Bacterial isolation from internal organs of rats (Rattus rattus) captured in Baghdad city of Iraq

Nagham Mohammed Ayyal1, Zainab Abdulzahra Abbas2, Abdulkarim Jafar Karim3, Zainab Majid Abbas4, Karima Akool Al-Salihi5, Jenan Mahmood Khalaf6, Dunya Dhafir Mahmood7, Eman Abdullah Mohammed8, Rawaa Saladdin Jumaa9 and Dhuha Ismaeel Abdul-Majeed9

1. Unit of Zoonotic Diseases, College of Veterinary Medicine, University of Baghdad, Baghdad, Iraq; 2. Department of Pathological Analysis, Babylon Technical Institute, Al-Furat Al-Awsat Technical University, Babylon, Iraq; 3. Department of Internal and Preventive Medicine, College of Veterinary Medicine, Al-Muthanna University, Al-Muthanna, Iraq; 4. Department of Internal and Preventive Medicine, College of Veterinary Medicine, University of Baghdad, Baghdad, Iraq; 5. Department of Parasitology, College of Veterinary Medicine, University of Baghdad, Baghdad, Iraq; 6. Department of Microbiology, College of Veterinary Medicine, University of Baghdad, Baghdad, Iraq.

Corresponding author: Abdulkarim Jafar Karim, e-mail: karimjafar59@yahoo.com
Co-authors: NMA: drvet2011@yahoo.com, ZAA: zabbasa@yahoo.com, ZMA: zainabmajid90@gmail.com, com, KAA: kama_akooll18@yahoo.co.uk, JMK: jenanm28@yahoo.com, DDM: aboalsoof@gmail.com, EAM: emankazzaz@yahoo.com, RSJ: rawaa.saladdin84@gmail.com, DIA: doha.ismaeel@yahoo.com

Received: 10-08-2018, Accepted: 07-12-2018, Published online: 22-01-2019

doi: 10.14202/vetworld.2019.119-125 How to cite this article: Ayyal NM, Abbas ZA, Karim AJ, Abbas ZM, Al-Salihi KA, Khalaf JM, Mahmood DD, Mohammed EA, Jumaa RS, Abdul-Majeed D1 (2019) Bacterial isolation from internal organs of rats (Rattus rattus) captured in Baghdad city of Iraq, Veterinary World, 12(1): 119-125.

Abstract

Aim: Rats are accused in disseminating many zoonotic diseases. This study aimed to isolate and identify bacteria from internal organs of rats captured in Baghdad City, Iraq.

Materials and Methods: A total of 120 black rats (R. rattus) were trapped from different areas in Baghdad city. Rats were kept in individual plastic cages for 3 h before euthanizing. Deep pharyngeal swab, intestinal content, urine, and pieces of the liver and spleen, lung, kidney, and brain were obtained aseptically. The specimens were inoculated into peptone water and incubated at 37°C for 24 h for enrichment. A loopful of each specimen was then subcultured onto MacConkey Agar, Blood Agar, and Mannitol Salt Agar. CHROMagar O157 H7 and CHROMagar Listeria were used to detect Escherichia coli O157:7 and Listeria spp., respectively. Biochemical tests on analytical profile index, microscopic examination, and commercial kit for latex agglutination test for serotyping E. coli O157:H7 were used.

Results: Mixed bacterial isolates were recorded as 116, 52, 36, 28, 18, 6, and 4 from intestinal contents, deep pharyngeal, liver and spleen, urine, lung, brain, and kidney, respectively. Microorganisms included E. coli, Staphylococcus aureus, Streptococcus spp., Bacillus spp., Pseudomonas aeruginosa, Citrobacter freundii, Proteus vulgaris, E. coli O157:H7, Enterobacter cloacae, Listeria spp., Klebsiella spp., Ochrobactrum anthropi, Aeromonas spp., Brucella spp., Pseudomonas fluorescens, Escherichia fergusonii, Monas spp., Morganella spp., Proteus mirabilis, Pseudomonas luteola, and Streptobacillus spp. The highest bacterial prevalence (58; 73.33%) was recorded for E. coli, where 68 isolates were identified from the intestinal contents. Of these, four isolates were E. coli O157:H7.

Conclusion: Rats are important carriers and transmitters of a number of pathogens and can disseminate these microorganisms to humans and animals.

Keywords: bacteria, different organs, Escherichia coli O157:H7, Pseudomonas aeruginosa, rat, urine.

Introduction

Rats, not like all other mammals, inhabit all continents wherever human is present. Their serious role in dispersing diseases arises from contamination of food and living places. They are incriminated in transmitting several zoonotic and non-zoonotic microorganisms causing diseases in humans and animal due to their tendency to invade houses with subsequent contamination of foods [1]. These microorganisms include many species of bacteria, fungi, viruses, rickettsia, protozoa, helminths, and finally, their ecto-parasites such as fleas [2-5]. Many of these had rarely or never previously been investigated, for example, Cryptosporidium, Pasteurella, Listeria, Yersinia, and Coxiella [6,7]. Most of these organisms are not directly responsible for epidemics, while others such as Yersinia pestis, Streptococcus moniliformis, and Salmonella typhimurium are incriminated in outbreaks of plague, Haverhill fever, and salmonellosis, respectively [8,9]. Rats are capable of carrying and shedding Escherichia coli [10-12], and it has been isolated from several wildlife species including rodents, bats, and farmed and wildlife animals [13,14].

Closer contact with rats means more diseases. Rats transmit diseases directly or indirectly. They are incriminated for deaths more than any other causes. Threat to human health is well recognized when potentially life-threatening diseases that currently

Copyright: Ayyal, et al. Open Access. This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated.
have no specific treatment, cure, or vaccine [15], for example, Hantavirus pulmonary syndrome, leptospirosis, cutaneous leishmaniasis, toxoplasmosis, rat-bite fever, plague, salmonellosis, tularemia, lymphocytic choriomeningitis, plague, and Colorado tick fever are harbored by rats [6,16].

This study aimed to isolate and identify bacteria from internal organs of rats captured in Baghdad City, Iraq.

Materials and Methods

Ethical approval

The experiment was carried out in the Laboratory of Zoonotic Diseases, College of Veterinary Medicine, University of Baghdad, from September 1 to September 30, 2015, and approved by the Animal Care and Use Committee (Approval No. 1593/28 August 2015).

Animals

A total of 120 black rats (Rattus rattus) were trapped from different areas in Baghdad city. Rats were kept in individual plastic cages for 3 h before euthanized. Pellets and water were supplied *ad libitum*. The rats were administered 0.1 mL of 9:1, Ketamine + Xylazine per 100 g/BW intramuscularly [17].

Collection and processing of samples

Deep pharyngeal swab, intestinal content, urine, and pieces of the liver and spleen, lung, kidney, and brain were obtained aseptically. The specimens were inoculated into peptone water and incubated at 37°C for 24 h for enrichment. A loopful of each specimen was then subcultured onto MacConkey Agar, Blood Agar, and Mannitol Salt Agar. CHROMagar O157 H7 and CHROMagar Listeria were used to detect *E. coli* O157:7 and *Listeria* spp., respectively [18,19].

Identification of bacteria

Identification of bacteria was confirmed using biochemical tests on analytical profile index (Analytab Products, BioMerieux Canada, St. Laurent, Quebec) strips and microscopic examination. A commercial kit (Wellcolex *E. coli* O157:H7, Remel) for latex agglutination test was used to detect both the somatic antigen O157 and the flagellar antigen H7 for serotyping *E. coli* O157:H7. This test was performed according to the manufacturer’s instructions.

Results

Mixed bacterial isolates recorded 116, 52, 36, 28, 18, 6, and 4 were identified from intestinal contents, deep pharyngeal, liver and spleen, urine, lung, brain, and kidney, respectively (Table-1). The highest bacterial prevalence (88; 73.33%) was recorded for *E. coli*, where 68 isolates were identified from the intestinal contents. Of these, four isolates were *E. coli* O157:H7. Notably, *Staphylococcus* spp. (50; 41.66%), *Streptococcus* spp. (18; 15%), *Bacillus* spp. (14; 11.66%), and *Pseudomonas aeruginosa* (12; 10%) together comprised a high prevalence rate. *Proteus* spp., *Listeria* spp., *Klebsiella* spp., *Brucella* spp., and many other bacteria were isolated in low frequency, as shown in Table-1.

Discussion

Rats have been incriminated as the carriers of many pathogenic bacteria [20]. Results of this study indicated that rats harbor bacterial organisms, which are potentially pathogenic to humans or animals. Our findings recorded the isolation of 20 different genera of bacteria from different organs of the rat including *E. coli*, *Listeria*, *Brucella*, *P. aeruginosa*,

---

**Table-1:** Bacterial isolates from the internal organs of captured rats.

| Isolated bacteria                  | Intestinal content | Deep pharyngeal swab | Liver and spleen | Urine | Lung | Brain | Kidney | Total prevalence (%) |
|------------------------------------|--------------------|-----------------------|------------------|-------|------|-------|--------|----------------------|
| *Escherichia coli*                 | 68                 | 0                     | 10               | 10    | 0    | 0     | 0      | 88 (73.33)           |
| *Staphylococcus aureus*            | 6                  | 30                    | 0                | 6     | 8    | 0     | 0      | 50 (41.66)           |
| *Streptococcus* spp.              | 2                  | 6                     | 0                | 2     | 4    | 4     | 0      | 18 (15.00)           |
| *Bacillus* spp.                   | 6                  | 0                     | 0                | 4     | 4    | 0     | 0      | 14 (11.66)           |
| *Pseudomonas aeruginosa*           | 0                  | 4                     | 8                | 0     | 0    | 0     | 0      | 12 (10.00)           |
| *Citrobacter freundii*             | 4                  | 0                     | 4                | 2     | 0    | 0     | 0      | 10 (8.33)            |
| *Proteus vulgaris*                 | 0                  | 4                     | 2                | 4     | 0    | 0     | 0      | 10 (8.33)            |
| *E. coli O157:H7*                  | 8                  | 0                     | 0                | 0     | 0    | 0     | 2      | 8 (6.66)             |
| *Enterobacter cloacae*             | 4                  | 2                     | 0                | 0     | 0    | 2     | 0      | 8 (6.66)             |
| *Listeria* spp.                   | 6                  | 0                     | 0                | 0     | 0    | 0     | 0      | 6 (5.00)             |
| *Klebsiella* spp.                 | 6                  | 0                     | 0                | 0     | 0    | 0     | 0      | 6 (5.00)             |
| *Ochrobactrum anthropi*            | 0                  | 0                     | 4                | 0     | 0    | 2     | 0      | 6 (5.00)             |
| *Aeromonas* spp.                  | 0                  | 0                     | 4                | 0     | 0    | 0     | 0      | 4 (3.33)             |
| *Brucella* spp.                   | 0                  | 0                     | 4                | 0     | 0    | 0     | 0      | 4 (3.33)             |
| *Pseudomonas fluorescens*          | 0                  | 2                     | 0                | 0     | 0    | 0     | 0      | 4 (3.33)             |
| *Escherichia fergusonii*           | 2                  | 0                     | 0                | 0     | 0    | 0     | 0      | 2 (1.66)             |
| *Micrococcus* sp.                 | 0                  | 0                     | 0                | 0     | 2    | 0     | 0      | 2 (1.66)             |
| *Morganella* spp.                 | 2                  | 0                     | 0                | 0     | 0    | 0     | 0      | 2 (1.66)             |
| *Proteus mirabilis*                | 2                  | 0                     | 0                | 0     | 0    | 0     | 0      | 2 (1.66)             |
| *Pseudomonas luteola*              | 0                  | 2                     | 0                | 0     | 0    | 0     | 0      | 2 (1.66)             |
| *Streptobacillus*                 | 0                  | 2                     | 0                | 0     | 0    | 0     | 0      | 2 (1.66)             |

Total 116 52 36 28 18 6 4
Staphylococcus aureus, Streptococcus spp., and Streptobacillus (Table-1). *E. coli* is a normal microflora of the gut and causes gastrointestinal disruption. The more pathogenic serotype, *E. coli* O157:H7, has emerged as a major foodborne zoonotic pathogen responsible for the hemorrhagic colitis and hemolytic uremic syndrome in human [21]. In this study, the prevalence of *E. coli* and *E. coli* O157:H7 was 73.33 and 6.66%, respectively. Moine et al. [22] isolated these organisms from wild rodents. Previous recorded prevalence in intestinal content reached 47.56% [21], 61.8% [14], and 83.8% [12]. These data supported our findings. On the other hand, *Escherichia fergusoni*ii, an emerging zoonotic potential pathogen, was isolated (1.66%) from intestinal content (Table-1). It is incriminated in cystitis [23], cholangiosepsis [24], wound infections, bacteremia, diarrhea, and pleural infections in human [24-26], enteritis in broiler chickens [27,28] and ostriches [29], and diarrhea in farm animals [30-32]. Pure *E. fergusoni*ii growth was verified from postmortem intestinal sample, lung, liver, and kidney [30].

*Staphylococci* are diverse ubiquitous opportunistic colonizers of human epithelia involved in nosocomial infections that cause diseases of major importance in both human and animals, ranging from minor skin infections to life-threatening bacteremia as well as septicemia [33]. Kato et al. [34] recorded 18.1% for the prevalence of *S. aureus* from rats. Compared it to our findings (41.66%), this high prevalence may be due to the different sites of isolation included in our study. This agreed with Al-Edany [35] who recovered *S. aureus* from the respiratory tract of rats and the results of Khalaf et al. [36] who isolated *Staphylococcus* spp. and methicillin-resistant *S. aureus* (MRSA) from deep pharyngeal, feces, and urine. Globally, MRSA persists to be a big threatening concern in the emergency department patients [37-39].

*Streptobacillus* was isolated from deep pharyngeal swab (1.66%) of rats in our study. This organism is part of the normal flora of the rat oropharynx, and present in rat populations worldwide. It can be transmitted to people through the bite of an infected rat causing rat bite fever, and through ingestion of food contaminated by rats, causing Haverhill fever. Infection with *S. moniliformis* can progress to septicemia, and the mortality rate may record 7-13% [26,39,40].

*P. aeruginosa* is the most important antibiotic-resistant bacteria associated with nosocomial infections causing notable morbidity and mortality [41,42] with its serious mode of transmission through tap water [43]. It is incriminated in pneumonia, septicemia, surgical wound infections, and urinary tract infections [42,44,45]. The prevalence in a study performed by Gakuya et al. [20] was 0.6%. Our finding reported much higher prevalence peaked to 10%. Attention should be focused on this serious increment due to the involvement of this pathogen in persistent colonization of the respiratory tract and resistance for treatment [46,47]. Unlike *P. aeruginosa*, *Pseudomonas fluorescens* is an infrequent and low virulence cause of human infections which occur mostly in contaminated blood transfusion, catheter, and peritoneal dialysis in immunocompromised patients [48]. The isolation of *P. fluorescens* from deep pharyngeal swab obtained by our results (Table-1), in addition to kidney, might be a source for contamination of water sources often leading to nosocomial outbreaks [49]. Sporadic clinical infection of *Pseudomonas luteola* in which septicemia, meningitis, endocarditis, or peritonitis observed following peritoneal dialysis [50-53] or pneumonia and bacteremia occurred sequenced to multiple tick bites and leg ulcers [54]. Although our finding was confined with only two cases of *P. luteola* from deep pharyngeal swab, this might be an important source for contaminating food and utensils.

*Listeria* spp., in particular, *L. monocytogenes*, is the most important species involved in a global human health hazard affecting mammals, poultry, fish, and ticks [55,56]. The previous study reported high incidence reached 39.9% of *L. monocytogenes* in meat and its related utensils with a mortality rate peaked to 24% among human [57]. This organism was also reported in wild animals [58]. Its prevalence in the intestinal content of rats varied ranging from 6.5 to 77.8% [59,60] wherein our study was 5%. The frequent isolation of *Listeria* from rats suggests the possibility of rats as a reservoir of *Listeria* spp. and the continual environmental contamination. Another Gram-negative bacteria, *Brucella abortus*, was isolated from rats with active brucellosis trapped from a cattle farm and suggests that cattle are an important source of infection for rats [61]. Real incidence of brucellosis is variable due to underreporting and difficult diagnosis, and it can be up to 5 times higher. *B. abortus* as well as *Brucella melitensis* has been isolated from rats [62,63]. Rats play a crucial role in vertical transmission of brucellosis and may become potentially latent carriers providing a reservoir for future transmission [63]. Our findings revealed a prevalence of *Brucella* at 3.33% affecting liver and spleen, although species have not been identified.

Streptococci may, or not, be associated with diseases in rats [64]. Unlike, in humans, *S. pyogenes* colonizes the oropharynx [65] causing many diseases with wide range of symptoms manifested by acute rheumatic fever, carditis, and valvulitis [66,67]. Moreover, streptococci are commensal opportunistic pathogens of the human vaginal, intestinal, and respiratory tracts causing sepsis, pneumonia, or meningitis [66-68]. Although species identification for *Streptococcus* is not carried out in our study, its prevalence (15%) in intestinal contents, deep pharynx, urine, and lung tissues predicted the transmission of diseases through rat droppings or interfering with human food. Many previous studies referred to the isolation of *Streptococcus* mutants from the oral cavity of human and rats [69,70].

Our findings showed a cumulative prevalence
(10%) for Proteus vulgaris and Proteus mirabilis. Although the trend was recorded for the former, the disruptive capability attributed to the latter. Proteus mirabilis, occasionally, can be a primary pathogen, concomitantly with another pathogen, or alone can cause ascending pyelonephritis [71]. It is mainly in soil and the gastrointestinal tract, giving rise to opportunistic disease in children and the elderly [72]. It persists in the rat kidney for up to 8 weeks and induces many morphological changes including tubular atrophy and interstitial fibrosis resulting in chronic pyelonephritis and may extend to the prostate [72,73]. It can cause serious renal damage, such as acute pyelonephritis, renal stone, and bacteremia [73]. Similar to the prevalence of P. vulgaris, Citrobacter freundii record (8.33%) is considered a serious alert for its destructive role.

Citrobacter spp. are well known to be unique in their frequent association with brain abscess formation and neonatal meningitis [72]. After invading and transcytosing them, Citrobacter freundii is able to replicate within human brain microvascular endothelial cells causing meningitis and brain abscesses and resulted in unacceptable rates of morbidity and mortality in neonates [74].

Many opportunistic pathogens, for example, Klebsiella, Enterobacter, and Pseudomonas have become increasingly relevant as the causative agents of clinical diseases and pathological lesions in laboratory animals [72,75]. As K. pneumoniae can cause severe fatal pyogenic pneumonia in humans, with a lesser extent in K. oxytoca, it serves experimentally as a model for many diseases, while K. oxytoca is infrequent naturally occur [75-77]. Our finding regarding Klebsiella, despite its species, reported six cases from intestinal content, putting the risk of contaminating the surroundings by rat droppings is highly predicted. Klebsiella infections in rats are widely documented experimentally as well as naturally [72,78-81], and antibiotic resistance is very common in human as well as rats [7-77,82]. Another Gram-negative bacteria, Enterobacter cloacae, a normal gut flora, is responsible for increasing nosocomial infections and antibiotic resistance. This microorganism causes sepsis and meningitis mainly in immunocompromised patients [83-85]. Our records regarding E. cloacae reached 6.66% from intestinal content, and deep pharyngeal swab and kidney predispose the contamination of food and places. The threats of genus Enterobacter may extend to high mortality rates in premature infants [85]. Hunter et al. [86] used rat model for an experimental Enterobacter infection.

Other opportunistic bacteria such as Morganella sp., Aeromonas sp., Ochrobactrum anthropi, and Micrococcus sp. are infrequently causing disease in healthy individuals and usually occur in the environment as normal flora [87-89]. The risk of these bacteria is in their resistance to antibiotics [90,91], residing as emerging pathogens of low virulence. Although some strains of M. morganii are enteropathogenic [92], most bacteremic cases (0.69% up to 3.6% among nosocomial infections) were opportunistic community-acquired infections [93,94]. Mostly, clinical infections involve the urinary tract, skin and soft tissue, hepatobiliary infection, peritonitis, septic arthritis, pericarditis, meningitis, otitis media, gastroenteritis, tubo-ovarian abscess, and neonatal sepsis [93,95]. Rats under the influence of antibiotics are able to shed Proteus mirabilis and Morganella morganii in feces [96]. They, in concomitant with Aeromonas sp., are usually involved in summer diarrhea in healthy individuals [92,97-99]. Regarding Aeromonas sp., a common zoonotic pathogen mainly of aquatic animals [100], it produces enterotoxin and alpha- and beta-hemolysin, resulting in hemorrhagic enteritis, and usually develops antibiotic resistance [91]. Our records 5.00, 3.33, 1.66 and 1.66% for O. anthropi, Aeromonas sp., Micrococcus sp. and Morganella sp., respectively, are in accordance with many authors who stated the role of rat in contaminating the environment and dispersing diseases [20,96,101,102]. Nosocomial infections through dialysis fluids and contaminated hospital water supplies, mostly by carrier rats, suggest a good indicator for bacterial pollution of fresh water and promote spread of nosocomial infection [87-89,102].

In this study, we reported mixed bacterial isolates from urine, deep pharyngeal swab, and many organs of rats which are usually incriminated in zoonotic diseases. Some of these bacteria, for example, O. anthropi have not been reported previously from captured rats.

Conclusion

Findings of our microbiological investigation concluded that rats are important carriers and transmitters of a number of pathogens and can disseminate these microorganisms to humans as well as animals.

Authors’ Contributions

AJK, JMK, ZAA, NMA, and ZMA designed the experiment. AJK, JMK, and NMA interpreted the data. AJK and NMA wrote the draft of manuscript. ZMA, DDM, KAA, and EAM captured rats. RSJ, DIA, and AJK euthanized the rats. All researchers participated in dissecting and sample collections. NMA, ZAA, AJK, JMK, and ZMA were responsible for collecting and biochemicals. AJK edited the manuscript.

Acknowledgments

Authors owe sincere thanks to Dr. Nawal Dhahd Mahmood for her support during the experiment. This study was funded by the College of Veterinary Medicine (grant no; 2705/2016), University of Baghdad, Baghdad, Iraq.

Competing Interests

The authors declare that they have no competing interests.
Veterinary World remains neutral with regard to jurisdictional claims in published institutional affiliation.

References

1. Fayemwo, J.O., Olakojo, S.A., Akande, M., Amusa, N.A. and Olujiimi, O.A. (2007) Comparative evaluation of vertebrete pest damage on some newly developed quality protein maize (QPM) varieties in southwestern Nigeria. Afr. J. Agric. Res., 2(11): 592-595.

2. Edman, J.C., Kovacs, J.A., Masur, H., Santi, D.V., Elwood, H.J. and Sogin, M.L. (1988) Ribosomal RNA sequence shows Pneumocystis carinii to be a member of the fungi. Nature, 334(6182): 519-522.

3. Laudsioit, A., Falay, D., Amundala, N., Akaibe, D., de Simmons, K., Rempel, H., Block, G., Forgetta, V., Nkogwe, C., Raletobana, J., Stewart-Johnson, A. and Yan, Y., Zhao, Z., Wan, H., Wu, R., Fang, J. and Liu, H. (2007) A longitudinal study of Yersinia pestis in wildlife, birds, and reptiles in Trinidad. J. Zoo Wildl. Med., 31(3): 353-360.

4. Van, Y., Zhao, Z., Zhu, W. and Liu, H. (2014) A novel fungus concentration-dependent rat model for acute invasive fungal rhinosinusitis: An experimental study. BMC Infect. Dis., 14(1): 3856.

5. Mohebali, M., Zarei, Z., Khanaliha, K., Kia, E.B., Motavalli-Hagh, A., Davoodi, J. and Rezaeian, M. (2017) Natural intestinal protozoa in rodents (Rodentia: Gerbillinae, Murinae, Cricetinae) in Northwestern Iran. Iran. J. Parasitol., 12(3): 382-388.

6. Psaroulaki, A., Antoniou, M., Tournazos, P., Mazeras, A., Ioanou, I., Chochlakis, D., Christophi, N., Loukaides, P., Patsias, A., Moschandrea, I. and Tsolentis, Y. (2010) Rats as indicators of the presence and dispersal of six zoonotic microbial agents in Cyprus, an Island ecosystem: A seroepidemiological study. Trans. R. Soc. Trop. Med. Hyg., 104(9): 733-739.

7. Zahedi, A., Poparini, A., Jian, F., Robertson, I. and Ryan, U. (2016) Public health significance of zoonotic Cryptosporidium species in wildlife: Critical insights into better drinking water management. Int. J. Parasitol. Parasites Wildl., 5(1): 88-109.

8. Wullnenwerber, M. (1995) Streptobacillus moniliformis a zoonotic pathogen. Taxonomic considerations, host species, diagnosis, therapy and geographical distribution. J. Lab. Anim. Dis., 29(1): 1-16.

9. Cleri, D.J., Varnaleo, J.R., Lombardii, L.J., Rabbat, M.S., Mathew, C., Kovacs, R. and Revelt, M.C. (1997) Plague pneumonia caused by Yersinia pestis. Semin. Respir. Infect., 12(1): 12-23.

10. Burriel, A.R., Kritas, S.K. and Kontos, V. (2008) Some microbiological aspects of rats captured alive at the port city of Piraeus, Greece. Int. J. Environ. Health Res., 18(2): 159-164.

11. Guenther, S., Grobbel, M., Beutlich, J. and Guerra, B. (2010) Detection of pandemic B2-O25-ST131 Escherichia coli harrowing the CTX-M-1 extended-spectrum beta-lactamase type in a feral urban brown rat (Rattus norvegicus). J. Antimicrob. Chemother., 65(3): 582-584.

12. Nkogwe, C., Raleotana, J., Stewart-Johnson, A. and Suepaul, S. (2011) Frequency of detection of Escherichia coli, Salmonella spp., and Campylobacter spp. In the faeces of wild rats (Rattus spp.) in Trinidad and Tobago. Vet. Med. Int., 2011(20): 1-7.

13. Adegusiyan, A.A., Stewart-Johnson, A. and Thompson, N.N. (2009) Isolation of enteric pathogens from bats in Trinidad. J. Wildl. Dis., 45(4): 952-961.

14. Gopee, N.V., Adegusiyan, A.A. and Caesar, K. (2000) A longitudinal study of Escherichia coli strains isolated from captive mammals, birds, and reptiles in Trinidad. J. Zoo Wildl. Med., 31(3): 353-360.

15. Desvars-Larriue, A., Pascal, M., Gasqui, P., Cosson, J.F., Benot, E., Latturd, V., Crespin, L., Lorveeoe, O., Pisuan, B., Teynié, A., Vaysiss-Taussat, M., Bonnet, S., Marianneau, P., Lacotte, S., Bourhy, P., Bemy, P., Pavia, N., Le Poder, S., Gilot-Fromont, E., Jourdain, E., Hammmed, A., Fourel, I., Chikh, F. and Vourc’h, G. (2017) Population genetics, community of parasites, and resistance to rodenticides in an urban brown rat (Rattus norvegicus) population. PLoS One, 12(9): e0184015.

16. Tsakmakidis, I., Angelopoulou, K., Dovas, C.J., Dokianakis, E., Tamvakis, A., Symeonidou, I., Antoniou, M. and Diakou, A. (2017) Leishmania infection in rodents in Greece. Trop. Med. Int. Health, 22(12): 1523-1532.

17. Struck, M.B., Andrunis, K.A., Ramirez, H.E. and Battles, A.H. (2011) Effect of a short-term fast on ketamine-xylazine anesthesia in rats. J. Am. Assoc. Lab. Anim. Sci., 50(3): 344-348.

18. Chow, V.T.K., Inglis, T.J.I. and Peng-Song, K. (2006) Diagnostic clinical microbiology. In: Kun, L. Y., editor. Microbial Biotechnology. World Scientific Publishing Co. Pte. Ltd., Singapore. p539-593.

19. Islam, N.N., Akter, M., Farzana, Z. and Bin Kader, A. (2014) Detection of Staphylococcus aureus in frozen chicken rinse through bacteriological and Nuc gene-specific PCR methods and their drug resistance patterns in Southern Bangladesh. Res. J. Microb., 9(5): 251-264.

20. Gakuya, F.M., Kyule, M.N., Gathura, P.B. and Kariuki, S. (2005) Antimicrobial resistance of bacterial organisms isolated from rats. East Afr. Med. J., 78(12): 646-649.

21. Karmali, M.A., Gannon, V. and Sargeant, J.M. (2010) Verocytotoxin producing Escherichia coli (VTEC). Vet. Microbiol., 140(3-4): 360-370.

22. Moine, V.L., Vannier, P. and Jestin, A. (1987) Microbiological studies of wild rodents in farms as carriers of pig infectious agents. Prev. Vet. Med., 4(5-6): 399-408.

23. Savini, V., Catavitello, C., Talia, M., Manna, A., Pompeetti, F., Favaro, M., Fontana, C., Febbro, F., Balbinot, A., Di Berardino, F., Di Bonaventura, G., Di Zacomo, S., Esattore, F. and D’Antonio, D. (2008) Multidrug-resistant Escherichia fergusonii: A case of acute cystitis. J. Clin. Microbiol., 46(4): 1531-1552.

24. Fumke, G., Hany, A. and Allweg, M. (1993) Isolation of Escherichia fergusonii from four different sites in a patient with pancreatic carcinoma and cholangiosepsis. J. Clin. Microbiol., 31(8): 2201-2203.

25. Mahapatra, A. and Mahapatra, S. (2005) Escherichia fergusonii: An emerging pathogen in South Orissa. Ind. J. Med. Microbiol., 23(3): 204-208.

26. Gastra, W., Boot, R., Ho, H.T.K. and Lipman, L.J.A. (2009) Rat bite fever. Vet. Microbiol., 133(3): 211-228.

27. Oh, J.Y., Kang, M.S., An, B.K., Shin, E.G., Kim, M.J. and Kwon, J.H. (2012) Isolation and epidemiological characterisation of heat labile enterotoxin producing from a healthy chickens. Vet. Microbiol., 160(1-2): 170-175.

28. Simmons, K., Rempel, H., Block, G., Forgetta, V., Vaillancourt, R. and Malouin, F. (2014) Duplex PCR methods for the molecular detection of Escherichia fergusonii isolates from broiler chickens. Appl. Environ. Microbiol., 80(6): 1941-1948.

29. Herranz, P., Rodriguez, A.F., de los Monteros, A.E., Acosta, A.B., Jaber, J.R., Castellano, J. and Castroa, A. (2005) Fibrinonecrotic typhlitis caused by Escherichia fergusonii in ostriches (Struthio camelus). Avian Dis., 49(1): 167-169.

30. Harirhan, H., Alfonso, L., Gary, C., Mada, C. and Tannyn, M. (2007) Isolation of Escherichia fergusonii from the feces and internal organs of a goat with diarrhea. Can. Vet. J., 48(6): 630-631.

31. Wragg, P., La Ragione, R.M., Best, A., Reichel, R., Anjum, M.F. and Mafura, M. (2009) Characterisation of Escherichia fergusonii isolates from farm animals using an Escherichia coli virulence gene array and tissue culture
adherence assays. Res. Vet. Sci., 86(1): 27-35.

32. Weiss, A.T.A., Lubke-Becker, A., Krenz, M. and van der Grinten, E. (2011) Enteritis and septisemia in a horse associated with infection by Escherichia fergusonii. J. Equine Vet. Sci., 31(7): 361-364.

33. Aklili, E., Zumita, Z., Hassan, L. and Chen, H.C. (2010) Phenotypic and genotypic characterization of Methicillin-resistant Staphylococcus aureus (MRSA) isolated from dogs and rats at University Veterinary Hospital, Universiti Putra Malaysia. Trop. Biomed., 27(3): 483-492.

34. Kato, Y., Matsunaga, S., Misuna, Y., Ushioda, H. and Yamamoto, T. (1995) Isolation and characterization of Staphylococcus aureus in rats trapped at restaurants in buildings in downtown Tokyo. J. Vet. Med. Sci., 57(3): 499-502.

35. Al-Edany, O.S. (2015) Isolation and Identification of Zoonotic Bacteria from Wild Rats and Mice. MSc Thesis. College of Veterinary Medicine-University of Baghdad. Baghdad-Iraq.

36. Khalaf, S.K., Nagham, M.A., Abdullah, J.K. and Jaben, M.K. (2015) Isolation of Methicillin-resistant Staphylococcus aureus (MRSA) from Rattus rattus from Adhamiyah district in Baghdad governorate. MVRSA, 4(3): 9-23.

37. Bouchiat, C., Curtis, S., Spiliopoulos, I., Bes, M., Coccuzza, C., Codita, I., Dupieuxm, C., Giormezis, N., Keams, A.L., Laurent, F., Molinos, S., Musumeci, R., Prat, C., Saadatian-Elahi, M., Taconnelli, E., Tristan, A., Schulte, B., Vandenesch, F. (2017) MRSA infections among patients in the emergency department: A European multicentre study. J. Antimicrob. Chemother., 72(2): 372-375.

38. Al Jalaf, M., Fadali, H., Alance, R., Najjar, F., Al Deesi, Z., Seliem, R.M. and Nilles, E.J. (2018) Methicillin-resistant Staphylococcus aureus in emergency department patients in the United Arab Emirates. BMC Emerg. Med., 18(1): 12.

39. Elliott, S.P. (2007) Rat bite fever and Streptobacillus moniliformis. Clin. Microbiol. Rev., 20(1): 13-22.

40. Meerburg, B.G., Singleton, G.R. and Kijlstra, A. (2009) Rodent-borne diseases and their risks for public health. Crit. Rev. Microbiol., 35(3): 221-270.

41. Verbiest, L. (1993) Epidemiology and sensitivity of 8625 ICU and hematot/oncology bacterial isolates in Europe. International Study Group. Scand. J. Infect. Dis., 91(1): 14-24.

42. Agodi, A., Barchitta, M., Cipriannia, R., Gianguita, L., Romeo, M.A. and Denaro, C. (2007) Pseudomonas aeruginosa carriage, colonization, and infection in ICU patients. Intensive Care Med., 33(7): 1155-1161.

43. Kerr, K.G. and Snelling, A.M. (2009) Pseudomonas aerugi- nosa: A formidable and ever-present adversary. J. Hospital Infect., 73(1): e338-e344.

44. Lee, J.R., Kim, H., Daudhia, D., Bartlett, E., Allon, M.J., Satlin, M. and Muthukumar, T. (2015) Independent risk factors for urin-ary tract infection and for subsequent bac-teremia or acute cellular rejection: A single center report of 1166 kidney allograft recipients. Transplantation, 96(8): 10.

45. Badamchi, A., Masoumi, H., Javadnia, S., Asgarian, R. and Tabatabaee, A. (2017) Molecular detection of six virulence genes in Pseudomonas aeruginosa isolated from children with urinary tract infection. Microb. Pathog., 107(22): 44-47.

46. Breidenstein, E.B., de la Fuente-Núñez, C. and Hancock, R.E. (2011) Pseudomonas aeruginosa: All roads lead to resistance. Trends Microbiol., 19(8): 419-426.

47. Rybtke, M.T., Jensen, P.O., Hoiby, N., Givskov, M., Toller-Nielsen, T. and Bjaernsholt, T. (2011) The implication of Pseudomonas aeruginosa biofilms in infections. Inflamm. Allergy Drug Targets, 10(2): 141-157.

48. Hsueh, P.R., Teng, L.J., Pan, H.J., Chen, Y.C., Sun, C.C., Ho, S.W. and Luh, K.T. (1998) Outbreak of Pseudomonas fluorescens bacteremia among oncology patients. J. Clin. Microbiol., 36(10): 2914-2917.

49. Anaissie, E.J., Penzak, S.R. and Dignani, M.C. (2002) The hospital water supply as a source of nosocomial infections: A plea for action. Arch. Int. Med., 162(13): 1483-1492.

50. Connor, B.J., Kopecky, R.T., Frymoyer, P.A. and Forbes, B.A. (1987) Recurrent Pseudomonas luteola (CDC group Ve-1) peritonitis in a patient undergoing continuous ambulatory peritoneal dialysis. J. Clin. Microbiol., 25(6): 1113-1114.

51. Chibah, W., Alaoui, A.S. and Amer, M. (2004) Chryseomonas luteola identified as the source of serious infections in a Moroccan university hospital. J. Clin. Microbiol., 42(4): 1837-1839.

52. Casalta, J.P., Fournier, P.E., Habib, G., Riberi, A. and Raoult, D. (2005) Prosthetic valve endocarditis caused by Pseudomonas luteola. BMC Infect. Dis., 5(7): 82.

53. Su, S.Y., Chao, C.M. and Lai, C.C. (2014) Peritoneal dialysis peritonitis caused by Pseudomonas luteola. Perit. Dial. Int., 34(1): 138-139.

54. Arnold, F., Sciortino, C. and Riede, K. (2004) New associations with Pseudomonas luteola bacteremia: A veteran with a history of tick bites and a trauma patient with pneumonia. Internet J. Infect. Dis., 4(2): 9005.

55. OIE. (2016) The 5th Global Animal Health Conference. Available from: http://www.healthforanimals.org/resources-and-events/resources/news/25-global-animal-health-conference-addresses-regulatory-barriers.html. Last accessed on 25-04-2018.

56. Mehlhase, P.J., Neumann, G.E. and Pruckner, A. (2003) Brucella infection in nature. Rev. Sci. Tech., 22(3): 459-474.

57. Farber, J.M. and Petrick, P.I. (1991) Listeria monocytogenes: An emerging foodborne pathogen. Int. J. Food Microbiol., 19(4-5): 89-96.

58. Yoshida, T., Tomoki, S., Moritoshi, S. and Katsuha, Y. (2000) Incidence of Listeria monocytogenes in wild animals in Japan. J. Vet. Med. Sci., 62(6): 673-675.

59. Ryu, C.-H., Iizumi, S., Inoue, S. and Kamagai, S. (1992) The incidence of Listeria species in retail foods in Japan. Int. J. Food Microbiol., 16(2): 157-160.

60. Inoue, S., Tanikawa, T., Kawaguchi, J., Iida, T. and Morita, C. (1992) Prevalence of Listeria spp in wild rats captured in the Kanto area of Japan. J. Vet. Med. Sci., 54(3): 461-463.

61. Moore, C.G. and Schnurrenberger, P.R. (1981) A review of naturally occurring Brucella abortus infections in wild mammals. J. Am. Vet. Med. Assoc., 179(1): 1105-1112.

62. Zheludkov, M.M. and Tsirelson, L.E. (2010) Reservoirs of E. coli in large animals. Food Microbiol., 62(6): 673-675.

63. Hamada, S. and Slade, H.D. (1980) Biology, immunology, and events/resources/news/25-global-animal-health-conference-addresses-regulatory-barriers.html. Last accessed on 25-04-2018.

64. Islam, M.A., Khatun, M.M. and Baek, B.K. (2012) Rats born to Brucella abortus-infected mothers become latent carriers of Brucella. J. Infect. Dev. Ctries., 6(3): 256-261.

65. Shuster, A.A., Hish, G.A., Selles, L.A., Chowdhury, M.A., Wiggins, R.C., Dysko, R.C. and Bergin, L.L. (2013) Naturally occurring disseminated Group B Streptococcus infections in postnatal rats. Comp. Med., 63(1): 55-61.

66. Cohen-Poradosu, R. and Kasper, D.L. (2007) Group A streptococcus epidemiology and vaccine implications. Clin. Infect. Dis., 45(7): 863-865.

67. Ralph, A.P. and Carapetsis, R.J. (2013) Group A streptococcal diseases and their global burden. Curr. Top. Microbiol. Immunol., 368(1): 1-27.

68. Parks, T., Barrett, L. and Jones, N. (2015) Invasive strepto-tococcal disease: A review for clinicians. Br. Med. Bull., 115(1): 77-89.

69. Hamada, S. and Slade, H.D. (1980) Biology, immunology, and events/resources/news/25-global-animal-health-conference-addresses-regulatory-barriers.html. Last accessed on 25-04-2018.

70. Shaffer, J.N. and Pearson, M.W. (2015) Proteus mirabilis
and urinary tract infections. Microbiol. Spectr., 3(5): 1-66.
72. Guentzel, M.N. (1996) Escherichia, Klebsiella, Enterobacter, Serratia, Citrobacter and Proteus. In: Baron S, editor. Medical Microbiology. 4th edition. University of Texas Medical Branch, Galveston (TX).
73. Flores-Mireles, A.L., Walker, J.N., Caparon, M. and Hultgren, S.J. (2015) Urinary tract infections: Epidemiology, mechanisms of infection and treatment options. Nat. Rev. Microbiol., 13(5): 269-284.
74. Badger, J.L., Stins, M.F. and Kim, K.S. (1999) Citrobacter freundii invades and replicates in human brain microvasculcar endothelial cells. Infect. Immun., 67(8): 4208-4215.
75. Coonrod, J.D. (1981) Enterobacter meningitis and challenges in treatment. J. Clin. Diag. Res., 25(2): 95-100.
76. Darby, A., Lertpiriyapong, K., Sarkar, U., Seneviratne, U.I. and Fox, J.G. (2014) Cytotoxic and pathogenic properties of Klebsiella oxytoca isolated from laboratory animals. PLoS One, 9(7): e100542.
77. Bleich, A., Kirsch, H.P., Sahly, H., Fahey, J., Smoczek, A., Hedrich, H.J. and Sundberg, J.P. (2008) Klebsiella oxytoca: Opportunistic infections in laboratory rodents. Lab. Anim., 42(3): 369-375.
78. Berendt, R.F., Long, G.G., Abeles, F.B., Canonicof, P.G., Elwell, M.R. and Powanda, M.C. (1977) Pathogenesis of respiratory Klebsiella pneumoniae infection in rats: Bacteriological and histological findings and metabolic alterations. Infect. Immun., 15(2): 586-593.
79. Dong, F., Wang, B., Zhang, L., Tang, H., Li, J. and Wang, Y. (2012) Metabolic response to Klebsiella pneumoniae infection in an experimental rat model. PLoS One, 7(11): e51060.
80. Shatzkes, K., Singleton, E., Tang, C., Zueva, M., Shukla, S., Gupta, S., Dharani, S., Onyile, O., Rinaggio, J., Connell, N.D. and Kadouri, D.E. (2016) Predatory bacteria attenuate Klebsiella pneumoniae burden in rat lungs. MBio, 7(6): e01816-e01847.
81. Schauler, K., Nowak, K., Düx, A., Semmler, T., Villa, L., Kourouma, L., Bangoura, K., Wieler, L.H., Leendertz, F.H., Upperman, J.S. and Kadouri, D.E. (2016) Predatory bacteria alter alterations. Bacteriological and histological findings and metabolic alterations. Infect. Immun., 23(2): 220-241.
82. Khan, E. and Sami, S. (2000) Infective endocarditis and septic embolization with Ochrobactrum anthropi: Case report and review of literature. J. Infect., 40(3): 287-290.
83. Sanders, W. and Sanders, C.C. (1997) Enterobacter, Serratia, Citrobacter and Proteus. In: Baron S, editor. Medical Microbiology. 4th edition. University of Texas Medical Branch, Galveston (TX).
84. Shukla, S., Gupta, S., Dharani, S., Onyile, O., Rinaggio, J., Connell, N.D. and Kadouri, D.E. (2016) Predatory bacteria attenuate Klebsiella pneumoniae burden in rat lungs. MBio, 7(6): e01816-e01847.
85. Khan, E. and Sami, S. (2000) Infective endocarditis and septic embolization with Ochrobactrum anthropi: Case report and review of literature. J. Infect., 40(3): 287-290.
86. Hunter, C.J., Singamsetty, V.K., Chokshi, N.K., Boyle, P., Camerini, V., Grishin, A.V., Upperman, J.S. and Prasadarao, N.V. (2008) Enterobacter sakazakii enhances epithelial cell injury by inducing apoptosis in a rat model of necrotizing enterocolitis. J. Infect. Dis., 198(4): 586-593.
87. Mahmod, M.S., Sarwari, A.R., Khan, M.A., Sophie, Z.,