

Effectiveness of transdermal, needle-free injections for reducing pork carcass defects

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Abstract

A needle-free, transdermal injection device was evaluated for effectiveness of vaccine delivery and for injection site lesions in swine. A total of 130 pigs were vaccinated for pseudorabies virus (PRV) and *Mycoplasma hyopneumoniae* (*M. hyopneumoniae*). Pigs were divided into three groups; one group served as unvaccinated controls, the second group was vaccinated with conventional hypodermic needles and the third group was vaccinated with a needle-free, airpowered transdermal injection device. Blood samples collected for up to 36 days post-injection showed that both injection methods produced similar serological responses that were significantly greater than for unvaccinated controls. Injection sites, collected at slaughter from each carcass, showed minimal development of lesions and no carcass defects. The results show the needle-free, transdermal injection system to be effective and safe. Elimination of needles will prevent residual needle fragments in carcasses and associated carcass defects that develop from needle-induced injection-site lesions.

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1. Introduction

Pork carcass defects resulting from intramuscular injections of vaccines and antibiotics is a well-recognized problem in the meat industry (Straw, MacLachlan, Corbett, Carter, & Schey, 1985; Morgan, Cannon, McKeith, Meeker, & Smith, 1993). A study of pork quality in US commercial plants by the National Pork Producers Council in 1993 reported that as many as 11.3% of the carcasses were damaged to some extent as a result of improper injections (Morgan et al., 1993). In the US, this affects about 10 million carcasses. The cost of trimming away damaged tissue at injection sites was estimated at \$3.55 USD per head in that study. A more

recent comprehensive study of pork quality in the US by the National Pork Board identified injection sites as the cause of 3% of all carcass condemnations in commercial plants. This would affect up to 60,000 carcasses per year, and would add additional cost of about \$0.47USD per head to all carcasses (Meisinger, 2003).

While the abscesses and muscle damage that can develop at injection sites are clearly undesirable, a potentially more serious problem for the meat industry is the presence of broken needles and needle fragments in carcasses. Breakage of needles typically occurs when needles are bent, re-straightened and continued in use for injections (Hoff & Sundberg, 1999). The meat industry, particularly processors who use shoulder cuts for further processing, has resorted to a variety of techniques including visual inspection and use of metal detectors in attempt to remove needle fragments. However, it has been reported (Sundberg, 2000) that

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metal detectors are likely to detect less than half of the needle fragments present in fresh pork cuts. Detectability of needle pieces is affected by the alloys used in the needles as well as the size of the needle pieces. A very significant difference in detectability was observed between needles from different manufacturers, with detectability ranging from 8% to 85% (Sundberg, 2000). Orientation of the needle pieces relative to the metal detectors also affects detectability. Recent modifications in the alloys used by needle manufacturers have improved detectability of needles in finished products (Stier, 2003), but size and orientation of needle fragments still allow a significant number to go undetected in meat raw materials.

Because detectability of needle fragments in muscle and meat is limited, a significant number of needle fragments are likely to be found in finished, processed meat products. The potential for consumer dissatisfaction is obvious. Lawsuits for several millions of US dollars have been filed by consumers who have encountered needle fragments in processed meats (Murphy, 2001).

Consequently, if needles are used, it is clear that even the best efforts of the meat industry cannot ensure the detection and removal of needles or needle fragments that remain in pork carcasses. An alternative that would unequivocally remove all risk of needle fragments in pork products is use of needle-free, transdermal, jet injection devices for delivery of vaccines, sera and antibiotics. These devices have been found to have several advantages in human applications, including faster delivery of injected compounds to the circulatory system than traditional subcutaneous injections (Henry, 2000), and have been suggested for use in the swine industry. However, it is important to determine if vaccine delivery by this method results in similar immune response to that of conventional needle injections. Secondly, it is important to evaluate transdermal injection sites for potential tissue lesions and/or muscle damages.

Therefore, the objectives of this study were to evaluate the effectiveness of a needle-free injection device for delivery of vaccines in swine and to compare the injection sites of the needle-free device to conventional needle injection sites for muscle damage and potential carcass defects.

2. Materials and methods

A total of 130 pigs were selected from the Iowa State University swine breeding herd for this study. Pigs were selected from two separate farrowing groups that were farrowed approximately two months apart. Both groups were of similar genetic background. Pigs were selected at 4–5 weeks of age and randomly assigned to one of three treatment groups. The treatment groups included con-

trols (no injection), hypodermic needle injection for vaccinations, and needle-free transdermal injections for the same vaccinations. Pigs were assigned to the two injection treatments in a ratio of approximately 2:1 relative to the control group so that each injection group included twice as many pigs as the control group. The control group served to confirm seronegative response as result of receiving no vaccinations. Each pig was tattooed on the left neck to provide a marker for the location of the injection sites. Blood samples were collected from all pigs prior to injections.

2.1. Injections

Three injections were given to each pig in the injection treatment groups. Injections were given 2.54 cm from the tattoo and were equally dispersed to form a triangle of three injection sites around the tattoo (anterior, posterior and ventral). For hypodermic needle injections, an 18-gauge \times 1.59 cm needle was used for the first injection and an 18-gauge \times 2.54 cm needle was used for the second and third injections to achieve appropriate intramuscular deposition of vaccines. Needles were changed after every 6th pig was injected. For needle-free injections, an air-powered device developed by Felton International, Inc. (Lenexa, Kansas, USA) was used to achieve transdermal delivery of vaccines. The operating air pressure was adjusted, according to the manufacturers recommendations, for pig size to achieve appropriate depth of the injection for intramuscular deposition.

The pigs were vaccinated with two doses of a commercial *Mycoplasma hyopneumoniae* (*M. hyopneumoniae*) vaccine (RespiSure[®], Pfizer Animal Health, Terre Haute, Indiana, USA), first at 5–6 weeks of age and again 2 weeks later. Pigs were also vaccinated with a commercial pseudorabies (PRV) vaccine (PR-VacPlus[®], Pfizer Animal Health, Terre Haute, Indiana, USA), administered at 9–10 weeks of age. Pigs selected for this study came from a herd that was free of PRV and endemically infected, but for the most part seronegative to *M. hyopneumoniae*.

2.2. Serological response

Blood samples were collected prior to vaccination, at 11–13 days following the second *M. hyopneumoniae* vaccination and at 23–25 days after the PRV vaccination (35–36 days after the first *M. hyopneumoniae* vaccination). Serum was tested for *M. hyopneumoniae* antibodies by Tween 20 enzyme-linked immunosorbent assay (ELISA) (Bereiter, Young, Joo, & Ross, 1990) and the results recorded as optical density (OD) values. Known positive and negative sera were included as controls in each ELISA plate. Readings more than two standard deviations above the mean value of the nega-

tive control (optical density of 0.220) were considered positive. For PRV evaluation, a commercial ELISA (IDEXX, Westbrook, Maine, USA) kit for the PRV was used. Test values are reported as *S/P* ratios; the sample optical density value as a ratio of the positive control provided in the kit. An *S/P* ratio of 0.4 or greater was considered positive.

2.3. Injection site evaluation

Injection sites were visually inspected and palpated two days after each injection and at each time of blood collection. When the pigs reached market weight (~118 kg), they were harvested at the Iowa State University Meat Laboratory. Injection sites were removed from the carcasses immediately post-mortem, utilizing the skin tattoos to identify the injection site locations. Dissection of each injection site was performed using a No. 22 scalpel blade to section the site in two directions at intervals of 1 cm or less. The sectioned tissue was visually observed. If a lesion was suspected following visual observation, the lesion and surrounding tissue were excised and placed in formalin fixative for histopathological evaluation. If no lesion was observed, an area estimated to be the site of injection, based on the skin tattoos, was excised and fixed. The fixed tissue was then prepared for microscopic evaluation as routinely performed by the Iowa State Veterinary Diagnostic Laboratory.

The dorsal superficial cervical lymph node was also observed, excised and assessed in the same manner as described for the injection sites.

2.4. Statistical analysis

Immune response data were analyzed as a randomized complete block design with unbalanced data in each block. Farrowing time was the blocking criteria with injection type as the treatment. Data were analyzed by the MIXED procedure (SAS, 2001) with injection type and farrowing time as the fixed effects. The level of significance for determination of differences of least squares means was set at an α -level of 0.05 and adjusted

for comparing all pairwise differences with the Tukey–Kramer procedure.

The gross and histological lesion data were analyzed utilizing 2×2 contingency tables by Fisher's Exact Test.

3. Results and discussion

The serological data are shown in Table 1. Pigs that developed illnesses unrelated to the study or that died during the study were not included in the final analysis. Consequently, the final number of pigs in each group was slightly different. All pigs were seronegative for *M. hyopneumoniae* and PRV prior to vaccination. The control pigs (no injection) showed very low serological response for both *M. hyopneumoniae* and PRV. The serological responses of the vaccinated pigs in all cases was significantly ($P < 0.05$) greater than the control pigs. Most importantly, there was no difference between the injection types for the serological responses induced by either vaccine. Consequently, the needle-free, transdermal delivery of the vaccines was equally as effective as the traditional hypodermic needle injection. The control pigs remained seronegative for both *M. hyopneumoniae* and PRV, indicating that endemic *M. hyopneumoniae* infections were very limited and that the herd remained PRV-free.

Table 2 shows the results of the dissection of injection sites and lymph nodes for detection of gross lesions. Two pigs from each treatment group showed small, mild muscle and lymph node lesions that would be of no consequence in terms of carcass defects or meat quality. No abscesses or granulomas were observed. The results for the histological examination of injection sites and suspected lesions are shown in Table 3. For muscle lesions, 3 of the 48 pigs injected with needles had microscopically visible lesions compared with 2 of the 45 pigs injected with the needle-free air jet. For the lymph nodes, three pigs of each injection group were found to have lesions. There was no significant difference in the number of observed lesions in any case between the two

Table 1
Results of serological testing of pigs vaccinated for *M. hyopneumoniae* and Pseudorabies virus

Injection type	<i>M. hyopneumoniae</i>				<i>n</i>	Pseudorabies virus		
	Pre-vaccination		Post-vaccination			<i>S/P</i> ratio	SEM	<i>n</i>
	OD value	SEM	OD Value	SEM				
Control (no injection)	0.074 ^a	0.011	0.057 ^a	0.040	22	0.03 ^a	0.16	18
Needle	0.071 ^a	0.007	0.45 ^b	0.026	51	1.62 ^b	0.098	49
Needle-free	0.078 ^a	0.007	0.50 ^b	0.026	53	1.57 ^b	0.014	53
Total					126			120

^{a,b} Means within the same column with different superscripts are significantly different ($P < 0.05$).

Table 2
Pigs with gross muscle or lymph node lesions after vaccination with hypodermic needles or needle-free injections

Injection type	Gross muscle lesions ($P = 1.0$)		
	Positive	Negative	Total number
Needle	2	46	48
Needle-free	2	43	45
Injection type	Gross lymph node lesions ($P = 1.0$)		
	Positive	Negative	Total number
Needle	2	46	48
Needle-free	2	43	45

Table 3
Pigs with histological muscle or lymph node lesions after vaccination with hypodermic needles or needle-free injections

Injection type	Histological muscle lesions ($P = 0.768$)		
	Positive	Negative	Total number
Needle	3	45	48
Needle-free	2	43	45
Injection type	Histological lymph node lesions ($P = 1.0$)		
	Positive	Negative	Total number
Needle	3	45	48
Needle-free	3	42	45

injection treatments for gross lesions or for histological lesions.

4. Conclusions

The needle-free, transdermal, jet-injection delivery of vaccines for pigs was found to be safe for the treated animals and effective. Clearly, this system completely eliminates the risk of residual needles and needle fragments in pork carcass and subsequent meat products. The use of transdermal injections might also be expected to reduce the number of lesions and abscesses that result from the skin punctures that occur with a hypodermic needle. However, in this study there was no difference in the number of injection site lesions resulting from the two injection systems used. The transdermal, jet-injection delivery of vaccines is

fast, convenient, safe, and was effective for the vaccines used in this study. Further studies using different vaccines and challenge experiments are warranted to fully evaluate the potential for broader applications of transdermal injections for swine.

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