Pasteurella multocida and *Bordetella bronchiseptica* in Atrophic Rhinitis and Pneumonia in Swine

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ABSTRACT

A total of 163 pigs from nine farrow-to-finish herds representing various levels of atrophic rhinitis (AR) were selected for postslaughter examination of AR and pneumonia. Nasal swabs and lungs were cultured for detection of *Bordetella bronchiseptica* and *Pasteurella multocida*. Seventy-three pigs were examined at eight weeks of age and 90 contemporaries at six months of age. Mean AR scores were 1.21 and 1.11 for the eight week and six month old pigs, respectively (0 = normal, 3 = severe). In individual pigs increasing AR score was related to increasing pneumonia score in eight week old pigs but not in six month old hogs. In eight week old pigs, *B. bronchiseptica* and *P. multocida* were isolated more frequently from pigs with higher AR scores. From nasal swabs of six month old hogs, *Bordetella* was almost never recovered while *Pasteurella* was frequently isolated but not found to be related to AR score. Toxigenic type D *P. multocida* was isolated from nasal cultures of only seven (4%) pigs and from lung cultures of only one pig. *Pasteurella* was never isolated from lungs of the eight week old pigs and *Bordetella* never from the six month old hogs. The isolation rate of *P. multocida*, predominantly type A, from lungs of six month old pigs increased from 11% in grossly normal lungs to 86% in lungs with severe pneumonia. Pigs from one herd free from lesions of AR and pneumonia were also examined; type A *P. multocida* was isolated from nasal cultures of one of six eight week old pigs.

Somatic antigens of *P. multocida* were determined for 94 nasal and 20 lung isolates. Somatic serovar 3 was found in 93% of the nasal isolates and in all lung isolates. Serovars 4, 5, 7 and 12 were found in low numbers, either alone or in combination with 3. The somatic serovar showed no relationship with either capsule type or pathology.

RÉSUMÉ

Cette expérience portait sur 163 porcs, issus de neuf troupeaux où s'observaient divers degrés de rhinite atrophique, que les auteurs choisirent pour étudier les lésions de rhinite atrophique et de pneumonie. Ils utilisèrent la culture bactériologique pour rechercher *Bordetella bronchiseptica* et *Pasteurella multocida*, dans des écouvillons nasaux et des échantillons pulmonaires. Cet examen porta sur 73 sujets, âgés de huit semaines, et sur 90 de leurs congénères, âgés de six mois. La gravité moyenne des lésions de rhinite atrophique, selon un barème de 0 à 3, s'établit à 1,21, chez les premiers, et à 1,11, chez les seconds. Chez les premiers, mais non chez les seconds, la gravité de la rhinite atrophique se révéla proportionnelle à celle de la pneumonie. Chez les premiers, l'isolement de *B. bronchiseptica* et de *P. multocida* s'avéra proportionnel à la gravité de la rhinite atrophique. Chez les seconds, les écouvillons nasaux ne recelèrent presque jamais *B. bronchiseptica*, tandis qu'on en isola souvent *P. multocida*, mais sans rapport avec la gravité de la rhinite atrophique. *Pasteurella multocida* du type D toxinogène se retrouva dans les écouvillons nasaux de seulement sept (4%) porcs et dans les poumons d'un seul. On n'isola jamais *P. multocida*, des poumons des porcs âgés de huit semaines, ni *B. bronchiseptica*, de ceux des sujets âgés de six mois. Le taux d'isolement de *P. multocida*, surtout du type A, des poumons des porcs âgés de six mois, passa de 11%, pour ceux qui semblaient normaux, à 86%, pour ceux qui affichaient des lésions marquées de pneumonie.

L'examen bactériologique des cornets et des poumons de sujets d'un troupeau témoin se solda par l'isolement du type A de *P. multocida*, à partir d'écouvillons nasaux de seulement un porc âgé de huit semaines.

La recherche des antigènes somatiques des souches de *P. multocida*, isolées de 94 échantillons nasaux et 20 pulmonaires, permit d'identifier le sérovar 3, dans 93% des isolats nasaux et 100% de ceux des poumons. Elle permit également d'identifier les sérovars 4, 5, 7 et 12 moins fréquemment, seuls ou en association avec le

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sérovar 3. Le sérovar somatique n'afficha aucune relation avec le genre de capsule ou les lésions nasales et pulmonaires.

INTRODUCTION

Throughout the 1980's, annual polls conducted by the National Pork Producers Council have indicated that atrophic rhinitis (AR) is one of the most important disease problems affecting the swine industry in the United States (1). In a slaughterhouse survey in Illinois in 1980, Bäckström *et al* reported AR lesions in 50% of both finishing hogs and sows (2). Elanco in 1984 found AR lesions in more than 70% of finishing hogs and in 100% of herds investigated nationwide (3).

Even though AR has been described as a multifactorial disease with etiological components of heredity (4-6), nutrition (7) and environment (8,9), infectious agents appear to be the most important (10). *Bordetella bronchiseptica* has long been considered an important cause of AR (11), but Nielsen *et al* (12) later confirmed by Underdahl *et al* (13) and others (14,15), showed that *B. bronchiseptica* infections in young pigs were self-limiting and that other bacteria, in particular *Pasteurella multocida*, had the ability to enhance or even initiate more severe and persistent turbinate lesions (16-18). In Europe and North America, certain toxin-producing capsule type D *P. multocida* strains have been specifically related to AR (10,16,19,20), although the significance of these toxigenic strains has been questioned in other parts of the world, especially in Japan (21-23). The toxin is a thermolabile protein that is dermonecrotic in guinea pigs and lethal for mice (10,24-26).

In some studies, pneumonia in swine and AR have been found to be related (27,28); however in other work with individual herds (2,4) and test stations (29,30), no such relationship was revealed. Pijoan *et al* reported a predominance of *P. multocida* type A isolates from pneumonic swine lungs (31), whereas type D isolates have more often been associated with AR (10,16,20).

Previous studies in the United States, including an Illinois study in 1982 (32), on the role of *P. multocida* in AR and pneumonia utilized a conventional nonselective blood agar culture technique that might have favored identifying the relatively large mucoid type A colonies over the smaller type D colonies. deJong (16) and Pedersen and Barfod (17) showed that *P. multocida* type D strains are more easily detected in cultures from livers of mice inoculated with the contents of nasal swabs, and that the toxigenicity of *P. multocida* could be determined by guinea pig skin tests.

The objectives of the present investigation were to apply these techniques to study the occurrence of dermonecrotic toxin-producing strains of *P. multocida* within selected Illinois swine herds affected by AR and to determine their association with *P. multocida* capsular and somatic antigens, lesions of AR, pneumonia and the presence of *B. bronchiseptica*.

MATERIALS AND METHODS

Nine farrow-to-finish Illinois swine herds known to be affected with AR at varying levels were selected on the basis of clinical history and records of postslaughter snout examinations of market hogs. One herd (Herd 10), completely free of clinical or slaughter check evidence of AR, was added to the study as an AR-free control. Herd size varied between 100 and 300 sows. All pigs were kept in confinement and fed standard corn-soybean meal rations fortified with minerals and vitamins. In all herds, 250 parts per million of antibiotics (chlortetracycline-sulfamethazine-penicillin) were added to feed for nursery and grower pigs. In five herds (2,3,5,6,7) commercial *Bordetella/Pasteurella* bacterins had been administered to sows and piglets for several years without apparent success in reducing snout lesions. Those bacterins were not characterized for the toxin-producing ability of the *P. multocida* component.

A minimum of six or more eight week old pigs were selected from each herd and euthanized by electrocution. The external nares were cleaned with alcohol and dried with cotton; then a sterile cotton-tipped swab was inserted into each nostril to the level of the ethmoid turbinates. Snouts were cross-sectioned between the first and second premolar teeth and scored for gross evidence of turbinate atrophy according to the method described by Bäckström *et al* (0 = normal, 1 = mild, 2 = moderate, 3 = severe) (32).

The lungs of each pig were examined for gross evidence of pneumonia and scored from 0 to 3 based on the severity of lesions. Lungs with no evidence of consolidation were given a score of 0. If less than the volume of one of the anterior lobes was affected, a score of 1 was assigned. A score of 3 was given if 2 or more whole lobes were affected with pneumonia. Intermediate lesions were assigned a score of 2. Cultures were taken from lesions when present or from the right cranial lobe of normal lungs. The surface of each lung sample was seared with a hot spatula and flamed scissors were used to dissect into a bronchus or bronchiole; then material for culture was collected from the airway and surrounding tissue with a sterile cotton-tipped swab. In each herd, seven to 14 contemporaries of the eight week old pigs examined were allowed to grow to a slaughter weight of approximately 100 kg at about six months of age. Examination and culture of the slaughter pigs were similar to that performed on younger pigs. Nasal swabs were taken after killing and before scalding if the routine of the slaughterhouse permitted. Otherwise, nasal swabs were taken from the live pig immediately prior to slaughter.

Each nasal and lung swab was streaked directly onto 5% sheep blood agar and MacConkey agar plates. In addition to the direct streaking, each nasal swab was suspended in 1 mL of sterile saline and 0.2 mL of this suspension was injected intraperitoneally into a mouse as described by Pedersen and Barfod (17). Mouse livers were also cultured on blood agar and MacConkey agar. Colonies suspected of being either *P. multocida* or *B. bronchiseptica* were identified by standard bacteriological techniques (Minitek, BBL, Becton Dickinson and Co., Cockeysville, Maryland).

TABLE I. Herd Scores of Atrophic Rhinitis and Pneumonia, and Percentage of Isolations of *Bordetella bronchiseptica* and *Pasteurella multocida* From Snouts and Lungs of Eight Week and Six Month Old Pigs

Herd	No. Examined	Atrophic Rhinitis Score[a]	Snouts Bb	Snouts PmA-	Snouts PmD-	Snouts PmD+	Pneumonia Score[a]	Lungs Bb	Lungs PmA-	Lungs PmD-	Lungs PmD+
8 Week Old Pigs											
1	6	1.83 ± 0.98	33	0	50	17	0.17 ± 0.41	0	0	0	0
2	21	1.76 ± 0.77	38	19	5	5	1.00 ± 0.71	0	0	0	0
3	6	1.50 ± 0.55	17	83	0	0	0.67 ± 0.82	0	0	0	0
4	6	1.33 ± 1.03	17	50	33	0	1.00 ± 1.10	33	0	0	0
5	6	1.17 ± 0.41	0	0	0	33	0.00 ± 0	0	0	0	0
6	6	1.00 ± 1.10	0	0	0	0	0.17 ± 0.41	0	0	0	0
7	6	0.83 ± 0.75	17	17	0	0	0.83 ± 0.75	0	0	0	0
8	8	0.50 ± 0.53	0	25	0	0	0.13 ± 0.35	0	0	0	0
9	8	0.13 ± 0.35	13	0	0	0	0.00 ± 0	0	0	0	0
10	6	0.00 ± 0	0	17	0	0	0.17 ± 0.41	0	0	0	0
6 Month Old Pigs											
1	11	1.91 ± 0.83	0	45	9	9	1.60 ± 0.97	0	45	0	0
2	7	1.86 ± 0.69	0	14	29	0	0.86 ± 1.21	0	14	0	0
3	10	1.80 ± 1.03	0	40	20	0	0.50 ± 0.53	0	0	10	10
4	11	1.18 ± 0.75	9	36	27	0	0.64 ± 0.81	0	0	18	0
5	8	0.63 ± 0.52	0	38	0	0	1.00 ± 0.53	0	0	0	0
6	10	0.90 ± 0.88	0	60	20	0	1.70 ± 0.95	0	30	0	0
7	10	1.10 ± 0.74	10	50	50	10	0.60 ± 0.70	0	50	0	0
8	9	0.67 ± 0.50	0	0	0	11	0.22 ± 0.44	0	11	0	0
9	14	0.29 ± 0.47	0	57	36	0	0.71 ± 0.91	0	14	0	0
10	10	0.00 ± 0	0	0	0	0	0.00 ± 0	0	0	0	0

[a]Data are expressed as mean ± SD; scores are based on a 0-3 scale (0 = normal, 3 = severe)
Bb = *B. bronchiseptica*; PmA- = toxin-negative *P. multocida* type A; PmD- = toxin-negative *P. multocida* type D; PmD+ = toxigenic *P. multocida* type D

The capsule types of all isolates of *P. multocida* were determined by standard methods (33,34). One hundred and fourteen *P. multocida* isolates were further characterized for somatic antigens by the Heddleston gel diffusion precipitin test (35) using chicken antisera (National Animal Disease Center, Ames, Iowa). All *P. multocida* isolates were tested for production of dermonecrotic toxin in guinea pigs as described by deJong *et al* (16) and Pedersen and Barfod (19).

Data were summarized using a computerized statistical analysis system (SAS Institute, Cary, North Carolina). Frequency distributions were tested for significance by the chi-square procedure and correlations were tested using Spearman's rank correlation coefficient.

RESULTS

From the nine herds investigated a total of 73 eight week old pigs and 90 six month old market hogs were examined. Mean herd scores for atrophic rhinitis varied from 0.13 to 1.83 in the young pigs and from 0.29 to 1.91 in the market hogs (Table I). A total of 17 (23%) of the eight week old pigs showed no gross lesions of AR, 31 (42%) had mild lesions, 18 (25%) moderate lesions and seven (10%) severe lesions (Table II). The overall mean AR score was 1.21. Corresponding figures for the older hogs were 23 (25%), 43 (48%), 15 (17%) and nine

TABLE II. Distribution of Eight Week and Six Month Old Pigs by Atrophic Rhinitis Score, and Means of Atrophic Rhinitis Scores in Relation to Nasal Isolation of *Bordetella bronchiseptica* and *Pasteurella multocida*

Bacteria Isolated	No. of Pigs	Atrophic Rhinitis Score 0	1	2	3	Mean ± SD
8 Week Old Pigs						
Bb	9	1	3	3	2	1.67 ± 1.00
Bb and PmA-	3	1	0	2	0	1.33 ± 1.15
Bb and PmD-	2	0	0	1	1	2.50 ± 0.71
PmA-	12	1	6	5	0	1.33 ± 0.65
PmD-	4	0	2	1	1	1.75 ± 0.96
PmD+	4	0	2	1	1	1.75 ± 0.96
No isolation of Bb or Pm	39	14	18	5	2	0.87 ± 0.83
Total	73	17	31	18	7	
6 Month Old Pigs						
Bb	1	0	1	0	0	1.00 ....
Bb and PmA-D-	1	0	1	0	0	1.00 ....
PmA-	30	10	12	4	4	1.07 ± 1.01
PmA- and PmD-	5	3	2	0	0	0.40 ± 0.55
PmD-	14	1	8	4	1	1.36 ± 0.74
PmD+	3	0	1	1	1	2.00 ± 1.00
No isolation of Bb or Pm	36	9	18	6	3	1.08 ± 0.87
Total	90	23	43	15	9	

Bb = *B. bronchiseptica*; PmA- = toxin-negative *P. multocida* type A; PmD- = toxin-negative *P. multocida* type D; PmD+ = toxigenic *P. multocida* type D

(10%), respectively, with an overall mean AR score of 1.11. None of the six eight week old pigs and ten six month old pigs in the tenth herd showed gross lesions of AR.

Among eight week old pigs, *B. bronchiseptica* and *P. multocida* were more frequently isolated from pigs with higher AR scores ($p < 0.05$). There was no significant association between bacterial isolation rate and AR score among the six month old hogs. The herd isolation rate of *B. bronchiseptica* varied from 0% to 38% in nasal swabs from the eight week old pigs; however, *B. bronchiseptica* was isolated from only two of the six month old hogs (Table I).

Isolation rates for *P. multocida* varied from 0% to 83% in the young pigs and from 11% to 90% in the older hogs. *Pasteurella multocida* type A was isolated from nasal swabs of one of six eight week old pigs from the AR-free herd (herd 10); neither *Pasteurella* nor *Bordetella* was isolated from the six month old hogs in this herd. The isolation rate of *P. multocida* from nasal swabs was markedly improved by mouse inoculation. *Pasteurella multocida* was isolated by direct blood agar culture from 20.9% of nasal swabs, while it was isolated after mouse inoculation from 43.5%. Using both methods, 47.9% of all pigs were identified as intranasal carriers of *P. multocida*.

The distribution among herds of different capsule types and toxigenic *P. multocida* strains did not show any consistent relationship to herd AR scores or type of herd therapy used on either age group of pigs (Table I). Toxin-producing type D strains were isolated from nasal swabs of only 4% of all pigs (a total of four eight week old pigs and three six month old hogs in herds 1, 2, 5, 7, 8). Toxin-negative type D strains were found in six (8%) of the eight week old pigs and in 20 (22%) of the six month old hogs; toxin-negative type A strains in 15 (21%) and 36 (40%) of the eight week and six month old pigs, respectively; and toxigenic type A *P. multocida* was never isolated. Of all nasal swabs, six were positive for both *B. bronchiseptica* and *P. multocida* and five were positive for both *P. multocida* capsule types A and D. Toxin-positive *P. multocida* was never isolated together with a toxin-negative strain in the same pig.

TABLE III. Pneumonia Scores in Eight Week and Six Month Old Pigs in Relation to Atrophic Rhinitis Scores and Correlation Coefficients

Atrophic Rhinitis Score	Eight Week Old Pigs No. Examined	Eight Week Old Pigs Pneumonia Score[a]	Six Month Old Pigs No. Examined	Six Month Old Pigs Pneumonia Score[a]
0	17	0.24 ± 0.56	23	0.70 ± 0.63
1	31	0.42 ± 0.62	42	0.76 ± 0.88
2	18	0.89 ± 0.83	15	0.93 ± 1.03
3	7	0.86 ± 0.90	9	1.67 ± 1.12

Spearman's correlation coefficients of atrophic rhinitis score and pneumonia score.

Eight Week Old Pigs No. Examined	R	P	Six Month Old Pigs No. Examined	R	P
73	0.34	< 0.01	89	0.18	> 0.05

[a]Data are expressed as mean ± SD; scores are based on a 0-3 scale (0 = normal, 3 = severe)

For a total of 94 *P. multocida* nasal isolates, somatic antigens were determined. Seventy-six percent of the isolates were serovar 3; 17% gave strong precipitation lines with serovar 3 antisera and weak cross-reactions with serovars 4, 5 and 12 antisera; 5% of the isolates were serovar 12 alone or 12 with cross-reactions with serovars 4 and 7; and 2% of the isolates were serovar 4. Of 20 lung isolates of *P. multocida*, 80% were serovar 3 and 20% serovar 3 with cross-reactions with serovars 4 and 12. No apparent relationship was found between somatic antigen serovars or capsule types of *P. multocida* and AR score or pneumonia score in individual pigs.

Pneumonic gross lesions were more common in the six month old hogs than in the eight week old pigs (Table I). Mild lesions were found in 19 (26%), moderate lesions in ten (14%) and severe lesions in none of the young pigs and in 36 (40%), ten (11%) and seven (8%), respectively, of the older hogs. On a herd basis no significant correlation was found between scores for AR and pneumonia; however, in individual pigs AR score was correlated with pneumonia score in eight week old pigs but not in six month old hogs (Table III).

Bordetella was isolated from the lungs of only two of the eight week old pigs and never in the six month old hogs (Table I). *Pasteurella* was never isolated from the young pigs but was cultured from 21 of the 90 market hogs (17 type A toxin-negative, three type D toxin-negative and one type D toxin-positive). The isolation rate of *P. multocida* from grossly normal lungs was 5% compared to 86% from lungs with severe pneumonia (Table IV).

The capsule types of *P. multocida* isolated from the lungs did not correspond with those of *P. multocida* isolated from the snouts of the same pigs. Of 17 *P. multocida* type A lung isolates, nine corresponded to type A in nasal cultures of the same pig, five to type D and four to negative nasal cultures. Of four *P. multocida* type D lung isolates, two corresponded to type A in nasal cultures and two to negative nasal cultures.

TABLE IV. Distribution of Six Month Old Pigs by Pneumonia Score, and Means of Pneumonia Scores in Relation to Lung Isolation of *Pasteurella multocida*

Bacteria Isolated	No. of Pigs	Pneumonia Score 0	1	2	3	Mean ± SD
PmA-	17	3	5	3	6	1.71 ± 1.16
PmD-	3	1	2	0	0	0.67 ± 0.58
PmD+	1	0	1	0	0	1.00 ....
No isolation of Bb or Pm	66	32	27	6	1	0.64 ± 0.72
Total	87	36	35	9	7	

DISCUSSION

Rather than a random sample, the herds selected for this survey represented different disease levels of atrophic rhinitis independent of herd environment and therapy. Therefore, no statistical comparisons were made between herds. In a previous study, clinical signs were found to be nonspecific and poorly related to turbinate and lung lesions assessed by postslaughter examination (32). For that reason, it was decided to use only snout and lung pathology scores in individual pigs as the basis for comparison in this study.

The main objective of this investigation was to determine the prevalence and significance of various characteristics of *P. multocida* in relation to the isolation rate of *B. bronchiseptica* and to scores of AR and pneumonia in the herds selected. In the eight week old pigs, a positive association was found between the isolation rates of both *B. bronchiseptica* and *P. multocida* and AR lesions. No progression of AR from the age of eight weeks to six months was apparent from the data on these herds. Similar results were recently reported in another study (38). Analysis of results showed an overall low prevalence (4%) of toxigenic *P. multocida* and an inconclusive relationship between the isolation rates of these strains and turbinate lesions, similar to what has been reported in other studies (36-39) but different from reports indicating a very strong correlation between AR and toxigenic *P. multocida* (10,18-20). While the overall isolation rate of toxigenic *P. multocida* was low, it was isolated from five of the ten herds, representing more severe (Herds 1 and 2), as well as moderate (Herd 5) and milder forms of AR (Herds 7 and 8). Nontoxigenic *P. multocida* were more prevalent; these strains were isolated from 44% of the pigs and from all of the herds examined.

All toxigenic isolates of *P. multocida* were capsule type D which agrees with most other investigations (10,16,20,21,40); however, toxigenic type A *P. multocida* has also been found in association with AR (36,37,41). The ability of the toxin to produce turbinate lesions when administered intramuscularly or intraperitoneally as reported by deJong (42) and Rutter (43) raises questions concerning the sensitivity of culture techniques for recovery of toxigenic *P. multocida* from nasal swabs. If *P. multocida* colonizes the pharyngeal and/or tonsillar areas, as has been suggested (10,32), its toxin might affect the turbinates of the pig without being detected in nasal swabs. Recent development of serological techniques shows promise in assessing more exactly the role of *Pasteurella* in AR (44).

Among the six month old hogs, *P. multocida* was isolated more frequently from grossly pneumonic lungs than from grossly normal lungs. The eight week old pigs were remarkably free of *Pasteurella*, even in the presence of pneumonia.

A positive association between AR scores and lung scores is consistent with the traditional view of a link between the two diseases. One hypothesis explaining this link is that both diseases are caused by the same infectious agent; another hypothesis is that AR compromises upper airway defenses making the lungs more susceptible to disease; yet a third suggests that pneumonia makes the pig more susceptible to AR. In this study the severity of snout and lung pathology was directly related in the eight week old pigs (Table III). The numerical differences found in the six month old hogs were not significant and similar to reports from other studies (27, 30). The differences between age groups might be related to the more chronic appearance of AR lesions compared to the reversible nature of pneumonic consolidations which can develop and heal within four to five weeks. The differences between capsule types of *P. multocida* from snouts and lungs of the same pig, with a predominance of type A in the lungs and type D in the snouts, indicate no direct correlation between *P. multocida* infections in the snout and lungs.

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