Clinical and Reproductive Pathological Changes Associated with \textit{Brucella melitensis} and its Lipopolysaccharides in Female Mice Via Oral Inoculation

1,3 Faez Firdaus Jesse Abdullah, 1,5 Lawan Adamu, 1 Nur Hazirah, 1 Abdinasir Yusuf Osman, 1 Rozaihan Mansor, 1,3 Abdul Wahid Haron, 4 Mohd Zamri Saad, 4 Abdul Rahman Omar and 1 Abdul Aziz Saharee

1 Department of Veterinary Clinical Studies, 2 Department of Veterinary Pathology and Microbiology, Faculty of Veterinary Medicine, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia 3 Research Centre for Ruminant Disease, Faculty of Veterinary Medicine, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia 4 Institute of Bioscience, Universiti Putra Malaysia, Serdang, Selangor, Malaysia 5 Department of Veterinary Medicine, Faculty of Veterinary Medicine, University of Maiduguri, PMB1069, Borno State, Nigeria

ABSTRACT

\textit{Brucella melitensis} are Gram-negative, aerobic, facultative intracellular bacteria that cause brucellosis that usually leads to abortion in sheep and goats. Three groups of equal number of 24 healthy female mice were used as animal models. They were orally inoculated with 0.4 mL of phosphate Buffered Saline (PBS-Control group), 0.4 mL of $10^9$ cfu of \textit{B. melitensis} and 0.4 mL of Lipopolysaccharides (LPS) extracted from $10^9$ cfu of \textit{B. melitensis} (both as treatment groups). Clinical signs exhibited by the mice were observed for 10 days, after which the survived mice were euthanized by cervical dislocation. Following that, post mortem was conducted and histopathological study of the reproductive organs was carried out. \textit{B. melitensis} group showed mild clinical signs compared to LPS group which showed normal behaviours except for mild ruffled fur, 14 and 34 h post-inoculation, respectively. The control group (PBS) showed normal behaviours. Histopathology results revealed that both \textit{B. melitensis} and LPS groups showed mild to moderate infiltration of inflammatory cells in the reproductive organs, along with normal to mild findings of necrosis. Mild to moderate haemorrhage were found in the mice of \textit{B. melitensis} group, while LPS group showed normal to mild haemorrhage and moderate to severe congestion of the ovary. The study proved that mice infected orally with \textit{B. melitensis} developed mild clinical signs whereas mice orally inoculated by its LPS showed normal behavior except for the mild ruffled fur. Moreover, both groups of mice inoculated with \textit{B. melitensis} immunogens developed pathological changes in the reproductive organs. The LPS of \textit{B. melitensis} could be a potential candidate for the development of vaccines.

Keywords: \textit{B. Melitensis}, Lipopolysaccharides, Female Mice, Histopathology, Reproductive Organs

1. INTRODUCTION

Brucellosis is one of the most important infectious diseases caused by \textit{Brucella} sp. that affects humans as well as domestic and wild animals, with reproductive disorders as the main problem in domestic animals (Megid \textit{et al.}, 2010; Silva \textit{et al.}, 2011). The validly published species of \textit{Brucella} are \textit{B. melitensis}, \textit{B. abortus} and \textit{B. suis}. The earliest isolation of \\textit{B. melitensis} strains were retrieved from patients with abortion in sheep and goats (Sneath et al., 2000). The specific disease is referred to as \textit{Brucella} melitensis abortion syndrome (BMA) which is mainly seen in goats and sheep. Infection is encountered most frequently in ruminants, particularly goats and sheep, with clinical manifestations that are generally restricted to the reproductive systems of the infected animals. The ovary is the organ and site of infection in female goats which manifest clinical signs of abortion, stillbirth, maternal mortality or premature parturition (Tomich \textit{et al.}, 2009). Moreover, the infection can also affect the respiratory, digestive, and udder tissues, especially in goats (Perez-Perez \textit{et al.}, 2010). In pregnant goats, the abortifacient effect of the infection may also be observed in the form of abortion or stillbirth (Institut Pasteur, 2008).

Corresponding Author: Faez Firdaus Jesse Abdullah, Department of Veterinary Clinical Studies, Faculty of Veterinary Medicine, University Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia Tel: +60389463924
abortus, B. suis, B. ovis, B. canis and B. neotome (Lopes et al., 2010); with Brucella melitensis and Brucella ovis as the main causes of brucellosis in sheep and goats (Megid et al., 2010). Brucella melitensis are Gram-negative, aerobic, partially acid fast and facultative intracellular coccobacilli or short rods bacteria that cause brucellosis in sheep and goats and also the most common species that infect humans (Yohannes et al., 2013). Brucellosis infection in goats and sheep causes abortion, stillbirths, the birth of weak offsprings and infertility of the females while the males usually develop orchitis, epididymitis, seminal vesiculitis and also infertility (Megid et al., 2010). At herd level, there will be a general decrease in herd fertility, an increase in lamb or kid mortality with a low weaning percentage, a decrease on milk production and an increased culling of males due to chronic lesion on reproductive organs (Megid et al., 2010).

B. melitensis infection in sheep and goats occurs mainly through the mucous membrane of nasopharynx, apart from vertical transmission from the dam to the offsprings through “in uterus” or via the ingestion of colostrums or milk. The pathogens are then shed to the environment in large numbers through the placenta, vaginal fluids and milk (Megid et al., 2010). This facultative intracellular bacterium is able to invade into and survive within macrophages and non-professional phagocytes which results in its ability to cause chronic infection in the host (Paixao et al., 2009; Sa et al., 2012). Brucella does not evade phagocytosis by macrophages or neutrophils but inhibits the degranulation of both primary and secondary neutrophil granules and the myeloperoxidase-hydrogen peroxide-halide system.

As in other Gram-negative bacteria, the Lipopolysaccharide (LPS) in brucellae is one of the most biologically active and an important component of the outer membrane (Seyed et al., 2011) and it is the major virulence factor of Brucella (Carlos et al., 2011). B. melitensis may occur as either smooth or rough variants depending on the expression of O-Polysaccharides (OPS) as a component of the outer membrane LPS (Martin-Martin et al., 2011; Akhtar et al., 2012). The smooth LPS (S-LPS) are composed of three domains: the lipid A, the core oligosaccharide and the immunodominant portion of the molecule-the O side chain, also called the O antigen (Seyed et al., 2011). Apart from the ability to avoid the killing mechanism within macrophages, the low biological activity induced by Brucella S-LPS might be one of the factors contributing to the survival of these pathogens in phagocytic cells (Lopes et al., 2010; Akhtar et al., 2012).

Previously, Abdullah et al. (2013) has conducted a similar study in male mice intraperitoneally inoculated with Brucella and its LPS and it has shown significant changes in male reproductive organs. However, information on clinical response and reproductive pathology in female mice orally inoculated with Brucella and its LPS is scarce. Therefore, this study aims to investigate on the clinical and cellular changes in reproductive organ of female mice following oral inoculation with wild type B. melitensis and its LPS

2. MATERIALS AND METHODS

2.1. Brucella Melitensis Culture

The Brucella melitensis used in this study were obtained from stock culture from a previous outbreak of brucellosis in Malaysia was. The bacteria was then re-cultured on Brucella Agar which contains growth supplements; namely biotin, thiamin and nicotinamide. The optimum growth temperature is 36-38°C whereby the colonies can be visible after 2-4 days of incubation.

2.2. Preparation of 10⁹ CfU of Brucella Melitensis

Preparation of 10⁹ cfu of B. melitensis was done by adding distilled water onto pure cultures of B. melitensis before the bacteria was transferred into sterile test tubes. These sterile test tubes were then compared with Mac Farland standard to determine the 10⁹ cfu of B. melitensis.

2.3. LPS Extraction from 10⁹ of Colony of Brucella Melitensis

The Lipopolysaccharides (LPS) of B. melitensis was extracted using Intron Biotechnology® LPS extraction kit. In this study, 10⁹ cfu of B. melitensis was prepared for LPS extraction. The bacteria were firstly harvested by centrifugation in room temperature at 13, 000 rpm for 30 sec. Then, 1 mL of lysis buffer was added and vigorously vortexed. 200 µL of choloform was later added and vigorously vortexed for 10-20 sec before it was incubated for 5 min in room temperature. Following that, it was centrifuged at 13, 000 rpm for 10 min at 4°C, whereby 400 µL of the supernatant was transferred into a new 1.5 mL tube. Next, 800 µL of purification buffer was added and mixed well with the transferred supernatant after which it was incubated at-20°C for 10 min. It was then centrifuged again at 13, 000 rpm.
for 15 min at 4°C. The LPS pellet was obtained after the excess supernatant was discarded before the LPS pellet was washed with 1ml of 70% ethanol, which was then dried completely. Finally, 70 µL of 10 mM Tris-HCl buffer of pH 8.0 was added to the LPS pellet whereby it was dissolved by 2 min of boiling.

2.4. Experimental Design

A total of 24 healthy female mice of ICR were used in this study. These mice were divided into 3 equal groups consisting of 8 mice per group. Mice in group 1 were orally inoculated with 0.4 mL of Phosphate Buffer Saline (PBS) of pH 7; while mice in group 2 were orally inoculated with 0.4 mL of 10^9 cfu of *B. melitensis* and mice in group 3 were similarly inoculated with 0.4ml of LPS of 10^9 cfu of *B. melitensis* (Picture 1). All of these groups were then observed for 10 days for clinical signs such as ruffled fur, movements, closed eyes and ocular discharge and responsiveness. After the 10 days of observation, survived mice were euthanized by cervical dislocation and reproductive organs; namely ovary, oviduct, uterine body, vagina and vulva; were harvested for histopathological study.

2.5. Clinical Signs Scoring

Clinical signs of the three groups observed in this study were scored 0 to 3 based on the presence of ruffled fur, changes in movements, eye closure and presence of ocular discharge, as well as the mice’s responsiveness towards stimuli. The score of 0 represents no abnormality, score of 1 represents mild clinical signs, while score 2 and 3 represent moderate and severe clinical signs, respectively.

2.6. Pathological Lesion Scoring

Pathological cellular changes were scored following the evaluation of two slides for each organ per mouse. The reproductive organs evaluated were ovary, oviduct, uterine body, vagina and vulva. These organs were examined under ×40 to ×400 magnifications. Histopathological lesions were scored 0 to 3, whereby 0 = normal, 1 = mild (lesions involving less than 1/3 of the field), 2 = moderate (lesions involving 1/3 to 2/3 of the field) and 3 = severe (lesions involving more than 2/3 of the field).

2.7. Statistical Analysis

All the data’s were analyzed using Anova, Kruskal Wallis Test and Mann-Whitney U test. The analysis was done using JMP® 9. NC: SAS Institute Inc. software Version. The data were considered significant at p<0.05.

3. RESULTS

3.1. Clinical Signs

Mice orally inoculated with *Brucella melitensis* showed mild clinical signs compared to that of control and LPS group, except for mild ruffled fur of mice in LPS group. The onset of clinical signs in group 2 (*Brucella*) starts at 14 h of post-inoculation and they presented mild ruffled fur, movements and responsiveness. However, the onset of mild closure of the eyes of the mice in group 2 (*Brucella*) starts at 18 h of post-inoculation and the mice in group 3 (LPS) showed no abnormal clinical signs. Mice in group 3 (LPS) only showed mild ruffled fur at 34 h of post-inoculation. All the treatment groups of mice do not manifest severe clinical signs and survived until the end of the study and they were humanely euthanized. The mean scores of observed clinical signs in the mice are presented in Table 1.

Statistical analysis of the clinical signs scoring revealed significant differences (p<0.05) between each group for the parameters (movements, eyes and responsiveness) that are presented in Table 2. These clinical signs were further analyzed and showed significant differences between group 1 (Control) and group 2 (*Brucella*) and between group 2 (*Brucella*) and group 3 (LPS) for changes in movements (Table 3).

3.2. Histopathological Lesion

Statistical analysis of the histopathological lesions showed significant differences (p<0.05) between groups (Table 4). Further test revealed that there were significant differences between group 1 (Control) and group 2 (*Brucella*) and also between group 1 (Control) and group 3 (LPS). Meanwhile, significant differences (p<0.05) for the presence of inflammatory cells were only found between *Brucella* group and LPS group (Table 5).

Mild to moderate infiltration of inflammatory cells were observed in all the reproductive organs of the *Brucella* and LPS group. The reproductive organs of *Brucella* group were found to have mild to moderate haemorrhagic lesions, while mice in LPS group had normal to mild congestion or haemorrhage of the organs except for ovary in which moderate to severe congestions were found. Figure 1 and 2 represent the microscopic lesions of the reproductive organs.
Table 1. Mean score of clinical signs observed in mice throughout 10 days post-inoculation with immunogens

<table>
<thead>
<tr>
<th>Clinical signs</th>
<th>Group 1 (PBS)</th>
<th>Group 2 (Brucella)</th>
<th>Group 3 (LPS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ruffled fur</td>
<td>0.00±0.00</td>
<td>0.26±0.01</td>
<td>0.28±0.01</td>
</tr>
<tr>
<td>Movements</td>
<td>0.00±0.00</td>
<td>0.23±0.01</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>Closed eyes and ocular discharge</td>
<td>0.00±0.00</td>
<td>0.02±0.01</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>Responsiveness</td>
<td>0.00±0.00</td>
<td>0.22±0.01</td>
<td>0.00±0.00</td>
</tr>
</tbody>
</table>

Clinical signs scoring: 0 = Normal; 1 = Mild; 2 = Moderate; 3 = Severe

Table 2. Kruskal Wallis Test result on comparison of clinical signs scoring between each group

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Fur</th>
<th>Movements</th>
<th>Eyes</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi-square</td>
<td>3.74</td>
<td>9.12</td>
<td>6.54</td>
<td>6.54</td>
</tr>
<tr>
<td>Df</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td>P-value</td>
<td>0.15</td>
<td>0.01</td>
<td>0.04</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Test statistics: a, b: a = Kruskal Wallis test; b = grouping variables; group; df = degree of freedom Significant parameters with value p<0.05 were further analyzed by Mann-Whitney U test

Table 3. Mann-Whitney U Test result on comparison of clinical signs scoring

<table>
<thead>
<tr>
<th>Group</th>
<th>Movements</th>
<th>Closed eyes and ocular discharge</th>
<th>Responsiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBS</td>
<td>10.50</td>
<td>11.00</td>
<td>11.00</td>
</tr>
<tr>
<td>Brucella</td>
<td>16.50</td>
<td>15.50</td>
<td>15.50</td>
</tr>
<tr>
<td>LPS</td>
<td>10.50</td>
<td>11.00</td>
<td>11.00</td>
</tr>
</tbody>
</table>

Test statistics: a, b: a = Kruskal Wallis test; b = grouping variables; group; df = degree of freedom Significant parameters with value p<0.05 were further analyzed by Mann-Whitney U test

Table 4. Kruskal Wallis Test result on comparison of histopathological lesions scoring between each group

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Inflammatory cells</th>
<th>Degenerations/necrosis</th>
<th>Congestion/haemorrhage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi-square</td>
<td>84.53</td>
<td>22.39</td>
<td>44.68</td>
</tr>
<tr>
<td>df</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td>p-value</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Test statistics: a, b: a = Kruskal Wallis test; b = grouping variables; group; df = degree of freedom Significant parameters with value p<0.05 were further analyzed by Mann-Whitney U test

Table 5. Mann-Whitney U Test on comparison of histopathological lesion scoring

<table>
<thead>
<tr>
<th>Group</th>
<th>Inflammatory cells</th>
<th>Degeneration/Necrosis</th>
<th>Congestion/Haemorrhage</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBS</td>
<td>23.50</td>
<td>44.00</td>
<td>33.50</td>
</tr>
<tr>
<td>Brucella</td>
<td>90.12</td>
<td>70.25</td>
<td>73.40</td>
</tr>
<tr>
<td>LPS</td>
<td>67.88</td>
<td>67.25</td>
<td>74.60</td>
</tr>
</tbody>
</table>

 mean ranks in the same column differ at p<0.05; 1p<0.01, 2p<0.04 and 3p<0.04 with significant value of p<0.05 (from Kruskal Wallis Test)
Fig. 1. Histopathological lesions in reproductive organs of mice in group 2 (*Brucella*) (A) Necrosis of the lutein cells of ovary; (B) Moderate infiltration of inflammatory cells in the epithelial and submucosal layer of oviduct; (C) Severe infiltration of inflammatory cells and necrosis of the endometrium, (D) Necrosis (circle) and haemorrhage (arrow) of the stratified squamous epithelium; (E) Congested blood vessel of vulva
Fig. 2. Histopathological lesions in reproductive organs of mice in group 3 (LPS) (A) Congested blood vessels (arrow) and necrosis (circle) of the lutein cells in the ovary; (B) Haemorrhage (arrow) and necrosis (circle) of the epithelial layer of the oviduct; (C) Congested blood vessels (circle), haemorrhage (arrowhead) and infiltration of inflammatory cells (arrow) in the endometrium; (D) Mild necrosis (circle) of the stratified squamous epithelium and mild infiltration of inflammatory cells (arrow); (E) Congested blood vessels (circle) and infiltration of inflammatory cells of vulva (arrow)

4. DISCUSSION

In this present study, the clinical responses in female mice orally inoculated with wild type *Brucella melitensis* and its LPS were observed and compared. This study revealed that mice in group 2 which were orally inoculated with *B. melitensis* showed mild clinical signs compared to mice that were inoculated with the bacterial LPS, which only showed mild ruffled fur. In the present study, the mice manifested milder clinical signs compared to a similar study done by Abdullah *et al.* (2013), who reported manifestation of severe clinical signs in male mice intraperitoneally inoculated with *B. melitensis*, while male mice in LPS group manifested normal to mild clinical signs. Furthermore, a study conducted by Islam *et al.* (2009) reported that rat intraperitoneally inoculated with *B. abortus* became lethargic, anorexic and febrile within 24 hours. It was also reported that mice intraperitoneally inoculated with $5 \times 10^8$ cfu of *B. melitensis* showed extreme shivering, erection of hair coat, anorexia and dullness (Takele *et al.*, 2009).

This study also showed the onset of clinical signs that starts at 14 h post-inoculation for mice in *Brucella* group, while mice in LPS group showed mild ruffled fur at 34 h
post-inoculation. The onset of clinical signs observed in this study was longer compared to intraperitoneal inoculation of Brucella immunogens (Abdullah et al., 2013). These findings could be explained by a study conducted by Grillo et al. (2012) that stated that only low proportion of bacteria (1 to 2%) will translocate through the gut cells as the digestive tract holds many defenses towards colonization and multiplication of pathogenic microorganisms (Paixao et al., 2009).

Apart from that, the current study was also conducted to compare the cellular changes in the female reproductive organs of mice inoculated orally with wild type B. melitensis and its LPS. This study revealed mild to moderate infiltration of inflammatory cells in all of the female reproductive organs; namely ovary, oviduct, uterine body, vagina and vulva, for both Brucella and LPS group, along with normal to mild findings of degeneration or necrosis in those organs. Congestion or haemorrhage lesions were found to be mild to moderate in all of the reproductive organs of mice in Brucella group, while mice in LPS group has normal to mild congestion or haemorrhage of those organs, except for ovary which showed moderate to severe congestion. These findings proved that oral inoculation of 0.4 ml×10^9 of Brucella immunogens were able to produce cellular changes in the female reproductive organs, as supported by the study of Grillo et al. (2012) who stated that achievement of infection through oral inoculation needed very large numbers of Brucella (≥10^9 cfu/mouse) at about 0.1 to 0.25 mL per mouse.

Another study conducted by Islam et al. (2009) stated that the histopathological lesions in the uteri of infected pregnant rats were characterized by thickened muscular wall with moderate to diffuse infiltration of inflammatory cells such as lymphocytes, neutrophils, monocytes and macrophages. It was also reported that BALB/c pregnant female mice infected with 10^6 cfu of B. abortus virulent strain 2308 developed a moderate multifocal necrotic placentitis associated with severe neutrophilic infiltrate and intraloesional bacteria in trophoblastic cells (Silva et al., 2011).

The present study has revealed that mice orally inoculated with LPS only showed mild ruffled fur with the average of normal to mild histopathological lesions in the reproductive organs. This is consistent with the statement that the O-polysaccharide of S-LPS from B. abortus is less potent compared to S-LPS from Escherichia coli and thus considered as less likely to induce endotoxic shock in humans (Akhtar et al., 2012).

5. CONCLUSION

In conclusion, this study has proved that mice infected orally with B. melitensis developed mild clinical signs whereas mice orally inoculated by its LPS showed normal behavior except for the mild ruffled fur. Moreover, both groups of mice inoculated with B. melitensis immunogens developed pathological changes in the reproductive organs. Lastly, the LPS of B. melitensis could be a potential candidate for the development of vaccines.

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7. REFERENCES


