thoracic wall. In cases of generalised pleuritis, however, there is an obvious risk that surgery may damage the lung. In those cases surgery is excluded in favour of long-term treatment with penicillin after drainage of pleural exudate. The adverse effects of long-term chemotherapy, however, e.g. bacterial antibiotic resistance and a temporarily impaired sense of smell in the dogs (commonly recognised amongst hunters), suggest that this treatment regime should be restricted to inoperable cases. The purpose of the penicillin treatment is to suppress the infection in the biofilm around the foreign body until the plant part is broken down and can no longer serve as a surface on which the bacteria can adhere and form a biofilm. Two of the dogs with pyogranulomatous pleuritis in study III remained in good health for several months on penicillin treatment, but signs of pleuritis recurred two or three weeks after closed treatment. Edwards et al. (1988) described one case of canine pleuritis diagnosed as actinomycosis with pleural lesions indistinguishable from those in case 8 of study III. This dog was treated by penicillin for 19 months and was in good health at follow-up four years after presentation. According to the results of this study most of the dogs seem to be saved and return to normal health by the proposed treatment regime.

# General conclusions

The following conclusions may be drawn from the results of this investigation:

- The three seemingly different syndromes studied in the dog appear to constitute parts of a common disease complex that occurs in certain types of hunting dogs (e.g. Stövare, English and German pointers) that hunt intensively in areas with profuse grass undergrowth.

- The hallmark of this disease complex is a localised pyogranulomatous inflammation with a diffuse margin against the surrounding muscular tissue in the thoracic/abdominal wall, in the sublumbar muscles and in the pleura. A characteristic viscous, muddy, reddish-brown exudate occurs, usually accompanied by white or yellowish granules or flakes, in the affected tissue. This exudate may be found more abundantly in the form of subcutaneous abscesses or as empyema in cases of pleuritis.

- The common denominator underlying the three different syndromes seems to be the presence of one or more foreign bodies in the form of plant particles, which were found within the inflammatory lesions in all three locations, if not in all of the cases in the three syndromes. The usually very small plant particles (the smallest found measured 0.3 x 2.3 mm) may easily remain undetected in the voluminous inflammatory tissue or in the copious amount of exudate in an empyema, for which reason a more frequent occurrence cannot be ruled out.

- In all probability the plant particles are aspirated under the special conditions in which these dogs hunt, and penetrate the pleura into the pleural cavity, after which they are forced between the pleural layers in a caudal direction by respiratory movements. They finally become trapped at the peripheral attachment of the diaphragm. The presence of prodromal respiratory signs, the type of bacteriological findings, the direction of macroscopically detectable fistulous tracts and the final anatomical location of the foreign bodies, all speak in favour of this pathogenesis.

- Anaerobic or facultative anaerobic commensals of the oropharyngeal and respiratory tracts seem to be carried into tissues beyond their normal habitat by aspirated plant particles and become pathogenic. This is indicated by the bacteriological findings in the inflammatory tissue. The observation of bacterial colonisation of the plant particle found in the affected tissue in the pleural cavity in one of the cases further supports this theory.

- The described tissue changes show similarities in several respects to those seen in lesions referred to as actinomycosis in the dog and man. The possibility cannot therefore be ruled out that many cases reported as actinomycosis primarily may have been caused by an undetected migrating plant particle that was contaminated by a mixed flora of bacteria, including *Actinomyces sp*, residing in the respiratory tract mucosa.

- The lesions in the thoracic/abdominal wall and pleural cavity give rise to fewer diagnostic problems because of the obvious signs. In cases with lesions in the sublumbar muscles, however, the diagnostic difficulties are considerable, as the signs may be restricted to evidence of diffuse pain that may be difficult to locate. The diagnostic efforts are not made easier by the absence in many cases of the typical signs of infection, such as a raised body temperature and leucocytosis. The localization of the lesion is made even more difficult by the fact that primary radiological changes may be inconclusive. However, in suspected cases the region of affected tissue may be revealed by ultrasound examination or magnetic resonance imaging as a basis for surgical intervention. Occasionally the foreign body may be detected by ultrasound, but at the present time there is a risk for under- or over-diagnosis of a foreign body at this examination.

- In addition to chemotherapy, the treatment should include radical surgery of the affected tissue so as to remove any foreign bodies, even those that are not detected on direct inspection at surgery. This treatment regime applies particularly to inflammatory lesions in the thoracic/abdominal wall. For anatomical and functional reasons the surgical intervention cannot be as radical in the lumbar region. In these cases the operation has to be restricted to a meticulous search for conceivable foreign bodies in the region of the affected tissue. Radical surgery in the pleural cavity should be confined to cases in which the lesions are clearly demarcated. In cases of vast new tissue masses, the treatment is restricted to efficient drainage of the pleural cavity ( the period of drainage depending on the amount of exudate) combined with local and oral treatment with antibiotics. These cases may require long-term oral antibiotic therapy so as to suppress the infection until the foreign body remaining in the pleural cavity is broken down and thus can no longer serve as a surface for bacterial colonisation.

- The conventional technique for pleural drainage, which includes the introduction of a trocar catheter, involves considerable risks for complications and is inhumane because of the pain inflicted on the animal on laceration of the usually occurring pleural adhesions between the lung and the chest wall in the type of pleuritis described. The new technique described in this work for pleural drainage, using a small-diameter Teflon catheter which is introduced over a flexible guide with increased flexibility at its anterior end, seems to be virtually painless to the animal and provides efficient drainage even in cases of viscous pleural exudate.

- The prognosis after treatment according to the proposed routines must be considered good, as 34 of 38 treated dogs returned to normal health.

# References


Ackerman, N., Grain, E. & Castleman, W. (1982) Canine Nocardiosis. *Journal of the American Animal Hospital Association* **18,** 147-153

Aronson, L.R. & Gregory, C.R. (1995) Infectious Pericardial Effusion in Five Dogs. *Veterinary Surgery* **24,** 402-407

Axelrod, F.B., Fonda, J.N. & Bradley III, E.L. (1982) Retroperitoneal Actinomycosis: A Rare Manifestation of an Uncommon Disease. *Southern Medical Journal* **75,** 1156-1157

Bahr, L. (1902) Ueber Actinomycose beim Hunde. *Zeitschrift für Thiermedicin* **8,** 47-67

Bartlett, J.G. (1981) Anaerobic lower respiratory tract infections. *Scandinavian Journal of Infectious Disease* suppl. **26,** 118-122

Bashkatov, G.A. (1969) Economic losses caused by feather-grass disease in sheep. *Veterinariya, Moscow* **6,** 69-72

Bauer, T. (1989) Mediastinal, pleural, and extrapleural diseases. Chapter. 70. In: *Textbook of Veterinary Internal Medicine* (ed. S.J. Ettinger) 3rd edn, Vol. 1, pp. 867-880. W.B. Saunders, Co., Phildelphia, Pennsylvania

Beischer and Robbins (1993) Vertebral Osteomyelitis, Ataxia, and Paraparesis Caused by a Satay Stick. *Australian Veterinary Practitioner* **23,** 7-10

Bell, D.A. (1978) A grass seed in the parotid duct of a dog. *Veterinary Record* **102,** 340

Bergeaud, P. (1994) Pathologies liées aux épillets. *Le Point Veterinaire* **26,** 105-113

Bergey´s Manual of Systematic Bacteriology (1984) vol. 1 (ed. N.R. Krieg) Williams & Wilkins Baltimore/London

Bowman, D.O., Hall, R.D. & Bird, K. (1982) Grass awn foreign body in a dog. *Veterinary Medicine/Small Animal Clinician* **77,** 759

Bradney, I.W. (1985) Vertebral osteomyelitis due to *Nocardia* in a dog. *Australian Veterinary Journal* **62,** 315-316

Brennan, K.E. & Ihrke, P.J. (1983) Grass awn migration in dogs and cats: A retrospective study of 182 cases. *Journal of the American Veterinary Medical Association* **182,** 1201-1204

Brion, A. (1939) L´Actinomycose du chien et du chat. *Revue de Medicine Veterinair Toulouse* **91,** 121-159

Brown, R.M. (1985) Vegetative stomatitis in dogs. *Modern Veterinary Practice* **66,** 856-858

Brownlie, S.E., Davies, J.V. & Clayton, D.G. (1986) Bronchial foreign bodies in four dogs. *Journal of Small Animal Practice* **27,** 239-245

Buchanan, A.M., Beaman, B.L., Pedersen, N.C., Anderson, M. & Scott, J.L. (1983) *Nocardia asteroides* Recovery from a Dog with Steroid- and Antibiotic-Unresponsive Idiopathic Polyarthritis. *Journal of Clinical Microbiology* **18,** 702-708

Carter, G.R. & Chengappa, M.M. (1991) In: Essentials of Veterinary Bacteriology and Mycology, 4th edn. Lea & Febiger, Philadelphia

Carter, G.R. & Cole, J.R. (1990) In: Diagnostic Procedures in Veterinary Bacteriology and Mycology, 5th edn. Academic Press, Springfield

Carter, M.G. & Welch, K.J. (1948) Bronchiectasis following aspiration of timothy grass: Report of eight cases. *New England Journal of Medicine* **238,** 832

Cedervall, A. (1954) Über Streptothrikose bei Karnivoren. *Nordisk Veterinär Medicin* **6,** 159-172

Chastain, C.B., Grier, R.L., Hogle, R.M., Glock, R.D. & Mitten, R.W. (1976) Actinomycotic Peritonitis in a Dog. *Journal of the American Veterinary Medical Association* **168,** 499-501

Cheng, K.J., Irvin, R.T. & Costerton, J.W. (1981) Autochtonous and pathogenic colonization of animal tissues by bacteria. *Canadian Journal of Microbiology* **27**, 461-498

Cheville, N.F. (1988) *Introduction to Veterinary Pathology* 1st edn. Iowa State University Press, Ames, p 14.

Clery, A.P., Ellis, F.H. & Schmidt, H.W. (1959) Problems associated with aspiration of grass heads (inflorescences). *Journal of the American Medical Association* **150**, 1478

Collins, J.D., Grimes, T.D., Kelly, W.R., Kealy, J.K. & Murphy, E.C. (1968) Pleuritis in the Dog Associated with Actinomyces-like Organisms. *Journal of Small Animal Practice* **9**, 513-518

Cope, V.Z. (1951) Actinomycosis of Bone with Special reference to infection of the vertebral column. *Journal of Bone and Joint Surgery* **33B**, 205-214

Costerton, J.W. & Lapin-Scott, H.M. (1989) Behavior of bacteria in biofilms. *ASM news* **55**, 650-654

Davenport, M.T., Carter, G.R. & Schirmer, R.G. (1974) Canine actinomycosis due to *Actinomyces viscosus*: report of six cases. *Veterinary Medicine/Small Animal Clinician* **69**, 1442 and 1444-1447

Dean, P.W. & Kraus, K.H. (1986) Chronic sinus tract caused by a foreign body in a dog. *Modern Veterinary Practice* **67**, 266-268

Deguelle, B. & LeNihouannen, J.C. (1977) Perforation Bronchique et Necrose Lobarie par un Epi Migrateur D'hordeum murinum. *Revue de Medicine Veterinaire* **128**, 1695-1700

Dobbie, G.R., Darke, P.G.G. & Head, K.W. (1986) Intrabronchial foreign bodies in dogs. *Journal of Small Animal Practice* **27**, 227-238

Dow, S.W., Jones, R.L. & Adney, W.S. (1986) Anaerobic bacterial infections and response to treatment in dogs and cats: 36 cases (1983-1985). *Journal of the American Veterinary Medical Association* **189**, 930-934

Dow, S.W. & Jones, R.L. (1987) Anaerobic infections. Part I. Pathogenesis and clinical significance. *Compendium on Continuing Education for the Practicing Veterinarian* **9**, 711-720

Dunbar, M. & Vulgamott, J.C. (1981) Thoracic and vertebral osteomyelitis caused by actinomycosis in a dog. *Veterinary Medicine/Small Animal Clinician* **76**, 1159-1161

Edwards, D.E., Nyland, T. G. & Weigel, J.P. (1988) Thoracic, abdominal and vertebral actinomycosis. *Journal of Veterinary Internal Medicine* **2**, 184-191

Elias, E & Shophet, R. (1980) Isolation of *Nocardia asteroides* from the lymph nodes of a dog. *Refuan Veterinarith* **37**, 136-142

Fawi, M.T., Tag-el-Din, M.H. & el-Sanowi, S.M. (1971) Canine distemper as a predisposing factor for Nocardia asteroides infection in the dog. *Veterinary Record* **88**, 326-328

Fethers, G. (1934) Streptotrichosis (Pseudo-actinomycosis) in a dog. *Australian Veterinary Journal* 10, 151-152

Finegold, S.M., Bartlett, J.G., Chow, A.W., Flora, D.J., Gorbach, S.L., Harder, E.J. & Tally, F.P. (1975) Management of Anaerobic Infections. *Annals of Internal Medicine* **83**, 375-389

Flynn, M.W. & Felson, B. (1970) The roentgen manifestations of thoracic actinomycosis. *American Journal of Roentgenol/ Radium Therapy/ Nuclear Med* **110**, 707-716

Flynn, R. & Gillies, A.D. (1938) Actinomycosis of the Vertebral Column. *Australian and New Zealand Journal of Surgery* **8**, 193-198

Forsell (1948): Quoted by Frendin and Obel (1997).

Frendin, J. & Persson, F. (1987) Behandling av Nocardios-liknande inflammatoriska förändringar i bröst- och bukvägg hos hund. *Svensk Veterinärtidning* **39**, 255-258

Frendin, J. Greko, C., Hellmén, E., Iwarsson, M., Gunnarsson, A. & Chryssantou, E. (1994) Thoracic and abdominal wall swellings in dogs caused by foreign bodies. *Journal of Small Animal Practice* **35,** 499-508

Frendin, J., Funkquist, B., Hansson, K., Lönnemark, M. & Carlsten, J. (1997) Diffuse back pain in the dog caused by migrating plant parts. Submitted.

Frendin, J. (1997) Pyogranulomatous Pleuritis with Empyema in Hunting Dogs. *Journal of Veterinary Medicine* A**44,** 167-178

Frendin, J. & Obel, N. (1997) Catheter drainage of pleural fluid collections and pneumothorax. *Journal of Small Animal Practice* **38,** 237-242

Grain, E, Ackerman, N. & Castleman, W. (1978) Disseminated Nocardiosis in a Dog. *California Veterinarian* **32:5** 9-13

Harz, C.O. (1879) *Actinomyces bovis,* ein neuer Schimmel in den Geweben der Rindes. Jahresbericht der K. Central-Tierharztliche, Hochschule in Munchen fur, 1877-1878, 5:125

Hardie, E.M. & Barsanti; J. A. (1982) Treatment of canine actinomycosis. *Journal of the American Veterinary Medical Association* **180,** 537-540

Hargis, A.M., Liggit, H.D., Lincoln, J.D., Chandler, F.W. & Haupt, K.H. (1986) Noninvasive Nasal Aspergillosis (Fungal Ball) in a Six-Year-Old Standard Poodle. *Journal of the American Animal Hospital Association* **22,** 504-508

Head, J.R., Suter, P.F. & Ettinger, S.J. (1975) Lower respiratory tract diseases. In: Textbook of Veterinary Internal Medicine, Volume 1. (ed. S.J. Ettinger.) W.B. Saunders, Philadelphia. pp 678-682

Herbert, C.R. (1977) More grass seeds. *Veterinary Record* **101,** 192

Holm, P. (1950) Studies of the aetiology of human actinomycosis: I. The other "microbes" of actinomycosis and their importance. *Acta Pathologica et Microbiologica Scandinavia* **27,** 736-751

Holm, P. (1951) Studies on the aetiology of human actinomycosis: II. Do the "other microbes" of actinomycosis possess virulence. *Acta Pathologica et Microbiologica Scandinavia* **28,** 391-406

Horne, R.D. (1981) Grass awn migration in the dog. *Canine Practice* **8,** 21-32

Hur, D.E. (1974) Foxtail foreign bodies in dogs and cats. *Modern Veterinary Practice* **55,** 29-31

Høiby, N, Espersen, F., Fomsgaard, A. Giwercman, B., Tvenstrup Jensen, E., Krogh Johansen, H., Koch, C., Kronborg, G., Stenvang Pedersen, S., Pressler, T. & Kharazmi, A. (1994) Biofilm, fremmedlegemer og kroniske infektioner. *Ugeskrift Laeger* **156,** 5998-6005

Jackson, C. (1952) Grasses as foreign bodies. *Laryngoscope* **62,** 897

Jacobs, S.L.W. (1988) Personal communication. Royal Botanic Gardens, Sydney, Australia 2000

Jansen, B. & Kohnen, W. (1995) Prevention of biofilm formation by polymer modification. *Journal of Industrial Microbiology* **15,** 391-396

Johnston, D.E. & Christie, B.A. (1985) The canine retroperitoneal space. Chapter 45. In: *Textbook of Small Animal Surgery.* (ed. D.H. Slatter) Vol. 1, pp. 595-603. W.B. Saunders Co., Phildelphia

Johnston, D.E. & Christie, B.A. (1990) The Retroperitoneum in Dogs: Retroperitoneal Infections. *Compendium on Continuing Education for the Practicing Veterinarian* **12,** 1035-1045

Johnston, D.E. & Summers, B.A. (1971) Osteomyelitis of the lumbar vertebrae in dogs caused by grass-seed foreign bodies. *Australian Veterinary Journal* **47,** 289-294

Jones, B.D. & Roudebush, P. (1984) The Use of Fiberoptic Endoscopy in the Diagnosis and Treatment of Tracheobronchial Foreign Bodies. *Journal of the American Animal Hospital Association* **20,** 497-504

Jordan, H.V. & Kelly, D.M. (1983) Persistence of associated gram negative bacteria in experimental actinomycete lesions in mice. *Infection and Immunology* **40,** 847-849

Jordan, H.V., Kelly, D.M. & Heeley, J.D. (1984) Enchancement of experimental actinomycosis in mice with *Eikenella corrodens*. *Infection and Immunology* **46,** 367-391

Kannangara, D.W.T., Tanaka, T. & Thadepalli, H. (1981) Spinal epidural abscess due to *Actinomyces israeli*. *Neurology* **31,** 202-204

Kirpensteijn, J & Fingland, R.B. (1992) Cutaneous actinomycosis and nocardiosis in dogs: 48 cases (1980-1990). *Journal of the American Veterinary Medical Association* **201,** 917-920

LaCroix, J.A. (1973) Vertebral body osteomyelitis: a case report. *Journal of the American Veterinary Radiology Society* **17,** 17-21

Lindsey, J.O. & Pierce, A.K. (1978) An Examination of the Microbiologic Flora of Normal Lung of the Dog. *American Review of Respiratory Disease* **117,** 501-505

Lotti, U. & Niebauer, G.W. (1992) Tracheobronchial Foreign Bodies of Plant Origin in 153 Hunting Dogs *Comp.on Cont.Ed. for the Pract.Vet.*

Loughnan, R.J.M. (1964) Economic losses from barley grass. Proceedings of the seventeenth New Zealand weed and pest control conference. 40-43

McGaughey, C.A. (1952) Actinomycosis in Carnivores: A Review of the Literature. *British Veterinary Journal* **108,** 89-93

Mckeever, P.J. & Klausner, J.S. (1986) Plant Awn, Candidal, Nocardial, and Necrotizing Ulcerative Stomatitis in the Dog. *Journal of the American Animal Hospital Association* **22,** 17-24

McKiernan, B.C. (1983) Lower Respiratory Tract Diseases. Chapter 42. In: *Textbook of Veterinary Internal Medicine* (ed.S.J. Ettinger) 2nd ed., Vol. 1., pp. 789-792

McKiernan, B.C., Smith, A.R. & Kissil, M. (1984) Bacterial Isolates From the Lower Trachea of Clinically Healthy Dogs. *Journal of the American Animal Hospital Association* **20,** 139-142

Merriam, J.C., Storrs, R.C. & Hoefnagel, D. (1964) Lung Disease caused by Aspirated Timothy-grass heads. *American Review of Respiratory Disease* **90,** 947-952

Mitten, R.W. (1974) Vertebral osteomyelitis in the dog due to *Nocardia*-like organisms. *Journal of Small Animal Practice* **15,** 563-570

Morgan, J.P. (1972) Radiology in Veterinary Orthopedics pp. 257-264 Lea & Febiger, Philadelphia

Murbach, L. (1900) Note on the mechanisms of the seed-burying awns of Stipa avenacea. *Botanical gazzete* **30,** 113-117

Nicholson, F.R. & Horne, R.D. (1973) Grass Awn Penetration in the Dog. *Auburn Veterinarian* **29,** 59-65

Norris, A.M. & Laing, E.J. (1985) Diseases of the Nose and Sinuses. *Veterinary Clinics of North America: Small Animal Practice* **15,** 865-890

North, D.C. (1977) Grass-seed problems. *Veterinary Record* **101,** 124

Odman, P. (1959) Radiopaque polyethylene catheter. *Acta Radiologica* **52,** 52-54

Orton, E.C. (1985) Pleura and the pleural space. Chapter 42. In: *Textbook of Small Animal Surgery* (ed. D.H. Slatter) pp. 547-566. W.B. Saunders, Co., Philadelphia, Pennsylvania

Parker, A.J. (1980) Clinical Neurology in Small animal practice. *Modern Veterinarv Practice* **61,** 302-305

Peeters, M.E. (1992) The treatment of recurrent abscessation in the neck region of the dog, evaluation of 35 patients. *Tijdschrift voor Diergeneeskunde* **117,** suppl. 1, 305

Rippon, J.W. (1988) Actinomycosis. Chapter 2. In: *Medical Mycology. The Pathogenic Fungi and the Pathogenic Actinomycetes* (ed. M. Wonsiewicz) pp. 30-52. W.B. Saunders, Co., Philadelphia, Pennsylvania

Robertson, S.A., Stoddart, M.E., Evans, R.J., Gaskell, C.J. & Gibbs, C. (1983) Thoracic empyema in the dog; a report of twenty-two cases. *Journal of Small Animal Practice* **24,** 103-119
Sanford, A.H. & Voelker, M. (1925) Actinomycosis in the United States. *Archives of Surgery* **11,** 809-841
Sato, Y. & Mochizuki, A. (1986) A case of canine systemic Nocardiosis. *Japanese Journal of Veterinary Science* **48,** 629-632
Schaal, K.P. & Gatzer, R. (1985) Serological and numerical phenetic classification of clinically significant fermentative actinomycetes. In: Filamentous Microorganisms. Biomedical Aspects. Ed. T. Arai. Japan Scientific Press, Tokyo. pp 85109
Schaal, K.P. & Pulverer, G. (1973) Fluoreszen serologische differenzierung von fakultativ anaeroben Aktinomyzeten. *Zentralblatt. Bakteriol. Veterinarmed* **15B,** 995-970
Schmitt, A.H. (1962) Zur Kasuistik des intrabronchialen Fremdkörpers beim Hund. *Kleintierpraxis* **7,** 173-174
Schnelle, G.B. (1929) Streptotrichosis canum-Pseudoactinomycosis of a dog. *Journal of the American Veterinary Medical Association* **27,** 789-790
Seldinger, S.I. (1953) Catheter replacement of the needle in percutaneous arteriography. *Acta Radiologica* **39,** 368-376
Staman, J, Hazewinkel, H.A.W., Goedegebuure, S.A., Koeman, J.P. & Beyer, E.G.M. (1978) Pyogranulomatous swellings in the submandibular region of the dog, caused by *Actinomyces spp. Tijdschrift voor Diergeneeskunde* **103,** 1139-1144
Stead, A.C. (1984) Osteomyelitis in the dog and cat. *Journal of Small Animal Practice* **25,** 1-13
Suter, P.F. & Lord, P.F. (1984) Lower airway and pulmonary parenchymal diseases. Chapter 11. In: Thoracic Radiography. (ed. P.F. Suter), pp 517-682 Selbstverlag Peter F. Suter, Wettsvil, Switzerland
Suter, P.F. & Zinkl, J.G. (1983) Mediastinal, Pleural, and Extrapleural Thoracic Disease. Chapter 44. In: *Textbook of Veterinary Internal Medicine* (ed. S.J. Ettinger) 2nd ed. pp. 840-883.
Swerczek, T.W., Schiefer, B. & Nielsen, S.W. (1968a) Canine Actinomycosis. *Zentralblatt Veterinarmed* **15B,** 955-970
Swerczek, T.W., Schiefer, B. & Nielsen, S.W. (1968b) Canine Nocardiosis. *Zentralblatt Veterinarmed* **15B,** 971-978
Trees, A.J. (1970) Death from a Grass Seed. *Veterinary Record* **87,** 450
Turner, W.D. & Breznock, E.M. (1988) Continuous suction drainage for management of canine pyothorax - a retrospective study. *Journal of the American Animal Hospital Association* **24,** 485-494
Vachetta (1882): Quoted by Brion (1939).
van der Pijl, L. (1982) Principles of Dispersal in Higher Plants. Springer Verlag, Berlin.
Van Noppen, K. (1987) Foxtail (grass) centered in a struvite urolith in a dog. *Vlaams Diergeneeskundig Tijdschrift* **56,** 340-342
Vasseur, P.B., Berger, B. & Leighton, R.L. (1981) The volume and Distribution of Surgical Cases in 78 Small Animal Practices in California. *Journal of the American Animal Hospital Association* **17,** 161-166
Wachowitz, R. & Weber, A. (1987) Nachweis von *Actinomyces viscosus* und *Fusobacterium necrophorum* in Pyogenen Hautveränderungen eines Hundes. *Tierärztliche Umschau* **42,** 718-720
Wooley, P.V. (1955) Grass inflorescences as foreign bodies in respiratory tract. *Journal of Pediatricsz* **46,** 704
Young, W.B. (1960) Actinomycosis with involvment of the vertebral column: Case report and review of the literature. *Clinical Radiology* **11,** 175-182

# Acknowledgements

This study was carried out at the Departments of Small Animal Clinical Sciences, Radiology, Pathology, Clinical Microbiology and Anatomy and Histology at the Swedish University of Agricultural Sciences, the Botanical Garden and the Department of Diagnostic Radiology of the University of Uppsala, the Department of Bacteriology at the Swedish National Veterinary Institute, and the National Bacteriological Laboratory, Stockholm.

I wish to express my sincere gratitude to:

Professor Berit Funkquist, my supervisor, friend and teacher in surgery, for introducing me to the field of scientific research, for encouragement and support, for the inspiration she has given me through her own devotion to research, for fruitful discussions and criticism regardless of the day of the week or the time of the day.

Intendent Mattias Iwarsson for generously sharing his great knowledge in the field of botany and for enthusiastic and skilful detective work in identifying the plant material.

Dr. Kerstin Hansson for indefatigable and expert analysis of radiographs and sonograms.

Dr. Christina Greko for being deeply commited to the bacteriological part of the work - from the original search for Nocardia in the soils arround Ultuna, to the analysis of the so-called "Frendinarna".

Dr. Eva Hellmén for invaluable histopathological expertees.

Professor Nils Obel for the ingenious invention of the catheter pleural drainage technique.

My colleagues and the staff at the section for small animals for invaluable help with the dogs.

Professor Leif Plöen, my assistant supervisor, for advice in matters of histology and for teaching me perfusion-fixation.

Dr. Johan Carlsten for introducing me to the field of magnetic resonance imaging.

Dr. Maria Lönnemark for expert analysis of magentic resonance images.

Mrs Britt-Marie Bolinder for invaluable techniqual MR assistance.

Dr. Per Eksell for expert analysis of scintigrams.

Ms Anne-Marie Löfgren for techniqual and photographic assistance and for making the illustrative drawings.

Ove Wattle, my colleague and room-mate, for fruitful discussions, encouragement and friendship

Dr. Anders Gunnarsson and his staff for invaluable analysis of anaerobes.

Mr Bengt Pettersson, secretary of the Stövare Association in Gotland, for acting as an intermediary in the contact with dogs owners on the island of Gotland.

Mr Johnny Carlsson for expert library service and for being patient when rentals have been due.

Ms Maud Marsden for linguistic revision of manuscripts.

My parents Maj and Bengt and the rest of the family, who supported me in every possible way.

Mikaela, Joakim, Carl and Harald, my two pairs of twins, for being constant sources of inspiration and for being the most valuable part of my life.

The merry men of the Round Table 151 Uppsala Östra Aros for good friendship and support when times have been tough.

This work was supported in part with grants from the Agria Insurance Co. and the Thure F and Karin Forsberg Foundation.

**Acta Universitatis Agriculturae Sueciae**
presents doctoral theses from the faculty of agriculture, landscape architecture and horticulture, the faculty of forestry and the faculty of veterinary medicine at the Swedish University of Agricultural Sciences. Each faculty has its own subseries, Agraria, Silvestria and Veterinaria, respectively, with separate numbering.

ISSN 1401-6257
ISBN 91-576-5408-5

REPRO PRINT AB
Stockholm 1997