Sudan University of Sciences and Technology
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Radiographic Imaging, Endoscopy and Haematological Profile as Indispensable Diagnostic Tools in Falcon Health and Disease

التصوير الشعاعي والتنظير الداخلي وصورة الدم كأدوات تشخيصية ضرورية في صحة الصقور ومرضها

A Thesis Submitted in Fulfillment of the Requirements for a Doctor of Philosophy (Ph.D) Degree of Veterinary Medicine (Pathology)

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DEDICATION

Dedicated to my lovely parents, wife, brothers and sisters

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ABSTRACT

This study was undertaken to assess the heath status of saker falcons (*Falco cherrug*) based on the results of radiographic, endoscopic and haematological examination. The study was also intended to investigate the

significance of haematology as a useful health assessment diagnostic tool in falcons in correlation with some common abnormal radiographic findings in these birds. The degree of heterophil toxicity was also assessed on a scale of +1 to +4 as classified by Campbell. Clinical records including case history of the avian patient, radiographic, endoscopic and haematological findings were reviewed for **898** captive female saker falcons of different ages, which presented for clinical examination at the Fahad Bin Sultan Falcon Center (FBSFC), Riyadh, Kingdom of Saudi Arabia, from July 12, 2011, to July 11, 2012. Out of the total number of falcons presented for clinical examination, **407**(45.32%) falcons presented for health screening and **491**(54.68%) falcons because of sickness. The sick birds exhibited varied clinical signs. However, dyspnoea, poor flight performance, reduced appetite and passage of lime green feces were the most common complaints by the falconers. Predominant radiographic abnormalities identified in falcons examined were homogeneous (15.37%) and non-homogeneous (11.36%) increased radiopacity of the lung fields and air sacs, excessive amounts of sand in the gastrointestinal tract (10.91%), splenomegaly (10.02%), hepatomegaly (9.47%), gas formation in the gastrointestinal tract with or without an accompanying dilatation (8.91%), bone fractures due to trauma (6.68%), overdistended air sacs (6.24%), and reduction or loss of muscle mass (6.12%). The most common abnormalities detected by esophago-ingluvioscopy in all birds examined, were trichomonal and candida lesions in the esophagus and/or crop (confirmed by cytology). Other disorders affecting the esophagus and/or crop were detected by endoscopy; they included presence of decomposed food materials, paleness and redness of crop mucosa, injury to crop mucosa, presence of foreign body and bacterial lesions in the crop (confirmed by cytology), and infestation with *Physaloptera* species worms, presence of stuck bone in the esophagus and displaced esophageal wall. Of the total falcons that presented for clinical examination, tracheoscopy was performed selectively on **288** falcons, namely only on birds with breathing abnormalities, change or loss of voice, and/or when radiographs showed abnormalities in the respiratory system. Based on the result of tracheoscopy, **30** falcons were diagnosed with tracheal abnormalities. Among these syringeal aspergilloma (confirmed by cytology) was the most common abnormality detected (13/30).Other abnormalities

detected by tracheoscopy included presence of foreign body and excessive accumulation of mucous in the trachea, and displaced trachea. Endoscopic examination of air sacs and pulmonary base (laparoscopy) was performed selectively on **26** falcons with breathing difficulty and radiographic abnormalities of the distal respiratory tract; of these, **17** birds were diagnosed with aspergillosis (confirmed by cytology), one of the most lethal diseases in captive falcons, while **9** birds were found infested with filarial worms (air sac worms) of the genus *Serratospiculum*. The most common haematological abnormalities identified in falcons examined were eosinophilia (51.34%), increased Hb and PCV values (50.67%), thrombocytosis (47.77%), heterophilia (38.98%), leucocytosis (23.72%), monocytosis (15.48%) and presence of *Haemoproteus* species (9.02%). *Haemoproteus tinnunculi* infection was associated with an increase in the splenic size. The infection also produced a strong eosinophilic response. Monocytosis was the most common feature observed in falcons with non-homogeneous increased radiopacity of the lung fields and air sacs which is more likely to be seen in birds with aspergillosis. Of the total number of falcons examined, toxic heterophils were identified in the blood films of **391**(43.54%) falcons; out of these **70** (7.8%) falcons showed severe cytotoxic changes (+3 or +4). The prevalence of other haematological changes observed in the falcons included in descending order, lymphocytosis, heteropenia, leucopenia, thrombocytopenia, anemia and lymphocytopenia. An adult female saker falcon presented with a history of intermittent regurgitation, dyspnea, and squawking sound. Physical, radiographic, and endoscopic examination revealed a markedly enlarged thyroid gland. On further examination the condition was diagnosed clinically as unilateral thyroid hyperplasia, a condition which has not been previously reported in saker falcons. Out of the total falcons examined, only **104** (11.58%) birds were diagnosed negative in all categories (radiography, endoscopy and haematology). These findings indicate that radiography, endoscopy and haematological profile are important diagnostic tools in falcon medicine. These findings also contribute to the scant information available about health and diseases of falcons in the Kingdom of Saudi Arabia in particular and the Middle East in general.

التصوير الشعاعي والتنظير الداخلي
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المستخلص:

أجريت هذه الدراسة لتقييم الحالة الصحية للصقور من النوع الحر (*Falco cherrug*) بناءا على نتائج فحص التصوير الشعاعي والتنظير الداخلي و الدم. وقصد من الدراسة أيضا بحث أهمية مبحث الدم كأداة تشخيصية مفيدة لتقييم الصحة لدى الصقور بالربط ببعض نتائج التصوير الشعاعي العامة غير السوية في هذه الطيور. وتم أيضا تقييم درجة السمية الغيروية (Heterophil toxicity) على مقياس +1 إلى +4 وفقا لما صنفه كامبل. تم استعراض السجلات السريرية بما في ذلك تاريخ الحالة للطائر المريض ونتائج التصوير الشعاعي والتنظير الداخلي والدم لعدد 898 أنثى صقر حر مأسورة مختلفة الأعمار تم إحضارها للفحص السريري في مركز فهد بن سلطان للصقور في الرياض بالمملكة العربية السعودية في الفترة من 12 يوليو 2011م إلى 11 يوليو 2012م. ومن بين العدد الكلي للصقور التي أحضرت للفحص السريري كان منها 407 صقرا (45.32%) للتحري الصحي و 491 صقرا (54.68%) بسبب المرض. وأظهرت الطيور المريضة علامات سريرية متنوعة. لكن كان عسر التنفس والأداء الضعيف في الطيران وقلة الشهية إلى الطعام وإخراج براز أخضر ليمي هي الشكاوى الأكثر شيوعا التي ذكرها الصقارون. وكانت الحالات غير السوية السائدة في التصوير الشعاعي التي تمت تحديدها في الصقور التي جرى فحصها هي زيادة العتامة الشعاعية المتجانسة (15.37%) وغير المتجانسة (11.36%) في حقول الرئتين والأكياس الهوائية، الكميات الزائدة من الرمل في القناة المعدية المعوية (10.91%) ضخامة الطحال (10.02%)، ضخامة الكبد (9.47%)، تكون الغاز في القناة المعدية المعوية مع أو بدون توسع مصاحب (8.91%)، كسور في العظم ناجمة من الرض (6.68%)، التمدد المفرط للأكياس الهوائية (6.24%) ونقص أو انعدام كتلة العضل (6.12%). وكانت الحالات الغير طبيعية الأكثر شيوعا المستبانة بتنظير المريء والحوصلة في كل الطيور التي جرى فحصها هي آفات المشعرات والمبيضات في المريء و/ أو الحوصلة (وقد أكد ذلك بالفحص السيتولوجي). وقد تمت استبانة اعتلالات أخرى بالمريء و/ أو الحوصلة بواسطة التنظير الداخلي، وقد شملت هذه المواد الغذائية المتحللة، الشحوب واحمرار الغشاء المخاطي للحوصلة، جروح الغشاء المخاطي للحوصلة ، وجود جسم غريب و آفات بكتيرية في الحوصلة (أكد ذلك بالفحص السيتولوجي)، والإصابة بديدان من نوع الحوجنية (Physaloptera)، العظم الملصق في المريء وإزاحة جدار المريء. ومن بين كل الصقور التي أحضرت للفحص السريري تم تنظير القصبة الهوائية بنحو إنتقائي على 288 صقر، وبالتحديد فقط على الطيور التي لديها اختلالات في التنفس، تغير أو فقدان الصوت، و/ أو عند إظهار الصور الشعاعية حالات غير سوية في الجهاز التنفسي. وبناءا على نتيجة

تنظير القصبة الهوائية تم تشخيص 30 صقرا بأن لديها حالات لا سوية في القصبة الهوائية. وبين هذه كان الورم الرشاشي في الصفار (syringeal aspergilloma) (وقد أكد ذلك بالفحص السيتولوجي) هو الحالة

المستبانة اللاسوية الأكثر شيوعا (13/30). وقد شملت الحالات اللاسوية الآخرى التي تمت استبانتها بتنظير القصبة الهوائية وجود جسم غريب وتراكم مفرض للمخاط في القصبة الهوائية وإزاحة القصبة الهوائية. وتم الفحص بالتنظير الداخلي للأكياس الهوائية وقاعدة الرئتين (تنظير البطن) بنحو انتقائي على 26 صقرا لديها صعوبة في التنفس وحالات لا سوية أظهرها التصوير الشعاعي في المجارى التنفسية السفلى؛ ومن بين هذه تم تشخيص 17 طائرا لديها داء الرشاشيات (Aspergillosis)، (أكد ذلك الفحص السيتولوجي)، وهو أحد أكثر الأمراض فتكا بالصقور المأسورة، في حين وجدت 9 طيور مصابة بديدان الفيلاريا (ديدان الاكياس الهوائية) من نوع ال (Serratospiculum). وكانت أكثر الحالات اللاسوية في الدم شيوعا والتي تم تحديدها في الصقور المفحوصة هي ازدياد الحمضات في الدم (51.34%) (Eosinophilia)، زيادة قيم الهيموغلوبين وحجم الخلايا المكدسة (50.67%)، كثرة الصفيحات (47.77%)، كثرة الخلايا المغايرة (38.98%)، كثرة الكريات البيضاء (23.72%)، كثرة الوحيدات (15.48%) ووجود نوع من المتنجعة (Haemoproteus) (9.02%). وكانت الإصابة بـل(*Haemoproteus tinnunculi*) مرتبطة بزيادة في حجم الطحال. وأنتجت الإصابة أيضا استجابة قوية بزيادة الحمضات في الدم (Eosinophilic Response). وكانت كثرة الوحيدات هي المعلم الأكثر شيوعا في الصقور التي لديها زيادة عتامة شعاعية غير متجانسة في حقول الرئتين والأكياس الهوائية والأرجح أن يرى هذا في الطيور المصابة بداء الرشاشيات. ومن بين العدد الكلي للصقور التي تم فحصها تم استبانة الغيرويلت السامة في الشرائح الدموية لـ 391 صقرا (43.54%)؛ ومن بينها أوضحت 70 صقرا (7.8%) تغيرات شديدة متعلقة بالسم الخلوي (+3 أو +4). وقد تضمن انتشار التغيرات الدموية الاخرى التي لوحظت في الصقور بترتيب تنازلي كثرة الخلايا اللمفاوية، قلة الخلايا المغايرة، قلة الكريات البيضاء، قلة الصفيحات الدموية، فقر الدم ونقص الخلايا الليمفاوية. وقد أحضر صقر حر أنثى بالغ بتاريخ قلس متقطع و ضيق فى التنفس وصوت حاد. وأظهر الفحص البدني والتصوير الشعاعي والتنظير الداخلي تضخما واضحا في الغدة الدرقية. وبمزيد من الفحص شخصت الحالة سريريا بأنها فرط تنسج الغدة الدرقية وحيد الجانب، وهي حالة لم يبلغ عنها من قبل في الصقور من النوع الحر. ومن بين كل الصقور التي تم فحصها كان هناك 104 صقرا فقط (11.58%) سلبية لكل فئات الفحص (التصوير الشعاعي، التنظير الداخلي والدم). وتدل هذه النتائج على أن التصوير الشعاعي والتنظير الداخلي وصورة الدم هي أدوات تشخيصية مهمة في طب الصقور. ومن ناحية ثانية تضيف هذه النتائج إلى المعلومات القليلة المتوفرة عن صحة الصقور وأمراضها في المملكة العربية السعودية خصوصا وفي الشرق الأوسط بنحو عام.

CHAPTER ONE

INTRODUCTION

Birds of prey have touched the hearts of many people since time immemorial because of their beauty, great strength, commanding presence, and superlative skill as hunters. Falcons and falconry have formed an integral part of the Arab cultural heritage, and falcons have had a central respected place in the Middle East since the 8th century BC (Sargeant, 1976). Among the falconidae family, the saker falcon (*Falco cherrug*) from central Eurasia is a favourite species used by falconers in the Middle East due to its large size, speed, strength, and ability to survive in the desert environment. Females are generally preferred to males due to their larger size (reverse sexual dimorphism).These birds are found increasingly in captivity. Lack of good care, poor management and exposure to stress factors predispose them to many types of potentially dangerous diseases. When these birds get sick they often show very subtle signs of disease until almost terminal (Parga *et al*, 2001), making the diagnosis of disease difficult.

Clinical examination is the most important step in the diagnosis of diseases. This comprises the complete case history as well as the physical examination of the falcon. Sample taking such as blood sample for haematological analysis is another vital part of the examination. Apart from basic examination procedures, advanced procedures like radiography and endoscopy provide valuable information about the falcon’s conditions (Muller, 2009).

Radiography is an essential practical procedure in avian medicine that is applicable to the diagnosis of musculoskeletal disorders and disease of the coelomic cavity (Naldo, 2008). It is one of the most important diagnostic tools because of the availability of rapid interpretation. It is useful as a primary diagnostic technique and also as an adjunct to other procedures, such as endoscopy and haematology in making a differential diagnosis. In addition, radiography can prove valuable for the monitoring of progression of diseases and in evaluating the efficiency of therapeutic regimens. Radiographs of falcons are taken during general health examinations for baseline data, during pre- and post purchase examinations, and for diagnostic work up for sick birds.

Endoscopy means to look within a small space or cavity with a scope that is inserted through either an orifice or a small surgical opening as opposed to a large incision. Endoscopy has been one of the major advances in clinical avian practice in the past 15 years. The unique anatomy and physiology of birds makes them perfect candidates for endoscopic procedures. Birds do not have a diaphragm and they have air sacs in addition to lungs. Endoscopy enabled avian veterinarians to literally look within birds to either determine sex in monomorphic species or to aid in the diagnosis of disease by direct visualization or biopsy (McDonald, 1996).

Haematology is the discipline of medical science that studies the blood and blood forming tissues. In avian medicine, disease diagnosis and assessment of therapeutic efficacy often rely on haematological analysis (Howlett 2000, Cooper, 2002). Avian clinics and rehabilitation centers can use haematological changes to help detect sub-clinical disease, in pre-release assessment of individuals, and as prognostic indicators for new admissions. The health of raptor populations can be monitored similarly. Nutritional status, disease, or food supply differences among populations or immune suppression due to various stressors all can be detected using haematology (Van Wyk *et al*, 1998). The paucity of available literature on diseases of birds of prey and the sparse of biomedical information on these species impede the task of avian veterinarians who face with an urgent need in diagnosis and treatment. Because of the urgent need for conservation of endangered species, learning about the diseases of wild birds is one of the major challenges of our time. Thus, by collection of data on both sick and normal wild birds, the avian veterinarian will have a unique opportunity to contribute significantly to this important body of knowledge.

Therefore, the present study was undertaken to:

1. Determine the prevalence of abnormal radiographic findings and their indications in captive saker falcons.
2. Determine the prevalence of abnormal endoscopic findings in captive saker falcons.
3. Assess the degree of heterophil toxicity on a scale of +1 to +4 as classified by Campbell (1995).

4. Assess the health status of captive saker falcons by comparing the haematological result with normal reference values.

5. Investigate the significance of haematology as a useful health assessment diagnostic tool in falcons based on radiography, by correlating the result of haematological findings (haemo-response) in general with some common abnormal radiographic findings.

CHAPTER TWO

LITERATURE REVIEW

2:1: Diseases of birds of prey

2:1:1: Causes of disease

The causes of disease in birds of prey can be either infectious, including viral, bacterial, protozoal and fungal infections and parasitic infestations, or non-infectious, including injuries or changes caused by trauma, poisons, and environmental stressors (Cooper, 2002). In addition, degenerative, nutritional and metabolic diseases have also been reported (Naldo and Samour, 2004a).

Morishita *et al* (1997) stated that the most common reasons that raptors are presented to the center of the California Raptor Center are traumatic injuries and emaciation. Other causes for presentation include infectious diseases (bacterial, viral and parasitic), toxicosis, neoplasia, genetic and developmental disorders and diseases of unknown causes.

In the Middle East diseases reported in falcons include avian pox, bumblefoot, trichomoniasis, pseudomonas infection, lead toxicosis, clostridial enterotoxemia, aspergillosis and serratospiculiasis. Of these, bumblefoot, parasitism, avian pox and aspergillosis accounted for the largest number of medical admissions in Abu Dhabi falcon hospital, UAE (Riddle and Hoolihan, 1993).

The most common cause of morbidity in falcons in Kingdom of Saudi Arabia are infectious diseases, traumatic injuries and metabolic or nutritional diseases, while the most common cause of mortality are bacterial and fungal diseases, bumblefoot, collision-type injuries, injuries inflected by other birds, lead and ammonium chloride toxicosis, gout, sour crop and low body condition (Naldo and Samour, 2004a).

2:1:1:1: Bacterial diseases

The bacterium *Pseudomonas aeruginosa* is often associated with respiratory infections in birds. In some cases, caseous lesions produced by *Pseudomonas aeruginosa* cause partial obstruction of the tracheobroncheal syrinx. In captive falcons, stomatitis produced by *Pseudomonas aeruginosa* as a sequelae to trichomoniasis has been reported (Samour, 2000).

Clostridial enterotoxaemia caused by *Clostridium perfringens* type A/B and *C. histolyticum* was diagnosed in captive falcons in the United Arab Emirates. Wernery *et al* (2000) reported that twenty-three hunting falcons of different species died per acutely from clostridial enterotoxaemia. Gross pathological lesions comprised severe haemorrhagic enteritis of the duodenum and jejunum, and these parts of the intestines were filled with bloody fluid. *Clostridium perfringens* enterotoxemias in falconiform birds was also induced by feeding meat contaminated with the anaerobic organisms (Heidenreich, 1997).

Enteric infections in raptors may be parasitic, bacterial or viral. Common bacterial infections include *Salmonella entertidis* and *Salmonella typhimurium, Escherichia coli* and *Pseudomonas* spp. (Forbe, 1996 b).

The commonest respiratory bacterial pathogens isolated from raptors are *Klebsiella pneumonia*, *Pseudomonas aeruginosa* and *Pasteurella multocida.* Other organisms, such as *Yersinia pseudotuberculosis, Escherichia coli, Streptococcus* and *Staphyloccous* spp., have also been occasionally implicated (Forbes, 1996 a).

Chlamydia psittaci infection in raptors may be present with air sacculitis, hepatosplenomegaly, green faecal staining of the urates or intractable conjunctivitis. The condition is seen most often in stressed birds which may have *Serratospiculum* spp. infection and air sacculitis concurrently (Forbes, 1995).

2:1:1:2: Mycoplasmal diseases

Mycoplasma infections in raptors have been described by different authors. Air sacculitis, catarrhal tracheitis and catarrhal-fibrinous pneumonia were described by Poveda *et al* (1990) and Lierz *et al* (2002). Several different mycoplasma species have been isolated from diseased raptors. Mycoplasma organisms were isolated from twenty falcons in the United Arab Emirate; of these birds eighteen suffered from air sacculitis, poor flight performance, rales and weight loss. Nine mycoplasma isolates were identified as *Mycoplasma buteonis* and two as *Mycoplasma falconis*.The remaining nine mycoplasma isolates could not be identified (Wernery *et al*, 2007).

2:1:1:3: Parasitic diseases

Trichomoniasis is a widespread protozoan disease among falcons in the Kingdom of Saudi Arabia and the Middle East as a whole. The occurrence of the disease appears to be directly linked to the falconry practice of feeding falcons live or freshly killed domestic pigeons. Infections with *Trichomonas gallinae* produce classical white lesions in the oropharynx, esophagus and crop (Samour *et al*, 1995).

Coccidiosis has been reported as an incidental finding in many raptorial species. Reported coccidian species include those of the genera *Eimeria*, *Caryospora*, *Sarcocystis* and *Isospora* (Munday *et al*, 1979).

Clinical disease in raptors in the United Kingdom, and more specifically in merlins, has been associated with *Caryospora neofalconis* (Forbes and Cooper, 1991). Affected birds exhibited clinical signs of regurgitation, depression, reduced appetite, dysentery, weight loss, or acute death (Forbes and Simpson, 1997).

A Sarcocystis-associated encephalitis in a goshawk with unilateral debilitation and paralysis has been reported (Aquilar *et al*, 1991).

Avariety of haemoprotozoal parasites such as *leucocytozoon*, *haemoproteus* and *plasmodium* species have been reported in raptors (Cheke *et al*, 1976).

Marked splenic enlargement was reported during plasmodial infection in raptors and canaries (Schmidt, 1997).

A total of 144 captive female saker falcons were diagnosed with *Haemoproteus tinnunculi* infection at Fahad Bin Sultan Falcon Center, Riyadh, Kingdom of Saudi Arabia. The infection was associated with an increase in the splenic size. The infection also produced a strong eosinophilic response. Other hematological changes recorded in some of the infected birds included leucocytosis, heterophilia and anemia (Rahim *et al*, 2013b)

Olsen and Gaunt (1985) demonstrated that raptors infected with haematozoa had a longer recuperation period and a higher mortality rate than did non-infected birds at rehabilitation facilities.

Birds of prey are commonly parasitized by a wide variety of helminths, including numerous species of nematodes, trematodes, cestodes, and acanthocephalans. Infections usually cause little or no distress to healthy individuals in the wild. However, parasites can become a significant problem in birds held in

prolonged captivity and confined housing, as well as birds that have recently come into captivity that are stressed by illness, injury, and/or acclimatization to new surroundings (Smith, 1993).

Serratospiculiasis is the most widespread parasitic disease among falcons in the Middle East. In several falcons with high loads of parasites, *Serratospiculum seurati* was associated with pneumonia, airsacculitis, and early lesions of aspergillosis (Samour and Naldo, 2001).

Ectoparasites are common in raptors. Large numbers may cause weakness and lethargy through anemia. However, high levels of ectoparasitic infestation are usually indicative of birds which were ill prior to parasitism, rather than as a consequence of parasitism (Forbes, 1996 b).

Lice are common external parasites in raptors, especially in birds with poor nutritional health. Infestation often results in a moth-eaten appearance of the feathers and the presence of nits at the base of feather shafts (Cooper, 1969a).

The most important mites in raptors are red mites (*Dermanyssus gallinae*) and Northern fowl mites (*Ornithonyssus slyviarum*) (Cooper, 1971). Other external parasites reported in raptors include ticks, fleas, flies and bed bugs.

Hippoboscids have been reported in both *Falconiformes* and *Strigiformes* (Young *et al*, 1993).

2:1:1:4: Fungal diseases

Aspergillosis is the most common infectious disease reported in raptors. *Aspergillus fumigatus* is the most common etiological agent reported. The infection occurs by inhalation of spores, which are ubiquitously distributed in the environment. The incubation period is extremely variable, depending on the immunocompetency and exposure dose of the host. The disease may be classified as an acute form, tracheal form and chronic granulomatous form (Redig, 1981). Clinical signs are usually associated with the respiratory system or organ (s) affected. The most common clinical signs are depression, anorexia, dyspnea, change or loss of voice; exaggerated respiratory efforts (tail bob) are frequently reported. Weight loss or emaciation may be seen in more chronic disease. Belpharitis and dermatitis have also been reported in a hybrid falcon (Abrams *et al*, 2001).

Infection with *Aspergillus fumigatus* is considered one of the most common causes of death in captive raptors. Redig *et al* (1980 a) reported that aspergillosis was the most commonly encountered non-traumatic disorder of wild raptors. Lesions due to aspergillosis include caseous, yellow-white foci on the lungs, air sacs and pericardium (Cooper, 1969a).

A caseous mass at the tracheal bifurcation associated with severe dyspnea has often been reported in birds with pulmonary aspergillosis (Ward *et al*, 1970).

A mixed case of chronic tracheal (syringeal) and pulmonary (lungs and air sacs) aspergillosis was diagnosed in an adult gyrfalcon at Fahad Bin Sultan Falcon Center. The bird presented with a history of severe dyspnea, exercise intolerance, depression and reduced appetite. Haematological analysis showed leucocytosis, heterophilia, monocytosis, and thrombocytosis. Radiological examination showed thickening of the air sac walls and increased radiopacity within lung fields. Caseous granulomatus lesions were observed during tracheoscopy and laparoscopy procedures (Rahim *et al*, 2012).

Candidiasis is a mycotic disease that affects mucocutaneous areas of the body, particularly gastrointestinal and genital tracts of animals and humans. The disease is produced by yeasts of the genus *Candida* and *Candida albicans* is the species most commonly associated with diseases in animals (Quinn *et al*, 1994). In birds, candidiasis, also referred to as “thrush” or “moniliasis”, is caused by *Candida albicans*, and has been associated with preexisting disease conditions(eg. Plumbism) or prolonged antibiotic therapy (Redig *et al*, 1980b).

Bacterial and mycotic airsacculitis with granuloma formation has been well documented in a variety of avian species (Phalen, 2000).

Granulomas within the lungs and airsacs are commonly associated with either chronic bacterial or mycotic airsacculitis and pneumonia or might be a consequence of previous bouts of acute respiratory disease (Clippinger, 1997).

2:1:1:5: Viral diseases

Pox is a very common disease in raptors and has been reported in numerous captive species including falconids (Cooper, 1969b). Avian pox is common in falcons and results from pox virus gaining entry through abraded skin. Infected

falcons display typical avian pox lesions on unfeathered areas of the head, legs and toes. These lesions can be classified as first-stage lesions, consisting of papules, vesicles, pustules and scabs formation (Samour and Cooper, 1993).

Newcastle disease has been reported in falconid species in the UAE (Wernery et al, 1992). Falcons are susceptible to avian paramyxovirus. Infected falcons showed anorexia, vomiting, delayed crop emptying and paralytic ileus. Later in the disease course, neurologic signs develop. Several infected falcons develop respiratory and gastrointestinal signs. Newcastle disease virus was isolated from the liver of an osprey *(Pandion haliaetus)* with pneumonia and liver degeneration (Zuydam, 1952).

Avian influenza is an infectious disease transmitted by a virus of the family *Orthomyxoviridae*. Avian influenza virus phenotypes H5, H7 and H9 represent a high pandemic potential (Webster and Hulse, 2004). The virus is commonly transmitted through direct contact with faeces and aerosols from infected birds and through contaminated water in overcrowded ponds and lakes (Ritchie, 1995). Different avian influenza strains have been isolated in the Middle East mainly from domestic chickens, quails, houbara and red-crested bustards (Wernery *et al*, 2001). Falcons are highly susceptible to avian influenza virus infections, especially with highly pathogenic avian influenza viruses such as H5N1 (Lierz *et al*, 2007). In Kuwait, 20 falcons were confirmed to be infected with HPAI H5N1 (Rueters, 2007). Samour *et al* (2007) reported a highly pathogenic avian influenza H5N1 infection in a saker falcon in the Middle East. Post-mortem examination showed a distended ventriculus with petechial haemorrhages around the isthmus, slightly enlarged and congested liver and hydropericardium with mild pericarditis. Both lungs were slightly congested.

Infection caused by herpesvirus has been reported in both Falconidae and Strigidae (Mare, 1975). This disease has been referred to as “inclusion body disease” in falconids and “hepatosplenitis” in strigids. Pathological lesions include necrotic foci in the liver and spleen (Morishita *et al*, 1997).

The falcon herpes virus is called Falconid HV1 and causes inclusion body hepatitis in the falcon. Infection can be asymptomatic or show classical symptoms like necrosis in the liver and pharyngeal epithelium. Moreover, other symptoms like

mild to severe depression, weakness and anorexia can be observed within 24-72 hours before death. In the postmortem examination, typical findings are light coloured necrotic areas in the liver and necrosis in the spleen and intestine lymph follicles (Gylstorff and Grimm, 1998). Hemorrhagic enteritis and inclusion body hepatitis were reported in captive American kestrels with cloacal hemorrhages caused by adenovirus infection (Sileo *et al*, 1983).

West Nile virus (WNV) infection is a rapidly fatal disease in avian species caused by a Flavivirus. Numerous species of raptors, including Falconiformes and Strigiformes have been reported to be infected and died from WNV infection (Wünschmann *et al*, 2005) .Transmission of WNV occurs primarily through ornithophilic mosquitoes, Ingestion of infected prey species (house sparrows and pigeons) may also serve as a means of acquiring the infection. Clinical signs of the disease are highly variable and sometime, depending upon the age of the raptor, infected bird may show signs ranging from slight depression and weight loss to marked depression, anoeroxia, blindness, ataxia, head tremors, seizures and sudden death (Malkinson and Banet, 2001).

2:1:1:6: Trauma-related medical conditions

Trauma-related injuries have been extensively documented in raptors and include accidental collision injuries, shooting, trapping and raptor predation (Weir, 1971).

The main causes of death and decline in free-living raptors often include environmental factors such as habitat destruction, human persecution, inadvertent human-related injury and poisoning (Zalles and Bildstein, 2000). Automobile collisions are responsible for most of the traumatic injuries. Besides muscle and tendon injuries and bone fractures, brachial plexus injuries have been reported in red-tailed hawks *(Buteo jamaicensis)* that have been hit by cars (Shell *et al*, 1993). Confinement also causes traumatic injuries in captive raptors. Trauma to the plantar surfaces of the feet will frequently progress to bumblefoot. Foot trauma can be caused by a variety of factors such as rough perching surfaces or the weight of the bird (Halliwell, 1975).

Pododermatitis (bumblefoot) is an inflammatory condition of the feet that commonly involves the plantar surfaces. It is characterized by local abrasion of the

foot pad, ulceration and swelling of one or more digital or metatarsal pads, which lead to scab formation and infection of internal tissue of the foot. *Staphylococcus aureus* is commonly isolated from pododermatitis lesions (Remple and Remple, 1987).

Pododermatitis (bumblefoot) is a common disease of the large species of falcons maintained in captivity, often resulting in a chronic, progressive, invasive, disabling condition that is clinically resistant to medical and surgical therapy, and is frequently recurrent. Etiology and pathogenesis are unclear, but trauma and devitalization of the weight-bearing plantar structures of the foot with secondary bacterial infections are generally suggested to initiate the disease (Oaks, 1993). *Saphylococcus aureus* is the common pathogen isolated from affected feet (Riddle, 1980). Calle *et a l* (1982) reported distal extremity necrosis in captive birds as a sequela of frostbite.

2:1:1:7: Nutritional and Metabolic Diseases

Emaciation is one of the major reasons that raptors are brought to veterinarians. Most of the raptors presented with emaciation presumably have suboptimal hunting skill. Emaciated birds are especially common during the winter, when the food supply is reduced (Morishita, 1997).

In young birds, inadequate nutrition may result in hunger streaks or stress marks in the feathers, which are transverse defects of the shafts and barbs (Halliwell *et al*, 1973).

Low condition is severe debilitation resulting from insufficient food intake and is the most common emergency encountered among raptors. It results from prolonged starvation to reduce the falcon’s weight, compounded by the prevalent cold weather in the hunting ground (Naldo and Samour, 2004a).

Crop impaction can occur in raptor if an excessive amount of undigestable material is present in their diets (MacDonald, 1962).

Sour crop is a condition resulting from the presence of decomposing food in the crop from previous meal; crop stasis develops and endotoxins produced by bacterial proliferation in the crop worsen the condition of the bird, frequently leading to death (Redig, 1996).

Nutritional secondary hyperparathyroidism, or rickets, develop in birds that are fed inadequate diets or diets improperly balanced in calcium and phosphorus (Keymer, 1958).

A case of thyroid hyperplasia was diagnosed in an adult female saker falcon at Fahad Bin Sultan Falcon Center. The bird presented with a history of intermittent regurgitation, dyspnea, and squawking sound. The markedly enlarged thyroid gland displaced the distal portion of the trachea ventrally and the esophageal wall of the thoracic esophagus, causing partial obstruction of the lumen of the thoracic esophagus due to the direct pressure caused by the enlarged thyroid gland (Rahim *et al*, 2013).

Vitamin A deficiency, manifested by keratitis, conjunctivitis, and white pustules in the oral cavity due to squamous epithelial metaplasia, is common when raptors are fed an all-meat diet (Halliwell *et al*, 1973).

Thiamine deficiency has been observed in raptors, especially those on fish diets, and can result in seizures or star-gazing posture.

Hypoglycemia can produce an acute, short-term convulsive behavior. This has been observed in accipiters that have had their food withheld and are subsequently allowed to hunt intensively (Halliwell *et al*, 1973).

Gout is a disorder caused primarily by kidney malfunction usually associated with urinary tract diseases, prolonged dehydration, and hereditary factors. In falcons, this condition recently found associated with clostridial infection (Keymer, 2000).

Deposition of urate crystals on the pericardium and the thoracic and abdominal airsacs is the most common abnormality reported at necropsy in birds with visceral gout (Murnane and Garner, 1987). Other metabolic diseases reported in raptors include fatty liver and kidney syndrome in merlins (Cooper and Forbes, 1983) and diabetes mellitus in a red-tailed hawk (Wallner *et al*, 1993).

2:1:1:8: Toxicosis

Lead toxicosis is one of the most commonly diagnosed diseases in captive falcons in the Kingdom of Saudi Arabia (Samour and Naldo, 2002a). The Falcon is usually exposed to lead by feeding shot birds by the falconers. Falcons with lead

toxicosis show clinical signs of ataxia, paresis or paralysis of the leg, convulsions, depression, anorexia, and green, watery faeces.

Lead toxicosis can occur in raptors after ingesting lead shotgun embedded in the flesh of their prey species. Raptors with lead toxicosis had closed eyes, tilting head and were depressed, anorectic and had green watery feces (Redig *et al*, 1980b).

Ammonium chloride is routinely administered by a considerable number of falconers in the Gulf to the falcons under their charge, with the aim of improving their hunting ability. Several minutes after administration of ammonium chloride, the falcon usually vomits violently bringing up large quantities of thick green-yellow mucus. Of the total falcons that died during the hunting trip, ammonium chloride toxicosis accounted for 50% of all deaths (Naldo and Samour, 2001).

Organophosphate insecticides, such as pour-on insecticides for livestock, have indirectly affected raptors. Franson *et al* (1985) reported famphur toxicosis in a bald eagle that was recumbent, unable to move and had extensor rigidity in its extremities.

Organochlorine compounds include DDT and its analogs have the most long lasting effects on the environment, and their subsequent build-up in the environment has a devastating effect in raptors (Cramp, 1963).

Mercury once used as a dressing to protect seeds from fungal growth, caused toxicosis in raptors that preyed on small birds that consumed mercury-coated seeds (MacDoland, 1962).

2:1:1:9: Neoplastic diseases

Various types of neoplasia have been reported in raptors. Connective tissue tumors have often been observed. Occasionally, these are benign tumors such as lipomas (Keymer, 1972). Malignant tumors of connective tissue origin include mast cell tumors, malignant histiocytomas, sarcomas and fibrosarcomas (Stetter and Nichols, 1993).Tumors of hematopoietic origin include myeloproliferative diseases, visceral lymphomatosis, malignant lymphoma, lymphoid leukosis, and Marek’s disease (Halliwell and Graham, 1986).

2:1:1:10: Degenerative diseases

Amyloidosis is a disorder usually associated with chronic infections such as bumblefoot, aspergillosis and tuberculosis. Clinical signs of amyloidosis include rapid weight loss with normal appetite, normal feces until the terminal stages, lime green discolouration of the urates, abnormal feather molt and exercise intolerance. A firm, swollen liver is palpable just caudal to the sternum, and the abdominal cavity is usually filled with ascitic fluid (Keymer, 2000).

2:1:1:11: Developmental disorders

Developmental ocular lesions are the only commonly reported developmental disorder in raptors. The most common of these lesions is microphthalmia (Dukes and Fox, 1983).

2:1:1:12: Diseases of unknown etiology

Two neurologic syndromes in which the cause remains unknown have been reported in raptors. Idiopathic epileptiform seizures have been described in captive African vultures (Mundy and Foggin, 1981). Another syndrome called “fits” or “short-wing” encephalitis is characterized by convulsions and nervous symptoms (Cooper, 1969a).

2:2: Diagnosis of falcon diseases

The signs of diseases in birds are often subtle and non-specific; so avian clinicians must rely on diagnostic aids, as well as observation and clinical skills to make a diagnosis. All diagnostic procedures commonly used in small animal practice can be adapted for the avian patient and will frequently provide a diagnosis and allow one to make a reasonable prognostic judgement. These include haematology, biochemistry, microbiology, urine and faecal analysis, radiology and endoscopy (Vogelnest, 1994).

Health monitoring, essentially, is an early-warning system that can either help to confirm that a population of raptors is free of significant diseases or pathogens or, if these are present, help to ensure that appropriate action is taken without delay.

Health monitoring of captive birds of prey is now a standard practice in zoos and other establishments (Cooper, 2002).

The principles of clinical investigation in raptors include the following sequential stages: (1) history (environmental for free-ranging birds; management for captive birds) (2) observation (3) clinical examination (4) taking sample for laboratory investigation, (5) results and diagnosis and (6) treatment (Cooper, 2007).

Clinical examination including complete case history is vital for diagnosing diseases. The comprehensive examination includes general physical examination, sampling and advanced examination techniques like Radiography and Endoscopy. Determining which examination techniques are to be chosen by the avian veterinarian depends on the case history, disease symptoms and general condition of the falcon (Muller, 2009).

Laboratory investigations, post-mortem examination, and analysis of environmental samples are important parts of clinical work. Suitable samples are taken from live birds, dead birds, or the environment for performing selective laboratory procedures such as bacteriology, virology, mycology, DNA technique, serology, histopathology, direct and transmission electron microscopy, chemical analysis and toxicology (Cooper, 2007).

Hemocytology and diagnostic cytology in avian medicine provide a means for better disease definition, which allows for a more specific therapeutic regimen. Hemocytology is a diagnostic tool in the clinical avian patient and cytology can provide microscopic information of many different disease processes. At necropsy, cytology is an invaluable tool for defining the presumptive diagnosis and starting treatment in the flock situation (Dorrestein, 1996).

Cytology can be useful antemortem and postmortem diagnostic tools in raptor medicine. It often gives a rapid definitive or strong presumptive diagonosis that helps provide quick, specific therapy for the raptorial patient (Campbell, 1993).

2:2:1: Radiography

2:2:1:1: Diagnostic value

Radiology is an extremely useful diagnostic aid in avian medicine. Most veterinary practices have radiographic equipment that can be used for birds, and interpretation, particularly of skeletal injuries and diseases, is usually rapid. Radiology is also very useful for evaluation of diseases of the gastrointestinal tract and other abdominal organs and the respiratory tract (Vogelnest, 1994).

The most common radiographic findings in falcons in the Kingdom of Saudi Arabia were homogeneous and nonhomogeneous increased radiodensity and localized soft tissue densities of the lung and air sacs, hepatomegaly, presence of lead particles or excessive amounts of sand in the gastrointestinal tract, gastrointestinal tract dilation and bone fractures (Naldo and Samour, 2004b).

2:2:1:2: Radiographic abnormalities

2:2:1:2:1: Musculoskeletal System

The avian bone is characterized by thin cortex, lack of ossification center in the epiphyses and very delicate pattern of the trabeculae. Periosteal reactions and sclerosis indicate an inflammatory process. Mycobacterial infections may show multiple osteolytic and sclerotic lesions in the medullary cavity of the long bones. Other radiographic signs, such as granulomas in the lungs and liver are frequently associated with alterations in the bones. Chronic rhinitis and sinusitis may lead to alterations of the radiograph of the head. Septic pododermatitis shows various degrees of arthritic and osteolytic lesions in the radiograph (Krautwald and Hendrich, 1996). In arthritis, narrowing of joint space, subchondral sclerosis, periosteal reactions and extensive swelling of soft tissue may be seen on radiograph (Krautwald, 1996).

With infectious or neoplastic processes, osteolysis is the predominant radiographic change. Septic arthritis and osteomyelitis may develop secondary to open fractures, pododermatitis, penetrating wounds, hematogenous sources, extension from air sac disease, or iatrogenic contamination (Smith and Smith, 1997).

Bone fracture is the sixth most common radiographic finding in falcons presented for examination in KSA. Fractures commonly occur as a result of

improper handling by novice keepers, car collision accidents during training or hunting, accidents (collision) inside the molting room and accidental shooting of the falcon during trapping (Naldo and Samour, 2002).

Diaphyseal fractures of the extremities are the most common type of fractures detected in falcons. In addition, fractures of the ribs, coracoid, clavicle, or scapula were also observed (Naldo and Samour, 2004b).

Fracture healing in birds should be assessed by the extent of the endosteal callus formation (Bush *et al*, 1976).

2:2:1:2:2: Respiratory System

Alterations of the trachea and syrinx in birds are uncommon and most are not radiographically evident (Newell *et al*, 1997). A massive overdistension (air trapping) can be caused by a valve like action of the stenosed syrinx (commonly caused by syringeal granuloma), making expiration more difficult (Ruebel, 1985).

The possible causes of airsacculitis are multiple and include bacterial, chlamydial, viral and fungal infection (Tully and Harrison, 1994).

A homogeneous, increased radiodensity of the lung field is a non-specific signs of pneumonia. In bacterial pneumonia, the increased pulmonary radiodensity tends to be more homogeneously distributed, whereas in mycotic infections it is often irregular or patchy. Mycotic granulomas may be seen as irregular focal dense areas. Granulomatous lesions in the lungs also occur in mycobacterial infection. A rounding of the caudal border of the lung field may represent congestion of this area in chronic diseases (Krautwald, 1996).

The membrane of normal air sacs is not usually visible radiographically, but in later stages of chronic inflammatory disease, including airsacculitis, the membrane may be well defined (Krautwald and Trinkaus, 2000). Radiographic changes that may indicate inflamed air sacs include diffuse thickening, nodular infiltration and consolidation (Mc Millan, 1994).

A homogeneous increased radiodensity of the air sacs is seen with bacterial airsacculitis or may result from superimposed fat (Naldo, 2000).

A non-homogeneous increased radiodensity of the thoracic or abdominal air sac field suggests chronic mycotic airsacculitis or neoplasia. Focal radiodense

lesions of the air sacs suggestive of granulomas are commonly seen in birds with mycotic or mycobacterial infection (Silverman, 1990).

Airsacculitis in raptors is often a sequel of infestation with *Serratospiculum* species. However, fungal infection caused by *Aspergillus* species is the most common pathological condition of the air sacs in raptors. In falcons with clavicular air sac disease, radiographs reveal a loss of air space and an increased radiodensity of the clavicular air sac on the affected side. The condition may be caused by a foreign-body penetration or aspergillosis (Forbes, 1996a).

2:2:1:2:3: Coelomic Cavity and Digestive system

Radiographic abnormalities of the coelomic cavity and digestive tract are commonly observed. Thickening of the wall of the esophagus or crop may be seen in falcons with vitamin A deficiency, endoparasitic infestation or chronic inflammation due to an infection with *Candida* species (Naldo, 2000).

Infection with *Trichmonas gallinae* can cause thickening of the esophagus and crop wall (Samour and Naldo, 2003).

Gas formation in the gastrointestinal tract is rare in birds, and any gas present should be considered abnormal. A uniformly distended gastrointestinal tract is most commonly associated with functional ileus due to viral or bacterial infection, toxicity (eg, heavy metal), septicemia, hypoxemia, peritonitis and anesthesia (Mc Millan, 1994). Extensive gas filling of the intestines may indicate paralytic ileus, bacterial gastroenteritis or obstruction (Krautwald and Trinkaus, 2000).

In the Kingdom of Saudi Arabia obstruction or impaction of the gastrointestinal tract with sand is often seen in captive falcons, particularly during the molting season (Naldo and Samour, 2004a).

Falcons that feed on shot prey occasionally ingest lead. The lead collects in the proventriculus and gizzard and appears as radiopaque material, either as dust particles, fragments or whole lead shot (Cooper, 1996).

Ascites may accompany severe hepatitis and is seen as diffuse (ground-glass appearance) increase in radiodensity of the entire coelomic cavity, except for the air-filled lungs, with no differentiation of various organs (Krautwald, 1996).

Hepatopathy in raptors is characterized radiographically by an enlarged liver. Other organs that may be enlarged are the spleen and kidneys (Forbes, 1996b).

Herpes viruses causing hepatosplenitis have been isolated from raptors (Kaleta, 1990).

Avian tuberculosis, lymphoma, chlamydial infections and some viral infections have been reported to cause splenic enlargement in raptors (Harcourt, 1996).

2:2:1:2:4: Urogenital System

In avian species, the kidneys can only be seen on the lateral view. An enlarged kidney shadow is frequently seen with enlarged shadows of other organs as a sign of generalized infection, secondary to vitamin A deficiency, or with renal neoplasia (Krautwald and trinkaus, 2000). Bilaterally symmetrical nephromegaly also occurs with metabolic disease, dehydration and post renal obstruction (Mc Millan, 1994).

Increased renal radiodensity without enlargement can be seen in birds with renal gout and dehydration (Smith and Smith, 1997).

2:2:1:2:5: Cardiovascular system

In birds, the most common finding in cardiac disease is an enlargement or an increased radiodensity of the heart shadow which may occur in pericarditis or epicarditis. Alterations of the heart's shape and contour caused by dilation of one chamber may be found as a genetic deformity (krautwald, 1996).

Cardiomegaly in birds may be caused by myxomatous valvular degeneration, endocarditis, chronic anemia, hemochromatosis, marked fatty deposition or secondary to chronic diseases (poxvirus, pododermatitis) (Mc Millan, 1994).

2:2:2: Endoscopy

2:2:2:1: Diagnostic value

Endoscopy is a widely used diagnostic tool in avian medicine. Body orifices including the choana, nares, cloaca and oviduct can be examined. Esophagus, trachea and proventriculus are also readily examined. The diagnostic laparoscopy can be used if the results of other procedures are inconclusive. Many organs including lung, air sacs and liver can be examined. Typical lesions of diseases such as aspergillosis, chlamydiosis and avian tuberculosis may be visualized and subsequently sampled (Vogelnest, 1994).

Endoscopy permits the examination of many organs for evidence of abnormalities. Those tissues and organs that can be readily observed from the different air sacs are as follows:

(a) Caudal thoracic air sac: lung, thoracic cavity, (occasionally) the cranial edge of the kidneys and adrenal gland;

(b) Cranial thoracic air sac: liver, stomach;

(c) Abdominal air sac: kidney, adrenal gland, gonads, gut, spleen, oviduct or vas deferense.

The surface of the air sac can be clearly seen in each case (Böttcher, 1981).

The results of the study of diagnostic value of laparoscopy and bronchoscopy in raptors were demonstrated. The techniques are particularly useful in assessing the status of birds which are apparently only traumatized (e.g. following road accidents), in monitoring treatment and in eliminating carriers of potentially dangerous diseases, such as tuberculosis, at early stage (Böttcher, 1981).

The success of diagnostic laparoscopy will depend on the technical proficiency of the observer and the proper choice of avian patient where such an examination is indicated. Indiscriminate use of the procedure, as a shortcut or instead of a good diagnostic evaluation, will bring about unsatisfactory results and disenchantment with the technique (Bush, 1981).

Birds presenting with lower respiratory tract disease may exhibit mild to severe respiratory signs depending upon the nature and extent of the lesions. Dyspnea, tachypnea, a fluffed-up appearance, and abnormal sounds on auscultation are common (Tully, 1995). A definitive diagnosis is usually confirmed by haematologic, radiographic, endoscopic, cytological/histological and microbiological evaluations. Radiographic changes are usually evident only once the disease is advanced (Phalen, 2000), and therefore greater diagnostic sensitivity is usually afforded through endoscopy (Taylor, 1994).

Endoscopy does not only help as routine diagnostic tool but also to take biopsies or remove lesions in the airsacs or trachea like, *Serratospiculum seurati* worms, *Aspergillus* spp. or *pseudomonas aeruginosa* lesions (Muller, 2009).

Endoscopy is the most useful aid to diagnose tracheal diseases. The trachea should be examined for *Syngamus trachea*, the degree of inflammation, hyperaemia

and the presence of excessive mucoid secretion. Collection of aspirates and, most importantly, full visualisation of the trachea and syrinx is easily confidently achieved with endoscopy (Forbes, 1996 a).

Avian laparoscopy has proven to be a useful diagnostic aid in avian medicine .A number of pathological conditions have been diagnosed in birds by laparoscopy including cardiomegaly, pericarditis, hepatic, splenic or renal amyloidosis and gout in the kidney. Visible granulomata of avian tuberculosis in the liver and spleen, aspergillosis and airsacculitis have also been diagnosed by laparoscopy (Bush, 1981).

Diagnosis of air sac aspergillosis is made on high quality lateral and ventrodorsal radiographs, followed by endoscopy. The value of endscopy cannot be overemphasized. Not only can the lesions be visualized, but samples can be aspirated for culture and biopsies taken for pathology (Forbes, 1996 a).

Candidiasis is a common infection of captive birds of prey (Heidenreich, 1997). *Candida albicans* infection in falcons is usually manifested by the presence of gray-green amorphous, diphtheritic membranes in the crop. The mucosal membrane of the affected area has a typical ((Turkish towel)) appearance. The diagnosis of clinical candidiasis is made from clinical signs, endoscopic examination of the upper digestive tract, cytologic observation of typical *Candida albicans* blastospores on samples obtained from the crop and positive fungal cultures (Samour and Naldo, 2002b).

A study was conducted by Abu Dhabi Falcon Hospital UAE, to assess the health status of newly bought falcons. Endoscopic examination revealed that 62.3% were healthy falcons, 20.0% falcons were diagnosed with aspergillosis, 7.3% suffering from different forms of airsacculitis, 3.2% falcons had *serratospiculum* species and 2.7% were diagnosed with hepatomegaly (Muller and Nafeez, 2004).

2:2:3: Haematology

2:2:3:1: Diagnostic value

Haematology provides important information during a post-purchase or routine health examination, assessment of a sick bird or reassessment of avian patient after treatment (Fudge, 1997a).

Because raptors are at the top of many food chains, their health can reflect the health of entire ecosystems (Cooper, 2002). Hematological alterations can indicate changing habitat quality and food availability or may imply exposure to pollutants or toxins (Hoffman *et al*, 1985).

The blood hematology examination of 210 falcons in Abu Dhabi Falcon Hospital in UAE showed that 174 falcons had normal hematology picture. In 28 falcons, the WBC count was elevated and 4 birds were diagnosed with increased Hb and PCV. Three falcons suffered from anemia, and 2 from *Haemoproteus* spp infection. Two other falcons were diagnosed with heterophilia (Muller and Nafeez, 2004).

The diagnosis of *Haemoproteus* is made by demonstrating the halter-shaped intraerythrocytic gametocytes in peripheral blood films that partially encircled the nucleus, appear pigmented and occupy more than 50% of the cytoplasm (Jennings, 1996). Only the gametocyte stage of this organism appears in the peripheral blood whereas schizogony occurs in tissues, such as lungs, spleen and liver (Soulsby, 1982).

Leucocytozoon is easily identified from blood films because it grossly distorts the host cell (usually immature erythrocytes) that it parasitizes. Only the gametocyte stage of leucocytozoon occurs in the peripheral blood of birds (Soulsby, 1982).

2:2:3:2: Changes in the Haemogram

2:2:3:2:1: Changes in the Erythron

In mammalian clinical hematology, classification of anemias on the basis of MCV findings as normocytic, microcytic or macrocytic provides a useful indication of their etiology (Schalm *et al*, 1975).

Anemia is evidenced by a decrease in the total erythrocyte count and PCV (Jain, 1986). Deficiency anemias have been reported experimentally in poultry (Austic and Scott, 1991) but are not recognized in exotic birds (Dein, 1983). Anemia in psittacine birds is usually of a hypochromic microcytic type (Hawkey *et al*, 1982). The most common cause of nonregenerative anemia in pet birds is infectious disease. It is common in both chronic and acute chlamydial infection (Fudge, 1989).

This condition can also be found in bacterial infections, sepsis, Aspergillus granulomas, viral infections and toxicosis (Jain, 1986).

An increase in RBC count, PCV, immature erythrocytes, anisocytosis and polychromasia signifies cessation of nonregenerative anemia and indicates an improving prognosis (Dein, 1983).

Relative polycythemia is caused by hemoconcentration as a result of dehydration. Absolute polycythemia is signaled by an increase in erythrocyte numbers in the absence of clinical signs of dehydration or laboratory evidence of hemoconcentration (Jain, 1986).

2:2:3:2:2: Changes in the leucogram

The white blood cells of birds consist of heterophils, eosinophils, basophils, lymphocytes and monocyte (Lucas and Jamroz, 1961).

Leukocytosis occurs in birds as a result of disease or stress. Stress leukocytosis occurs in a variety of avian species, including macaws and cockatoos (Rosskopf and Woerpel, 1991).

Mild leukocytosis correlates with bacterial, fungal, and chlamydial infections. Moderate elevations can be caused by yolk peritonitis, granulomatous disease, and septicemia (Vander Heyden, 1994).

The general causes of leukopenias in birds are depletion of peripheral leukocytes and depression or degeneration of leukopoiesis. Leukopenias associated with heteropenias can be associated with certain viral diseases and overwhelming bacterial infections (Olson, 1965)

True leucopenia usually stems from overwhelming bacterial infection, severe viral disease or occasionally, toxic substances (Zinkle, 1986).

A feature of bacterial leucopenia is the presence of intracellular bacteria, which can be seen in the cytoplasm of heterophils or monocytes (Campbell, 1988).

The most common change in avian leucograms and differential counts occurs with the heterophil. Increases in relative and absolute numbers occur due to stress (Maxwell, 1993), corticosteriod administration and acute inflammatory processes (Montali, 1988).

One of the most useful pathological changes affecting the white blood cells that can be observed on a stained blood film is the presence of immature heterophils (Hawkey *et al*, 1984). These cells are classified as heterophil mesomyelocytes. Immature heterophils occur rarely in the peripheral blood of most species of birds.When present they generally represent an overwhelming peripheral demand for heterophils and depletion of the mature storage pool in the hematopoietic tissues (Tangredi, 1981).

Mature heterophils appear to show toxic changes in a manner similar to the toxic changes identified in mammalian neutrophils (Campbell, 1988).

Toxic changes seen include increased cytoplasmic basophilia, vacuolation, abnormal granules, degranulation and degeneration of the nucleus. The degree of toxicity is reported subjectively on a scale of +1 to +4, where the lower rating reflects slight change and the higher indicates severe changes (Campbell, 1994a).

Toxic heterophilia in avian patients is mostly associated with bacterial infections, including mycobacteriosis, but can occur with chlamydiosis, fungal infections and some viral infections (Fudge, 1996).

Band heterophils are uncommonly seen in avian hemograms. Band heterophilia may occur in bacterial septicemias, acute life-threatening chlamydiosis, tuberculosis, and systemic fungal infections (Fudge, 1997a).

Eosinophilia can be observed in a variety of alimentary tract parasitism including giardiasis, ascaridiasis and cestodiasis, but is not a consistent finding. Birds with resolving tissue damage (trauma, organ damage) can sometimes show increases in peripheral eosinophils (Rosskopf and Woerpel, 1991).

In birds, high eosinophil counts are often associated with gastrointestinal parasitic infestation and haemoparasitism (Hawkey *et al*, 1983; Rosskopf and Woerpel, 1996; Samour *et al*, 1996).

Avian basophils are similar to mammalian basophils in their ability to produce, store and release histamine (Chad and Eyre, 1978). Basophils appear to participate in the initial phase of the acute inflammatory response in birds, but this is not always reflected as a basophilia in the leukogram (Carlson and Hacking, 1972).

Basophilia occurs in some cases of respiratory infection. Most notable are the basophilias observed in some budgerigars, cockatiels, and Amazon parrots that are actively ill with chlamydiosis (Fudge, 1997b).

Lymphocytes occur at a higher frequency than all other leukocytes, except heterophils. A relative lymphopenia appears to occur with marked heterophilia. In viral diseases, the typical hemogram shows virtual absence of heterophils, with lymphocytes predominating in number (Vander Heyden, 1989).

Lymphocytes can appear reactive. Reactive changes include cytoplasmic blobbing and vacuolization, nuclear changes, and deep blue cytoplasmic colouration (Fudge, 1989). Reactive lymphoctes are often associated with inflammatory diseases such as salmonellosis, tuberculosis, chlamydiosis and aspergillosis. They synthesize immunogloulins, lymphokines and other agents involved in the host immune system. Therefore, the presence of reactive lymphcytes in the peripheral blood is indicative of an immune response. Occasionally, plasma cells can be found in the peripheral blood of the birds (Campbell, 1995).

Lymphocytes containing azurophilic granules (large purple cytoplasmic granules) are considered abnormal in birds. Lymphocytes having scalloped cytoplasmic margins are found occasionally in avian blood films; however, large numbers of these cells are considered abnormal and suggestive of lymphoid leukosis or neoplasia (Campbell, 1984b).

Monocytosis can be found with certain diseases that produce chemotactic agents for monocytes. These conditions include avian chlamydiosis, mycotic and bacterial granulomas and massive tissue necrosis (Hawkey *et al*, 1983).

Avian thrombocytes play a primary role in hemostasis in a manner similar to mammalian platelets. They may also have a phagocytic function and participate in removing foreign material from the blood (Grecchi *et al*, 1980). Thrombocytopenias are often seen with severe septicemias, where a combination of excessive peripheral demand for thrombocytes and depression of thrombocyte production may occur. There are certain pathological conditions in which the presence of enlarged thrombocytes, commonly referred to as megathrombocytes, in the blood film appears to be a characteristic hemoresponse usually associated with chronic inflammation (Samour and Howlett, 2008).

CHAPTER THREE

MATERIALS AND METHODS

3:1: Study area

The study was carried out at the Falcon Specialist Hospital and Research Institute of the Fahad Bin Sultan Falcon Center (FBSFC), Riyadh, Kingdom of Saudi Arabia, during the period from July 12, 2011, to July 11, 2012. Clinical records of the avian patient including case history, radiographic, endoscopic and haematological findings were investigated for 898 captive female saker falcons of different ages. There were presented to the falcon center for health screening or because of sickness where the diagnostic plan required application of the above-mentioned diagnostic tools. Most of the falcons presented to the hospital originated from Riyadh area, Al-kharj Province, and Al-Qassim Province in the central region of Saudi Arabia. Some birds were also brought to the hospital by the falconers from distant places such Hail areas in the northern region and Hafr Al-Batin, Al-Dammam, Al-Hassa in the eastern region of Saudi Arabia.

3:2: Bird identification

For complete and accurate records each bird was identified by permanent electronic microchip device (Passive Induced Transponder (PIT)) (AVID Identification Systems, Inc. USA) implanted subcutaneously in the left prolateral region of the bird.

3:3: Clinical history

The clinical history of avian patients was gathered from the falconers as recommended by Samour (2008). This included information about the owner, falcon patient’s data, feeding, general clinical information and current clinical problems.

3:4: Haematological methods

These were carried out as per the technique described by Samour and Howlett (2008).

3:4:1: Collection of blood sample

Blood sample was obtained while the bird is under anesthesia. A total volume of 0.5ml of blood was obtained from a brachial vein of each bird using 1ml disposable syringes and 23- gauge ×5/8 inches disposable needles. After collection, the sample was immediately transferred to commercially available paediatric microtainer tubes (Impromini Guangzaho Improve Medical Instrument Co. Ltd China) containing anticoagulant agent ethylenediaminetetra-acetic acid (EDTA) for haematological analysis.

3:4:2: Preparation and staining of the blood films

Thin blood films were prepared immediately from the collected blood samples on a glass slides, air dried and stained with slightly modified Wright-Giemsa stain for the differential white blood cells counts, morphological characteristics of heterophil and haemoparasites examination.

3:4:3: Hemoglobin (Hb) concentration

The concentration of hemoglobin was determined as azide methemoglobin, using a hemoglobinometer system (Hemocue AB, sweden). The system consists of an analyzer (photometer) together with dry reagent-preloaded microcuvettes.

3:4:3:1: Principle of the method

The erythrocyte membranes are disintegrated by sodium deoxycholate, releasing the hemoglobin. Sodium nitrite converts the hemoglobin iron from the ferrous to the ferric state to form methemoglobin, which then combines with sodium azide to form azide methemoglobin. The analyzer measures at two wavelengths in order to compensate for turbidity, and hemoglobin concentration is calculated and estimated in gram per deciliter (g / dl) of blood.

3:4:4: Packed Cell Volume (PCV)

Fresh blood samples were collected in microhaematocrit capillary tubes and centrifuged using microhaematocrit centrifuge (Hawksley and Sons Ltd., England) for 5 minutes. Packed cell volume percent was read off on the scaling instrument provided with the centrifuge.

3:4:5: White Blood Cell (WBC) count

The white blood cells were counted by use of an improved Neubauer haemocytometer (Hawksley and Sons Ltd., England). 1% ammonium oxalate solution was used as a diluent. The total number of cells counted in the large 4 squares was divided by 20 and the number obtained expressed in 10^9 cells/ liter.

3:4:6: Differential white blood cell count

One hundred white blood cells were counted in the stained blood film using electronic cell counter and classified according to the morphologic and staining characteristics. The differential white blood cell count was expressed as a percentage of the individual cell groups. The percentage of each group was then converted into absolute numbers by reference to the total WBC using the following formula:

(Percentage of WBC counted × total WBC) /100 = absolute No. $\times 10^9$/Liter

3:4:7: Thrombocytes count

Thrombocytes were counted while performing the differential white blood cell count. The absolute number of thrombocytes was estimated by using the following formula:

(No. of thrombocytes counted / 100) × WBC = thrombocytes $\times 10^9$/Liter

3:4:8: Morphological characteristics of the heterophil

Morphological characteristics of heterophil were evaluated, to assess, if present, the degree of heterophil cytotoxicity based on Campbell (1995) scale of +1 to +4, which is indicated by the degree of cytoplasmic basophilia, vacuolization, nuclear degeneration, abnormal granulation, and degranulation as follows:

* A+1 toxicity is indicated by a slight cytoplasmic basophilia.
* A+2 toxicity shows a darker cytoplasmic basophilia, vacuolization and partial degranulation.
* A+3 toxicity shows a darker cytoplasmic basophilia, moderate degranulation, abnormal granulation and cytoplasmic vacuolation.

* A+4 toxicity shows deep cytoplasmic basophilia, moderate to marked degranulation, cytoplasmic vacuolation and karyorrhexis or karyolysis.

3:4:9: Haemoparasite examination

Haemoparasite examination was carried out on stained blood films prior to a differential white cell count using high power magnification.

3:5: Application of advanced diagnostic procedures:

3:5:1: Radiography

3:5:1:1: X-ray unit, Screens, Cassettes Films

Portable radiographic unit (super light 80 UK) with kVp setting ranging from 50 to 80 with high-definition screen in cassettes (Dr. Goos-Suprema GmpH Brechtelstr. Hedelberg, Germany) and regular film (Agfa (24×30cm) health care Nv septstraat 27 B 2640 mortsel Belgium) were used. The exposure settings used for all birds were 50 kV, 15mA and 0.04 second with focal film distance 22, 5 inches.

3:5:1:2: Restraint and Positioning

Prior to radiographic examination, birds were fasted for 12-24 hours and anaesthetized with a combination of isoflurane (isoflo, abbott laboratories) and oxygen administered by a face mask. As standard procedure, whole body (plus neck and proximal limbs) survey radiographs were taken in both ventrodorsal and lateral views. Detailed radiographs of an extremity (head, neck, wing and foot) were obtained when indicated. Perfect positioning of the avian patient for whole body survey radiographs were achieved with the following procedure.

3:5:1:2:1: In the ventrodorsal view (fig 1):

* The X-ray cassette was directly placed on the tabletop.
* The bird was placed on the cassette on dorsal recumbency.
* The neck of the bird was fully extended.

* Both legs were pulled backwards and fully extended by using jesses fitted around falcon's legs (tarsometatarsus), positioned symmetrically and jesses were secured with masking tape to the tabletop.
* The keel was superimposed over the vertebral column.
* Both wings were symmetrically slightly extended.
* For each radiograph, metallic identification number was set up to ensure clear identification of the x-ray of avian patient and the left side of the bird was clearly marked with an appropriate metallic ((L)) marker placed on the X-ray cassette to permit differentiation of right from left.
* The x-ray primary beam was centered over the avian patient at the point of the sternum, and was collimated to reduce scatter.

3:5:1:2:2: In the lateral view (fig 2)

***** The X-ray cassette was directly placed on the tabletop.
***** The bird was placed on left-to-right lateral recumbency.
* The neck of the bird was fully extended.
* Both legs were extended caudoventrally by using jesses fitted around falcon's legs (tarsometatarsus), and the dependent leg was positioned cranially to the contralateral leg and jesses were secured with masking tape to the tabletop.
* The wings were extended dorsally over the back of the bird, with the lower wing placed slightly cranial to the upper wing to permit differentiation of right from left.
* The upper wing was secured with masking tape across the carpometacarpal joints to the tabletop.
* The avian patient metallic identification number was set up on the X-ray cassette.
* The X-ray primary beam was centered on the midline cranial to the caudal tip of the sternum.

3:5:1:3: Processing of X-ray film

For developing of radiographic image, the exposed film was removed out of the cassette in the dark room and was processed with automatic X-ray film processor.

3:5:1:4: Radiographic Interpretation

The processed X-ray film was viewed on X-ray view box. A systematic approach to film interpretation was used (Naldo, 2008). The search pattern was an organ to organ system approach, proceeding from cranial to caudal, evaluating the head and neck and then the musculoskeletal, respiratory, cardiovascular, gastrointestinal tract, and urogenital systems. The radiographs were scrutinized according to the following criteria (Baumgartner, 1991):

1- Size of the organ.

2- Density of the organ and parts of organs.

3- Structure of the organ.

4- Evaluation of the contents of the gastrointestinal tract.

3:5:2: Endoscopy

3:5:2:1: Equipment and instruments:

These include:

Rigid endoscope (2,7mm outer diameter,180mm working length; 0˚angle of view), fiber optic cable, light source (xenon high-intensity light; lamps 300W), still camera for documentation, video camera designed for use with endoscope and video colour monitor (Olympus Optical Co. ,LTD. Tokyo, Japan).

Trocar, cannula, endoscope working channel, biopsy forceps, needle holder, absorbable suture (vicryl 3-0), curved haemostatic forceps, sterile scalpel blade No.15, soft rubber feeding tube and a 60cc syringe were also been provided.

3:5:2:2: Preparation and procedure

Prior to endoscopic procedure, birds were fasted for 12-24 hours and anaesthetized with isoflurane.

3:5:2:3: Alimentary system

3:5:2:3:1: Esophago-ingluvioscopy (Esophagus and crop)

Esophago-ingluvioscopy is a routine endoscopic procedure. It was performed on the all birds, because it is common to suspect traumas or infection (eg.trichomonas lesions) in these parts of the alimentary system.

* The bird was held in a straight position by an assistant after being wrapped with tea towel.
* The neck of the bird was fully extended.
* The beak was opened with one hand and the endoscope was then inserted into the oral cavity and down into the esoghagus and crop.
* The endoscope was slowly retrieved from the esophagus and crop to allow the examiner to visualize these parts of upper digestive tract.
* Visualization of the esoghagus and crop were enhanced (if needed) by insuffolation of the crop with air, using a soft rubber feeding tube attached to a 60 cc syringe.

3:5:2:4: Respiratory system

3:5:2:4:1: Tracheoscopy (Trachea)

Tracheoscopy was performed selectively only on those birds with breathing abnormalities, or change or loss of voice, and/ or when the radiographs showed abnormalities in the respiratory system of the bird examined, as this might be indicative of syringeal aspergilloma, foreign body or any other pathological problem.

* The avian patient was brought to a deep anesthetic level.
* The bird was held vertically by an assistant after being wrapped with tea towel.
* The neck of the bird was fully extended.
* With one hand, the beak was opened and the tongue was pulled forward, while with the other hand the endoscope was introduced into the trachea and syrinx was rapidly reached.
* The endoscope was slowly retrieved from the syrinx allow the examiner to visualize the entire length of the trachea.

3:5:2:4:2: Laparoscopy (Air sacs and pulmonary base)

Inspection of the air sacs and pulmonary base were performed by laparoscopy (Celoscopy) following lateral approach according to the technique described by Muller (2009). It was performed selectively as requested by the falconer only on those birds with breathing abnormalities and when the radiographs showed abnormal shadows in the lung fields and /or air sacs (e.g. focal density).

* The anesthetized avian patient was positioned in right lateral recumbencey on the surgery table
* The wings were extended dorsocranially over the back of the bird and taped with masking tape to the surgery table.
* Both legs were pulled caudally and taped with a masking tape to the surgery table by using jesses fitted around falcon's legs (tarsometatarsus).
* The lateral aspect of the abdomen (flank region) was prepared for surgery.
* The area of the last ribs was plucked of all feathers, scrubbed and disinfected with iodine solution and surgical spirit. Sterile window drape was placed over the bird.
* Small skin incision of approximately 3mm was made with sterile scalpel blade between the last two ribs at the medium height of the falcon's body. A hole was gently punched with a curved hemostatic forceps through the muscle into the caudal thoracic air sac. The tips of the hemostatic forceps were opened along the rib curvature and not against it to avoid fracturing the ribs.
* The trocar and cannula provided with endoscopy equipment were inserted into the hole in a craniomedial direction in the caudal thoracic air sac. When the instruments were correctly placed, the trocar was withdrawn and the inserted cannula was held with thumb and forefinger of the left hand directly in the place where the cannula exists from the falcon's body.
* The endoscope was held with right hand after being attached to the light source through the fiber optic cable and inserted into the cannula.
* After attaching a camera the endoscopic picture of the air sacs and pulmonary base were visualized on the adjunct monitor for any pathological abnormalities present.
* Once the procedure was completed, the endoscope and then the cannula were removed.
* The skin incision site closure was accomplished with vicryl using one single suture of simple interrupted pattern.
*Similar endoscopic procedure was performed in the right side of the bird.

3:5:2:2: Verification of endoscopic findings

To verify the results of endoscopic examination, samples from lesions visualized during endoscopic procedure were obtained for cytological examination

using endoscopy biopsy guided forceps or sterile cotton swab, depending on the characteristic of the tissue to be sampled, anatomic location and accessibility to the site of lesions. Wet mount and air dried smears were prepared from each sample to be examined as follows:

3:5:2:2:1: Swabs

The lesions were swabbed with sterile cotton swab moistened with sterile normal saline solution. After collection, the swab was gently rolled along the flat surface of a clean glass microscopic slide. Two slides were made. The first slide was examined immediately under the low power of microscope after the preparation of saline mount smear; the second one was air dried and stained with Diff-Quick stain, air dried and then examined under the microscope.

3:5:2:2:2: Imprints

Imprint smear was made from the biopsied sample onto a microscopic glass slide, air dried and stained with Diff-Quick stain. The cut surface of the biopsied sample was also swabbed with sterile moistened cotton swab to make wet mount smear. After preparation the samples were examined under the microscope.

Statistical analysis

Data were filtered and sorted with excel 2013 software and analyzed with SPSS software.

Fig.1. Positioning technique for ventrodorsal body radiograph of a saker falcon under isoflurene anaesthesia.

Fig.2 Positioning technique for lateral body radiograph of a saker falcon under isoflurene anaesthesia.

CHAPTER FOUR

RESULTS

4:1: Radiography

There were many radiographic abnormalities recorded in the falcons examined, totaling **1524** abnormalities. The radiographic examination of all falcons (**N=898**) showed that only **161**(17.93%) birds had no abnormalities detected on their radiographic images. Of the total number of abnormal radiographic findings (**N=1524**), **422**(27.69%) involved the respiratory system, **718**(47.11%) the coleomic cavity and digestive system, **255**(16.73%) the musculoskeletal system, **106**(6.96%) the cardiovascular system and **23**(1.51%) the urogenital system (**table 1**). Following the radiographs of the body of a normal saker falcon and digitalized pictures of the same bird that illustrated the different radiographic anatomical body parts, are case presentations demonstrating radiographic abnormalities in various organ systems of falcons examined. The reader was encouraged to compare the radiographic findings in these cases with the normal radiographs (fig.3 and 5) and digitalized pictures (fig.4 and 6) presented below.

RESULT	No. of abnormal findings and **%** **(N=1524)**	Percentage **(N=898)**
Respiratory system	**422** (27.69%)	**46.99**
Coelomic cavity and digestive system	**718** (47.11%)	**79.96**
Musculoskeletal system	**255** (16.73%)	**28.40**
Urogenital system	**23** (1.51%)	**2.56**
Cardiovascular system	**106** (6.96%)	**11.80**
TOTAL	**1524**	**169.71**

Table 1: Abnormal radiographic findings by system and their frequencies in captive saker falcons**(N=898)**examined at the Fahad Bin Sultan Falcon Center, Riyadh, Kingdom of Saudi Arabia from July 12, 2011, to July 11, 2012.

* Of the total birds examined (**N=898) 161**(17.93%) birds had no detectable abnormality.

* In the above mentioned table more than one diagnosis was possible in the birds examined, therefore the number of abnormal findings exceeds the total numbers of birds examined (**N=898**) and the sum of percentages exceeds 100%.

Fig.3 Ventrodorsal radiograph of the body of a normal saker falcon.

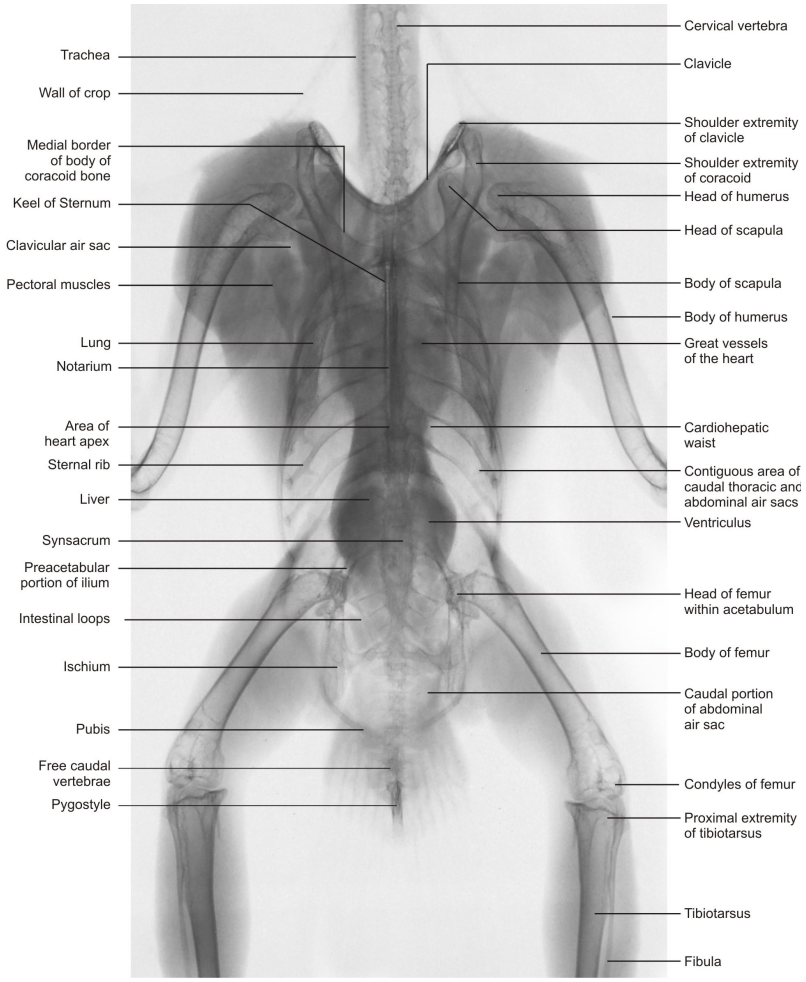

Fig.4 Digitalized picture of the same bird as in **fig.3** to illustrate the different body parts.

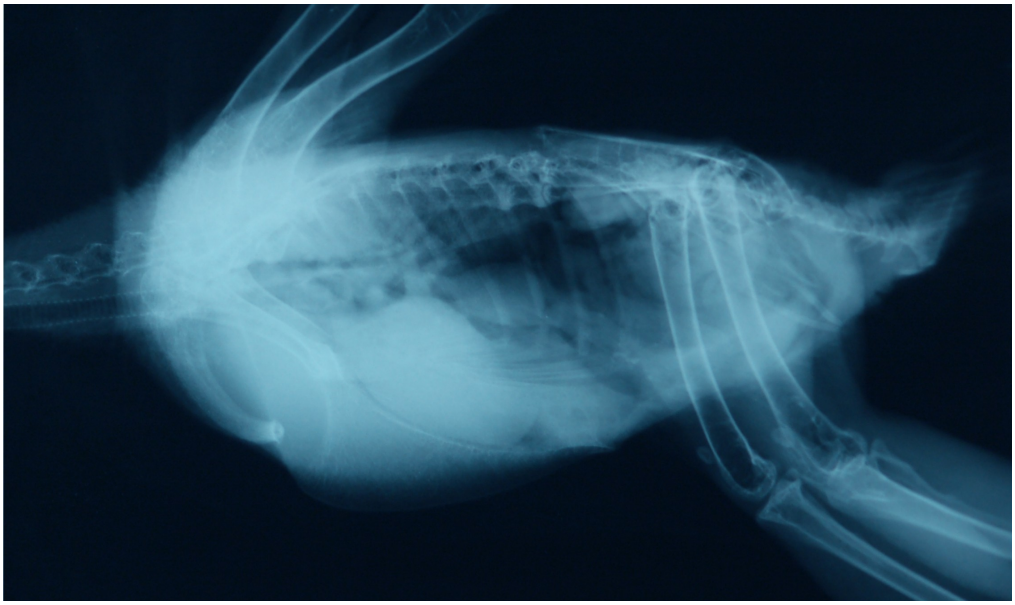

Fig.5 Lateral (Le-Rt) radiograph of the body of a normal saker falcon.

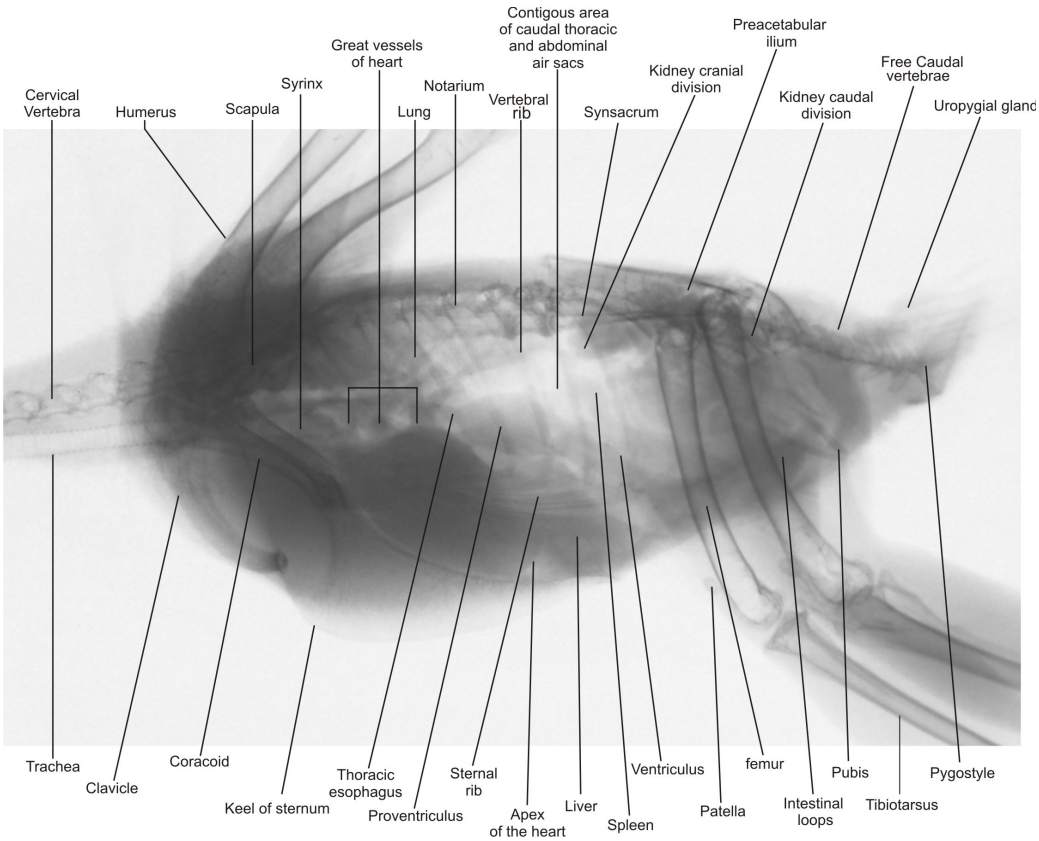

Fig.6 Digitalized picture of the same bird as in **fig.5** to illustrate the different body parts.

4:1:1: Radiographic findings in the respiratory system

Infectious conditions of the respiratory system are frequently associated with pulmonary changes in the radiographic images such as homogeneous (a uniform quality of radiographic image) and non-homogeneous (a non-uniform quality of radiographic image) increased radiopacity of the lung fields and air sacs.

The most common abnormal radiographic findings in the respiratory system of the falcons examined were homogeneous (fig.7) and non-homogeneous (fig.8 and 9) increased radiopacity of the lung fields and air sacs, overdistended air sacs (fig.8, 9 and 10) and thickened air sacs walls (fig.11). Of these abnormalities, homogeneous (15.37%) and non-homogeneous (11.36%) increased radiopacity of the lung fields and air sacs were the first and second most prevalent radiographic abnormalities recorded in falcons examined. Other radiographic abnormalities in the respiratory system recorded in some of the falcons examined included, loss of clavicular air sac space (fig.8), localized soft tissue densities (fig.12), rounding of the caudal lung border (fig.13) and displacement of the trachea (fig.14 and 23). These radiographic findings are presented in **table** (**2**).

Table 2: Abnormal radiographic findings in the respiratory system and their frequencies in captive saker falcons **(N=898)** examined at the Fahad Bin Sultan

Falcon Center, Riyadh, Kingdom of Saudi Arabia from July 12, 2011, to July 11, 2012.

Pathological findings	No. of abnormal findings	Percentage **(N=898)**
1. Thickened air sac wall	54	6.01
2. Homogeneous increased radiopacity of the lung fields and/or air sacs	138	15.37
3. Nonhomogeneous increased radiopacity of the lung fields and/or air sacs	102	11.36
4. Localized soft tissue densities or focal mass (granuloma)	34	3.79
5. Overdistended air sacs (air trapping)	56	6.24
6. Loss of clavicular air sac space	13	1.45
7. Rounding of caudal lung border (lung congestion)	21	2.34
8. Displaced trachea	4	0.45
TOTAL	**422**	**46.99**

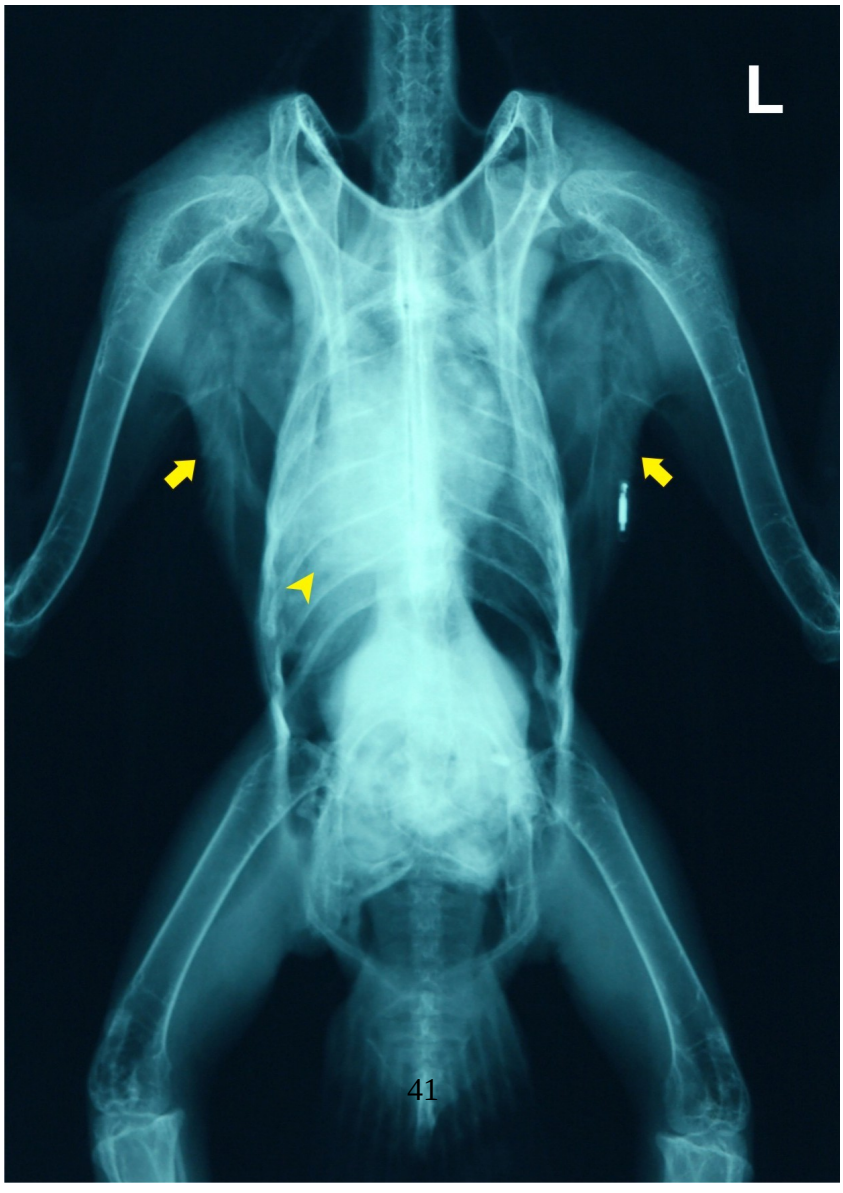

Fig.7 Ventrodorsal survey radiograph of a saker falcon which presented with a history of reduced appetite, dyspnoea and exercise intolerance. The radiograph showed unilateral homogeneous increased radiopacity of the heart - right lung field and thoracic air sacs (head arrow).There is severe loss of pectoral muscle mass visible on the lateral side of the chest (yellow arrows).

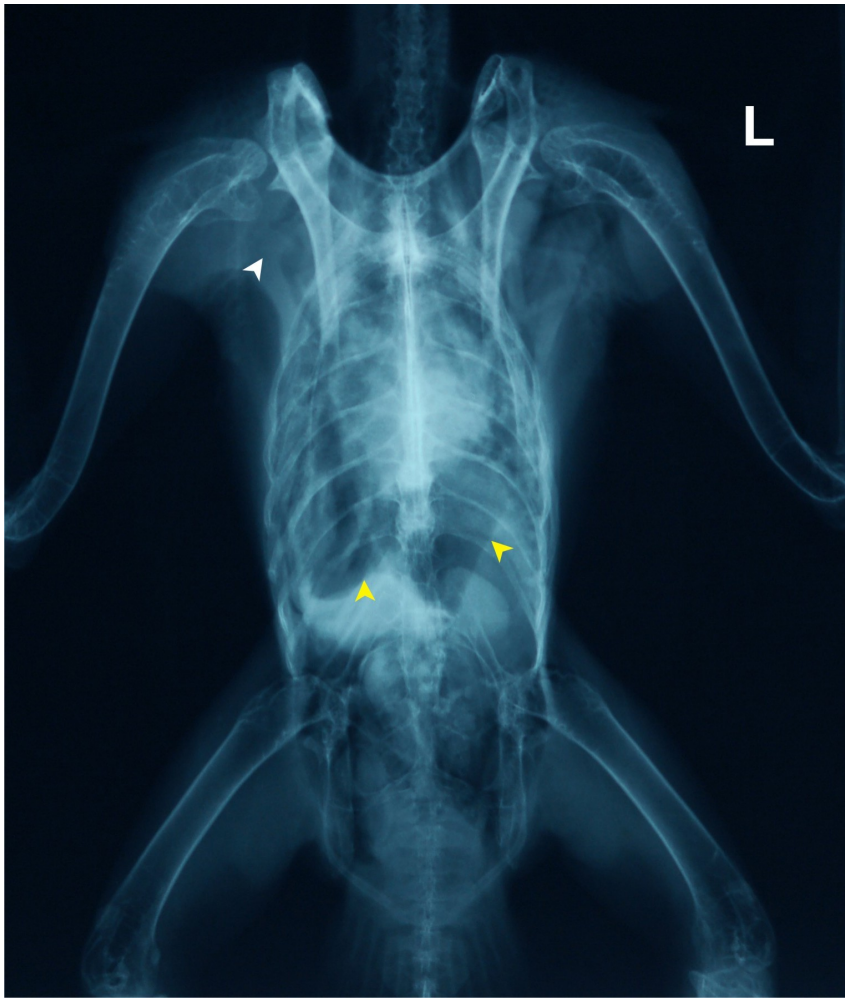

Fig.8 Ventrodorsal survey radiograph of a saker falcon with advanced aspergillosis that was presented with severe dyspnea. A generalized, non-homogeneous increased radiopcity of the heart - lung fields and thoracic and abdominal air sacs is present. Note the extensive air trapping in the caudal thoracic and abdominal air sac fields (yellow arrows).There is a loss of air space in right clavicular air sac (white arrow). Increased bone density of the shoulder extremity of clavicle, coracoid, scapula and humerus of right wing, probably as a result of extension of an existing infection to these bones via clavicular air sac.

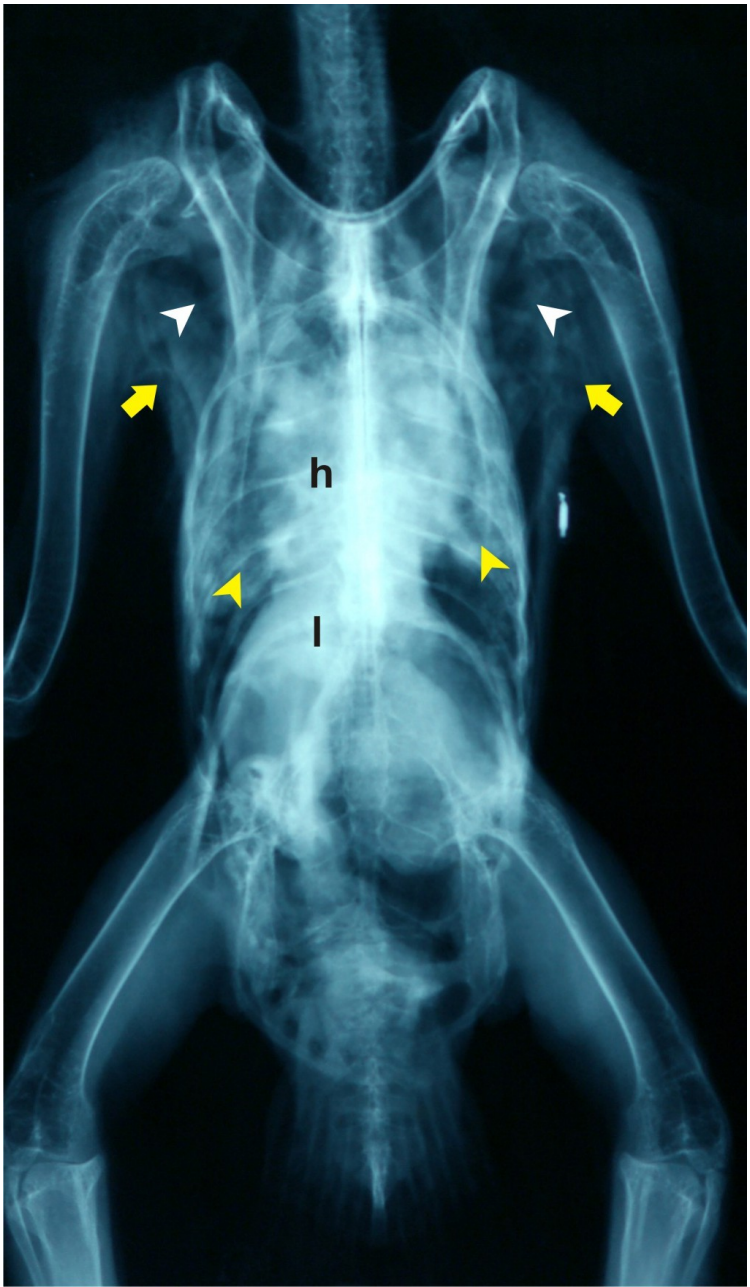

Fig.9 Ventrodorsal survey radiograph of a saker falcon that was presented with severe dyspnea, anorexia and passage of green urates. Bilateral non-homogeneous increased radiopacity is present in the heart (h)-lungs fields and thoracic air sacs (yellow head arrows).Air trapping is evident in the left abdominal air sac field displacing the liver (l) to the right lateral side. The axillary portion (white head arrows) of the clavicular air sacs appears overdistended. Note the severe loss of pectoral (yellow arrows) and shoulder muscles mass visible on the lateral side of the chest and around the wings.

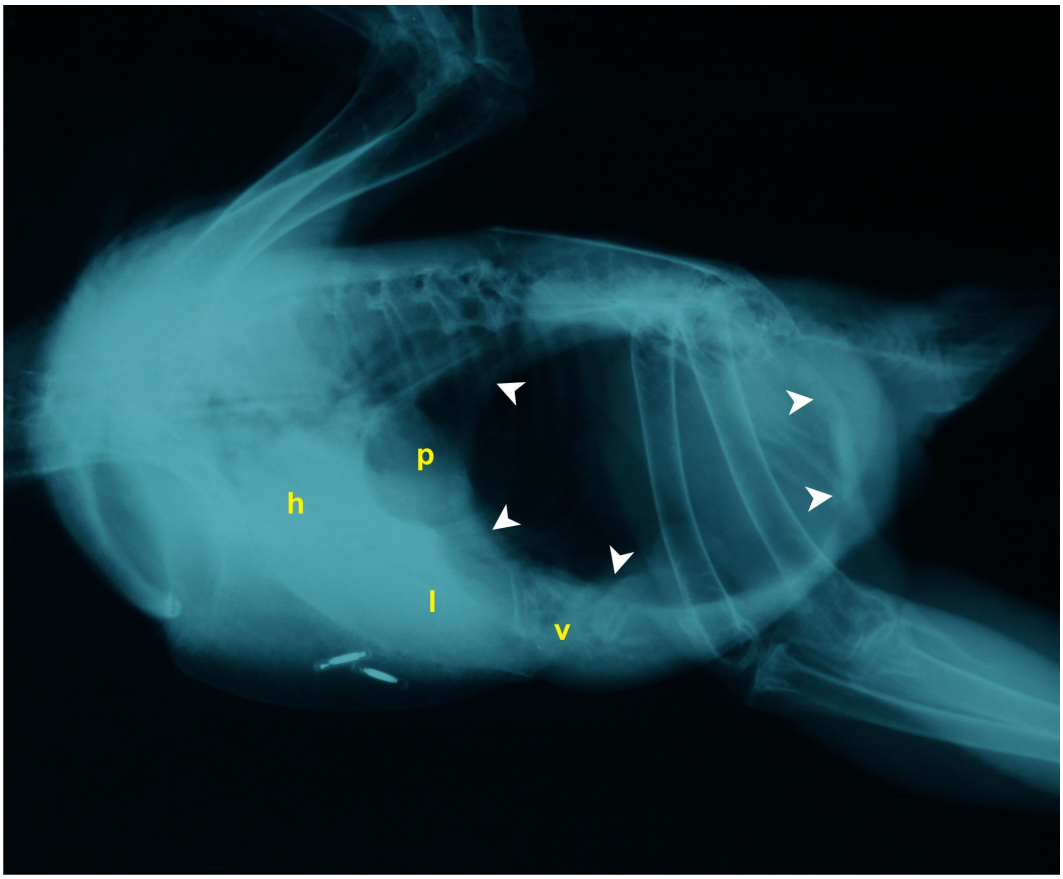

Fig.10 This saker falcon presented with a history of exercise intolerance and severe dyspnea including tail bob. Lateral survey radiograph revealed massively overdistended caudal thoracic and abdominal air sacs (extensive air trapping) (arrows), probably due to mechanical obstruction of *Ostia*

pulmonare with granulomatous lesions. The heart (h), liver (l), proventriculus (p) and ventriculus (v) were displaced cranially due to extensive pressure caused by air trapping; the size and shape of these organs appear altered and they cannot be easily differentiated. This bird has 2 PIT implants.

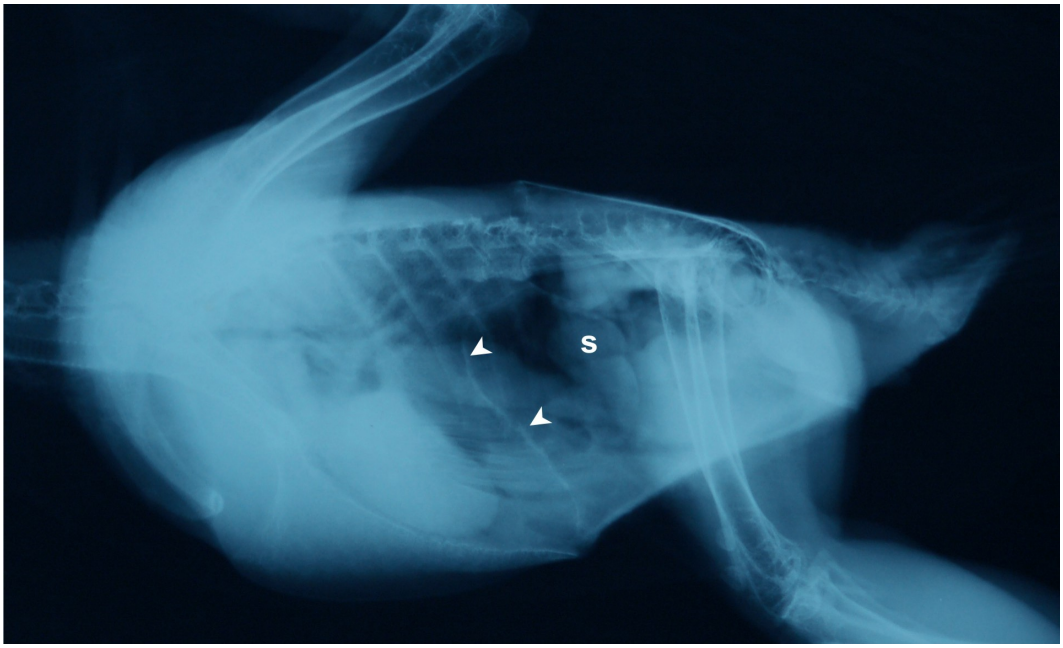

Fig.11 Lateral survey radiograph of a saker falcon showing thickened caudal thoracic and abdominal air sac walls (arrows) and slightly enlarged spleen shadow. Air sacculitis in falcon is very often associated with bacterial and fungal infections. However this finding can also be observed with severe infestation with *Serratospiculum* filarial worms.

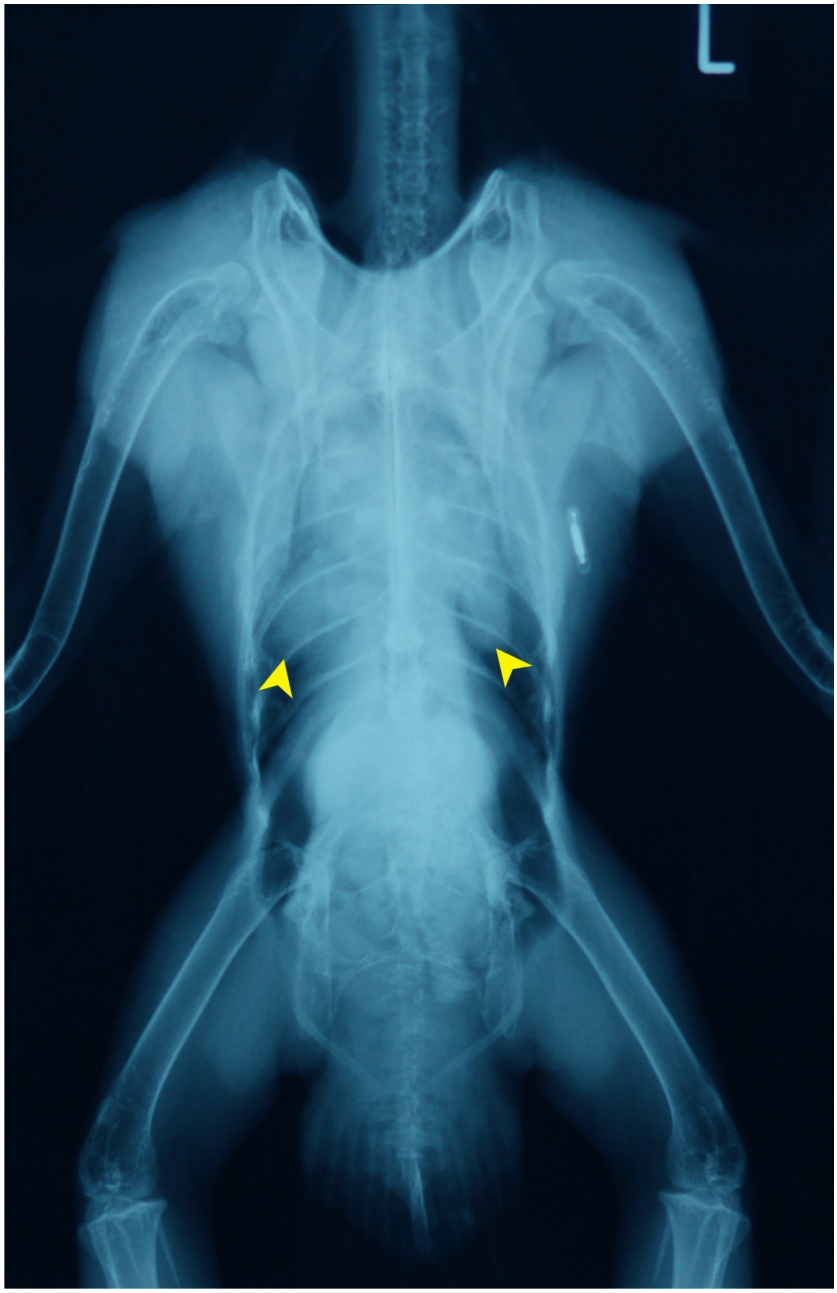
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Fig.12 This saker falcon presented for health screening (pre-purchase examination).Ventrodorsal survey radiograph showed bilateral large, localized soft-tissue densities (arrows) along the right and left cardiohepatic waist area. The largest focal radiodense mass present in the right thoracic air sac fields caused cranial displacement of the heart and the cardiac size and shape appeared altered. These focal radiodense masses were suggestive of encapsulated aspergillomas.

Fig.13 A saker falcon which presented for health screening (pre-purchase examination).Ventrodorsal survey radiograph revealed rounding of the caudal border of the lungs (arrows). In falcon lungs congestion may be seen in chronic respiratory disease.

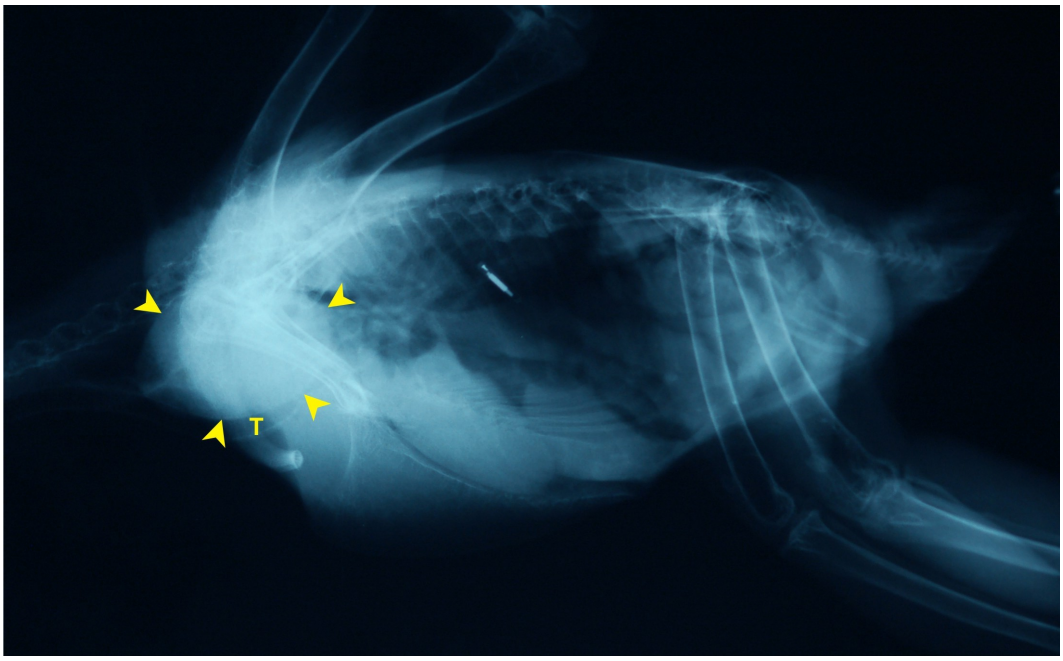

Fig.14 Lateral survey radiograph showing an oval, soft-tissue mass on the caudal region of the neck and thoracic inlet (arrows) of a saker falcon that presented with a history of intermittent regurgitation, inspiratory dyspnea and squawking sound. Note the oval shaped soft-tissue mass approximately measuring 5 x 3.5 cm, displacing the distal portion of the trachea (T) ventrally. On further examination the mass was diagnosed as an enlarged thyroid gland (thyroid hyperplasia).

4:1:2: Radiographic findings in the coelomic cavity and digestive system

There were many radiographic abnormalities recorded involving the coelomic cavity and digestive system of the falcons examined, totaling **718** abnormalities which comprised **(47.11%)** of all radiographic abnormalities **(N=1524)** recorded in the falcons examined (**table 1**).

Predominant radiographic abnormalities in the coelomic cavity and digestive system of the falcons consisted of excessive amounts of sand in the gastrointestinal tract (10.91%), splenomegaly (10.02%) and hepatomegaly (9.47%). These radiographic abnormalities comprised the third, fourth and fifth most prevalent radiographic abnormalities recorded in the examined falcons, respectively. Other radiographic abnormalities in the coelomic cavity and digestive system recorded in some of falcons examined are shown in **table** (**3**).

Table 3: Abnormal radiographic findings in the coelomic cavity and digestive system and their frequencies in captive saker falcons **(N=898)** examined at the Fahad Bin Sultan Falcon Center, Riyadh, Kingdom of Saudi Arabia from July 12, 2011, to July 11, 2012.

Pathological findings	No. of abnormal findings	Percentage **(N=898)**
1. Soft tissue density on abdomen (hernia)	1	0.11
2. Lead dust, fragments, pellets in the gastrointestinal tract (GIT)	27	3.01
3. Excessive sand in the gastrointestinal tract (GIT)	98	10.91
4. Food in the crop and/ or esophagus	18	2.00
5. Soft-tissue densities of the crop and/or esophagus (trichomoniasis)	33	3.67
6. Soft-tissue densities in the area of thoracic inlet (thyroid enlargement)	1	0.11

7. Thickening of the wall of crop and/or esophagus	40	4.45
8. Excessive casting material or meal present in the ventriculus	31	3.45
9. Gas formation in the GI tract (no dilatation)	51	5.68
10. Thickening of the wall of the ventriculus	31	3.45
11. Gas dilatation of the GI tract	29	3.23
12. Thickening of the wall of the proventriculus	33	3.67
13. Dilatation of the GI tract (no gas formation)	29	3.23
14. Displacement of the proventriculus and/ or ventriculus	35	3.90
15. Ascites	6	0.67
16. Displaced liver	41	4.57
17. Hepatomegaly	85	9.47
18. Microhepatica	39	4.34
19. Splenomegaly	90	10.02
TOTAL	**718**	**79.96**

Figures summerized in table 4 show the radiographic abnormalities in the coelomic cavity and digestive system of the falcons examined.

Table 4: Abnormal radiographic findings in the coelomic cavity and digestive system of the falcons examined presented in the following figures.

Pathological findings	FIGURES
Soft-tissue density in the area of thoracic inlet (thyroid enlargement)	**14**
Soft-tissue density on abdomen (hernia)	**15**
Lead dust, fragments, pellets in the gastrointestinal tract (GIT)	**(16 & 17)**
Dilatation of the GI tract (no gas formation)	**18**
Excessive sand in the gastrointestinal tract (GIT)	**18 , 19**
Food in the crop	**20 , 21**
Excessive casting material or meal present in the ventriculus	**20 , 21**
Gas formation in the GI tract (no dilatation)	**21**
Soft-tissue densities of the crop and/or esophagus (trichomoniasis)	**22 , 23**
Thickening of the wall of crop and/or esophagus	**24**
Thickening of the wall of proventriculus and ventriculus	**23, 25 , 26**
Gas dilatation of the GI tract	**19, 23, 26, 27**
Displacement of the proventriculus and/ or ventriculus	**10 , 28**

Ascites	**29 , 30**
Displaced liver	**10 , 48, 49**
Hepatomegaly	**23, 28 , 31**
Microhepatica	**32**
Splenomegaly	**33**

*Fig (16) shows a saker falcon presenting with clinical signs of delayed crop emptying, legs paresis, drooped wings and intermittent convulsion. The radiograph of the bird showed two lead pellets in the stomach (fig.17).

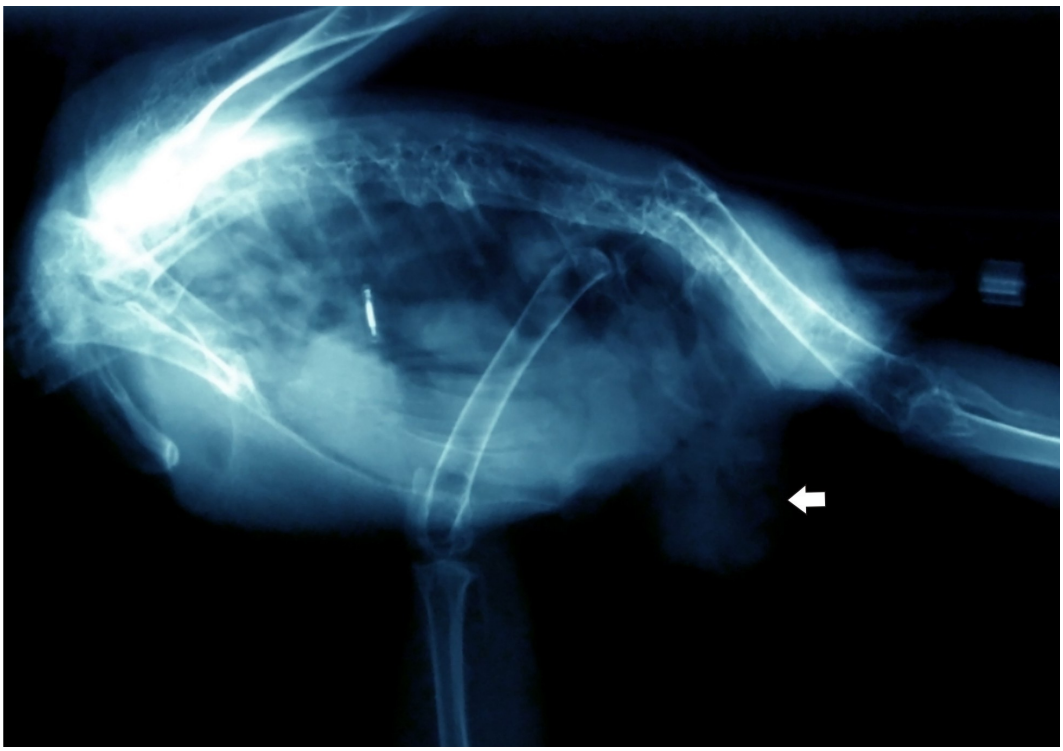

Fig.15 A saker falcon which presented for evaluation of a ventral abdominal mass. Lateral radiograph showed loss of integrity of the abdominal wall in association with a projecting soft tissue mass that consisted of displaced intestine (herniated intestine) (arrow).

Fig.16 A saker falcon which presented because of delayed crop emptying, vocalization (duck like sound), leg paresis, drooped wings and intermittent convulsion. The falconer used to feed this falcon on shot birds (collar dove).

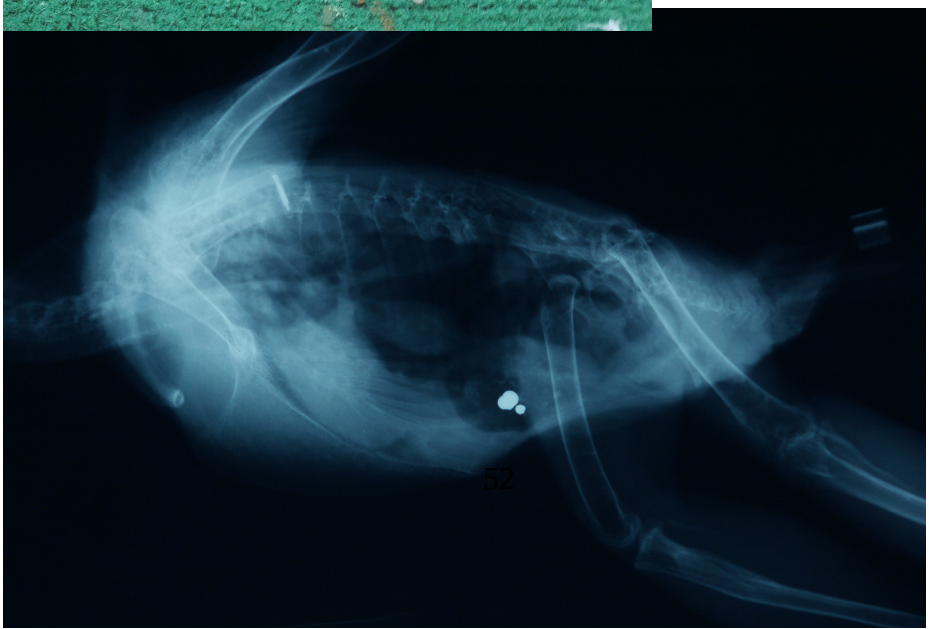

Fig.17 Lateral survey radiograph of the same bird as in **fig.16** showing two lead pellets in the ventriculus which appear as radiopaque objects. Blood lead level analysis revealed high lead level in this bird (lead toxicosis).

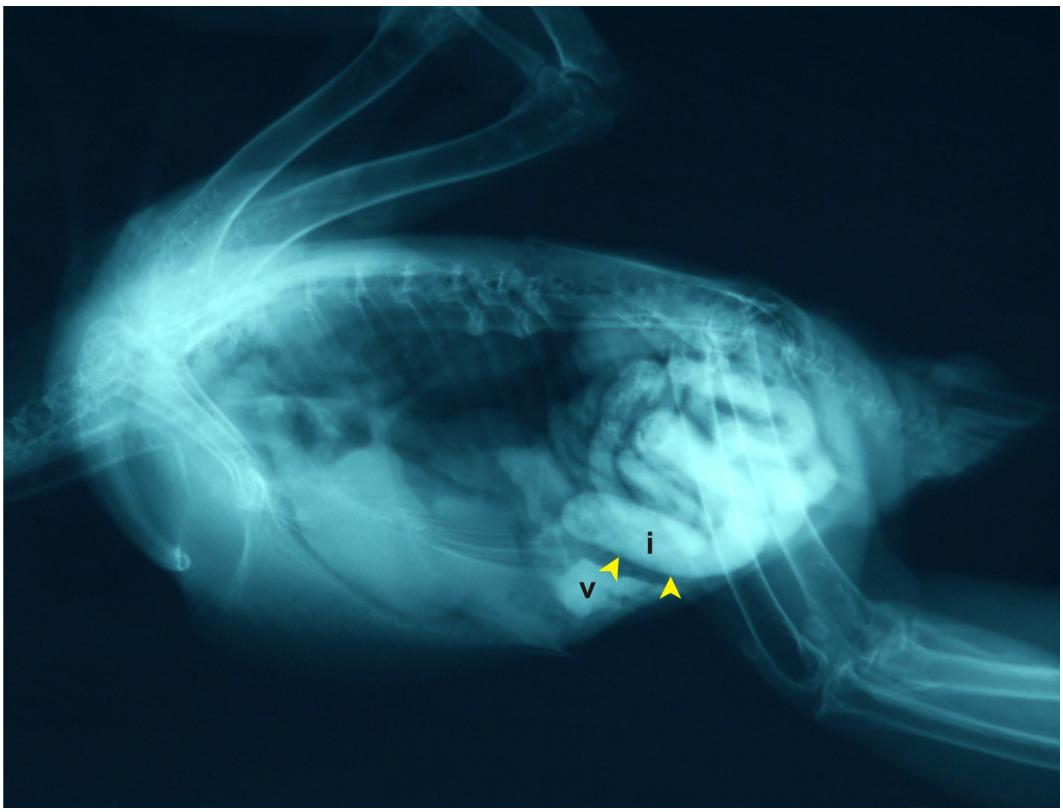

Fig.18 A saker falcon presented with a history of poor flight performance and inability to pass faeces .Lateral survey radiograph showed radiodense material in the ventriculus (v) and intestine (i). The intestinal loops appear massively dilated (arrows) due to excessive accumulation of sand (sand impaction). Falcons that always feed on sand commonly develop sand impaction. At FBSFC coccidiosis in falcons caused by the genus *Caryospra* was commonly observed associated with sand impaction probably due to

contamination of sand with the dropping of infected birds in the sand room (moulting room).

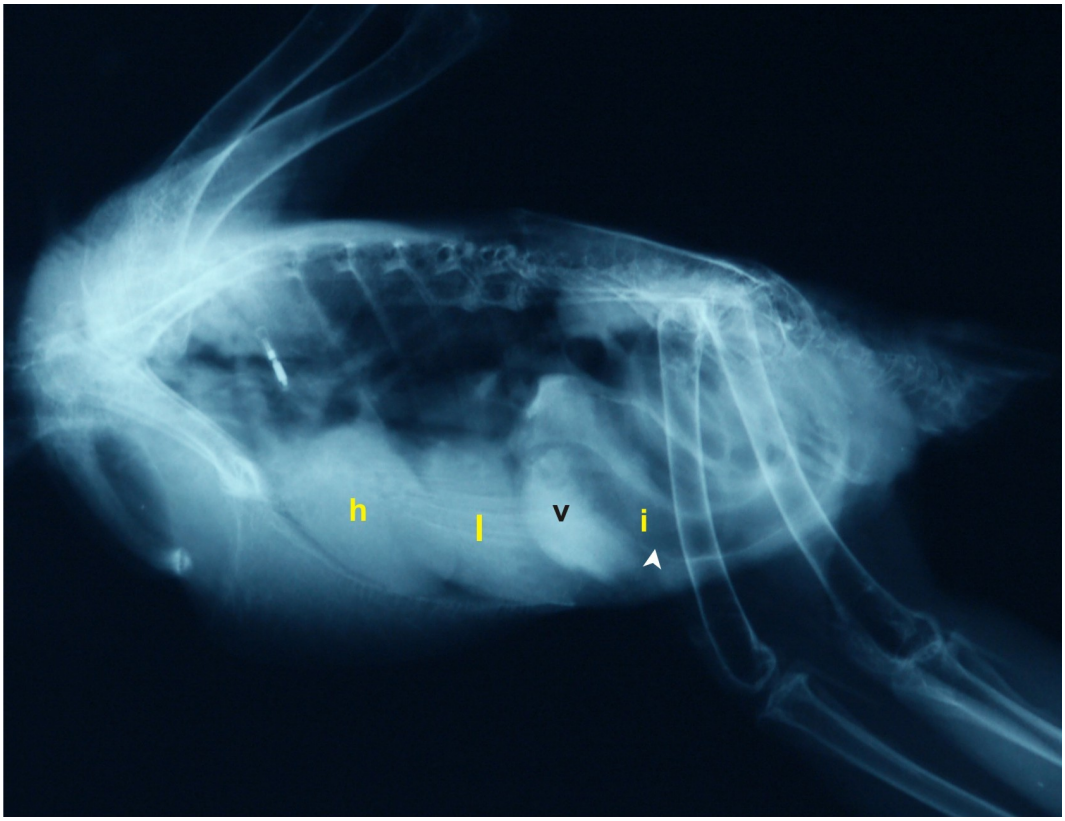

Fig.19 A saker falcon presented with a history of depression, anorexia and inability to pass faecal matter. Lateral survey radiograph showed radiodense material in the ventriculus (v) and proximal part of small intestine (i) loops due to excessive accumulation of sand. Note the massively dilated and extensive gas-filled intestine loops (arrow). Extensive gas filling of intestine in this bird may indicate paralytic ileus due to obstruction of the ventriculus and the proximal loops of small intestine with sand. Heart (h) and liver (l).

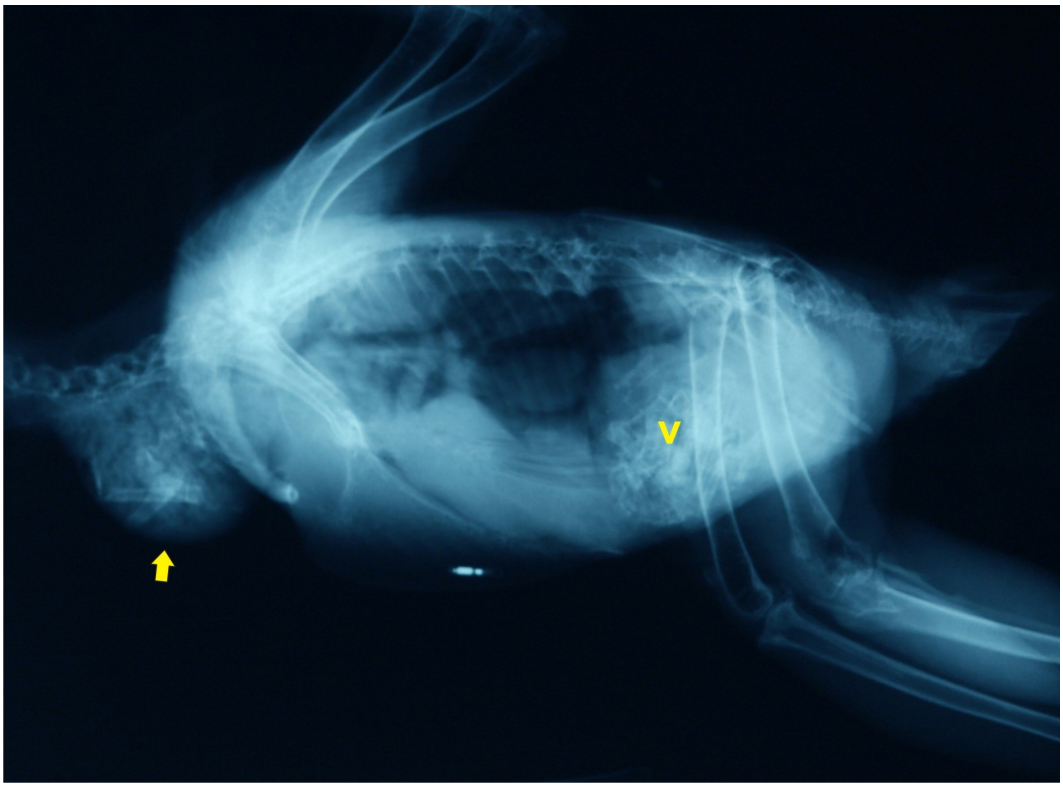

Fig.20 A saker falcon presented for delayed crop emptying and fetid odor from the mouth, after being overfed by the falconer. Lateral survey radiograph showed a large quantity of food material present in the crop (arrow) and ventriculus (v). In captivity over feeding of falcon with large a mount of food can cause indigestion, crop stasis, impaction and sour crop.

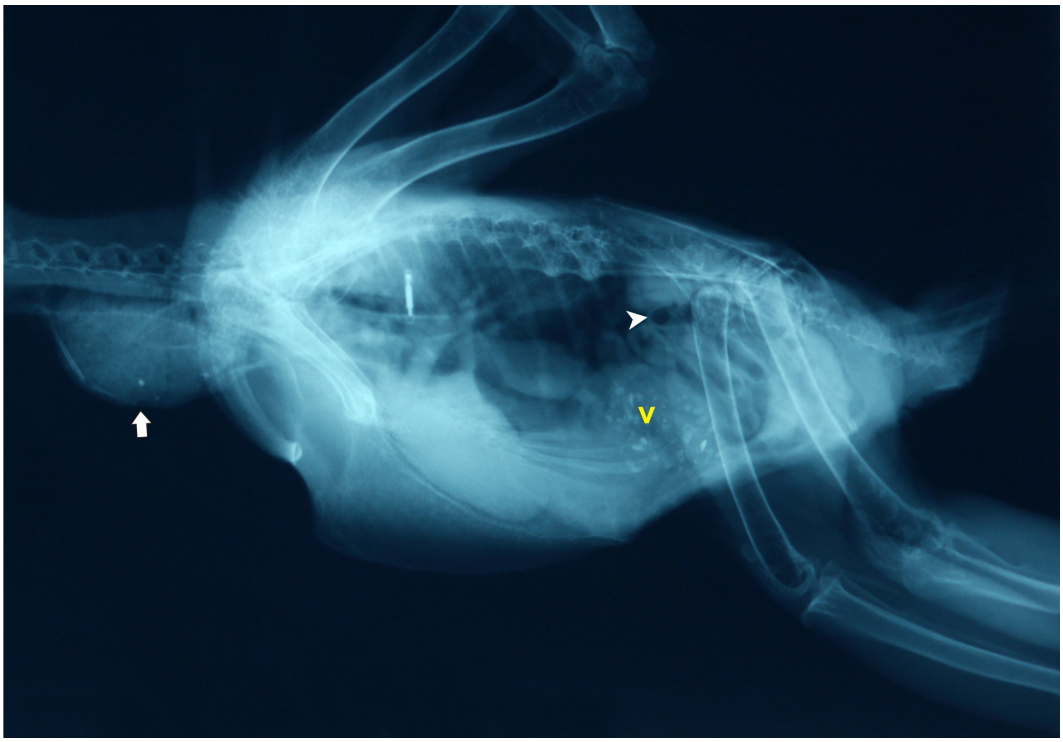

Fig.21 A saker falcon presented to the clinic because of delayed crop emptying, fetid odor from the mouth and inability to pass faecal matter. Lateral survey radiograph showed presence of excessive food material in the crop (arrow) and ventriculus (v) (sour crop). Gas filled the intestines without dilatation (head arrow).

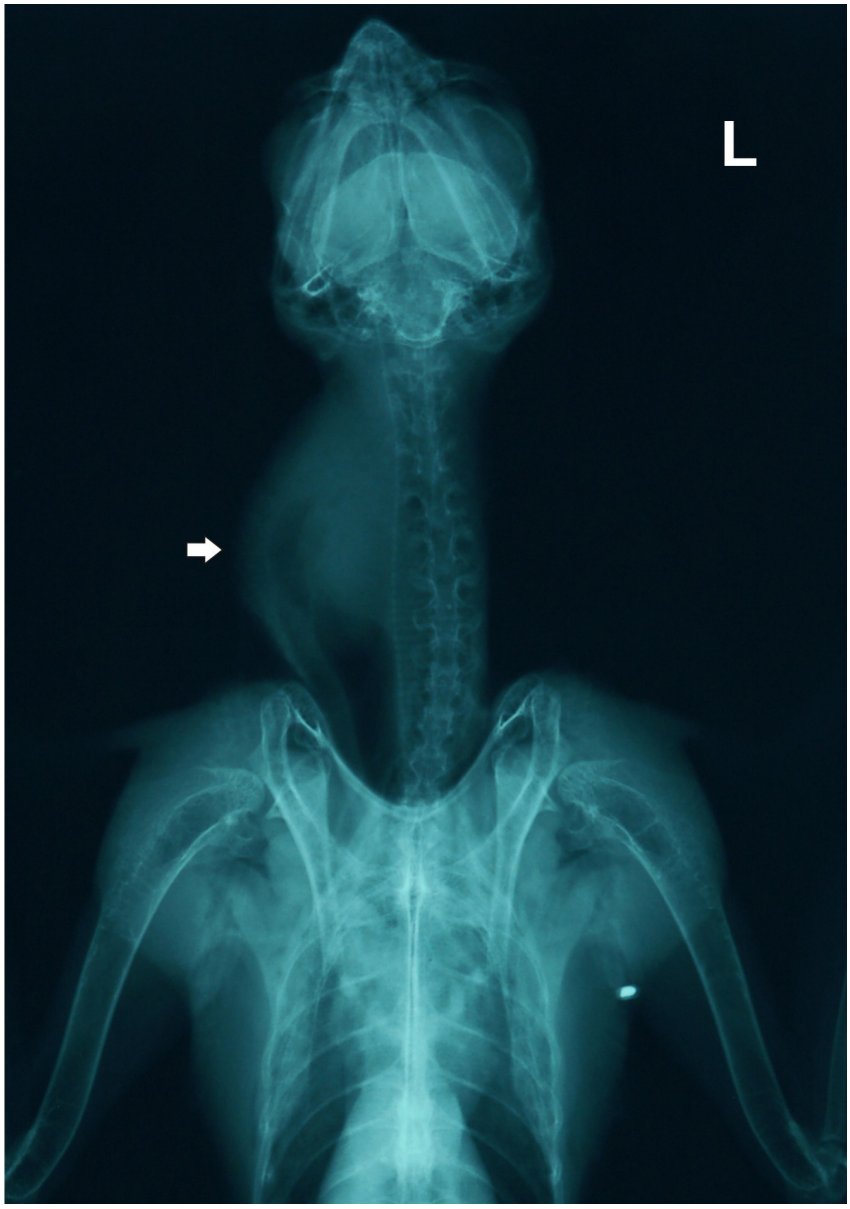
L

Fig.22 Ventrodorsal radiograph of the neck of a saker falcon that was presented because of loss of appetite and swollen neck.Clinical and radiological examination revealed a large soft – tissue density in the area of the esophagus and crop (arrow). The mass was produced by a chronic infection with *Trichomonas gallinae*. This infection is commonly acquired after feeding falcon on pigeons and collar doves commonly used as food items by the falconers.

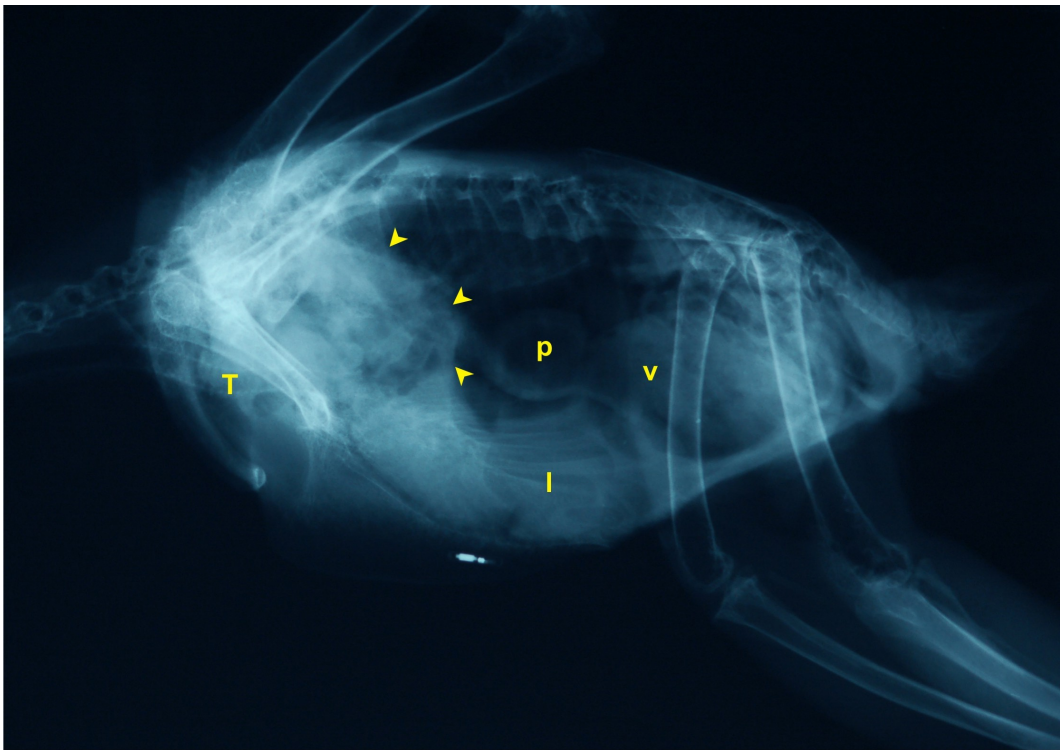

Fig.23 lateral survey radiograph of a saker falcon which presented with a history of anorexia, vomiting and progressive weight loss. Radiographic findings showed very large single radiodense mass in the area of the thoracic esophagus, proximal to the base of the heart (arrows).Displaced trachea (T), enlarged liver (l) shadow, gaseous distension and thickening of proventriculus (p) and ventriculus (v) walls.The radiodense mass observed was a large trichomoniasis caseous growth are seen within the thoracic esophagus (confimed by endoscopy and cytology).

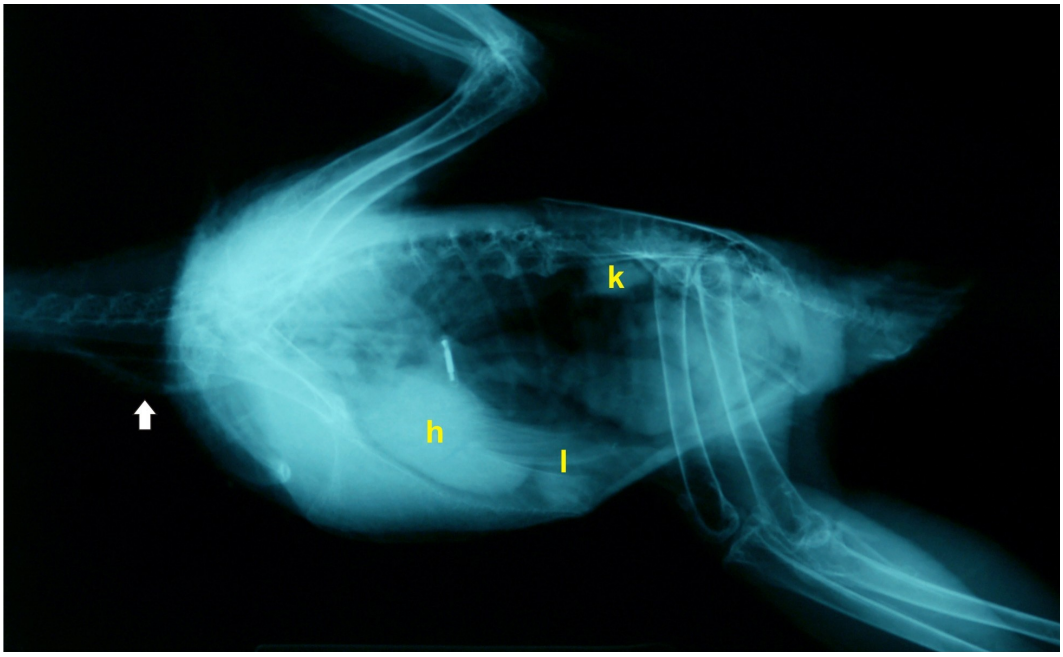

Fig.24 A saker falcon with candidiasis presented with a history of reduced appetite and flicking food. Lateral survey radiograph revealed thickened crop wall (arrow), slightly small liver shadow (l) and increased renal density without nephromegaly.

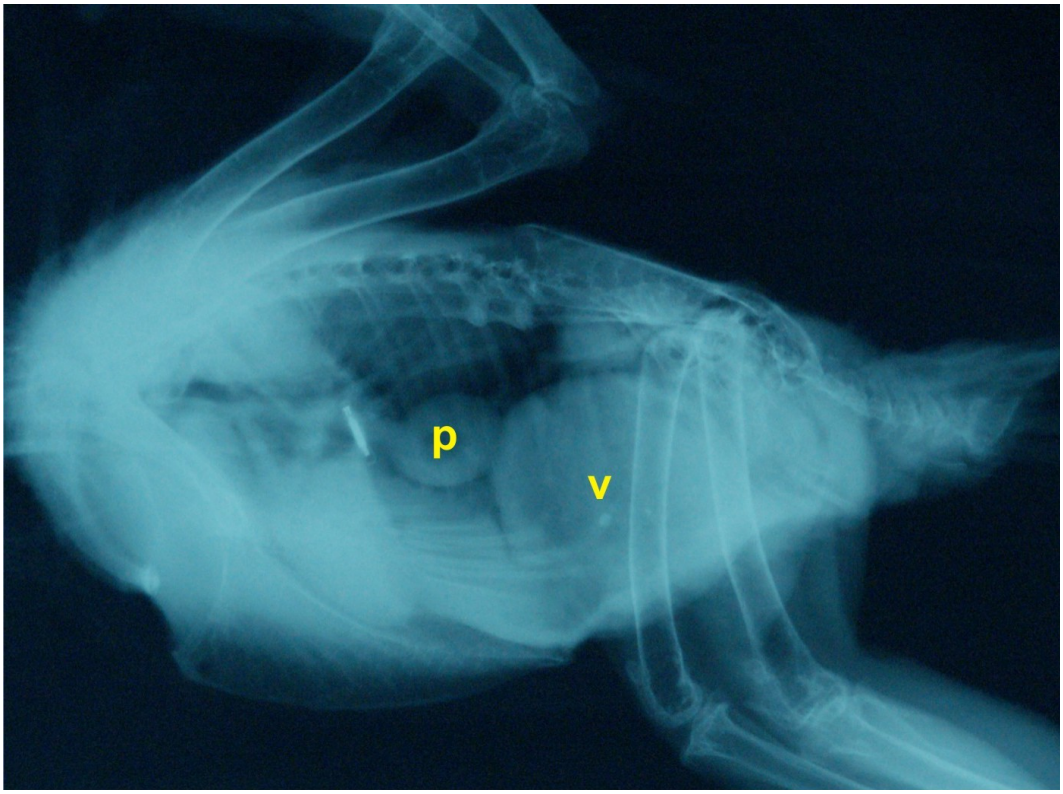

Fig.25 Lateral survey radiograph of a saker falcon with ammonium chloride toxicosis. The radiograph showed markedly thickened proventriculus (p) and ventriculus (v) walls.

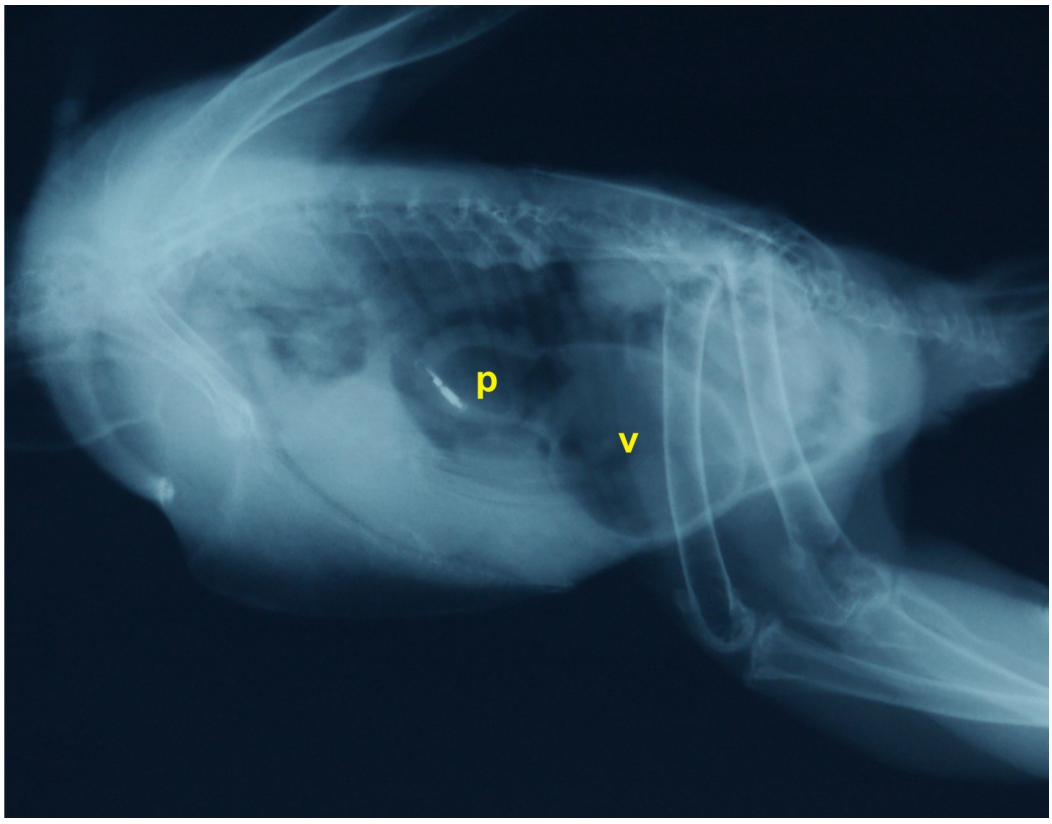

Fig.26 A saker falcon presented with a history of severe anorexia, closed eyes, regurgitation, mucoid - bloody diarrhoea and constant distress vocalization. Lateral survey radiograph showed marked gaseous distension and thickening of the proventriculus (p) and ventriculus (v) walls. The radiographic finding of gastritis in this bird, with above mentioned clinical signs, were suggestive of infection with viscerotropic form of Newcastle Disease.

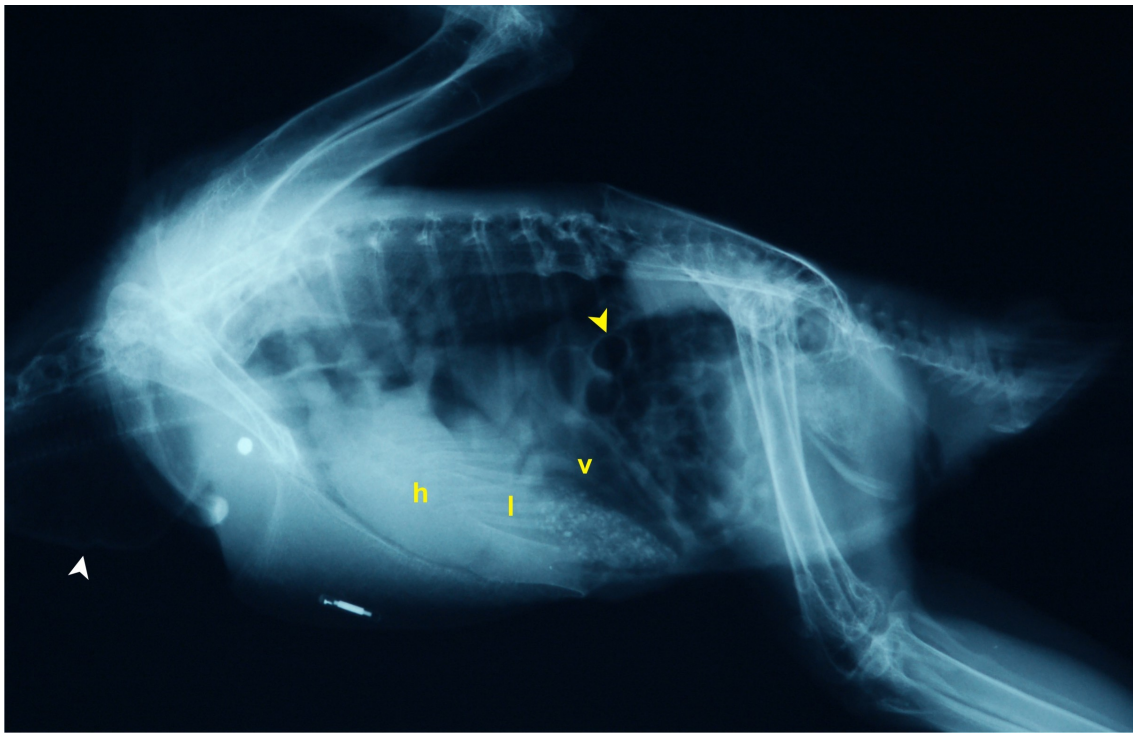

Fig.27 A saker falcon presented with a history of anorexia, vomition and weight loss. Lateral survey radiograph revealed severe gaseous distension of the crop (white arrow), ventriculus (v) and intestinal loops (yellow arrow), slightly thickened ventriculus wall and presence of sand in the ventriculus.The gaseous distension of the ventriculus displaced the liver (l) cranially. This case of severe gastroenteritis was found to be the result of a bacterial infection. Lead pellet embedded in the body (thoracic inlet area) was also seen.

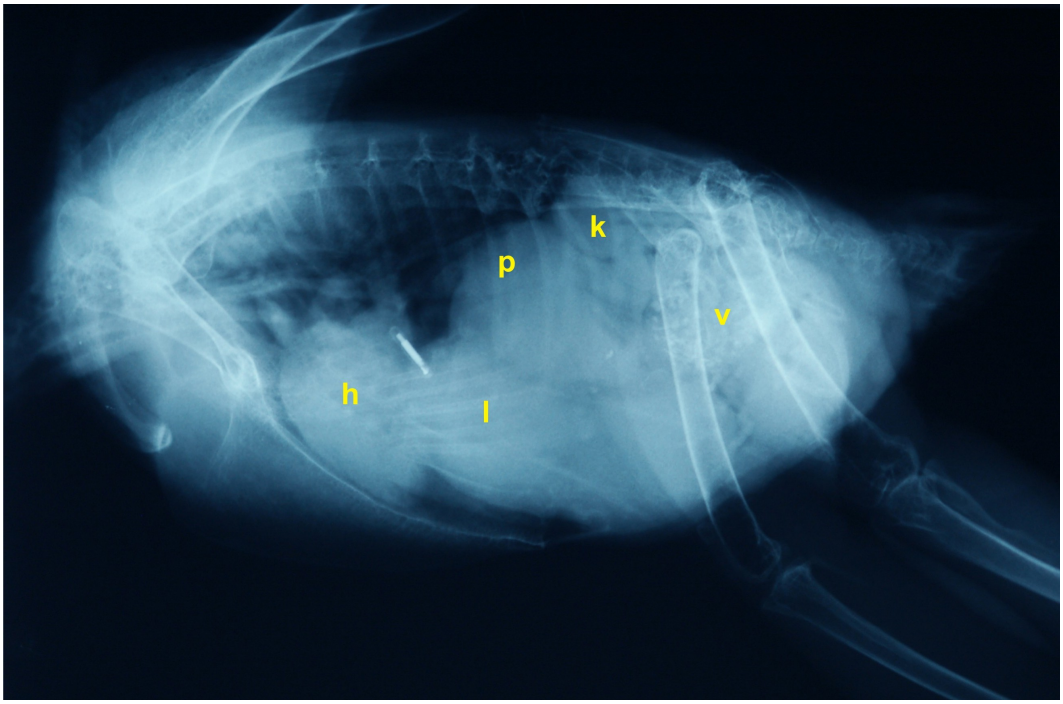

Fig.28 A saker falcon presented with a history of poor flight performance and passage of green urates. Lateral survey radiograph revealed a massively enlarged liver (l) shadow displacing the proventriculus (p) dorsally and ventriculus (v) caudodorsally. The heart (h) is being displaced cranially and the cardiac size and shape appear altered. Loss of air shadow around kidneys (k) as the result of displacement of the proventriculus and ventriculus by massively enlarged liver.

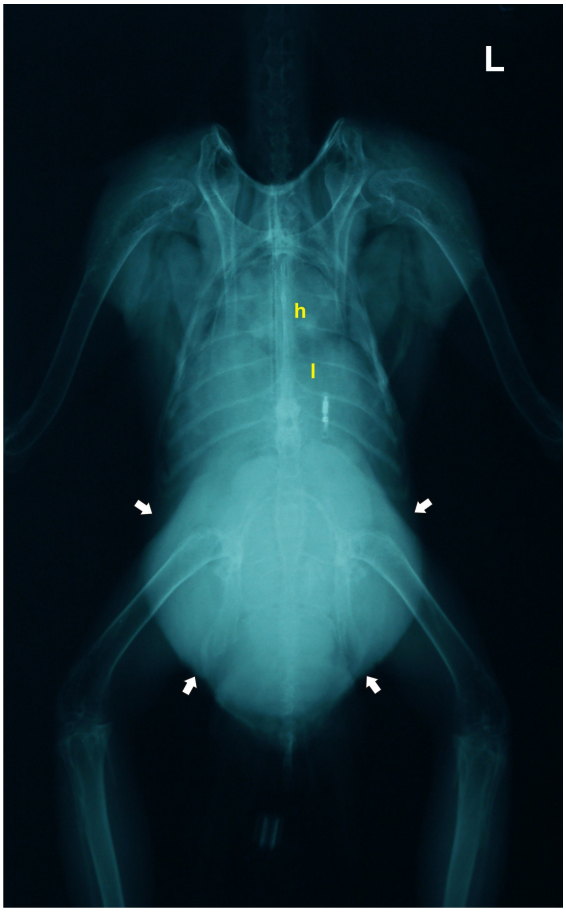

Fig.29 Ventrodorsal survey radiograph of a saker falcon that presented with severe dyspnea, distended abdominal cavity and passage of green urates. An extensive diffused radiopacity across the hepatic and peritoneal coelomic cavities is present (arrows). This bird had ascites most probably associated with severe amyloidosis affecting mainly the liver.

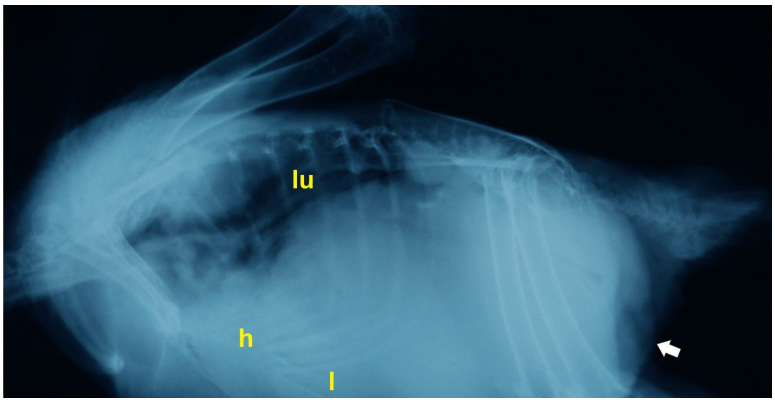

Fig.30 Lateral survey radiograph of same bird as in **fig.29** showing a large soft – tissue shadow in the caudal coelomic cavity (arrows). The lungs (lu) and air sacs were massively compressed. No differentiation between visceral organs could be made radiographically. The boundaries of the heart (h) and liver (l) shadows are not well defined (loss of hourglass shape). The heart is being displaced cranially and the cardiac size and shape appear altered.

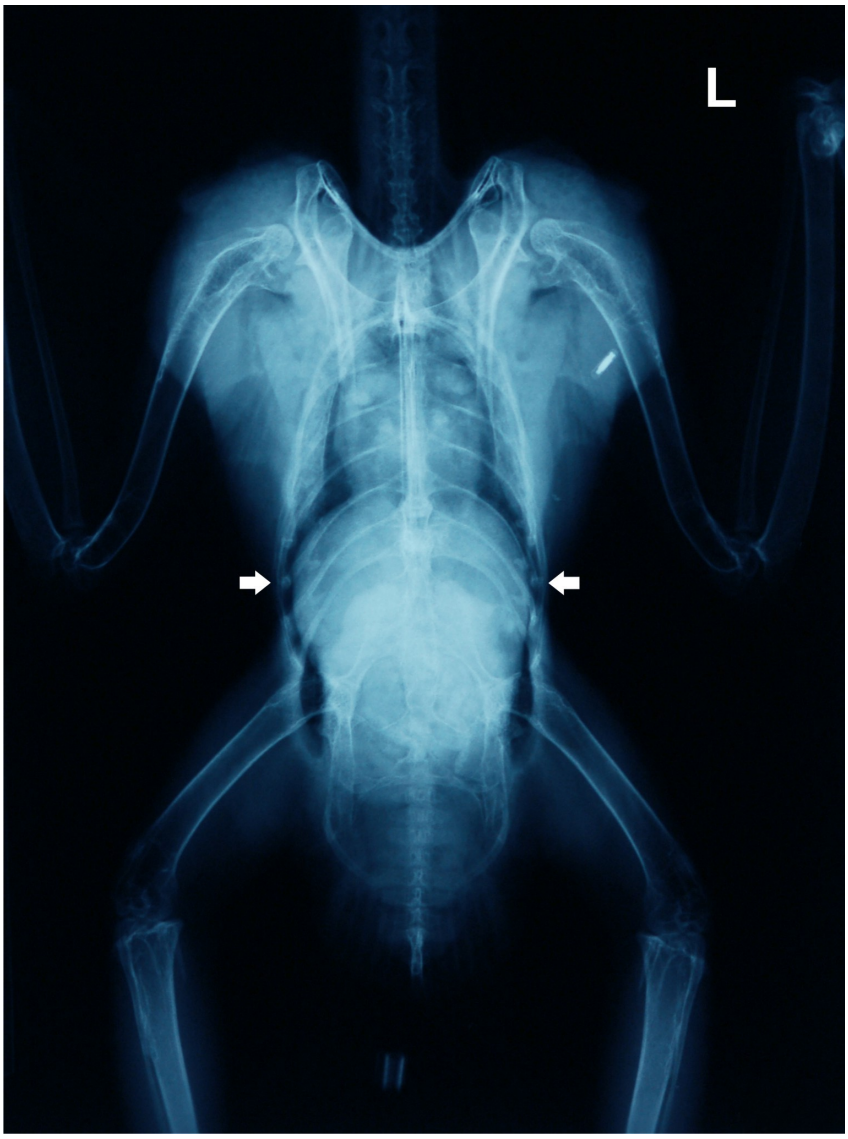

Fig.31 A saker falcon presented for health screening (pre-purchase examination). Ventrodorsal survey radiograph showed massively enlarged liver shadow (arrows).

Fig.32 Ventrodorsal survey radiograph of a saker falcon showing small liver (arrow) shadow (microhepatica). During hunting process this bird was extensively exposed to over exertion coupled with hunger. Microhepatica is commonly observed in

falcons recently returning from a hunting trip, most probably due to utilization of glycogen storage content in the liver, so as to meet the increased demand of high-energy requirement of the bird.

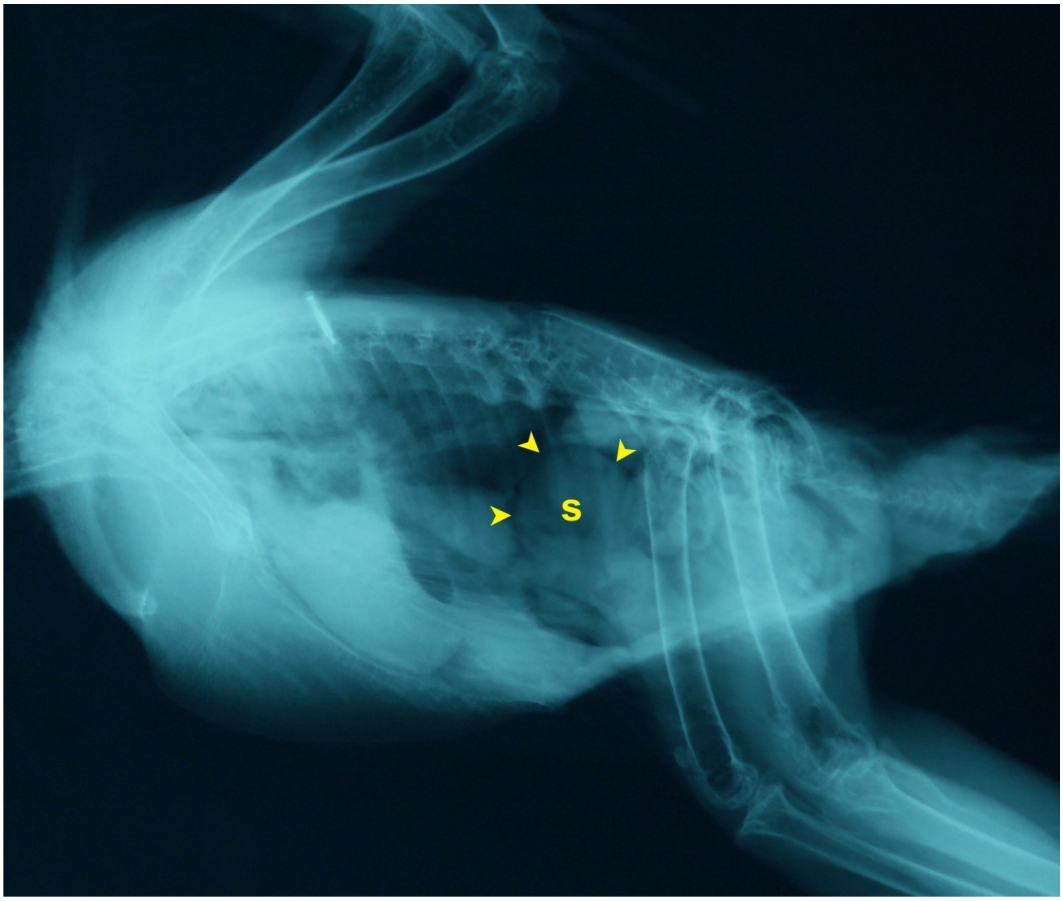

Fig.33 A saker Falcon presented with a history of exercise intolerance and poor flight performance. Lateral survey radiograph revealed greatly enlarged spleen (s) shadow (arrows). A massive splenic enlargement could be due to viral or bacterial (tuberculosis and chlamydophilosis) diseases.Haematologic examination of this bird demonstrated haematozoan parasites (*Haemoproteus tinnunculi*). At FBSFC splenomegaly was most commonly observed associated with haemoproteid infection. The size of spleen in this bird measured 30mm.

4:1:3: Radiographic findings in the musculoskeletal system

Fractures due to trauma (6.68%), low or reduced muscle mass (6.12%) and healed fracture (5.01%), were the most common radiographic abnormalities identified in the musculoskeletal system of the falcons examined. Other radiographic abnormalities in musculoskeletal system recorded in some falcons examined are shown in **table** (**5**).

Table 5: Abnormal radiographic findings in the musculoskeletal system and their frequencies in captive saker falcons **(N=898)** examined at the Fahad Bin Sultan Falcon Center, Riyadh, Kingdom of Saudi Arabia from July 12, 2011, to July 11, 2012.

Pathological findings	No. of abnormal findings	Percentage **(N=898)**
1. Lead dust, fragment, or pellets in body tissues	7	0.78
2. Fracture – trauma	60	6.68
3. Fracture – gunshot injury	2	0.22
4. Bone deformity/metabolic disease	1	0.11
5. Luxation/ subluxation/ dislocation	8	0.89
6. Healed fracture	45	5.01
7. Soft tissue swelling without bone involvement	23	2.56
8. Soft tissue swelling with bone involvement	8	0.89
9. Osteoarthritis	12	1.34
10. Osteomyelitis	7	0.78
11. Reduced or loss of muscle mass (low condition)	55	6.12
12. Osteolysis	8	0.89
13. Muscular atrophy (trauma)	19	2.12
TOTAL	**255**	**28.40**

The radiographic abnormalities in the musculoskeletal system of examined falcons are depicted in table 6.

Table 6: Abnormal radiographic findings in the musculoskeletal system of the falcons examined presented in the following figures.

RESULT	FIGURES
Reduced or loss of muscle mass (low condition)	**7, 9**
Lead dust, fragment, or pellets in body tissues	**34**
Fracture – trauma	**35, 36**
Bone deformity/metabolic disease	**37**
Luxation/ subluxation/ dislocation	**38**
Healed fracture	**39**
Soft-tissue swelling without bone involvement	**(42 & 43)**
Soft-tissue swelling with bone involvement	**40, 41, 44**
Osteoarthritis	**38, 45**
Osteomyelitis	**40, 46**
Osteolysis	**38, 40, 41**
Muscular atrophy (trauma)	**35, 39,40**

*Fig (42) shows the plantar surfaces of the feet of a saker falcon with severe swelling of the right foot (bumble foot). The radiograph of the bird shows severe soft-tissue swelling of the right foot without an apparent bone involvement (fig.43).

Fig.34 A saker falcon presented for health screening (pre-purchase examination). Ventrodorsal survey radiograph revealed 8 shot gun pellets embedded in different parts of the body. The blood lead level in this bird was within the normal reference range.

Fig.35 A saker falcon presented with non-load bearing of the left leg. Ventrodorsal radiograph revealed transverse distal femoral fracture (arrow) and muscular atrophy of the leg muscles (disuse atrophy).

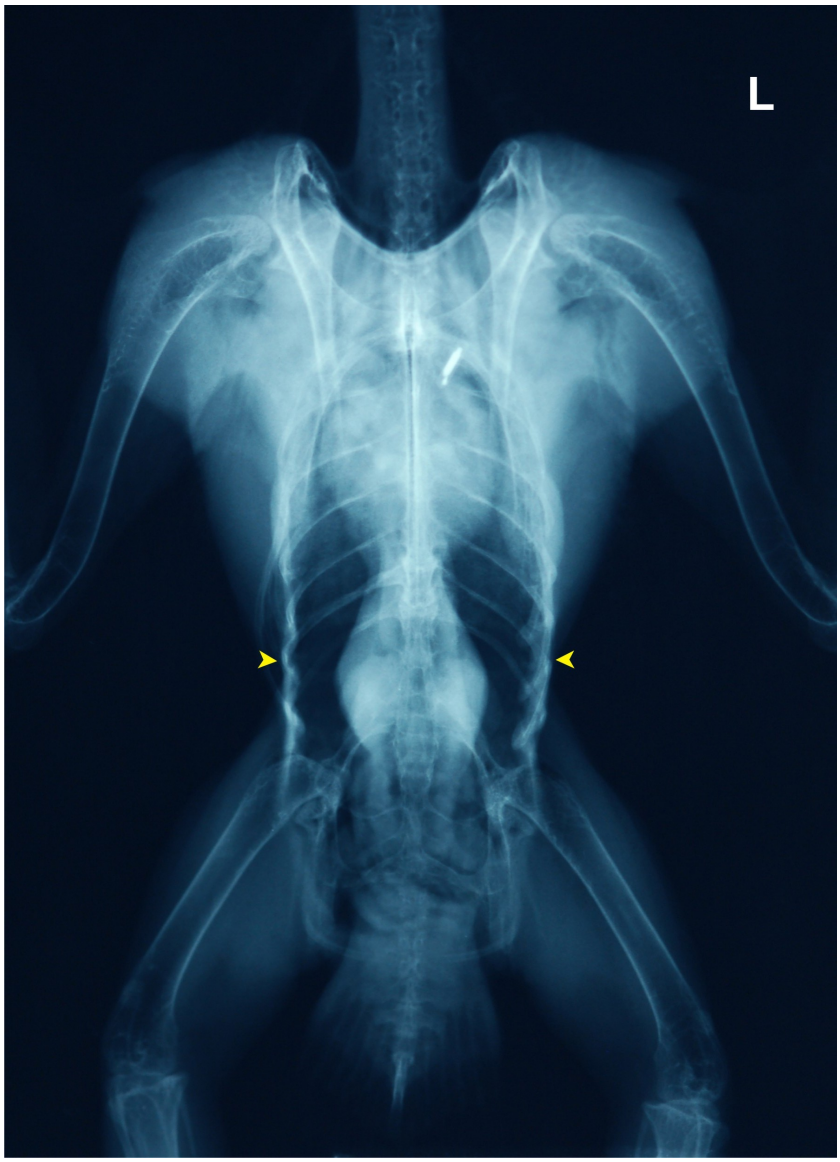

Fig.36 A saker falcon presented for health screening (pre-purchase examination).Ventrodorsal survey radiograph showed extensive ribs fracture (arrows).

Fig.37 A juvenile saker falcon which presented with neurologic signs, including leg paresis and intermittent convulsions. Ventrodorsal survey radiograph revealed bowing deformities of the ribs and both femurs and distal part of tibiotarsi (arrows).This radiographic findings suggestive of metabolic bone disease (rickets). A lead pellet is present in the ventriculus (lead toxicosis).

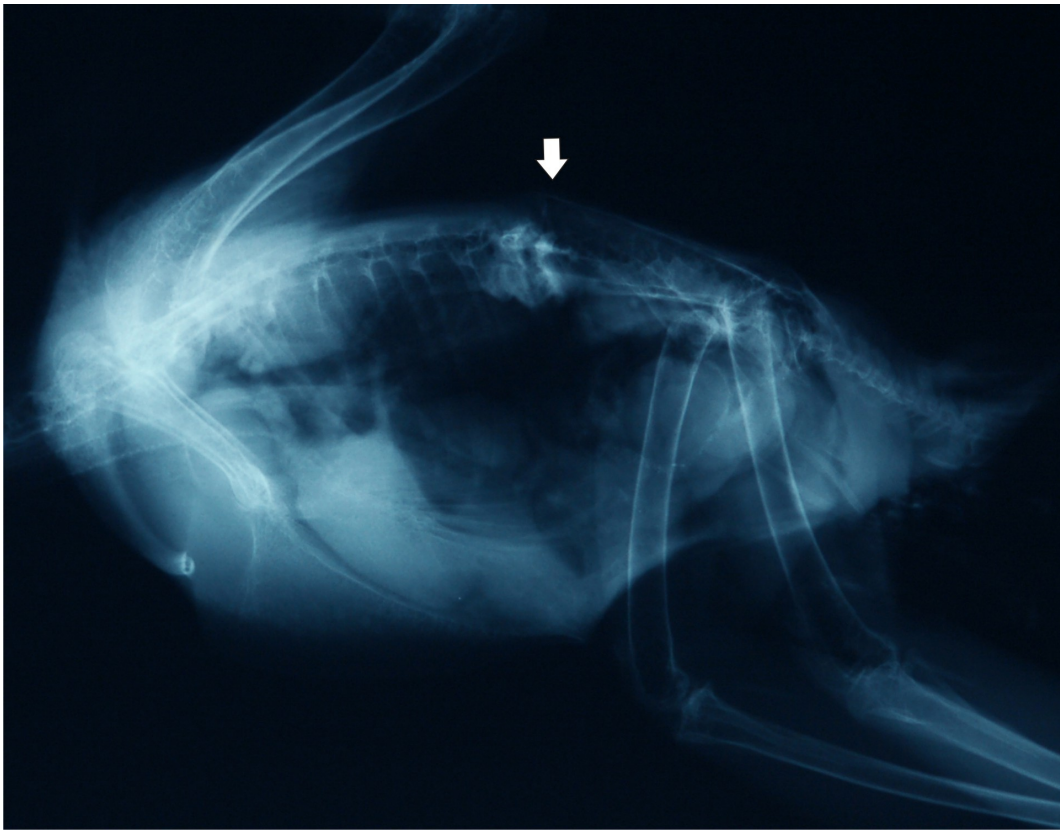

Fig.38 A saker falcon presented with lameness of both legs. Lateral survey radiograph showed extensive osteoarthritic and osteolytic changes of the thoracosynsacral junction (arrow) leading to luxation of the sixth thoracic vertebra. Damage in the caudal thoracic vertebrae, sixth thoracic and synsacrum tended to occur due to collision – type injuries.

Fig.39 Ventrodorsal radiograph of the right wing of a saker falcon showing a healed fracture of the ulna without good alignment (arrow).There is muscular atrophy of pectoral and shoulder muscles (head arrow), as a result of lack of normal function of affected wing.

Fig.40 Ventrodorsal radiograph of a saker falcon that presented with a drooped right wing. There was a soft-tissue swelling of the elbow joint (white arrow), osteomyelitis, increased joint space and marked osteolytic changes of the articular surfaces of the humerus,radius and ulna. Caseous pus was present in the abscess (septic arthritis). Muscular atrophy of extensor metacarpiradialis (yellow head arrow), shoulder and pectoral muscles (white head arrow) are evident as a result of loss of wing's normal function.

Fig.41 A saker falcon presented with right ear discharge, flicking food and weight loss. Physical examination revealed a large swelling on the right side of the base of the lower mandible. A ventrodorsal radiograph of the head of the bird revealed soft tissue swelling associated with osteolytic changes of the quadrate bone and its adjacent bony structures (arrow).

Fig.42 Plantar surfaces of the feet of a saker falcon with severe swelling of the right foot (bumble foot). There is a large thick scab on the central plantar surface of right foot, fibrosis and underlying infection.

Fig.43 Craniocaudal radiograph of the feet of the same bird as in **fig . 42** there is severe soft-tissue swelling of the right foot (arrow) with out an apparent bone involvement.

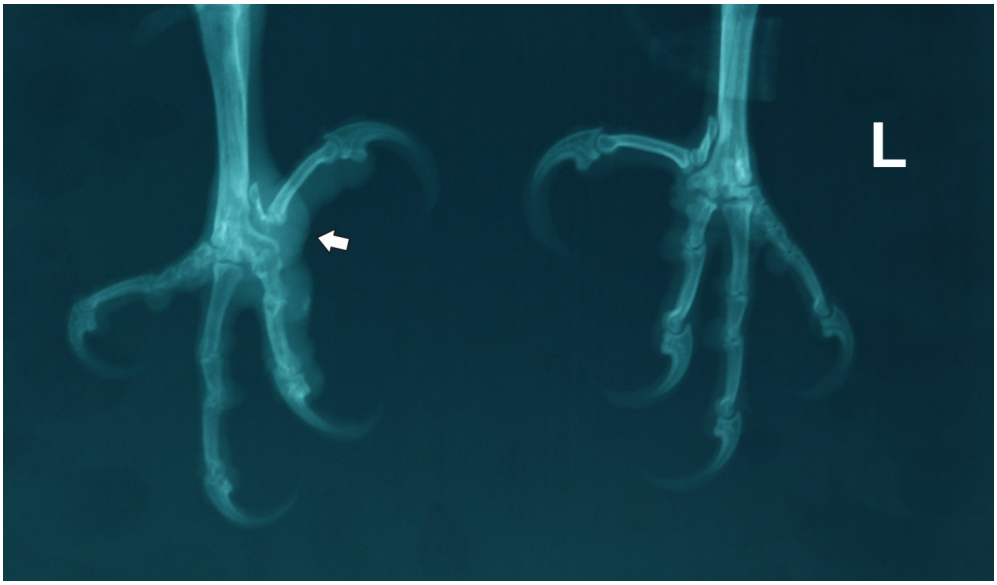

Fig. 44 Craniocaudal radiograph of the feet of a saker falcon presented with a swollen right foot and presence of scab on the digital pad of digit II (advanced bumble foot). There is severe soft-tissue swelling of the right foot (arrow) including the entire digits I and II accompanied with marked osteomyelitis of the distal tarsometatarsus and proximal phalangeal bone of digit II.

Fig.45 Ventrodorsal survey radiograph showing osteoarthritis of the left shoulder joint (arrow) in a saker falcon. This bird was hit with a hard object on its left shoulder while hunting one month ago. Note the increased bone density and narrowing of the joint space of the affected shoulder joint.

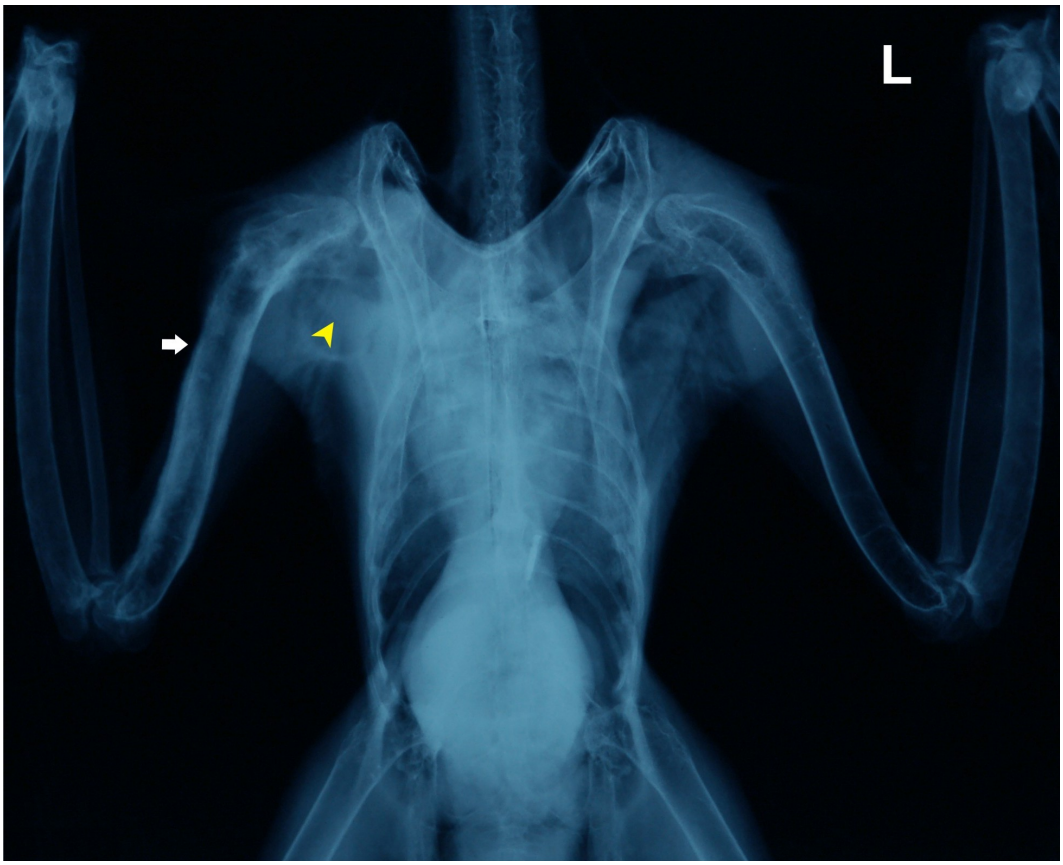

Fig.46 Ventrodorsal survey radiograph of a saker falcon showing loss of clavicuar air sac space (head arrow) and severe osteomyelitis of the humerus (arrow) of right wing, caused by fungal infection. This bird had a deep keel injury infected with *Aspergillus* species and probably the fungal infection extended to the clavicular air sac and humerus via the broken tissue resulting from an infected deep wound.

4:1:4: Radiographic findings in the cardiovascular and urogenital systems

Radiographic abnormalities recorded from the cardiovascular and urogenital systems of examined falcons are shown in Table (7).

Radiographic Abnormalities recorded in the cardiovascular system of falcons included, increased radiodensity of the heart shadow (fig.8), microcardia (fig.47), alteration of heart's size and shape associated with displacement (fig.10, 12 and 48) and cardiomegaly (fig.49). Of these abnormalities, increased radiodensity of heart shadow (4.45%), microcardia (3.23%) and alteration of the heart size and shape associated with displacement (3.01%) were the most frequent abnormal radiographic findings observed in the cardiovascular system **(Table 7**).

Increased renal density with or without nephromegaly, were the only abnormal radiographic findings observed in the urogenital system of falcons examined (**Table 7**). Out of **898** falcons examined, only **23** falcons were diagnosed with increased renal density; of these, **17**(1.89%) showed increased renal density with nephromegaly (fig.47 and 50), while **6**(0.67%) birds were diagnosed with increased renal density without nephromegaly (fig.24).

Table 7: Abnormal radiographic findings in the cardiovascular and urogenital system and their frequencies in captive saker falcons **(N=898)** examined at the Fahad Bin Sultan Falcon Center, Riyadh, Kingdom of Saudi Arabia from July 12, 2011, to July 11, 2012.

Pathological findings	No. of abnormal findings	Percentage **(N=898)**
Cardiovascular system:-	**106**	**11.80**
1. Increased radiodensity of the heart shadow	40	4.45
2. Alterations of the cardiac size and/or shape (associated with displacement)	27	3.01
3. Microcardia	29	3.23
4. Cardiomegaly	10	1.11
Urogenital system:-	**23**	**2.56**
1. Increased renal density with nephromegaly	17	1.89
2. Increased renal density without nephromegaly	6	0.67

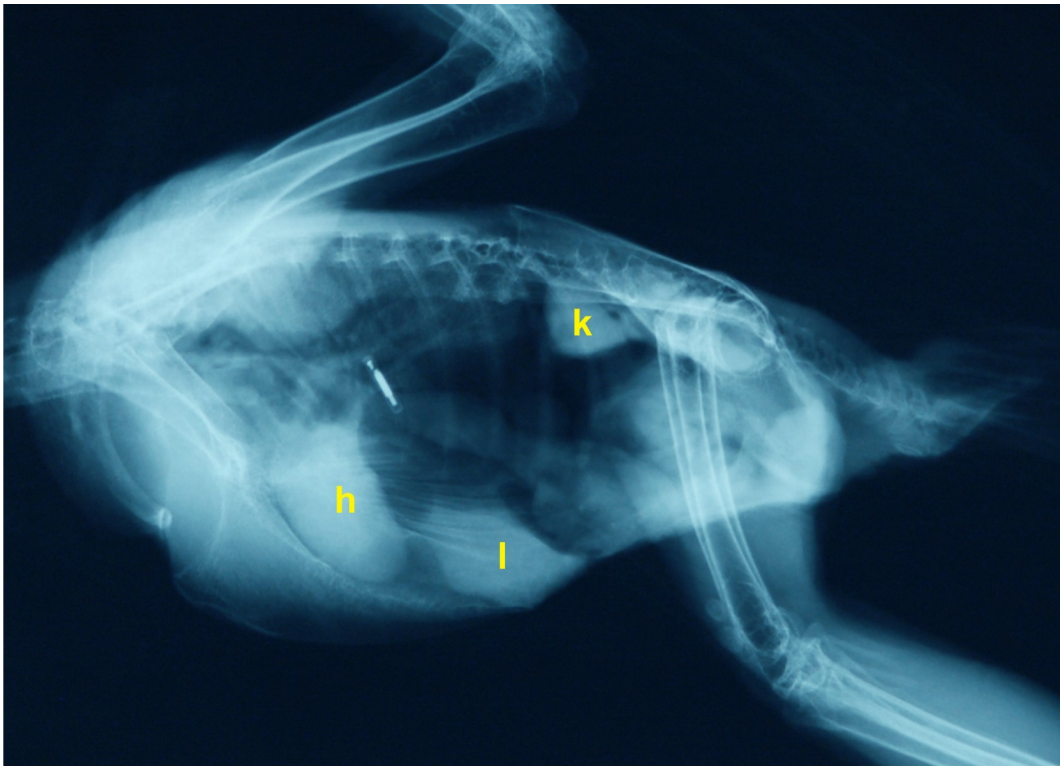

Fig.47 A saker falcon presented to the clinic because of reduced appetite, polyurea and general weakness. Lateral survey radiograph revealed increased renal density with enlarged cranial lobe of the kidney (k) shadows (nephromegaly). The heart (h) and liver (l) shadows were reduced in size (microcardia and microhepatica). Note the radiolucent gap between the heart and liver shadows which is most commonly seen in bird with hypovolemia and nutritional inadequency.

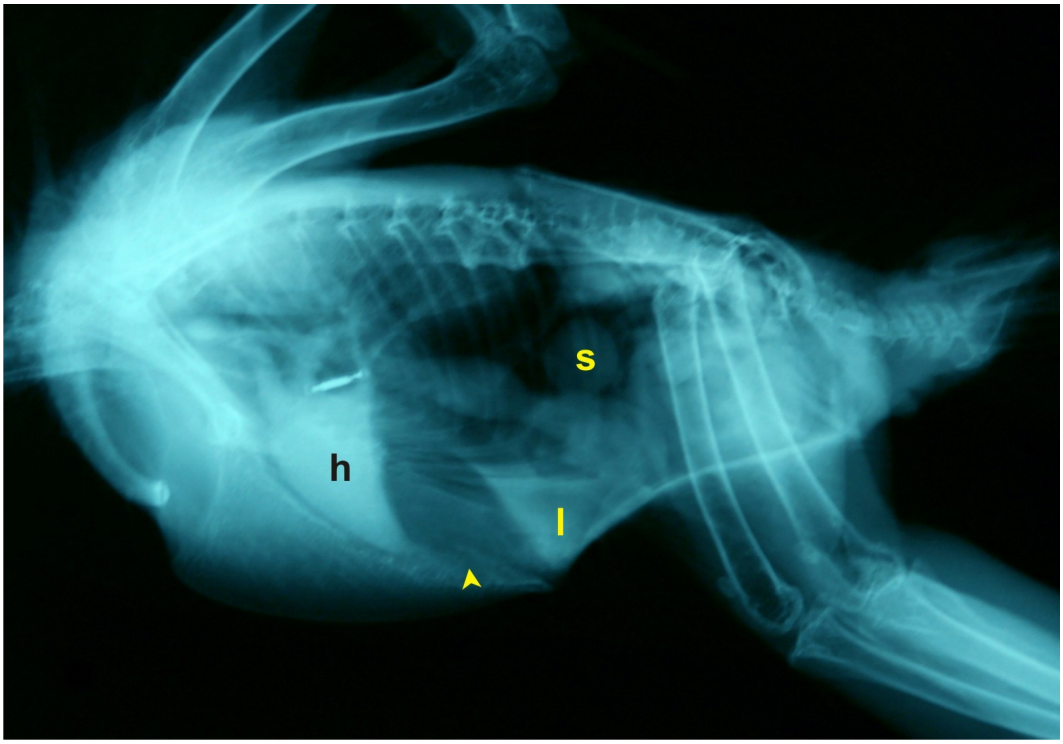

Fig.48 Lateral survey radiograph of a saker falcon which presented with severe dyspnea, reduced appetite and poor flight performance. Extensive air trapping (arrow) is evident in the cardiohepatic waist area displacing the heart (h) cranially and the liver (l) caudally, the cardiac and liver size and shape appear altered, and there was a slightly enlarged spleen (s) shadow.

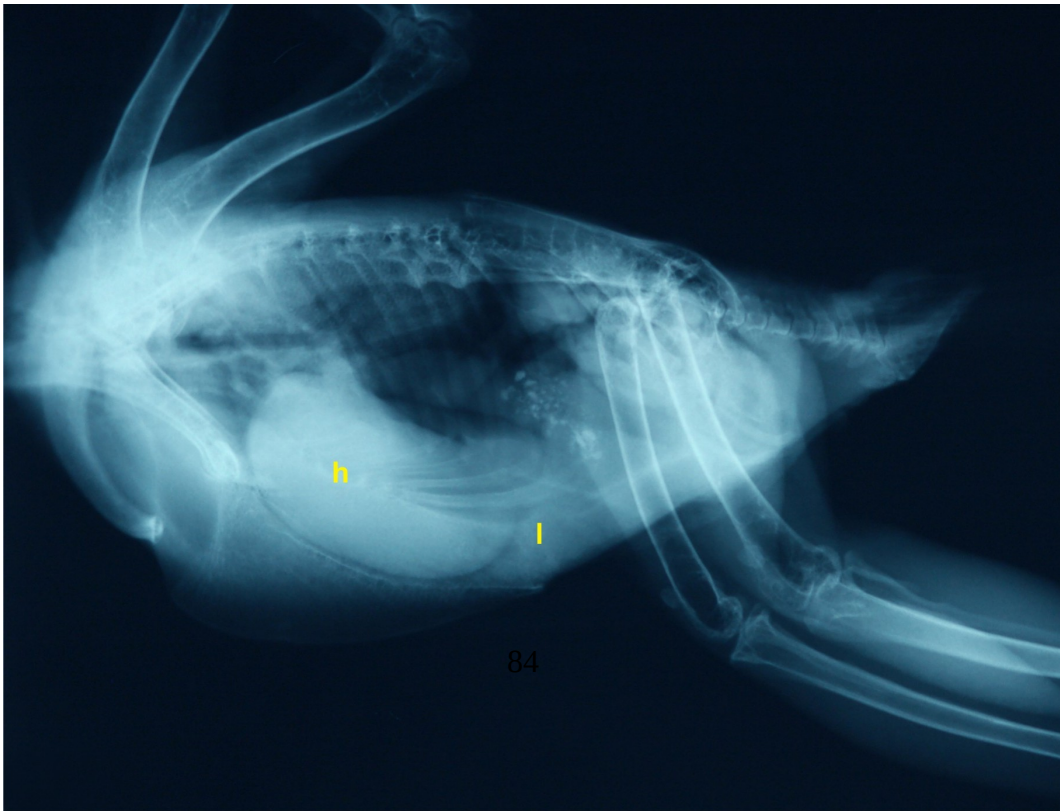

Fig.49 A saker falcon presented with severe dyspnea and exercise intolerance. lateral survey radiograph showed massively enlarged heart (h) shadow (cardiomegaly) and the apex of the heart became more rounded in appearance. The liver (l) was displaced caudally by the enlarged heart. The size of the heart (apex to base dimension) in this bird measured 65 mm. This condition may be caused by myxomatous valvular degeneration, endocarditis or secondary to chronic diseases.

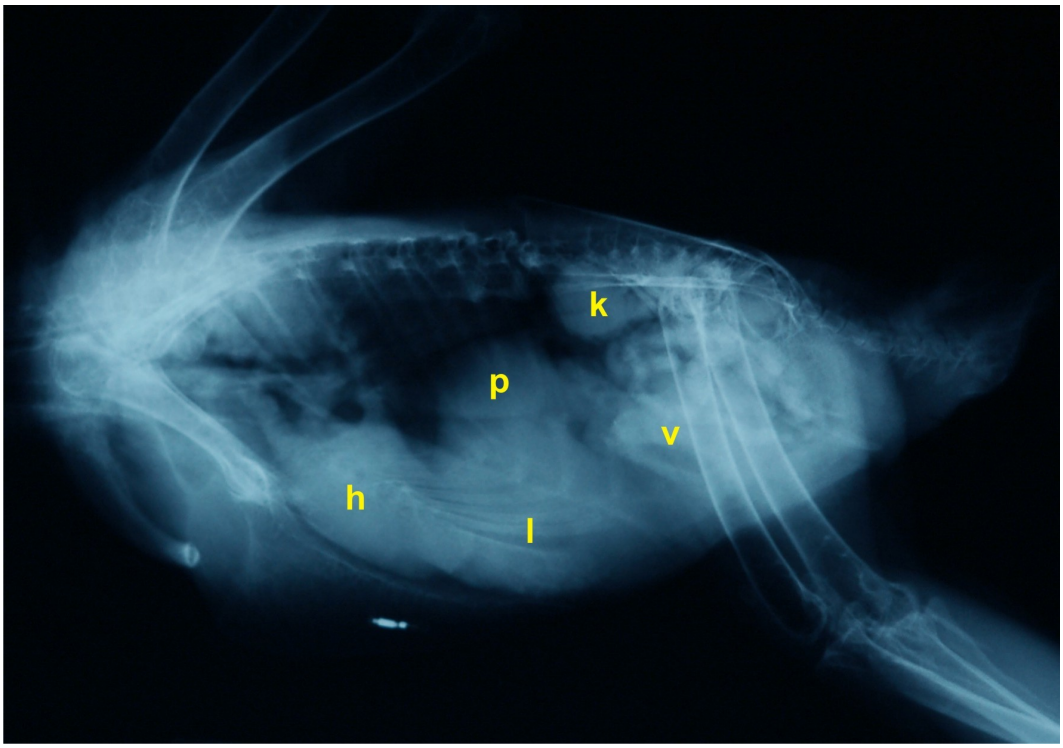

Fig.50 A saker falcon presented for health screening. Lateral survey radiograph revealed enlarged liver (l) shadow displacing the proventriculus (p) dorsally and ventriculus (v) caudodorsally. Slightly increased renal density with severely enlarged cranial lobe of the kidney (k) shadows (nephromegaly). Heart (h).

4:2: Endoscopy

4:2:1: Esophago - ingluvioscopy

The endoscopic examination of the esophagus and crop (esophago-ingluvioscopy) of the total birds examined **(N=898**) revealed **717**(79.84%) healthy falcons (fig.51). **44(**4.90%) falcons were diagnosed with trichomoniasis. **31**(3.45%) falcons were diagnosed with candidiasis. **29**(3.23%) falcons showed paleness of the crop mucosa (fig.52). **16(**1.78%) falcons had decomposed food material in the crop (fig.53). **15**(1.67%) falcons were diagnosed with Foreign body in the crop or esophagus (fig.54). **13**(1.45%) falcons had an Injury to the crop mucosa, and **12**(1.34%) falcons were found infested with *Physaloptera* spp. worms (fig.55) attached to the esophageal wall and another **12**(1.34%) falcons showed discolouration (redness) of crop mucosa. **Six** (0.67%) falcons showed bacterial lesions on their crop mucosa. In **2**(0.22%) cases, stuck bones in the thoracic esophagus (fig.56) were detected by endoscopy and only one falcon was diagnosed with displaced esophageal wall (fig.57). These endoscopic findings are presented in **table** (**8**).

Table 8: Esophago-ingluvioscopy results in captive saker falcons **(N=898)** examined at Fahad Bin Sultan Falcon Center, Riyadh, Kingdom of Saudi Arabia From July12, 2011, to July11, 2012.

Pathological findings	No. of birds diagnosed	Percentage (N=898)
Trichomoniasis	44	4.90
Candidiasis	31	3.45
Paleness of crop mucosa	29	3.23
Decomposed food in the crop	16	1.78
Foreign body in the crop and/ or esophagus	15	1.67
Injury to crop mucosa	13	1.45
Discolouration of crop mucosa	12	1.34
Physaloptera spp. Worms	12	1.34
Bacterial lesions	6	0.67
Stuck bone in the esophagus	2	0.22
Displaced esophageal wall	1	0.11
Total	**181**	**20.16**

*Of the total falcons (**N=898**) examined, **717**(79.84%) birds had no detectable abnormality.

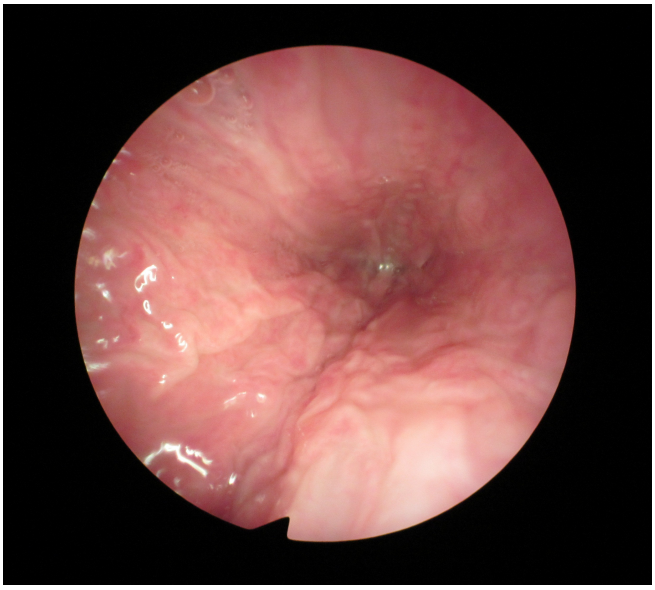

Fig.51 Endoscopic view of the upper digestive tract of a saker falcon showing normal crop mucosa.

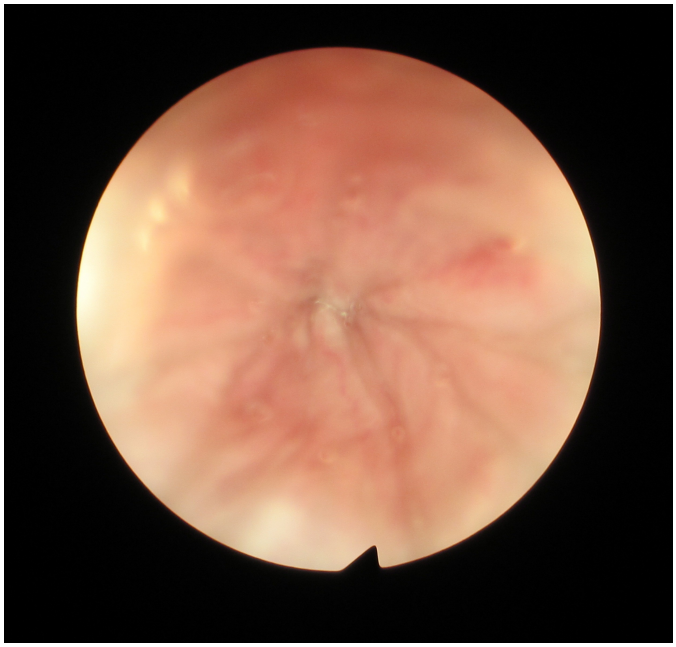

Fig.52 Endoscopic view of the upper digestive tract of a saker falcon showing paleness of crop mucosa as the result of anaemia.

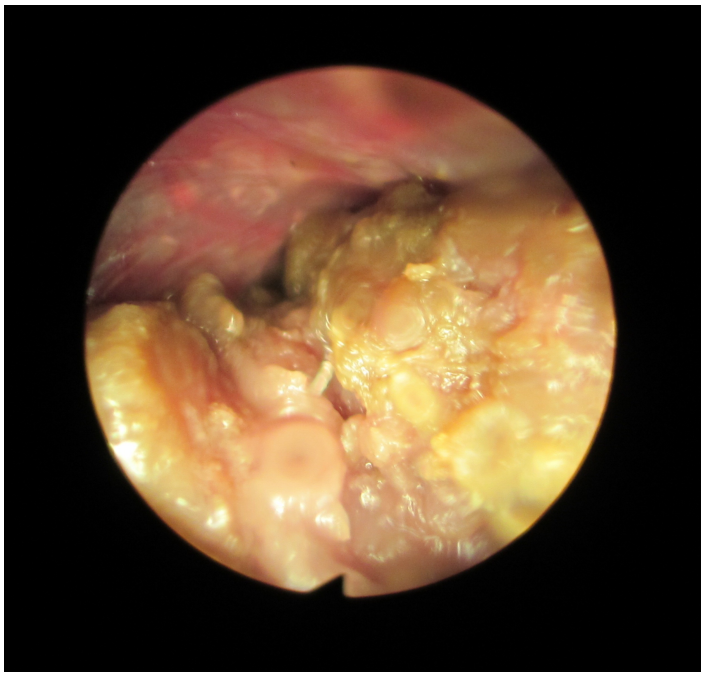

Fig.53 Endoscopic view of the upper digestive tract of a saker falcon showing decomposed food in the crop (sour crop).

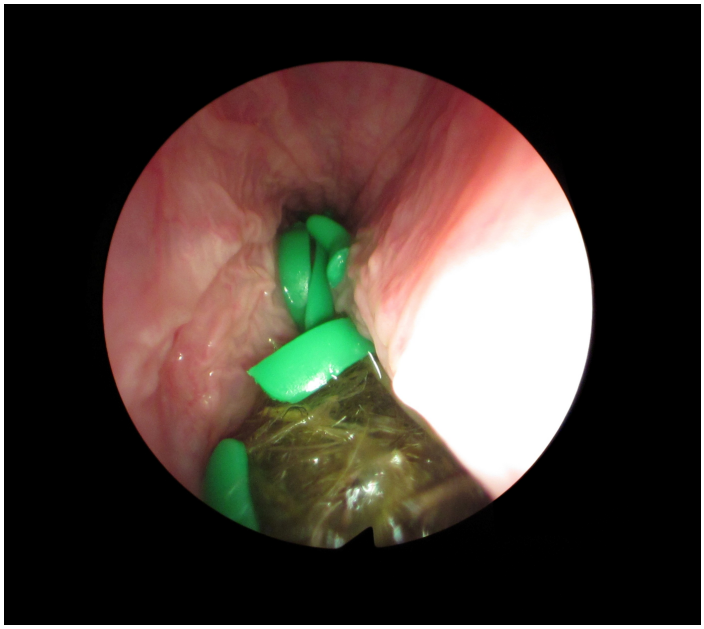

Fig.54 Endoscopic view of the upper digestive tract of a saker falcon showing presence of casting and foreign materials (synthetic strands from artificial turf) in the crop, causing complete obstruction of esophageal lumen.

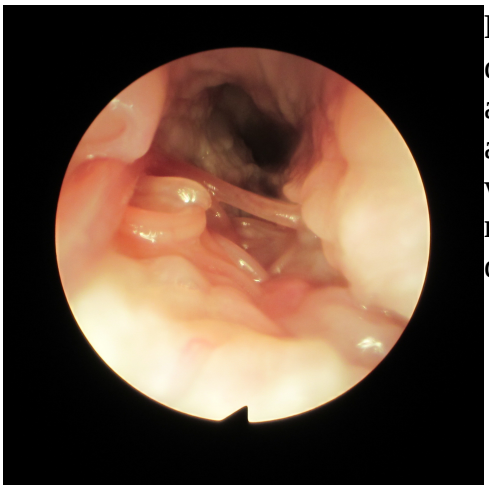

Fig.55 Endoscopic view of the upper digestive tract of a saker falcon showing an adult *Physaloptera* spp worms attached to the e was an incident routine endosco digestive tract.

Fig.56 Endoscopic view of the upper digestive tract of a saker falcon showing stuck bone in the thoracic esophagus.

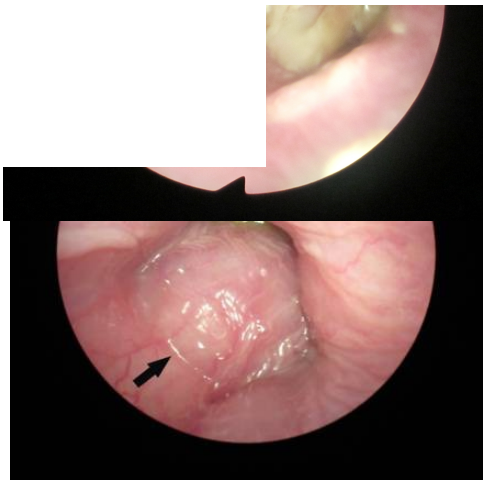

Fig.57 Endoscopic view of the thoracic esophagus of the saker falcon showing displaced esophageal wall (arrow) due to direct pressure caused by a massively enlarged thyroid gland, causing partial obstruction of the lumen of the thoracic esophagus

4:2:1:1: Verification of endoscopic findings of trichomoniasis, candidiasis and bacterial infection

4:2:1:1:1: Trichomoniasis

Trichomoniasis is a parasitic disease caused by a flagellated protozoan *trichomonas gallinae*. The disease, known in falconry terminology as frounce, is typically characterized by the appearance of white to yellow caseous lesions, most commonly found in the upper digestive tract of falcons including the crop and esophagus. Falcon usually acquired the disease by eating infected pigeon or dove. Trichomoniasis is the first most common prevalent disorder affecting the crop and esophagus of the falcons examined. The endoscopic finding of trichomoniasis (fig.58 and 59) was confirmed by observing *Trichomonas gallinae* on wet-mount preparations or by demonstrating the parasite (fig.60) on air dried stained smear of the sample obtained from the lesions visualized during endoscopic procedure.

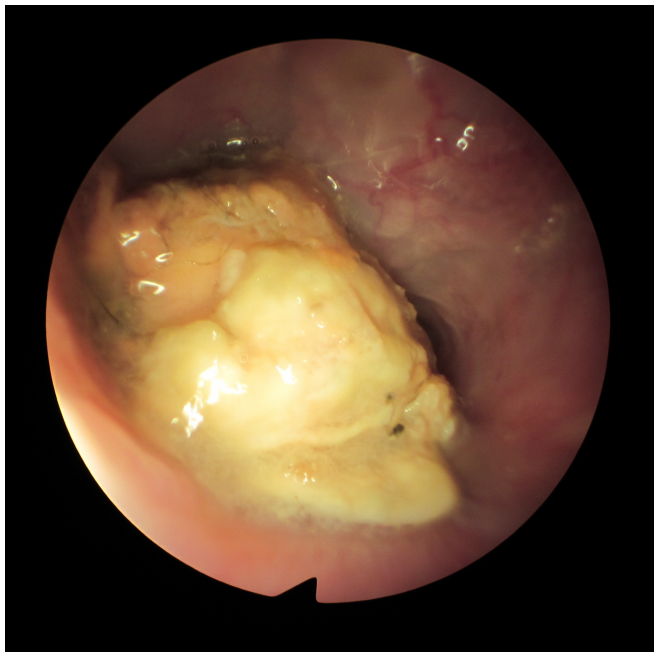

Fig.58 Endoscopic view of the thoracic esophagus of a saker falcon showing a large nodular, caseous trichomoniasis growth attached to the

wall of the thoracic esophagus causing almost complete obstruction of esophageal lumen. The growth was not palpable from the crop, therefore illustrating the need to examine the upper digestive tract by endoscopy.

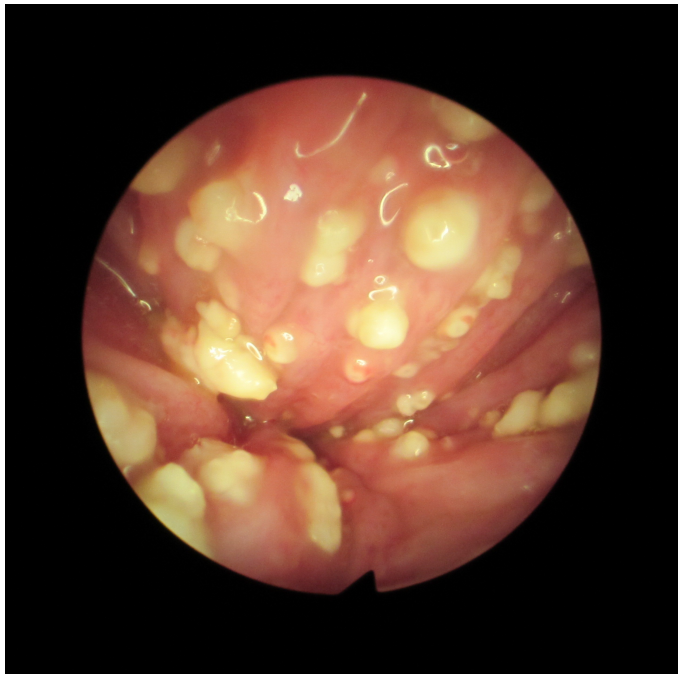

Fig.59 Endoscopic view of the upper digestive tract of a saker falcon showing multi nodular trichomoniasis growth attached to the wall of the crop (confirmed by cytology).

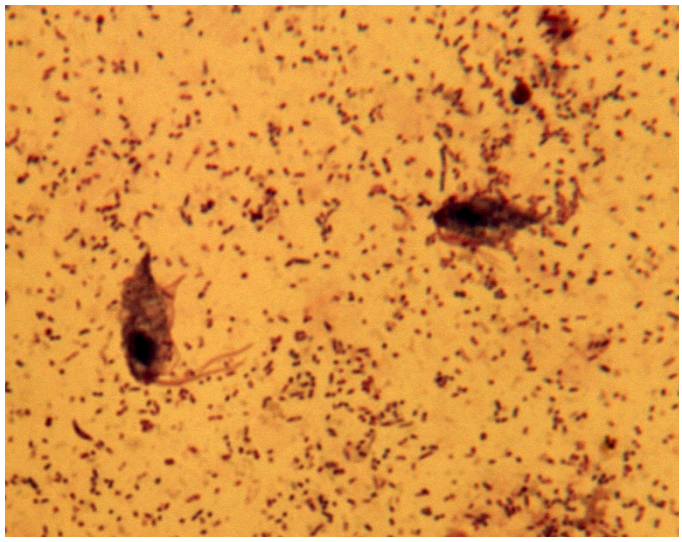

Fig.60 Smear from the upper digestive tract of a saker falcon with trichomoniasis showing *Trichomonas gallinae* (Diff Quick stain, x1000).

4:2:1:1:2: Candidiasis

Candidiasis is a fungal disease caused by yeasts of the genus *Candida*.The disease in falcons mainly affects the mucosal membrane of the crop and is characterized by the presence of amorphous diphtheritic membranes that are whitish gray to gray-green in colour. Candidiasis is the second most prevalent disorder encountered affecting the crop of the falcons examined. The endoscopic finding of candidiasis (fig.61) was confirmed by cytological observation of Candida blastospores (fig.62) on the samples obtained from the lesions in the crop.

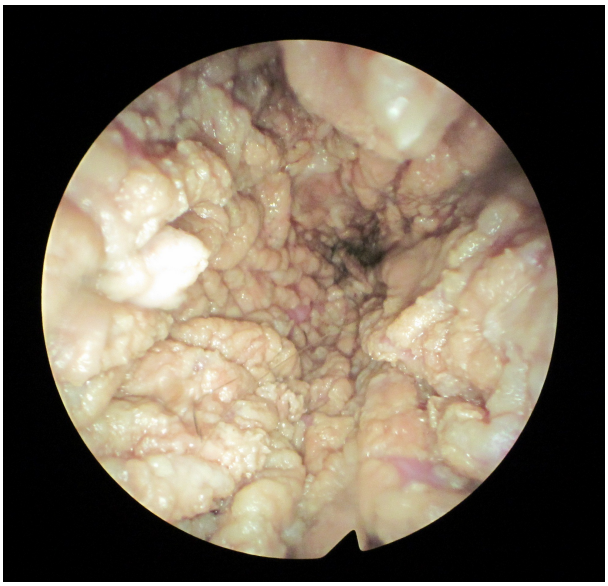

Fig.61 Endoscopic view of the crop of a saker falcon affected with clinical candidiasis. This falcon presented with a history of reduced appetite, flicking food and progressive weight loss. Note the gray "Turkish towel" appearance of the mucous membrane caused by infection with *Candida* species (confirmed by cytology).

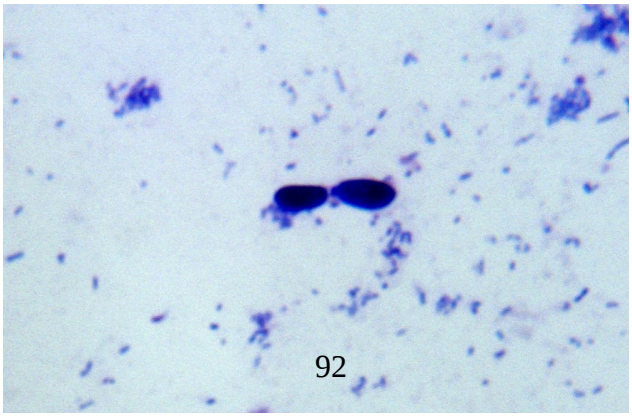

Fig.62 Smear from the upper digestive tract of a saker falcon with candidiasis showing Candida blastospores (Diff Quick stain, x1000).

4:2:1:13: bacterial infection

Inflammation of the crop (Ingluvitis) caused by bacterial infection was observed in 6 of the examined falcons. The endoscopic finding of bacterial lesions (fig.63) in the crop was verified by cytological demonstration of bacteria on the samples obtained from the lesions in the crop (fig.64).

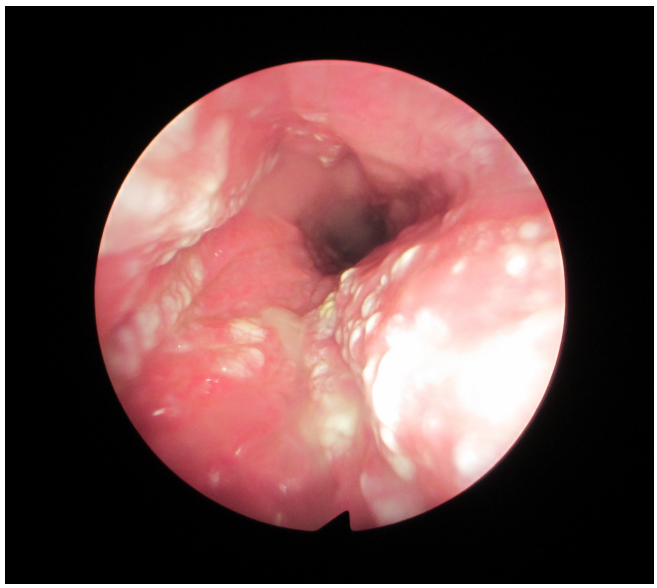

Fig.63 Endoscopic view of the upper digestive tract of a saker falcon showing extensive white caseous bacterial lesions in the crop (confirmed by cytology).

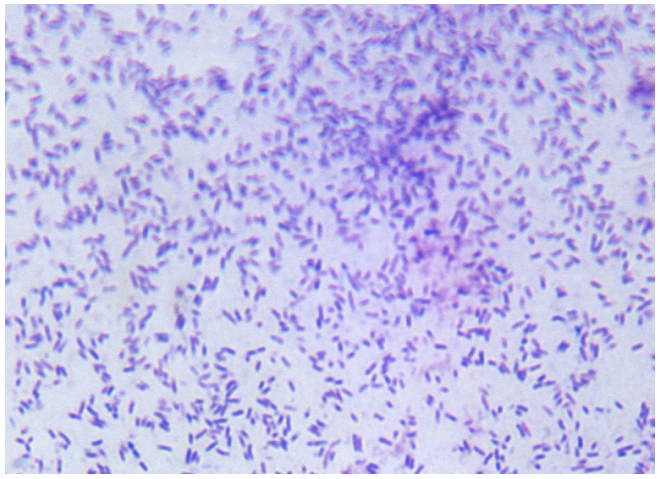

Fig.64 Smear from the crop of a saker falcon with severe bacterial ingluvitis obtained during endoscopic procedure, showing numerous bacterial rods (Diff Quick stain, x1000).

4:2:2: Tracheoscopy

Of the total falcons (**N-898**) that presented for clinical examination, endoscopic examination of the trachea (tracheoscopy) was performed selectively on **288** falcons. It was performed only on those birds with breathing abnormalities, or change or loss of voice, and/or when the radiographs showed abnormalities in the respiratory system of the examined bird, as this might be indicative of a pathological problem in this anatomical site. The result of endoscopic examination revealed no abnormality in **258**(89.58%) falcons. **13**(4.51%) falcons were diagnosed with syringeal aspergilloma(fig.65), **10(**3.47%**)** birds showed foreign body in the trachea (fig.66), **4**(1.39%) falcons were diagnosed with displaced trachea and **3(**1.04%**)** falcons showed presence of excessive accumulation of mucous in the trachea (fig.67). These endoscopic findings are presented in **table** (**9**)

Table 9: Tracheoscopy results in captive saker falcons **(n=288)** examined at Fahad Bin Sultan Falcon Center, Riyadh, Kingdom of Saudi Arabia From July12, 2011, to July11, 2012.

Pathological findings	No. of birds diagnosed	Percentage (n=288)
Aspergilloma in the syrinx	13	4.51
Foreign body in the trachea	10	3.47
Displaced trachea	4	1.39
Increased mucous in the trachea	3	1.04
Total	**30**	**10.42**

*Of the total falcons (**n=288**) examined, **258**(89.58%) birds had no detectable abnormality.

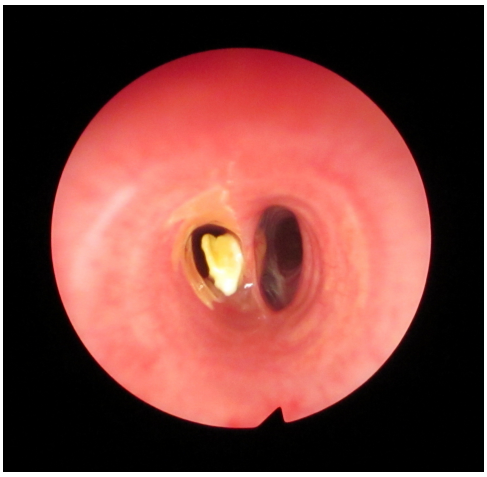

Fig.65 Endoscopic view of the trachea of a saker falcon showing unilateral aspergilloma in the bifurcation of the trachea partially occluding the right bronchus.

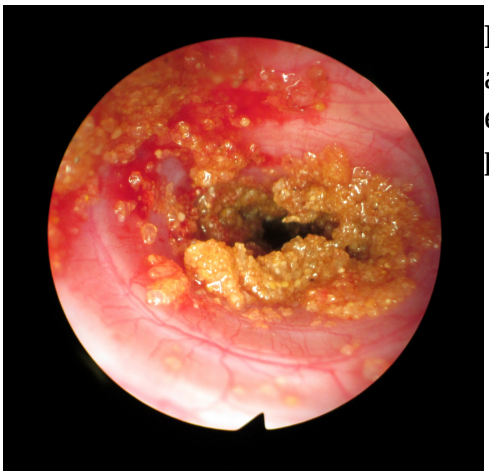

Fig.66 Endoscopic view of the trachea of a saker falcon showing presence of excessive amounts of sand in the proximal part of the trachea.

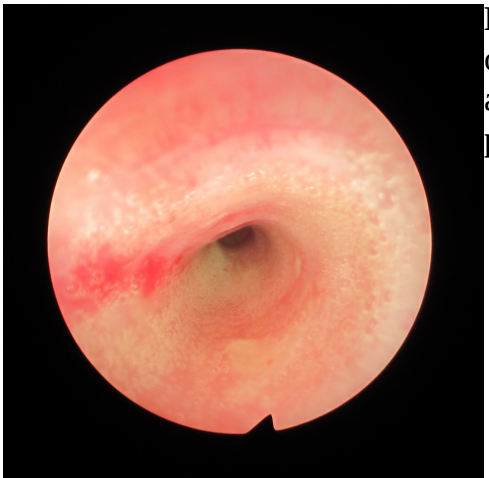

Fig. 67 Endoscopic view of the trachea of a saker falcon showing excessive accumulation of mucous in the proximal part of the trachea.

4:2:3: Laparoscopy

Of the total falcons (**N=898**) presented for clinical examination, endoscopic examination of the air sacs and pulmonary base (laparoscopy) was performed selectively on **26** birds as requested by the falconers. It was performed only on those birds with breathing abnormalities and when the radiographs showed abnormal shadows in the lung fields and/or air sacs (eg.focal density). The result of endoscopic examination revealed **17** falcons with aspergillosis, while **9** Falcons were found infested with filarial worms (air sac worms) of the genus *Serratospiculum*.

4:2:3:1: Verification of endoscopic finding of aspergillosis

Aspergillosis is an infectious, non contagious fungal disease of domestic and wild birds caused by ubiquitous soil saprophytes of the genus *Aspergillus*. It is one of the most feared infectious diseases in falcons. The disease mainly affects the respiratory system particularly the lungs and air sacs, the infection is usually acquired through inhalation of the fungal spores from the environment. In falcons examined white to yellow granulomatus lesions are commonly seen in the caudal thoracic and abdomoinal air sacs.The endoscopic finding of aspergillosis (fig.68) in falcons examined was confirmed by cytological demonstration of haphae and/or fungal spores (fig.69) on the biopsy samples obtained from lesions during endoscopic procedure.

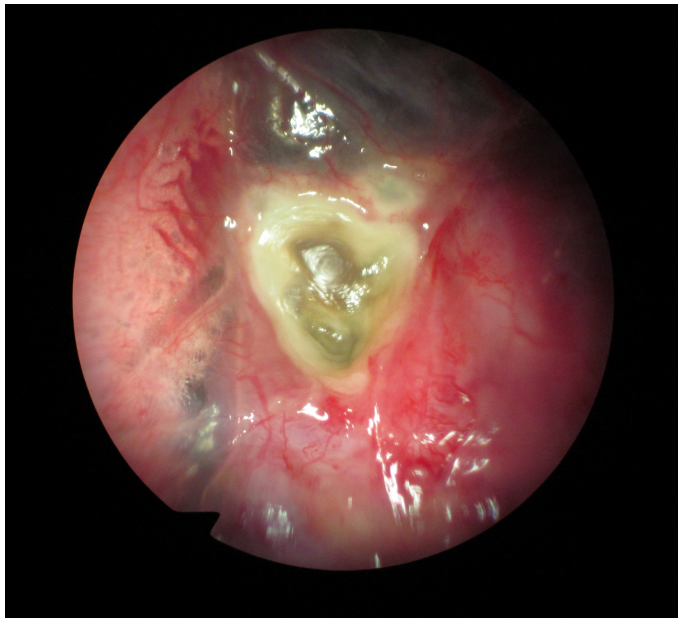

Fig.68 Endoscopic view of the air sac and pulmonary base of a saker falcon showing aspergilloma in the lung and thoracic air sac wall (confirmed by cytology).

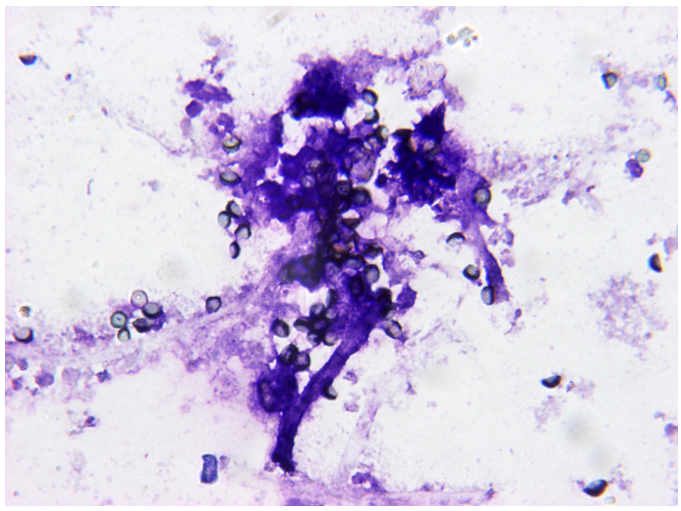

Fig.69 Smear from the air sac of a saker falcon with aspergillosis obtained during endoscopic procedure, showing aspergillus spores and hyphae (Diff Quick stain, x1000).

4:3: Haematology

The results of haematological examination of **898** falcons showed that **136**(15.14%) falcons had no changes in their haematological picture. **455**(50.67%) falcons were diagnosed with increased Hb and PCV values, while **37**(4.12%) birds showed low Hb and PCV values. In **213**(23.72%) falcons the WBC counts was high, while in **38**(4.23%) birds it was low. **350** (38.98%) falcons were diagnosed with heterophilia with or without toxic changes and **68**(7.57%) birds with heteropenia with or without cytotoxicity. **73**(8.13%) falcons showed lymphocytosis in their blood films and **19**(2.11%) birds had lymphocytopenia. **139**(15.48%) falcons were diagnosed with monocytosis. **461**(51.34%) falcons showed eosinophilia. **429**(47.77%) birds were diagnosed with thrombocytosis and **26**(2.90%) birds with thrombocytopenia, and **81**(9.02%) falcons were found infected with *Haemoproteus* species (**table 10 and 11**). Out of all falcons examined only 4 birds showed basophils in their haemogram.

Table 10: Haematological findings in captive saker falcons **(N=898)** examined at the Fahad Bin Sultan Falcon Center, Riyadh, Kingdom of Saudi Arabia from July 12, 2011, to July11, 2012.

Parameters	Categories	No. of birds diagnosed	Percentage (N=898)	Minimum- Maximum Values obtained	Mean±SE	Reference values
HB (g/dl)	High	455	50.67	16.6 – 21.0	17.94 ± 0.04	11.5 – 16.5
	Normal	406	45.21	11.5 – 16.5	15.20 ± 0.06	
	Low	37	4.12	7.70 – 11.4	10.49 + 0.13	
PCV (%)	High	455	50.67	49.1 – 63.20	54.49 ± 0.13	38 – 49
	Normal	406	45.21	38.0 – 49.0	46.04 ± 0.15	
	Low	37	4.12	23.30 – 37.60	33.38 ± 0.57	
WBC (×10^9/l)	High	213	23.72	11.55 – 120	20.63 ± 0.87	3.8 – 11.5
	Normal	647	72.05	3.80 – 11.50	7.39 ± 0.07	
	Low	38	4.23	1.80 – 3.70	3.01 ± 0.08	
Heterophils (×10^9/l)	High	350	38.98	5.82 – 96.00	12.27 ± 0.51	2.6 – 5.8
	Normal	480	53.45	2.60 – 5.80	4.16 ± 0.040	
	Low	68	7.57	0.28 – 2.57	1.81 ± 0.07	
Lympbocytes (×10^9/l)	High	73	8.13	4.22 – 15.80	5.58 ± 0.21	0.8 – 4.2
	Normal	806	89.76	0.80 – 4.20	2.23 ± 0.03	
	Low	19	2.11	0.38 – 0.76	0.61 ±0.02	
Monocytes (×10^9/l)	High	139	15.48	0.82 – 11.00	1.45 ± 0.10	0 – 0.8
	Normal	759	84.52	0 – 0.80	0.16 ± 0.01	
Eosinophils (×10^9/l)	High	461	51.34	0.22 – 4.90	0.61 ±0.02	0 – 0.2
	Normal	437	48.66	0 – 0.20	0.11 ± 0.004	
Basophils (×10^9/l)	High	0	0	0	0	0 – 0.4

	Normal	898	100	0 – 0.37	0.001 ± 0.0005	
Thrombocytes (×10^9/l)	High	429	47.77	25.20 – 198.4	39.55 ± 0.80	12 – 25
	Normal	443	49.33	12 – 25	20.82 ± 0.17	
	Low	26	2.90	1 – 11.8	8.27 ± 0.58	

*Reference values ranges for haematological parameters for saker falcon by Samour (2008).

Table 11: Haematological findings based on changes in haematological parameters, presence of heterophil toxicity and haemoparasitic infection, in captive saker falcons (**N=898**) examined at the Fahad Bin Sultan Falcon Center, Riyadh, Kingdom of Saudi Arabia from July 12, 2011, to July 11, 2012 .

Result	No. of birds diagnosed	Percentage (N=898)
HB & PCV High	455	50.67
HB & PCV Normal	406	45.21
HB & PCV Low	37	4.12
WBC High	213	23.72
WBC Normal	647	72.05
WBC Low	38	4.23
Heterophils High not toxic	114	12.69
Heterophils High toxic	236	26.28
Heterophils Normal not toxic	354	39.42
Heterophils Normal toxic	126	14.03
Heterophils Low not toxic	39	4.34
Heterophils Low toxic	29	3.23
Lympbocytes High	73	8.13
Lympbocytes Normal	806	89.76
Lympbocytes Low	19	2.12
Monocytes High	139	15.48
Monocytes Normal	759	84.52
Eosinophils High	461	51.34
Eosinophils Normal	437	48.66
Basophils High	0	0.00
Basophils Normal	898	100.00
Thrombocytes High	429	47.77
Thrombocytes Normal	443	49.33
Thrombocytes Low	26	2.90
Haemoproteus spp.	81	9.02
NAD	136	15.14

*No Abnormality Detected (NAD).

4:3:1: Toxic heterophilic changes (toxic heterophils)

Heterophils are the most common leukocytes found in the falcon haemogram. Normal heterophils of a saker falcon are round in shapes characterized by brick red, enlongated intracytoplasmic granules and bilobed nuclei (fig.70). Mature heterophils may exhibit toxic changes in response to severe systemic illnesses. Toxic changes in heterophils observed in the blood of the falcons examined included increased cytopasmic basophilia, vacuolization, nuclear degeneration (loss of lobulation), loss of granulation and abnormal granulation (toxic granules).The degree of toxic changes observed in the falcons examined varies from a slight to moderate (fig.71) or marked (fig.72 and 73) toxic changes, based on Campbell (1995) scales of +1 to +4. Out of the **898** falcons examined, **391**(43.54%) falcons were diagnosed with toxic heterophilic changes (**Table 11**), of these **70**(7.80%) falcons showed marked toxic changes.

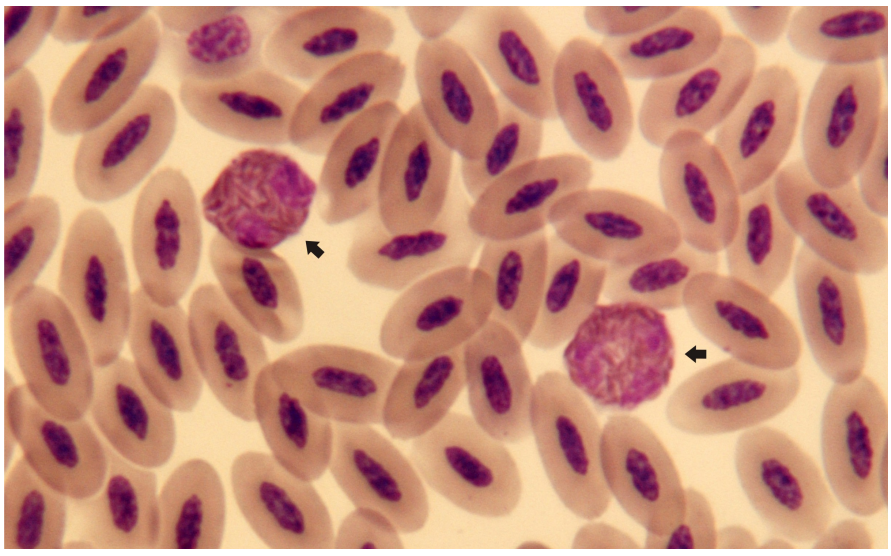

Fig.70 Normal heterophils (arrows) of a saker falcon (modified Wright-Giemsa stain, x1000).

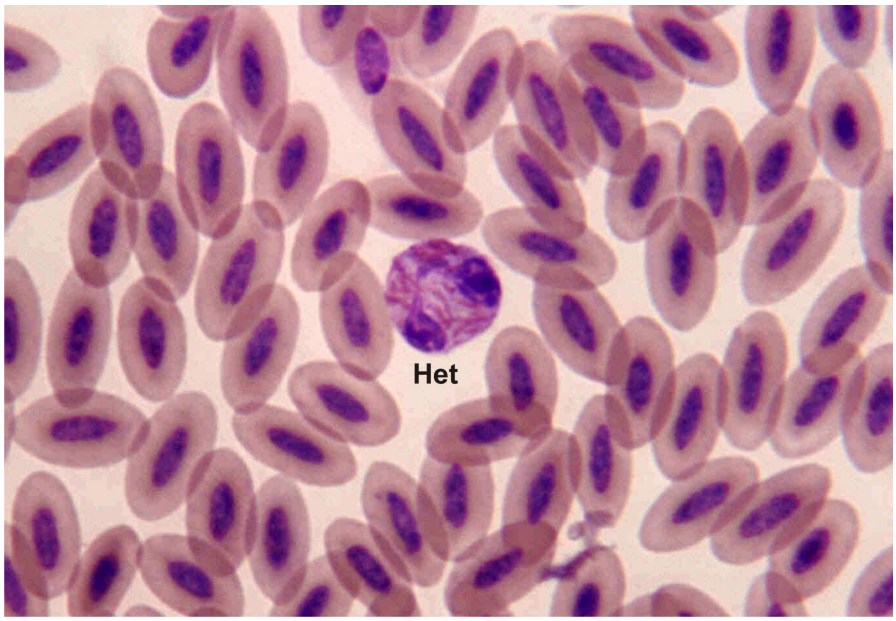

Fig. 71 Heterophil (Het) of a saker falcon with moderate toxic changes. (modified Wright-Giemsa stain, x1000).

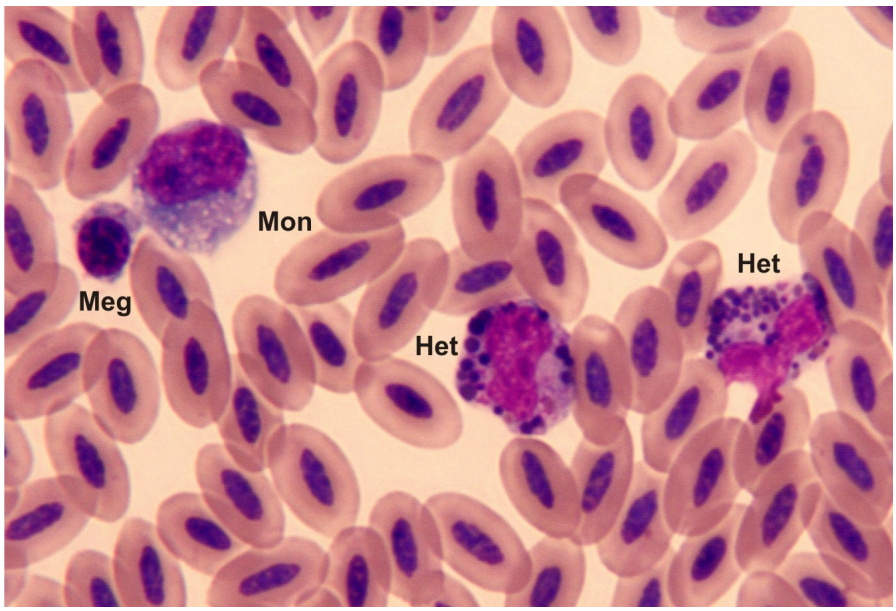

Fig.72 Heterophils (Het) of a saker falcon with severe toxic changes (+4) showing loss of granulation, toxic granules and loss of lobulation of the nucleus. Monocytes (Mon) and Megathrombocyte (Meg) (modified Wright-Giemsa stain, x1000).

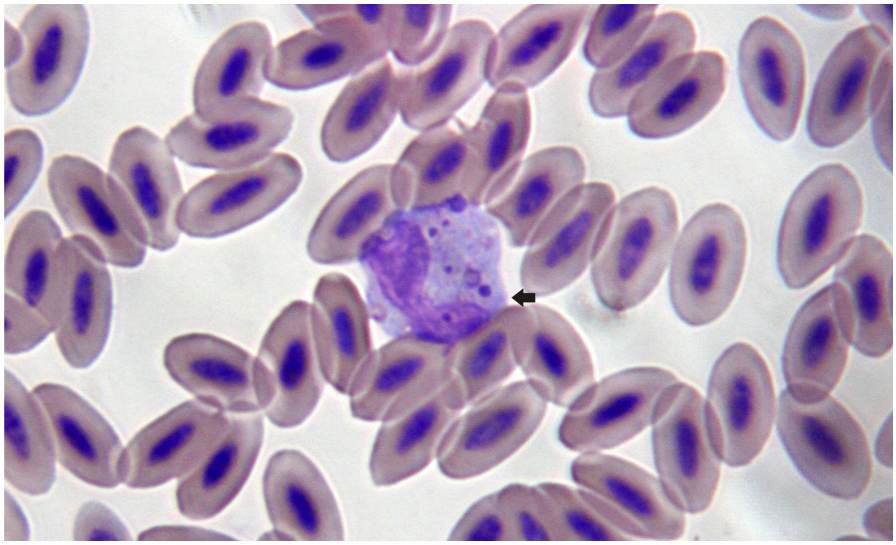

Fig.73 A heterophil (arrow) of a saker falcon showing marked toxicity (+4) including increased cytoplamic basophilia, toxic granules, cytoplasmic vacuolization, loss of granulation and loss of lobulation (modified Wright –Giemsa stain, x1000).

4:3:2: Haematological findings in falcons (n=138) with homogeneous increased radiopacity of the lung fields and air sacs

Homogeneous increased radiopacity of the lung fields and air sacs was the first most prevalent radiographic abnormality recorded in the falcons examined. This abnormality is more likely to be seen in birds with bacterial respiratory infection. Haematological findings observed in falcons with this radiographic abnormality are presented in **table** (**12**).

The most common haematological changes recorded in falcons with this radiographic abnormality included eosinophilia (66.37%), thrombocytosis (65.22%) and heterophilia (64.50%).

Table 12: Haematological findings in captive saker falcons **(n=138)** with **homogeneous** increased radiopacity of the lung field and/or air sacs**.**

Parameters	Categories	No. of birds diagnosed	Percentage (n=138)	Minimum-Maximum Values obtained	Mean±SE	Reference values
HB (g/dl)	High	77	55.80	16.60 – 20.10	17.95 ± 0.10	11.5 – 16.5
	Normal	55	39.85	11.60 – 16.50	15.09 ± 0.16	
	Low	6	4.35	7.70 – 11.20	10.10 ± 0.54	
PCV (%)	High	77	55.80	49.10 – 45.94	54.55 ± 0.33	38 – 49
	Normal	55	39.85	38.20 – 49.00	45.94 ± 0.41	
	Low	6	4.35	24.30 – 37.30	32.30 ± 2.10	
WBC (×10^9/l)	High	69	50.00	11.80 – 99.50	19.95 ± 1.62	3.8 – 11.5
	Normal	64	46.38	3.87 – 11.50	7.67 ± 0.25	
	Low	5	3.62	2.38 – 3.60	3.07 ± 0.22	
Heterophils (×10^9/l)	High	89	64.50	5.90 – 78.80	13.28 ± 1.13	2.6 – 5.8
	Normal	43	31.16	2.66 – 5.60	4.05 ± 0.13	
	Low	6	4.34	1.07 – 2.10	1.78 ± 0.14	
Lympbocytes (×10^9/l)	High	20	14.50	4.37 – 15.80	5.89 ± 0.55	0.8 – 4.2
	Normal	113	81.88	0.80 – 4.20	2.39 ± 0.07	
	Low	5	3.62	0.44 – 0.72	0.61 ± 0.04	
Monocytes (×10^9/l)	High	20	14.50	0.82 – 4.85	1.90 ± 0.23	0 – 0.8
	Normal	118	85.50	0.00 – 0.78	0.15 ± 0.02	
Eosinophils (×10^9/l)	High	92	66.37	0.22 – 4.90	0.69 ± 0.06	0 – 0.2
	Normal	46	33.33	0.00 – 0.20	0.07 ± 0.01	
Basophils (×10^9/l)	High	0	0	0	0	0 – 0.4
	Normal	138	100.00	0	0	
Thrombocytes (×10^9/l)	High	90	65.22	25.50 – 198.40	41.36 ± 2.18	12 – 25
	Normal	45	32.60	12.70 – 25.00	19.97 ± 0.50	
	Low	3	2.18	1.00 – 11.80	6.60 ± 3.12	

4:3:3: Haematological findings in falcons (n=102) with non-homogeneous increased radiopacity of the lung fields and air sacs

Non-homogeneous increased radiopacity of the lungs fields and air sacs was the second most prevalent radiographic abnormality recorded in the falcons examined. This radiographic abnormality is more likely to be seen in falcons with aspergillosis. Haematological findings observed in falcons with this radiographic abnormality are presented in **table** (**13**).

The most common haematological changes recorded in falcons with this radiographic abnormality included monocytosis (78.43%), eosinophilia (73.53%), thrombocytosis (72.55%) and heterophilia (61.77%).

Table 13: Haematological findings in captive saker falcons **(n=102)** with **non-homogeneous** increased radiopacity of the lung fields and/or air sacs**.**

Parameters	Categories	No. of birds diagnosed	Percentage (n=102)	Minimum-Maximum Values obtained	Mean±SE	Reference values
HB (g/dl)	High	50	49.02	16.60 – 20.30	17.82 ± 0.12	11.5 – 16.5
	Normal	41	40.20	11.50 – 16.40	15.07 ± 0.21	
	Low	11	10.78	10.00 – 11.10	10.59 ± 0.11	
PCV (%)	High	50	49.02	49.70 – 62.00	54.18 ± 0.38	38 – 49
	Normal	41	40.20	38.00 – 49.00	45.96 ± 0.58	
	Low	11	10.78	31.90 – 37.50	35.30 ± 0.65	
WBC (×10^9/l)	High	55	53.92	11.55 – 120.00	24.35 ± 2.21	3.8 – 11.5
	Normal	45	44.12	4.00 – 11.50	7.51 ± 0.27	
	Low	2	1.96	2.00 – 2.40	2.20 ± 0.20	
Heterophils (×10^9/l)	High	63	61.77	6.16 – 96.00	17.45 ± 1.72	2.6 – 5.8
	Normal	35	34.31	2.60 – 5.80	4.02 ± 0.15	
	Low	4	3.92	0.76 – 2.40	1.77 ± 0.38	
Lympbocytes (×10^9/l)	High	16	15.69	4.33 – 13.00	5.72 ± 0.50	0.8 – 4.2
	Normal	84	82.35	0.94 – 4.00	2.17 ± 0.07	
	Low	2	1.96	0.38 – 0.42	0.40 ± 0.02	
Monocytes (×10^9/l)	High	80	78.43	0.82 – 11.00	1.35 ± 0.15	0 – 0.8
	Normal	22	21.57	0.00 – 0.47	0.07 ± 0.03	
Eosinophils (×10^9/l)	High	75	73.53	0.22 – 2.40	0.62 ± 0.05	0 – 0.2
	Normal	27	26.47	0.00 – 0.20	0.06 ± 0.01	
Basophils (×10^9/l)	High	0	0	0	0	0 – 0.4
	Normal	102	100	0	0	
Thrombocytes (×10^9/l)	High	74	72.55	25.20 – 149.00	44.68 ± 2.76	12 – 25
	Normal	25	24.51	14.20 – 25.00	21.31 ± 0.61	
	Low	3	2.94	1.70 – 8.16	5.88 ± 2.09	

4:3:4: Haematological findings in falcons (n=98) with excessive sand in the gastrointestinal tract

Excessive amount of sand in the gastrointestinal tract was the third most common radiographic abnormality recorded in the falcons examined. This results from falconers feeding their birds on the ground rather than platforms. Haematological findings recorded in falcons with this radiographic abnormality are presented in **table** (**14**)

Eosinophilia (95.92%) and, increased Hb and PCV values (69.39%) were the most common haematological changes recorded in falcons with this radiographic abnormality.

Table 14: Haematological findings in captive saker falcons **(n=98)** with **Excessive sand** in the gastrointestinal tract.

Parameters	Categories	No. of birds diagnosed	Percentage (n=98)	Minimum - Maximum Values obtained	Mean±SE	Reference values
HB (g/dl)	High	68	69.39	16.60 – 21.00	17.96 ± 0.11	11.5 – 16.5
	Normal	30	30.61	12.60 – 16.50	15.24 ± 0.19	
	Low	0	0	0	0	
PCV (%)	High	68	69.39	49.70 – 63.20	54.60 ± 0.36	38 – 49
	Normal	30	30.61	38.70 – 49.00	46.28 ± 0.52	
	Low	0	0	0	0	
WBC (×10^9/l)	High	18	18.37	12.20 – 33.70	17.40 ± 1.63	3.8 – 11.5
	Normal	76	77.55	4.20 – 11.42	7.67 ± 0.22	
	Low	4	4.08	2.87 – 3.50	3.08 ± 0.14	
Heterophils (×10^9/l)	High	36	36.74	5.90 – 27.33	9.71 ± 0.90	2.6 – 5.8
	Normal	54	55.10	2.70 – 5.80	4.37 ± 0.11	
	Low	8	8.16	0.96 – 2.50	1.87 ± 0.22	
Lympbocytes (×10^9/l)	High	9	9.18	4.21 – 6.62	5.25 ± 0.27	0.8 – 4.2
	Normal	87	88.78	0.89 – 4.10	2.25 ± 0.08	
	Low	2	2.04	0.60 – 0.76	0.68 ± 0.08	
Monocytes (×10^9/l)	High	7	7.14	0.84 – 2.28	1.11 ± 0.19	0 – 0.8
	Normal	91	92.86	0.00 – 0.79	0.07 ± 0.01	
Eosinophils (×10^9/l)	High	94	95.92	0.22 – 2.70	0.53 ± 0.03	0 – 0.2
	Normal	4	40.08	0.00 – 0.20	0.15 ± 0.05	
Basophils (×10^9/l)	High	0	0	0	0	0 – 0.4
	Normal	98	100.00	0.00 – 0.24	0.00 ± 0.00	
Thrombocytes (×10^9/l)	High	53	54.08	25.40 – 52.00	33.96 ± 0.89	12 – 25
	Normal	42	42.86	14.00 – 25.00	19.89 ± 0.52	
	Low	3	3.06	7.0 – 10.12	0.93 ± 1.62	

4:3:5: Haematological findings in falcons (n=90) with splenomegaly

Enlargement of the spleen shadow (splenomegaly) was the fourth most prevalent radiographic abnormality recorded in the falcons examined. splenomegaly was most commonly observed in falcons with haemoproteid infection. Haematological findings recorded in falcons with this radiographic abnormality are presented in **table** (**15**)

Eosinophilia (85.56%) and thrombocytosis (63.33%) were the most common haematological changes recorded in falcons with this radiographic abnormality.

Table 15: Haematological findings in captive saker falcons **(n=90)** with **splenomegaly**.

Parameters	Categories	No. of birds diagnosed	Percentage (n=90)	Minimum-Maximum Values obtained	Mean±SE	Reference values
HB (g/dl)	High	49	54.44	16.6 – 20.90	18.06 ± 0.15	11.5 – 16.5
	Normal	26	28.89	11.5 – 16.40	14.37 ± 0.34	
	Low	15	16.67	9.40 – 11.40	10.77 ± 0.13	
PCV (%)	High	49	54.44	49.70 – 63.20	54.84 ± 0.49	38 – 49
	Normal	26	28.89	38.00 – 48.90	44.21 ± 0.86	
	Low	15	16.67	27.80 – 36.70	32.79 ± 0.66	
WBC (×10^9/l)	High	29	32.22	11.90 – 61.70	21.71 ± 2.19	3.8 – 11.5
	Normal	59	65.56	5.00 – 11.50	8.18 ± 0.23	
	Low	2	2.22	2.90 – 3.10	3.00 ± 0.10	
Heterophils (×10^9/l)	High	50	55.55	5.88 – 53.00	12.46 ± 1.38	2.6 – 5.8
	Normal	34	37.78	2.65 – 5.80	4.52 ± 0.14	
	Low	6	6.67	0.65 – 2.53	1.94 ± 0.29	
Lympbocytes (×10^9/l)	High	11	12.22	4.24 – 6.97	5.28 ± 0.29	0.8 – 4.2
	Normal	77	85.56	1.10 – 4.08	2.44 ± 0.07	
	Low	2	2.22	0.63 – 0.71	0.67 ± 0.04	
Monocytes (×10^9/l)	High	16	17.78	0.82 – 5.34	1.84 ± 0.37	0 – 0.8
	Normal	74	82.22	0.00 – 0.70	0.07 ± 0.02	
Eosinophils (×10^9/l)	High	77	85.56	0.22 – 1.90	0.58 ± 0.04	0 – 0.2
	Normal	13	14.44	0.00 – 0.20	0.06 ± 0.02	
Basophils (×10^9/l)	High	0	0	0	0	0 – 0.4
	Normal	90	100	0.00 – 0.37	0.00 ± 0.00	
Thrombocytes (×10^9/l)	High	57	63.33	26.00 – 96.00	37.13 ± 1.47	12 – 25
	Normal	31	34.44	12.00 – 25.00	20.15 ± 0.71	
	Low	2	2.22	8.00 – 11.80	9.90 ± 1.90	

*Of all falcons diagnosed with splenomegaly, **78**(86.7**%)** falcons were found to be infected with *Haemoproteus* species.

4:3:6: Haematological findings in falcons (n=85) with hepatomegaly

Enlargement of the liver shadow (hepatomegaly) was the fifth most prevalent radiographic abnormalities recorded in the falcons examined. Haematological findings recorded in falcons with this radiographic abnormality are presented in **table (16).**

The most common haematological changes recorded in falcons with hepatomegaly included, eosinophilia (72.94%), thrombocytosis (68.23%) and heterophilia (67.06%).

Table 16: Haematological findings in captive saker falcons **(n=85)** with **hepatomegaly**.

Parameters	Categories	No. of birds diagnosed	Percentage (n= 85)	Minimum-Maximum Values obtained	Mean±SE	Reference values
HB (g/dl)	High	21	24.71	16.60 – 20.40	18.04 ± 0.26	11.5 – 16.5
	Normal	53	62.35	11.50 – 16.50	14.35 ± 0.18	
	Low	11	12.94	9.40 – 11.40	10.51 ± 0.17	
PCV (%)	High	21	24.71	49.70 – 61.50	54.50 ± 0.81	38 – 49
	Normal	53	62.35	38.20 – 49.00	43.84 ± 0.48	
	Low	11	12.94	27.80 – 37.30	34.21 ± 0.88	
WBC (×10^9/l)	High	49	57.65	11.90 – 61.70	25.28 ± 1.63	3.8 – 11.5
	Normal	32	37.65	4.00 – 11.50	7.86 ± 0.37	
	Low	4	4.70	2.30 – 3.10	2.85 ± 0.18	
Heterophils (×10^9/l)	High	57	67.06	5.82 – 53.00	18.19 ± 1.47	2.6 – 5.8
	Normal	20	23.53	2.74 – 5.60	4.25 ± 0.18	
	Low	8	9.41	0.30 – 2.40	1.38 ± 0.26	
Lympbocytes (×10^9/l)	High	15	17.65	4.25 – 8.07	5.50 ± 0.28	0.8 – 4.2
	Normal	67	78.82	1.00 – 4.10	2.63 ± 0.10	
	Low	3	3.53	0.59 – 0.71	0.66 ± 0.03	
Monocytes (×10^9/l)	High	32	37.65	0.82 – 4.85	1.74 ± 0.17	0 – 0.8
	Normal	53	62.35	0.00 – 0.70	0.15 ± 0.03	
Eosinophils (×10^9/l)	High	62	72.94	0.22 – 2.60	0.66 ± 0.06	0 – 0.2
	Normal	23	27.06	0.00 – 0.20	0.07 ± 0.01	
Basophils (×10^9/l)	High	0	0	0	0	0 – 0.4
	Normal	85	100.00	0	0	
Thrombocytes (×10^9/l)	High	58	68.23	26.40 – 115.00	46.75 ± 2.19	12 – 25
	Normal	21	24.71	14.00 – 25.00	21.01 ± 0.68	
	Low	6	7.06	1.0 – 10.00	6.83 ± 1.52	

4:3:7: haematological findings in falcons (n=81) with haemoprotied infection

Haemoproteus tinnunculi is a protozoan blood parasite commonly seen in the falcons examined. Diagnosis *of H. tinnunculi* was confirmed by demonstrating the

halter-shaped intraerythrocytic gametocytes that partially encircled the nucleus, appeared pigmented, and occupied more than 50% of the cytoplasm (fig.74). Infection with this parasite was associated with an increase in splenic size (fig.33). Haematological findings recorded in falcons examined with haemprotied infection are presented in **table** (**17**).

Eosinophilia (85.19%) and thrombocytosis (61.73%) were the most common haematological changes recorded in falcons with haemoprotied infection.

Table 17: Haematological findings in captive saker falcons **(n=81)** with **Haemoproteid** infection.

Parameters	Categories	No. of birds diagnosed	Percentage (n=81)	Minimum-Maximum Values obtained	Mean±SE	Reference values
HB (g/dl)	High	47	58.02	16.60 – 20.50	18.07 ± 0.15	11.5 – 16.5
	Normal	22	27.16	11.50 – 16.40	14.20 ± 0.38	
	Low	12	14.82	10.10 – 11.40	10.94 ± 0.09	
PCV (%)	High	47	58.02	49.70 – 63.00	54.87 ± 0.48	38 – 49
	Normal	22	27.16	38.00 – 48.90	43.82 ± 0.94	
	Low	12	14.82	29.00 – 36.70	33.24 ± 0.07	
WBC (×10^9/l)	High	23	28.39	11.90 – 44.50	19.81 ± 1.94	3.8 – 11.5
	Normal	56	69.14	5.00 – 11.50	8.03 ± 0.24	
	Low	2	2.47	2.90 – 3.10	3.00 ± 0.10	
Heterophils (×10^9/l)	High	40	49.38	5.58 – 40.00	11.31 ± 1.20	2.6 – 5.8
	Normal	35	43.21	2.65 – 5.80	4.54 ± 0.14	
	Low	6	7.41	0.65 – 2.53	1.94 ± 0.20	
Lympbocytes (×10^9/l)	High	10	12.34	4.24 – 6.97	5.31 ± 0.32	0.8 – 4.2
	Normal	69	85.19	1.08 – 4.06	2.35 ± 0.37	
	Low	2	2.47	0.63 – 0.71	0.67 ± 0.04	
Monocytes (×10^9/l)	High	13	16.05	0.82 – 5.34	1.85 ± 0.42	0 – 0.8
	Normal	68	83.95	0.00 – 0.70	0.07 ± 0.02	
Eosinophils (×10^9/l)	High	69	85.19	0.22 – 1.90	0.58 ± 0.04	0 – 0.2
	Normal	12	14.81	0.00 – 0.20	0.09 ± 0.02	
Basophils (×10^9/l)	High	0	0	0	0	0 – 0.4
	Normal	81	100.00	0	0	
Thrombocytes (×10^9/l)	High	50	61.73	26.00 – 53.00	34.44 ± 0.98	12 – 25
	Normal	29	35.80	13.00 – 25.00	20.27 ± 0.69	
	Low	2	2.47	8.00 – 11.80	9.90 ± 1.90	

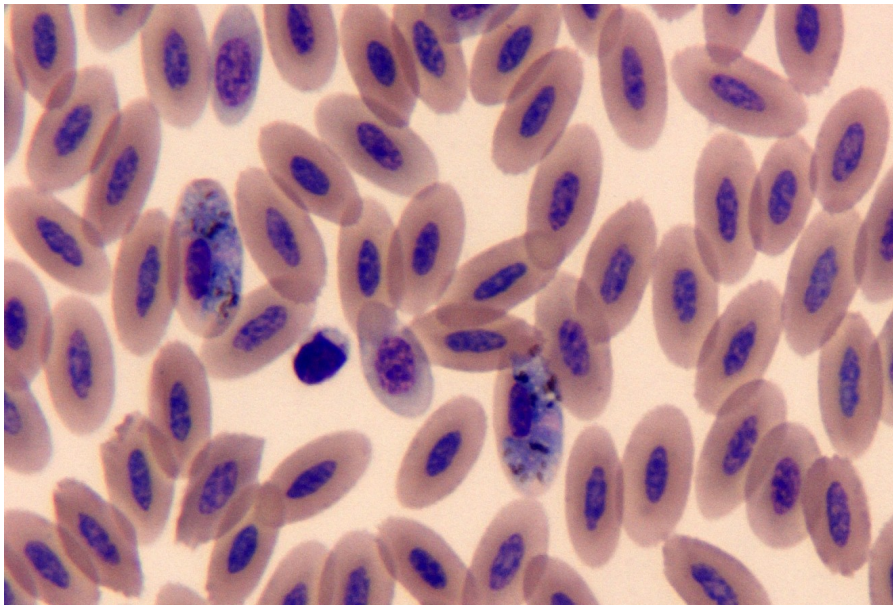

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Fig.74 *Haemoproteus tinnunculi* gametocytes in a blood smear from a saker falcon (modified Wright- Giemsa stain, x1000).

CHAPTER FIVE

DISCUSSION

5:1: Clinical history

Out of the total number of **898** falcons which presented for clinical examinations at the falcon center, **407** (45.32%) birds were presented for health screening and **491** (54.68%) birds because of sickness. The sick birds exhibited varied clinical signs. However, dyspnoea, poor flight performance, reduced appetite and passage of lime green feces were the most common complaints by the falconers. During the moulting period these birds were kept either free-flying or tied in a single platform-type perch placed around the moulting room, and provided with white desert sand as substrate. The basic diet of these birds mainly consisted of freshly killed or frozen quails, live or freshly killed pigeons, chicken liver and old day chicks; however, some falconers used mutton, beef, camel meat, gerbil, mice and shot birds (collar doves) as food items for their falcons.

5:2: Radiography

In the present study the two most common radiographic abnormalities in falcons were observed in the respiratory system. The changes varied from a homogeneous to non-homogeneous increased radiopacity of the lung fields and/or air sacs. Other common findings, in descending order of frequency, were excessive amounts of sand in the gastrointestinal tract, splenomegaly, hepatomegaly, gas formation in the gastrointestinal tract with or without an accompanying dilatation, fractures, overdistended air sacs and reduction or loss of muscle mass. No radiographic abnormalities of the trachea and syrinx were evident other than displacement of the trachea. Displacement of the trachea was observed in three falcons associated with large caseous trichomoniasis growth within the esophagus it was also observed in an adult saker falcon presenting with a large swelling in the neck, along with intermittent regurgitation, inspiratory dyspnea, and squawking sound. Lateral radiography revealed a large, oval soft tissue mass (5x3.5cm) on the caudal region of the neck and thoracic inlet displacing the distal portion of the trachea ventrally. On further examination, the mass was diagnosed as an enlarged thyroid gland. The present radiographic findings of tracheal abnormalities in falcons are in agreement with those of Newell *et al* (1997) who reported that alterations of the trachea and syrinx in birds were uncommon and that most of them were not radiographically evident. Massive overdistension of the abdominal airsacs, so-called

air trapping, suggested syringeal stenosis or obstruction of the *Ostium pulmonare* of the abdominal air sacs. Air trapping is caused by a valve like action of stenoid syrinx, making expiration more difficult (Krauwald-Junghanns, 1996). In the falcons examined, air trapping was commonly observed in birds with non-homogeneous increased radiopacity of the lung fields and air sacs. Endoscopic examination of the trachea and syrinx did not always reveal an abnormality. When present, caseous or granulomatus lesions in the tracheobronchial syrinx could be caused by infection with *Aspergillus* spp. as reported by Forbes (1996a) and *Pseudomonas aeruginosa* according to the findings of Naldo and Samour (2004a) or due to *Trichomonas gallinae* as stated by Samour *et al.*, (1995). However, air trapping can also be caused by mechanical obstruction due to fungal plaque attached to the walls of the *Ostium pulmonare* of the caudal thoracic and abdominal airsacs as suggested by Naldo, (2008) probably this was the most common cause of air trapping. The first and second most common radiographic findings observed in falcons were homogeneous (15.37%) and non-homogeneous (11.36%) increased radiopacity of the lung field and/or air sacs. These radiographic findings were similar to those reported by Naldo and Samour (2004b) in falcons in Saudi Arabia. A homogeneous increased radiopacity is a nonspecific sign of pneumonia. In bacterial pneumonia, the increased pulmonary radiopacity tends to be more homogeneously distributed, whereas in mycotic infections it is often irregular or patchy (Krautwald-junghanns, 1996). A rounding of the caudal border of the lung field may represent congestion of this area in chronic diseases (Krautwald-junghanns, 1996). In the present study air sacs abnormalities were most commonly observed lesions in falcons. The membrane of normal air sacs was not usually visible radiographically, but in later stages of chronic inflammatory diseases, including airsacculitis, the membrane may be well defined (Krautwald and Trinkaus, 2000). Radiographic changes that may indicate inflamed air sacs include diffuse thickening, nodular infilteration (Mc Millan, 1994), or simply the presence of an air sacs line not evident in a normal bird. The possible causes of airsacculits are multiple and include bacterial, chlamydial, viral, and fungal infection (Tully and Harrison, 1994). hypovitaminosis A, and parasitism (Samour and Naldo, 2001). Radiographically, a homogeneously increased radiopacity of air sacs was seen with bacterial air sacculitis it may also result from

superimposed fat (Naldo, 2000). However, a non-homogeneous increased radiopacity of the thoracic and abdominal air sac field suggests chronic mycotic airsacculitis. Focal radiodense lesions of the air sacs suggestive of granulomas are commonly seen in birds with mycotic or mycobacterial infection (Silverman, 1990). Airsacculitis in raptors is often a sequelae of infestation with *Serratospiculum* species. However, fungal infection caused by *Aspergillus* species is the most common pathologic condition of the air sacs in raptors (Forbes, 1996a). aspergillosis typically affects the thoracic air sacs. Soft-tissue masses in the lung parenchyma, thickening of air sacs membranes, or radiodense areas within the air sac field, suggest aspergillosis. In the present study, infections caused by *Aspergillus fumigatus* and, to lesser extent, *Aspergillus flavus* were responsible for most cases of non-homogeneous and localized soft-tissue radiopacities of the thoracic and abdominal air sac fields. The causative organisms were isolated from samples taken during endoscopic procedure. In falcons with clavicular air sacs disease, radiography revealed a loss of air space and an increased radiopacity of the clavicular air sac on the affected side. This condition may be caused by foreign-body penetration or aspergillosis (Forbes, 1996a). However at FBSFC aspergillosis was the only cause associated with this condition. Overdistension of the axillary portion of the clavicular air sac was observed in some falcons with increased respiratory distress. This condition is seen in birds either due to stenosis or overexertion of the lower respiratory tract leading to severe dyspnea (Krautwald-Junghanns, 1996). Radiographic abnormalities of coelomic cavity and digestive tract were also commonly observed. In the present study, thickening of the wall of the esophagus and/ or crop was observed in falcons with endoparasitic infestation, chronic inflammation due to an infection with *Candida* species or *Trichomonas gallinae* and ammonium chloride toxicosis. These findings are similar to those of Naldo (2000) who reported that thickened crop or esophageal wall can be seen in birds with endoparasitic infestation or *Candida* infection. Candidiasis was recently described in falcons in Saudi Arabia. Endoscopic examination of affected falcons demonstrated amorphous white - gray to gray - green diphtheritic membranes affecting the crop (Samour and Naldo, 2002b). Similarly, infection with *Trichomonas gallinae* can cause thickening of the esophagus and crop wall (Samour

and Naldo, 2003). In the present study two types of trichomoniasis growths, nodular or membranous, were observed in the crop and/or esophagus. The nodular type of growth was visible radiographically as small to large soft tissue densities whereas the membranous type of growth was characterized by the presence of a plaque like growth mostly causing thickening of the crop wall if the lesion was well developed. Endoscopy is a useful tool for diagnosing the membranous type. In the present study thickened stomach wall (proventriculus and/or ventriculus) was observed in falcons with chronic trichomoniasis and bacterial infections, ammonium chloride toxicosis and in two birds with clinical signs, suggestive of visceral form of ND infection. A recent meal or casting material in the stomach was visible radiographically as either moderately or highly radiodense masses, depending on the type of food items offered. This was a usual finding in falcons that presented for examination before the stomach was emptied of casting material or after a recent meal. The presence of food in the crop more than 4 hours after feeding suggests that crop emptying is delayed, which may lead to an acute toxemia commonly called sour crop. One common practice among inexperienced falconers is to allow falcons to gorge themselves with an exceedingly large meal in attempt to rapidly increase the body weight of their birds, as the result of over feeding, ingluvial stasis and impaction develops, leading to sour crop. This condition is commonly seen in falcons in Saudi Arabia. Gas formation in the gastrointestinal tract is rare in birds, and any gas present should be considered abnormal (Mc Millan, 1994). Extensive gas filling of the intestines may indicate paralytic ileus, bacterial gastroenteritis, or impaction (Krautwald and Trinkaus, 2000). Uniformaly distended gastrointestine tract is most commonly associated with functional ileus due to viral or bacterial infection, lead toxicity, septicemia (Mc Millan, 1994), parasitism or foreign-body ingestion. In the present study, gas formation in the gastrointestinal tract, with or without an accompanying dilatation, was commonly observed in falcons with bacterial gastroenteritis, trichomoniasis, endoparasitism, septicemia, lead toxicosis, ammonium chloride toxicosis or impaction of gastrointestinal tract with sand. The third most common radiographic finding was the presence of excessive a mounts of sand (10.91%) in the gastrointestinal tract. This results from falconers feeding their birds on the ground rather than on platforms. Obstruction, sand impaction or

dilatation of the gastrointestinal tract with sand is often seen in captive falcons in the Kingdom of Saudi Arabia particularly during moulting period. At FBSFC coccidiosis in falcons caused by the genus *Caryospora* was most commonly observed associated with sand impaction probably due to contamination of sand with the droppings of infected birds in the sand room (moulting room). Falcons that feed on shot birds occasionally ingest lead. The lead collects in the ventriculus and appears as radiopaque material, either as dust particles, fragments, or whole lead shot. In the Kingdom of Saudi Arabia, lead toxicosis is the most commonly diagnosed toxic disease in captive falcons (Samour and Naldo, 2002a).The fourth most common radiographic finding was splenomegaly (10.02%), the spleen is relatively small round organ located on the right side of the intersection between the proventriculus and ventriculus, and can be easily observed radiographically on the lateral view immediately above the caudal aspect of the proventriculus and it can be seen only on the ventrodorsal view if greatly enlarged. The size of the normal spleen measured along its length on the lateral view ranges from 9 -13.5 mm in saker falcons (Naldo and Samour, 2004b). A spleen which measures beyond this range is considered enlarged. Avian tuberculosis, lymphoma, chlamydophilosis, and some viral infections can cause splenic enlargement (Harcourt, 1996). Naldo and Samour (2004b) observed splenomegaly in falcon with bacterial septicemias and herpesviral hepatitis in Saudi Arabia, while Schmidt (1997) reported marked splenic enlargement during plasmodial infection in raptor and canaries. In the present study splenomegaly in falcons was most commonly observed associated with haemoproteid infection, the enlargement of this organ is related to gametocyte-infected erythrocyte being removed actively from the blood circulation. The hemozoin pigement produced by gametocytes deposited extensively in the spleen as the birds, immune system responds to infection. The consequence will be enlargement of spleen. This finding was similar to that recently reported by Rahim *et al* (2013b) in falcons in Saudi Arabia. The fifth most common radiographic finding was hepatomegaly (9.47%). In such cases, the proventriculus and ventriculus are often displaced dorsally and caudodorsally respectively on the lateral radiograph. However displacement of proventriculus and/or ventriculus was also commonly observed in association with extensive air trapping. Many infectious

diseases, such as chlamydophilosis, tuberculosis and inclusion body hepatitis are encountered with an enlargement of liver shadow in the radiograph (Naldo, 2008). At FBSFC hepatomegaly was commonly observed associated with chronic trichomoniasis possibly due to adverse toxic effects of the metabolites produced by this parasite on the liver of the bird. In addition amyloidosis is usually found associated with bumble foot and aspergillosis. On ventrodorsal view the liver shadow extends laterally past an imaginary line drawn from the coracoid to the acetabulum. However, a recent meal by a falcon can fill the proventriculus and ventriculus and spread the liver shadow so that it appears larger than normal. Ascites may accompany severe hepatitis and is seen as a diffuse increase in radiodensity of the entire coelomic cavity with the exception of the air-filled lungs, while no differentiation between air sac and inner organs can be made radiographically. Reduced size of the liver shadows (microhepatica) in falcons is commonly associated with generalized emaciation and poor nutrition (low condition), and according to our observation, this condition is most commonly seen in falcons after returning back from hunting trips, where the birds were exposed to prolonged starvation to reduce their body weight, over exertion due to extensive hunting, compounded by the prevalent cold weather in the hunting grounds. In the present study displaced liver shadow was commonly seen associated with extensive air trapping, severely enlarged heart shadow and massive gaseous distension of the stomach. Reports of abdominal hernias in birds are somewhat ambiguous. In the present falcons only one bird with abdominal hernia was reported; the radiograph showed loss of integrity of abdominal wall associated with projection of soft tissue mass consisting of displaced small intestinal loops. Bone fracture due to trauma (6.68%) was a common radiographic finding in falcons presenting for examination. Fractures commonly occur as a result of improper handling by novice keepers, car collision accidents during training or hunting, accidents inside moulting room, and accidental shooting of the falcon during trapping. Some falcons were presented to the falcon center with gunshot fracture and lead pellets were embedded in the body. Occasionally lead pellets were found during radiographic examinations of clinically normal falcons that were presented for health screening examination (pre - or post purchase examination). In the present study, up to 8 lead pellets have been found

embedded in different parts of the body of one saker falcon. Fractures of the ribs were the most common type of fractures detected, possibly due to the thin nature of the ribs which make it more likely to sustain to fracture when a falcon crash-landed during pursuit of its prey or during struggle on the ground with its prey. Fractures of the extremities were the second most type of fracture observed. In addition, fractures of the clavicle, scapula and coracoid were also observed. Several falcons that presented to the falcon center had an old healed fracture, most commonly of the ribs and/or extremites. Most of these falcons presented with healed fractures had unknown history because of the practice of Arab falconers selling or giving away unwanted birds without revealing their history to the new owner. In the present study, vertebral fractures, osteolytic and osteoarthritic changes or luxations were observed, located between the notarium and synsacrum on the sixth thoracic vertebra, which is the only free thoracic vertebra in the falcon. Falcons with this condition were presented with mild clinical signs of poor flight performance and lameness of one or both legs to more severe signs of paresis or leg paralysis. Muscular atrophy (disuse atrophy) was commonly observed associated with fracture of extremities, as results of impairment or lack of normal function of affected limb. Reduced or loss of muscle mass were commonly observed in falcons in low condition or in birds with chronic debilitating diseases. Osteoartheritis was commonly observed involving the shoulder joint as the result of old trauma. With the infectious processes, osteolysis was the predominant radiographic change. Fungal osteomyelitis may cause pronounced periosteal reaction or increased medullary opacity due to granuloma formation. Septic arthritis and osteomyelitis may develop secondary to open fractures, pododematitis, penetrating wounds, hematogenous sources, extension from air sacs diseases, or iatrogenic contamination (Smith and Smith, 1997). In falcons with acute septic arthritis joint effusion due to synovitis may be the only radiographic change. With advanced infection, destruction of articular cartilage results in loss of joint space and osteolysis and periosteal changes may develop in the metaphysis and epiphysis. Distal joints are commonly affected especially when the infection is secondary to septic pododermatitis. In the present study radiographic changes observed in falcons with pododermatitis ranged from soft-tissue swelling without an apparent bone involvement to osteolysis and

osteomyelitis of the digits or distal tarsometatarsus. In the present falcons examined only one juvenile bird with deformities (bowing) of long bones and ribs was reported, the condition suggestive of metabolic bone disorder. Radiographic changes in the urogenital system were also observed. On the lateral radiographic view, the kidneys are normally surrounded by air. Loss of the air shadow may indicate renal enlargement, presence of abdominal fat or fluid, or dorsal displacement of abdominal organs (Smith and Smith, 1997). In the present study an enlarged kidney shadow was commonly seen with the enlarged shadows of other organs such as liver or spleen. This finding was similar to those reported by Krautwald-Junghanns (1996) in others avian species. Renal gout and dehydration can produce increased renal radiodensity without enlargement (Smith and Smith, 1997). In the present study 15 birds with increased renal density with or without enlargement showed elevated uric acid level in their blood chemistry analysis.

The most common radiographic change in cardiovascular system observed in falcons examined was an increased radiodensity of heart shadow. This finding may be caused by pericardial effusion, pericarditis, pneumonia or airsacculitis (Naldo and Samour, 2004b). The body weight of an adult female saker falcon range from 900-1150g. The size of the normal heart measured from apex to base on the lateral radiographic view ranges from 39-46mm (Naldo and Samour, 2004b). Heart that measured beyond this range is considered enlarged. In the present study 10 falcons with radiographic evidence of cardiomegaly were detected; of these, one bird showed massively enlarged heart shadow. This condition in birds may be caused by myxomatous valvular degeneration, endocarditis, chronic anemia, marked fatty deposition, or secondary to chronic diseases (pox virus, pododermatitis) (McMillan, 1994). In the present study Alterations of the heart size and/or shape as the result of displacement caused by compression from extrinsic masses or pressure, were commonly observed with extensive air trapping, massively enlarged liver shadow or ascites and large granulomatus lesions present in the heart-lung and thoracic air sac fields. Reduced size of the heart shadow (microcardia) in falcons is commonly associated with hypovolemia and nutritional inadequancy. Similarly as in case of microhepatica, microcardia is commonly seen in falcons after returning back from hunting trips.

5:3: Endoscopy

5:3:1: Esophago - ingluvioscopy

The most common abnormality detected by endoscopic examination of the esophagus and crop in the birds were trichomonal lesions (4.9%). Trichomoniasis (frounce) is a widespread protozoal disease among falcons in the KSA and the Middle East as a whole (Samour *et al*, 1995). The occurrence of disease appears to be directly linked to the traditional Arab falconry practice of feeding live or freshly killed domestic pigeons (*Columbia livia*) which act as the main source of infection (Samour *et al*, 1995). In falcons infections with *Trichomonas gallinae* produce classical white yellow caseous lesions in the oropharynx, nasal cavities, infraorbital sinuses, crop, esophagus and tracheobronchial syrinx (Smour *et al*, 1995). In the present study two types of caseous growth were detected during routine endoscopic examination of the crop and esophagus, the nodular and membranous types. However, the occurrence of membranous type was less commonly observed than the nodular type which was more predominant. These endoscopic findings are in agreement with those of Samour and Naldo (2003) who reported the nodular and membraneous types of trichomonal caseous growth in the upper digestive tract of falcons in Saudi Arabia. In the present study trichomonal lesions were more commonly observed located in the crop than the esophagus. However in some birds both crop and esophagus were involved. In some cases ulceration of the crop and esophageal mucosa was found to be associated with large caseous trichomonal growth in these sites. Trichomonal infections of the thoracic esophagus are difficult to detect by palpation and considered to be dangerous, obstruction, stenosis even perforation of the esophagus were commonly observed as sequela to large trichomonal growth; therefore its diagnosis illustrates the need for endoscopic examination of this anatomical site. The diagnosis of trichomoniasis was confirmed by observing *Trichomonas gallinae* on wet-mount preparations and on air dried stained smears obtained from the lesions during endoscopic procedure. Infection with *Candidia* species (3.45%) was second most common disorder detected by endoscopy affecting the mucosal membrane of the esophagus and crop. Candidiasis (moniliasis) is a common mycotic infection of captive birds of prey (Heidenreich, 1997). Among *Candida* species, *Candida albicans* was the only species reported to

be associated with disease in captive falcon in Saudi Arabia (Smour and Naldo, 2002b). In the present study endoscopic examination of the esophagus and crop revealed amorphous diphtheritic membranes that were white to gray in color, affecting mainly the crop. The mucosal membrane of affected areas has a typical "Turkish towel" appearance. This type of lesion is a characteristic finding similar to that described by Heidenreich (1997) in captive birds of prey. The results of endoscopic examination were confirmed by observing the typical Candida blstospores on air dried stained smears obtained from lesions during endoscopic procedure. The third most common endoscopic finding was the paleness of crop mucosa (3.23%) which was commonly observed in anaemic birds. The fourth most common endoscopic finding associated with the sour crop (1.78%), where this condition results from the presence of decomposing food in the crop of falcons from a previous meal, causing crop stasis, a subsequent septicemia due massive bacterial proliferation in food may develop, frequently leading to the death of falcon (Redig, 1996). This condition is commonly reported in falcons in the Middle East (Naldo and Samour, 2004a). Other disorders affecting the crop and/ or esophagus detected by endoscopy in descending order of frequency including presence of foreign body such as sand, artificial truft strands and grass. Large quantity of foreign material can cause impaction of these sites. Injury to the crop or esophageal mucosa in falcon were more frequently caused by sharp bone fragment during ingestion of their meal. Discoularation (redness) of crop mucosa was observed, resulting from irritant effects of Ammonium chloride (NH4cl) administered to the falcons. Many falconers in the Arab Gulf countries routinely administer Ammonium chloride, best Known as "Shenadra" with the aim of improving their falcons' hunting ability. Despite the fact that most falconers are aware that ammonium chloride can kill their birds, they still continue to use it. Naldo and Samour (2004a) reported that of all falcons diagnosed with toxicosis in KSA, ammonium chloride toxicosis was the second most important being second only to lead toxicosis. *Physaloptera* species worms were found attached to the esophageal wall; these are round worms observed incidentally during routine endoscopic examination of the upper digestive tract. In 6 falcons with ingluvitis endoscopic examination revealed bacterial lesions (verified by cytology) which appeared as white smooth flattened colonies. Stuck or lodged bones in the

esophagus were observed in 2 falcons resulting from swallowing a large bone of pigeon's limbs. A case of thyroid hyperplasia, displacing thoracic esophageal wall as the result of direct pressure caused by massively enlarged thyroid gland, was recorded in one falcon. To our knowledge, this is the first report of a thyroid gland enlargement, diagnosed clinically as unilateral thyroid hyperplasia, in a live saker falcon. The bird presented with a history of intermittent regurgitation, inspiratory dyspnea and squawking sound. This condition was recently described by Rahim *et al* (2013a).

5:3:2: Tracheoscopy

The most common abnormality detected in the present sudy by endoscopic examination of the trachea was the presence of white to slight yellowish caseous granulomatous lesions (aspergillosis) at the syrinx area which was partially or completely obstructing the right or left bronchus. The results of endoscopic findings were verified by cytology. Cytological examination of specimens obtained from these lesions demonstrated *Aspergillus* species. Aspergillosis occurs frequently in birds of prey held in captivity (Friend and Franson, 1999). Change in the voice or respiratory noise, can be heard when the lesions involve the airways, specially the syrinx (Atkinson and Brojer, 1998).During the course of the study a mixed case of chronic tracheal (syringeal) and pulmonary (lung and air sacs) aspergillosis was diagnosed in an adult gyrfalcon. This condition was recently described by Rahim *et al* (2012). The bird presented with a 4-week history of severe dyspnea, exercise intolerance, depression and reduced appetite. Physical examination revealed slight emaciation. Haematological analysis showed leucocytosis, heterophilia, momocytosis, and thrombcytosis. Radiographic examination showed thickening of the air sac walls and increased radiopacity within the lung field. Caseous granulomatous lesions were observed during tracheoscopic and laparoscopic procedures. Cytological examination of specimens obtained from these lesions demonstrated *Aspergillus* species, which was isolated in culture and identified as *Aspergillus flavus*. In raptors, differential diagnosis of dyspnea caused by syringeal aspergilloma includes lesions at the tracheobronchial syrinx caused by pseudomoniasis and trichomoniasis. Samour and Naldo (2003) reported trichomonal

lesions at the syrinx area of falcons in Saudi Arabia. However, development of trichomonal lesions at the syrinx area is unusual and rare in the falcon. This type of syringeal trichomoniasis was not reported in the present study. This could be attributed to relatively low number of birds examined in the present study. The second abnormality detected was the presence of foreign body in the trachea including sand or feather danders stuck in the trachea of some falcons. Captive falcons have the tendency to face the dusty environment while kept in the moulting room (sand room) or tethered out in sand storms which are relatively common in desert areas during hunting and training season. Sometime, these particles find their way into the trachea and become stuck there. The third abnormality detected was remarkable displacement of the trachea associated with massive thyroid enlargement in one bird and large trichomonal growth within thoracic esophagus of 3 birds, as results of direct pressure to the trachea produced by these masses. The fourth abnormality detected was the presence of excessive accumulation of mucous in the trachea of 3 falcons probably as the result of faulty administration of liquid medicine by the falconer.

5:3:3: Laparoscopy

In the present study the most common abnormality detected by endoscopic examination of air sacs and pulmonary base (laparoscopy) was the presence of aspergillus lesions. Aspergillosis is a serious problem for falconers, being the commonest and most lethal disease in captive raptors (Tarello, 2011). Most cases of airsacculitis in the present falcons that were diagnosed based on radiographic findings were not confirmed by endoscopic examination because the owners declined laparoscopic testing. Therefore, the prevalence of aspergillosis in KSA is probably much higher. These findings were similar to those of Naldo and Samour (2004a) who reported that aspergillosis was the most common fungal disease diagnosed among falcons in Saudi Arabia. The diagnosis of aspergillosis in falcons on the basis of clinical signs alone is extremely difficult, particularly with regard to the chronic form of the disease in which the clinical signs are often non specific and variable while fungal mycelia are rarely visible in the body fluids or exudates. A definitive diagnosis of aspergillosis in birds required a combination of clinical and

physical examination as well as laboratory procedures including hematological and blood biochemical tests, radiography, endoscopic examination, cytological examination of lesions, and serological testing. However, endoscopy can be regarded as a gold standard tool in the diagnosis of aspergillosis. In the present study endoscopy shows clearly visible granulomatus lesions of *Aspergillus* species on the lungs and/or air sacs. The results of endoscopic examination are verified by cytology from the lesions obtained during endoscopic procedure. Infestation of air sacs with *Serratospiculum* filarial worm (air sac worm) was the second commonest abnormality detected in the falcons examined. This finding was similar to that of Samour and Naldo (2001) who reported that Serratospiculiasis was the most wide spread parasitic disease among falcons in the Middle East. *Serratospiculum seurati* is the only species identified in captive falcons in the Middle East. Infestation of falcons with large numbers of these parasites was associated with airsaculitis and early aspergillosis lesions (Samour and Naldo, 2001).

5:4: Haematology

In the present study, eosinophilia (51.34%) was the first most common haematological change identified in the falcons. Other common haematological abnormalities identified in the blood pictures of the birds, in descending order, were increased Hb and PCV values (50.67%), thrombocytosis (47.77%), heterophilia with or without toxic changes (38.98%), leucocytosis(23.72%), monocytosis(15.48%) and presence of *Haemoproteus* species (9.02%). In birds, high eosinophil counts are often associated with gastrointestinal parasitic infestation and haemoparasitism (Hawkey *et al*, 1983; Rosskopf and Woerpel, 1996; Samour *et al*, 1996). In the present study, eosinophilia was most commonly observed in falcons with haemoproteid and trichomonas infection, and in falcons with excessive accumulation of sand in the gastrointestinal tract, probably as the result of contamination of the sand during moulting period with dropping of falcons infected with genus *Caryospora*. High eosinophil counts were also commonly observed in falcons with airsacculitis as one of the seqeulae of heavy infestation with *Serratospiculum* spp. These findings are similar to those reported by Samour *et al* (1996) who found that eosinophilia was closely associated with parasitism in

falcons. Increased Hb and PCV values were the second most common abnormality detected, and most commonly observed in falcons associated with dehydration, which is more likely to be seen in falcons at the time of stress and extensive exercises during training and hunting process. The occurrence of anemia with decreased Hb and PCV values were most commonly observed in falcons associated with severe hemoproteid infection and in birds in low general condition. Redig (2003) reported that haemoparasites in birds can cause anaemia and death. Thrombocytosis was the third most common haematological abnormality detected in the falcons. An increase in thrombocyte count, is known to occur in association with bacterial infection in man (Wintrobe, 1962) and other mammals (Hawkey, 1983). Similarly as in case of mammals there is a tendency towards increased thrombocyte counts in birds with bacterial infections (Hawkey and Samour, 1988). While the finding of elevated numbers of megathrombocytes in the blood films on many birds examined in the present study appear to be associated with chronic inflammatory response (Samour and Howlett, 2008). Heterophilia with or without toxic changes was the fourth most common haematological change observed in the blood films of the birds examined. Increase in the number of heterophil counts occurs due to stress (Maxwell, 1993) and acute inflammatory (Montali, 1988) and infectious processes, including, chlamydial, bacterial and some viral infections (Fudge, 1996). In the present study heterophilia was commonly observed in falcons associated with many radiographic abonormalities, particularly hepatomegaly, homogeneous and nonhomogeneous increased radiopacity of the lung fields and air sacs. The finding of heterophilia in many of these cases is important since it shows that the causative agents associated with these radiographic abnormalities had produced a moderate to strong heterophils response in many affected birds. Mature heterophils appear to show toxic changes in a manner similar to the toxic changes identified in mammalian neutrophils (Campbell, 1988). In the present study, out of total falcons examined, toxic heterophils were identified in the blood smear of 391 (43.54%) falcons; of these 70 (7.80%) falcons showed severe toxic heterophilic changes (+3 or +4). The degree of heterophilic toxicity was reported subjectively on a scale of +1 to +4, where the lower rating reflects slight changes and the higher indicates severe changes (Campbell, 1994a, 1995). Toxic changes observed include increased

cytoplasmic basophilia. vaculation, abnormal granules (toxic granules), degranulation (loss of granulation) and degeneration of the nucleus (loss of lobulation). Toxic heterophilia in avian patients is mostly associated with bacterial infections, chlamydiophilosis, fungal and some viral infections (Fudge, 1996). In the present study toxic change was commonly observed with heterophilia and also identified in 126 (14.03%) falcons with normal heterophils counts. Toxic heterophils can be the only abnormal haematological finding, but they are very significant clinically (Fudge, 1989). At FBSFC it is most commonly observed that falcon with severe heterophilic toxicity shows very poor prognosis. Therefore these findings illustrate the need for evaluating the health status of the falcon based on heterophils toxicity, in addition to the other changes observed in the haematological parameters, and since the degree of heterophil toxicity indicates the severity of disease in the falcon, it can be used as a prognostic indicator. The fifth most common haematological abnormality observed was increased leucocyte counts. As in cases of other avian species, leucocytosis in the falcon is mainly due to heterophilia, as heterophils are the most predominant cells in an avian leucogram. Increase in the monocyte counts was the sixth most common haematological abnormality identified in the falcons examined. Monocytosis can be found in certain diseases that produce chemotactic agent for monocytes; these conditions include avian chlamydiophilosis, mycotic and bacterial granulomas and massive tissue necrosis (Hawkey *et al*, 1983). Haematological findings, namely heterophilia, with some degree of toxic changes, and monocytosis are initial indicators of aspergillosis (Redig, 2008). In the present study, monocytosis was most commonly observed in falcon associated with radiographic abnormality of nonhomogeneous increased radiopacity of the lung fields and air sacs which is more likely to be seen in advanced cases of the aspergillosis in captive falcons. The seventh most common haematological abnormality observed was the presence of haematozoan parasite, namely *Haemoprotus tinnuunculi* in the blood smears of the birds examined. As pointed earlier in this study, splenomegaly and eosinophilia are closely associated with haemoprotied infection in the captive falcons. Other common haematological changes identified in birds examined in descending order included lymphocytosis, heteropenia, leucopenia, anaemia, thrombocytopenia and lymphopenia. Of all

falcons examined, only 4 birds showed presence of small numbers of basophils in their blood films, while the remaining birds showed complete absence of basophils in their haemogram. The significance of basophils in falcon is unclear since most birds failed to show a basophil response; this finding is in agreement with those of Wernery *et al* (2004) who reported that basophils are quite rare in falcon's blood. In summary, radiographic, endoscopic and haematological examination are important diagnostic tools that are readily available to veterinarians who treat falcons. The results of this study contribute to the scant information available about health and diseases of falcons in the Kingdom of Saudi Arabia in particular and the Middle East in general. Out of the all falcons examined, only **104** (11.58%) falcons were found negative in all categories (radiography, endoscopy and haematology). Therefore further, more detailed studies into the prevalence, pathogenesis and epizootiology of infectious causes of disease in falcons in Saudi Arabia should be undertaken. Since newly acquired falcons are often kept together with other falcons, a complete health screening which is mainly based on radiographic, endoscopic and haematological examination must be performed to ensure not only the health status of the new falcons, but also to prevent disease transmission to other falcons in the collection.

CONCLUSION AND RECOMMENDATIONS

Conclusion

Health studies constitute an important part of raptor management in captivity. Many abnormal findings have been recorded in captive falcons examined at the Fahad Bin Sultan Falcon Center in Riyadh. Of 898 falcons examined, 794 (88.42%) showed one or more clinical abnormality, while only 104 (11.58%) falcons had no clinically detectable ailment.

Respiratory problems, obstruction or impaction of the gastrointestinal tract with sand, splenomegaly, hepatomegaly, gas formation in the gastrointestinal tract, fracture due to trauma and reduction or loss of muscle mass accounted for the largest number of radiographic abnormalities in falcons. Trichomoniasis, candidiasis and pallor of the crop mucosa are the most prevalent conditions diagnosed by esophago-ingluvioscopy. The problems detectable by tracheoscopy include syringeal aspergilloma, foreign body lodgement in the trachea, excessive mucous production and tracheal displacement. In a small number of falcons examined selectively by laparoscopic procedure, aspergillosis accounted for largest proportion of medical cases, followed by serratospiculiasis. Eosinophilia, increased Hb concentration and PCV values, thrombocytosis, heterophilia, leucocytosis, monocytosis and presence of haemoproteus species are the commonest haematological abnormalities recorded in falcons. Haemoprotied infection is associated with increased splenic size and a strong eosinophilic response. Monocytosis is the most common feature observed with non-homogeneous increased radiopacity of the lung field and air sacs which is more likely to be seen in falcon with aspergillosis. Toxic heterophils are recorded in nearly half (43.54%) of the birds examined.

These findings underscore the importance of radiography, endoscopy and haematological profile as diagnostic tools in falcon medicine, and contribute significantly to the scant information presently available regarding health aspects and prevailing diseases of falcons in the Middle East in general and the Kingdom of Saudi Arabia in particular.

Recommendations

* More detailed studies into the prevalence, pathogenesis and epizootiology of infectious causes of diseases in falcons in Saudi Arabia should be undertaken.

* Regarding imaging techniques, future work should include using advanced modalities such as computed tomography, magnetic resonance imaging and fluoroscopy as these techniques may enhance diagnostic capability in the field of falcon medicine.

* It is imperative to promote and enhance public awareness on falcon health and disease. This can be achieved through the use of photographic displays, a highly illustrative health brochure series and educational videos.

* Since newly acquired falcons are often kept together with other falcons, a complete health screening, based mainly on radiographic, endoscopic and haematological examination must be performed to ensure not only the health status of the new falcons, but also to prevent disease transmission to other falcons in the collection.

* Investing in prevention is investing in the future, to ensure the best interests of both newly acquired and existing falcons.

* Don’t buy a falcon without a thorough pre-purchase checkup, as these birds when get sick they often show very subtle and non specific signs of disease.

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