

# Study on the most common bacterial infections in falcons in the United Arab Emirates

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## Summary

*The problem of bacterial infections in falcons can be traced back to the 8<sup>th</sup> century. Studies in the literature on infectious diseases showed that the most common bacterial pathogen is E.coli, followed by Chlamydia psittaci, Pseudomonas sp. and Clostridium perfringens. Microbiological examinations of crop and fecal samples in the Abu Dhabi Falcon Hospital have confirmed that E.coli can be regarded as the major bacterial problem. The second frequent bacterium found is Clostridium perfringens, followed by Pseudomonas aeruginosa. The majority of infections showed a moderate or heavy number of pathogens. The sick falcons have been admitted to the Abu Dhabi Falcon Hospital with the frequent complains “not eating well”, “not flying well” and “vomiting”. These rather non specific disease symptoms should not be underestimated as they may be indicating serious bacterial infections which may lead to a fast deterioration of the falcon’s condition and in very advanced stages to the death of the falcons due to septicemia. The evaluation of the study results reveals clearly that falcons show a species specific susceptibility with respect to bacterial infections. Gyr-Saker hybrid falcons show a higher morbidity for E. coli infections whereas Gyr and Saker falcons are more frequently affected by Clostridium perfringens infections. Gyr-Peregrine hybrid falcons and Saker falcons are most susceptible for Pseudomonas aeruginosa infections whereby Peregrine and Gyr-Peregrine hybrid falcons are more prone to moderate and heavy Pseudomonas aeruginosa infections. Age and antibiotic sensitivity differences can be clearly seen among the bacterial infection in this study.*

## Keywords

United Arab Emirates, bacterial infection, E.coli, Clostridium perfringens, Pseudomonas aeruginosa, age, antibiotics

## 1. Introduction

As early as in the 8<sup>th</sup> century, Arab falconers were aware of the fact that falcons can suffer from general infections as well as infections in the throat (Al Gitrif, 1988). Until today, infections remain one of the most common health issues not only in living falcons, but also in post mortem findings of raptors (Schroeder, 1980; Gierse, 2001). Studies on infectious diseases in falcons have revealed that the main bacterial pathogen is *E. coli* (11,13%), followed by Chlamydiosis (4.75%), *Pseudomonas* infection (4.31%) and Clostridiosis (3.20%) (Gierse, 2001). The most frequently isolated bacterial pathogens in crop and fecal samples in the Abu Dhabi Falcon Hospital are *E. coli*, *Clostridium perfringens* and *Pseudomonas aeruginosa*. *E. coli* can be found in 90% of the fecal samples of clinically healthy raptors (Needham et al, 1979; Bangert et al, 1988). In addition to this bacterial basis, unhygienic conditions, stress and other infectious agents seem to contribute to a great extent to the disease outbreak (Zwart, 2000) as well as large

numbers of isolated *E.coli* bacteria (Gylstorff and Grimm, 1998). Regarding infections caused by *Clostridium perfringens*, the conditions for the disease outbreak are still not fully identified (Gierse, 2001). A *clostridium* enterotoxaemia does not seem to be caused by poor quality food. However, predisposing factors like emaciation, dehydration and training, transport, overeating, sudden ration changes, the addition of new groups to the collection (Wernery et al, 2000) seem to pave the way to an infection. The research on *Pseudomonas sp.* infections does not show a much unified picture, too. Being one of the most frequent bacterial infection in Saudi-Arabia among falcons (Gierse, 2001), a relationship between trichomonas infections and stress through training exists (Samour, 2000). Nevertheless, it is also stated that falcons are not affected by *Pseudomonas* infections (Zwart, 2000). The aim of this study is to identify the most common bacterial infections in hybrid falcons in correlation to their species, age and antibiotic sensitivity.

## **2. Material and Methods**

### **Material**

Between December 2002 and November 2003, 198 total number of samples, among them 78 crop, 110 fecal, 1 cloaca, 3 trachea, 5 eye and 1 ear samples were taken from 198 falcons tested. They consisted of 35 Gyr-Saker hybrid falcons (*Falco rusticolus x Falco cherrug*), 46 Gyr-Peregrine hybrid falcons (*Falco rusticolus x Falco peregrinus*), 63 Saker falcons (*Falco cherrug*), 39 Peregrine falcons (*Falco peregrinus*) and 15 Gyr falcons (*Falco rusticolus*).

### **Methods**

Crop samples are taken by sterile cotton soaked in a drop of sterile saline. The fecal samples are taken from fresh fecal and either streaked directly on the plate or kept in charcoal media for up to 24 hours.

#### *E.coli* identification

Specimen swabs are plated on blood agar and Mac Conkey agar (Himedia, India). Inoculated plates are incubated for 18-24 hrs at 37°C. Further identification is done by ID (32E) Manual API strips (Biomerieux). Swabs are also plated on Sorbitol Agar (Himedia, India) for the identification of enteropathogenic *E.coli*.

#### *Clostridium perfringens* identification

Faecal swabs are inoculated in cooked meat medium. Tubes are heated at 80°C and then cooled before plating. The swab is then plated on to blood agar and *Perfringens* agar base. Inoculated plates are then incubated at 37°C anaerobically for 18-24 hrs (Genbox, Biomerieux). Further identification is performed with ID API 20A Manual (Biomerieux).

#### *Pseudomonas aeruginosa* identification

Swabs are plated on blood agar, Mac Conkey agar and Cetrimide agar (Himedia, India). The plates are incubated at 37 °C for 18-24 hrs. An oxidase test is performed for primary identification. Further identification to the species level is done by API 20NE (Biomerieux).

Growth of only few bacteria isolated in the primary inoculum was not part of this study and might be considered as part of the normal bacterial flora. The amount of growth had been differentiated as scanty growth or (+) when the growth was found in the first streaking lines and as moderate growth or (++) in the second streaking lines. Heavy growth (+++ and above) was growth found in the third streaking line.

Regarding the antibiotic sensitivity performed with antibiotic discs, the number of antibiotics sensitive to one bacterium might be above one therefore the number in the table of effective antibiotics exceeds the number of bacterial infections.

### 3. Results

90 falcons tested suffered from *E.coli* infections, 67 from *Clostridium perfringens* infections and 41 falcons from *Pseudomonas aeruginosa* infections.

Species	<i>E.coli</i>	<i>Clostridium perfringens</i>	<i>Pseudomonas aeruginosa</i>	Total
Gyr-Peregrine	20	15	11	46
Gyr-Saker	23	7	5	35
Saker	24	24	15	63
Peregrine	19	13	7	39
Gyr	4	8	3	15
Total	90	67	41	198

#### *E.coli* infections

90 falcons tested were diagnosed with *E.coli* infections, equally distributed among the falcon species. Moreover, all falcons had been suffering from heavy, moderate and scanty infections in a similar way apart from Peregrine falcons with a high number of heavy *E.coli* infections.

Table 2. Species distribution for *E.coli* infections

Species	<i>E.coli</i>			Total
	Heavy	Moderate	Scanty	
Gyr-Peregrine	5	6	9	20
Gyr-Saker	5	8	10	23
Saker	7	11	6	24
Peregrine	12	4	3	19
Gyr	1	1	2	4
Total	30	30	30	90

49 falcons tested with one year of age were diagnosed more frequently of *E.coli* infections followed by 30 second year old falcons tested, but also falcons of up to 6 years of age can be affected.

Table 3. Age distribution for *E.coli* infections

Age (years)	<i>E.coli</i>			Total
	Heavy	Moderate	Scanty	
1	14	17	18	49
2	11	9	10	30
3	4	2	2	8
4	0	2	0	2
6	1	0	0	1

In 66 cases, Amoxicillin-Clavulanic acid was the most sensitive antibiotic, closely followed by Enrofloxacin in 63 cases. Another well acting antibiotic for *E.coli* infections is Piperacillin which was effective in 53 cases and Amoxicillin in 50 cases. Antibiotics like Ceftazidim, Ciprofloxacin, Cephalexin or Ticarcillin showed a more frequent resistance to *E.coli* and therefore a greater ineffectiveness in treating *E.coli* infections.

Table 4. Antibiotic sensitivity for *E.coli* infections

<i>E.coli</i>								
heavy	Amc	Amoxy	Enr	Prl	Cip	Caz	Cfx	Tic
<b>Gyr-</b>								
Peregrine	4	3	5	4	2	0	0	0
Gyr-Saker	4	2	3	4	0	2	0	2
Saker	6	4	7	5	1	1	1	3
Peregrine	10	8	11	5	2	0	3	5
Gyr	1	0	1	1	0	0	0	0
<b>Total</b>	<b>25</b>	<b>17</b>	<b>27</b>	<b>19</b>	<b>5</b>	<b>3</b>	<b>4</b>	<b>10</b>
<b>Moderate</b>								
<b>Gyr-</b>								
Peregrine	5	2	4	3	1	2	0	0
Gyr-Saker	4	4	4	3	2	1	0	0
Saker	6	5	7	7	3	1	1	1
Peregrine	4	4	0	4	0	0	0	0
Gyr	0	0	0	1	0	0	0	0
<b>Total</b>	<b>19</b>	<b>15</b>	<b>15</b>	<b>18</b>	<b>6</b>	<b>4</b>	<b>1</b>	<b>1</b>
<b>Scanty</b>								
<b>Gyr-</b>								
Peregrine	7	4	7	6	3	2	1	0
Gyr-Saker	6	7	6	6	3	1	0	1
Saker	5	4	5	3	2	2	0	0
Peregrine	3	2	2	3		1	0	0
Gyr	1	1	1	1	1	1	0	0
<b>Total</b>	<b>22</b>	<b>18</b>	<b>21</b>	<b>19</b>	<b>9</b>	<b>7</b>	<b>1</b>	<b>1</b>

### *Clostridium perfringens* infections

*Clostridium perfringens* infections were affecting by far more Saker falcons tested than Gyr-Peregrine and Gyr-Saker hybrid falcons tested. Moreover, more than half of the examined Gyr falcons tested suffered from this infection.

Table 5. Species distribution for *Clostridium perfringens* infections

Species	<i>Clostridium perfringens</i>			Total
	Heavy	Moderate	Scanty	
Gyr-Peregrine	2	8	5	<b>15</b>
Gyr-Saker	0	3	4	<b>7</b>
Saker	5	8	11	<b>24</b>
Peregrine	2	4	7	<b>13</b>
Gyr	2	3	3	<b>8</b>
<b>Total</b>	<b>11</b>	<b>26</b>	<b>30</b>	<b>67</b>

Regarding the age distribution, the table below shows that *Clostridium perfringens* infections mainly affect young one or two year old falcons and only few three year old falcons. During the study, no falcons above the age of three years were diagnosed with a *Clostridium* infection and even the three-year old falcons did not show any heavy growth of *Clostridium perfringens*.

Table 6. Age distribution for *Clostridium perfringens* infections

<i>Clostridium perfringens</i>				
Age (years)	Heavy	Moderate	Scanty	Total
1	9	15	17	40
2	3	9	9	21
3	0	2	4	6

For each stage of the infection, Amoxicillin has proved to be the most effective antibiotic with 52 cases of proven sensitivity, followed by Amoxicillin-Clavulanic acid in 43 cases. The third most effective drug is Piperacillin found sensitive in 35 cases, whereas Enrofloxacin responded only in 24 cases. Antibiotics like Ceftazidim, Ciprofloxacin, Cephalexin or Ticarcillin showed a rather high resistance to *Clostridium perfringens* infections.

Table 7. Antibiotic sensitivity for *Clostridium* infections

<i>Clostridium</i>								
Heavy	Amc	Amoxy	Enr	Prl	Cip	Caz	Cfx	Tic
Gyr-Peregrine	2	2	2	2	0	0	2	0
Gyr-Saker	0	0	0	0	0	0	0	0
Saker	2	3	2	4	1	1	1	0
Peregrine	1	2	1	1	0	0	1	0
Gyr	0	2	0	0	0	0	0	0
<b>Total</b>	<b>5</b>	<b>9</b>	<b>5</b>	<b>7</b>	<b>1</b>	<b>1</b>	<b>4</b>	<b>0</b>

**moderate**

Gyr-Peregrine	7	7	3	4	2	0	1	0
Gyr-Saker	3	3	1	1	0	0	0	0
Saker	7	8	1	4	1	1	1	0
Peregrine	2	4	4	3	1	0	1	0
Gyr	2	2	0	1	0	0	0	0
<b>Total</b>	<b>21</b>	<b>24</b>	<b>9</b>	<b>13</b>	<b>4</b>	<b>1</b>	<b>3</b>	<b>0</b>

**scanty**

Gyr-Peregrine	4	4	3	3	1	0	1	4
Gyr-Saker	3	3	0	2	1	0	1	0
Saker	7	7	4	5	3	2	0	2
Peregrine	3	5	3	3	0	0	3	4
Gyr	0	1	0	2	1	0	0	1
<b>Total</b>	<b>17</b>	<b>20</b>	<b>10</b>	<b>15</b>	<b>6</b>	<b>2</b>	<b>5</b>	<b>11</b>

**Pseudomonas aeruginosa infections**

*Pseudomonas aeruginosa* infections were found in 41 falcons tested, among them 11 Gyr-Peregrine hybrid falcons, 5 Gyr-Saker hybrid falcons, 15 Saker falcons, 7 Peregrine falcons and 3 Gyr falcons.

Table 8. Species distribution for *Pseudomonas aeruginosa* infections

<i>Pseudomonas aeruginosa</i>				
Species	Heavy	Moderate	Scanty	Total
Gyr-Peregrine	2	9	0	11
Gyr-Saker	1	2	2	5
Saker	3	4	8	15
Peregrine	3	3	1	7
Gyr	1	1	1	3
<b>Total</b>	<b>10</b>	<b>19</b>	<b>12</b>	<b>41</b>

In general, more than half of the falcons suffering from *Pseudomonas aeruginosa* infections are one year old. However, there are differences in the degree of the infection which can be observed in the various age groups. Heavy *Pseudomonas aeruginosa* infections can be more frequently found in falcons above 2 years of age, whereas a higher number of first and second year old falcons suffer from scanty and moderate *Pseudomonas* infections.

Table 9. Age distribution for *Pseudomonas aeruginosa* infections

<i>Pseudomonas aeruginosa</i>				
Age (years)	Heavy	Moderate	Scanty	Total
1	4	11	10	25
2	2	6	1	9
3	2	2	1	5
4	2	0	0	2

Regarding the antibiotic sensitivity, Piperacillin is highly sensitive to *Pseudomonas aeruginosa* infection in 35 out of 41 cases. Ciprofloxacin is the second most effective antibiotic with 24 sensitive results. Ceftazidim is still working in 17 cases. However, Enrofloxacin, Amoxicillin and Amoxicillin/Clavulanic acid are predominantly resistant to those infections.

Table 10. Antibiotic sensitivity for *Pseudomonas aeruginosa* infections

<i>Pseudomonas</i>								
heavy	Amc	Amoxy	Enr	Prl	Cip	Caz	Cfx	Tic
Gyr-Peregrine	0	0	0	2	2	2	0	0
Gyr-Saker	0	0	0	1	1	1	0	0
Saker	0	0	1	3	3	2	0	0
Peregrine	0	0	0	3	2	2	0	0
Gyr	0	0	1	1	1	0	0	0
<b>Total</b>	<b>0</b>	<b>0</b>	<b>2</b>	<b>10</b>	<b>9</b>	<b>7</b>	<b>0</b>	<b>0</b>

moderate								
Gyr-Peregrine	0	0	0	9	6	4	4	0
Gyr-Saker	0	0	0	1	0	0	1	0
Saker	0	0	1	3	2	2	0	0
Peregrine	0	0	1	1	1	1	0	0
Gyr	0	0	0	0	0	0	0	0
<b>Total</b>	<b>0</b>	<b>0</b>	<b>2</b>	<b>14</b>	<b>9</b>	<b>7</b>	<b>5</b>	<b>0</b>

Table 10 (cont'd). Antibiotic sensitivity for *Pseudomonas aeruginosa* infections

<b>Pseudomonas</b>								
<b>scanty</b>								
<b>Gyr-Peregrine</b>	0	0	0	0	0	0	0	0
<b>Gyr-Saker</b>	0	0	1	2	2	1	0	1
<b>Saker</b>	0	0	1	7	3	2	2	2
<b>Peregrine</b>	0	0	1	1	0	0	0	1
<b>Gyr</b>	0	0	0	1	1	0	0	0
<b>Total</b>	<b>0</b>	<b>0</b>	<b>3</b>	<b>11</b>	<b>6</b>	<b>3</b>	<b>2</b>	<b>4</b>

#### 4. Discussion

The results of this study support the findings of Gierse (2001) in the respect that the most common bacterial infection in falcons in the United Arab Emirates is the *E.coli* infection. In contrast to his results this study found the most susceptible species tested for *E.coli* infections in general were Gyr-Saker hybrid falcons. Among those 35 tested, 65.7% were diagnosed with *E.coli* infections followed by 48.7% of 39 Peregrine falcons and 43.5% out of 46 Gyr-Peregrine hybrid falcons. Only 38.1% of the 63 Saker falcons tested in this study were infected with *E.coli*. Interestingly, the highest number of heavy *E.coli* infections can be found in Peregrine falcons thus being in line with Gierse's (2001) observations. Regarding the age distribution, 54.5% of the first year falcons were infected with *E.coli*, followed by 33.3% second year falcons. 12.2% of falcons diagnosed with *E.coli* infections were 3 to 6 years old. With respect to the antibiotic sensitivity, Amoxicillin-Clavulanic acid is undoubtedly the most effective antibiotic in treating *E.coli* infections with 73.3% positive sensitivity results, followed by Enrofloxacin with 70.0%.

The *Clostridium perfringens* infections ranked in second place of bacterial infections in this study whereas in Gierse's (2001) study *Pseudomonas* infections were more frequent than *Clostridium* infections. Interestingly, the most affected species were Gyr falcons. Among the 15 falcons tested, 53.3% were infected with *Clostridium perfringens*. The second most susceptible group were Saker falcons tested with 38.1% infected falcons out of 63 Sakers. Peregrine falcons with 33.3% out of 39 peregrines and 32.6% out of 46 Gyr-Peregrine hybrid falcons were affected in a similar number. These findings contrast the findings of Gierse (2001) who found Peregrine falcons as most affected species, followed by Gyr falcons and hybrid falcons. The most infected age group was first-year old falcons with an infection rate of 59.7%, followed by 31.3% in second year old falcons tested and 9.0% in third year old falcons tested. This fully supports Gierse (2001) who stated that first year old falcons are significantly more infected with *Clostridium* bacteria. It has to be noted that no falcon above 3 years of age suffered from *Clostridium perfringens* infections in this study.

With regard to antibiotic sensitivity, Amoxicillin emerged as the most effective drug for *Clostridium perfringens* infections in 77.6% of all cases tested. The second most effective antibiotic was Amoxicillin-Clavulanic acid with 64.2% positive sensitivity, followed by Piperacillin with 52.2% sensitive cases.

41 falcons tested were diagnosed with *Pseudomonas aeruginosa* infections standing in direct contrast to Zwart (2000) who does not regard falcons as susceptible to this bacterium. However, these results stand in line with Gierse (2001) who states that this infection is one of the most common bacterial infections affecting falcons in Saudi-Arabia. He revealed that there are no significant species differences regarding *Pseudomonas* infections as Saker falcons and Peregrine falcons are the most affected species. In our study, 23.9% out of 46 Gyr-Peregrine hybrid falcons were infected whereas 23.8% of 63 Saker falcons were tested positive for *Pseudomonas aeruginosa*. The next frequent group was the one of Gyr falcons with 20.0% out of 15 Gyr falcons tested. However, Peregrine and Gyr-Peregrine hybrid falcons tested seemed to be more prone to moderate and heavy infections.

Although 61.0% of falcons infected with *Pseudomonas aeruginosa* were one year old and 21.9% two years old, it has to be noted that this bacteria affects older falcons in the highest number of all the three bacteria isolated. 12.2% infected falcons were 3 years and 4.9% four years old. Piperacillin is with 85.4% sensitive cases the antibiotic of choice for *Pseudomonas aeruginosa* infections. The second most effective drug is Ciprofloxacin with 58.5%.

## 5. Conclusion

Bacterial infections are a common, yet often highly underestimated feature in the United Arab Emirates and may pose a severe threat to the falcon populations. *E.coli* infections are not only the most common bacterial infections, but seem to be also the most dangerous one with the highest number of heavy infections. This directly points to the problem of *E.coli* septicemias which can end fatal if detected too late due to its rapid progression (Gylstorff, I. and F. Grimm., 1998). In the Abu Dhabi Falcon Hospital, cases of *E.coli* septicemia have been observed in direct connection with feeding and not digesting large amount of meat. Especially tired and over-trained falcons often have problems to pass their full crop properly and the food remains for several hours, sometimes even up to 24 hours in the crop. This results often in massive *E.coli* septicemias and fatal intoxication of the falcons. In *E.coli* septicemia cases, often only unspecific disease symptoms can be found like weight loss and tiredness (Gylstorff, I. and F. Grimm., 1998). Gyr-Saker hybrid falcons showed a higher susceptibility to *E.coli* infections compared to other species. One and second year old falcons are more at risk to get sick from this disease than older falcons although even up to six years old falcons can be affected. The two most effective antibiotics are Amoxicillin-Clavulanic acid and Enrofloxacin.

*Clostridium perfringens* infections are frequently observed in the United Arab Emirates and the numbers seem to rise over the past few years due to intensified training methods and increase of susceptible species (Gierse, 2001). Moreover, this bacterial infection affects much more young falcons and was not found in falcons above three years of age in this study. This might support the theory that falcons might be able to eliminate enteric *Clostridium* bacteria and that the exposure time to this bacterium in the environment might not be the main factor for the disease outbreak (Gierse, 2001). The age distribution with a large number of first year falcons found in this study supports the suggestions of Gierse (2001) that problems to adept to a new feeding scheme, lack of exercise and climatic change may favor the development of this kind of infections. Moreover, stress due to inadequate and long transportation as well as lack of hygiene should not be underestimated as predisposing factor for *Clostridium perfringens* infections. The most susceptible species are Gyr falcons, followed by Saker falcons, Peregrine and Gyr-Peregrine hybrid falcons. The assumption of Gierse (2001) that Saker falcons are more resistant to *Clostridium* infections due to their robust nature (Al Gitrif, 1988) was not proven in this study. *Clostridium perfringens* infections are responding well in most of the cases to Amoxicillin and Amoxicillin-Clavulanic acid.

Another very common bacterial infection in the Middle East is the *Pseudomonas aeruginosa* infection (Samour, 2000; Gierse, 2001) although not all authors do recognize the importance of this disease in falcons (Zwart, 2000). Despite a relative equal species distribution among the different stages of this infection, it has to be noted that Peregrine and Gyr-Peregrine hybrid falcons turned out to be much more susceptible to moderate and heavy *Pseudomonas aeruginosa* infections than any other species tested. Another interesting features of this infection is the fact that on one hand young first year old falcons are affected, but on the other hand also many old falcons up to four years are also suffering from this infection. The findings of Samour (2000) that *Pseudomonas aeruginosa* infections are frequently combined with *Trichomonas* infections can be fully supported by the observations in the Abu Dhabi Falcon Hospital. However,, at the current stage of research it cannot be determined whether this combined disease problem is a

special feature of Middle Eastern countries or whether it has simply not yet often been diagnosed in other countries. Unrecognized *Pseudomonas aeruginosa* infections might lead to either chronic cases often manifest as chronic sinusitis cases or especially in moderate and heavy stages to systemic diseases which ends often in a fatal way. Piperacillin is definitely the antibiotic of choice for *Pseudomonas aeruginosa* infections (Samour, 2000) with a sensitivity of 85.4%.

As the normal bacterial flora of falcons has not been fully studied yet, it is difficult to judge to which extent scanty bacterial agents like E.coli or Clostridium perfringens can be still regarded as part of the normal bacterial flora and from which level of occurrence they are pathogenic already. Nevertheless, observations in the Abu Dhabi Falcon Hospital have shown that even falcons with scanty (+) bacterial infections have a reduced flight performance, reduced appetite or are not well. Those falcons are improving well when given the appropriate antibiotics. Moderate (++) or heavy (+++ and above) bacterial infection definitely require appropriate treatment with suitable antibiotics following an antibiogramm.

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