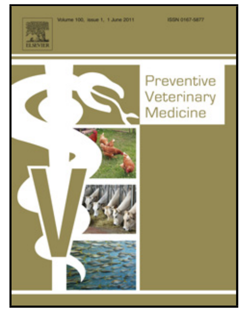

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Prevalence, distribution and risk factors of farmer reported swine influenza infection in Guangdong Province, China

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Abstract

A cross-sectional study was undertaken to better understand the husbandry, management and biosecurity practices of pig farms in Guangdong Province (GD), China to identify risk factors for farmer reported swine influenza (SI) on their farms. Questionnaires were administered to 153 owners/managers of piggeries (average of 7 from each of the 21 prefectures in GD). Univariable and multivariable logistic regression analyses were used to identify risk factors for farmer reported SI in piggeries during the six months preceding the questionnaire administration. The ability of wild birds to enter piggeries (OR 2.50, 95% CI: 1.01-6.16), the presence of poultry on a pig-farm (OR 3.24, 95% CI: 1.52-6.94) and no biosecurity measures applied to workers before entry to the piggery (OR 2.65, 95% CI: 1.04-6.78) were found to increase the likelihood of SI being reported by farmers in a multivariable logistic regression model. The findings of this study highlight the importance of understanding the local pig industry and the practices adopted when developing control measures to reduce the risk of SI to pig farms.

1. Introduction

Swine influenza (SI) is a respiratory disease of pigs caused by swine influenza virus (SIV) – a type A influenza virus (Brown, 2000). Typical clinical signs include coughing, labored breathing, nasal discharge, sneezing and pyrexia (Kothalawala et al., 2006). Since SI is a highly contagious disease, the morbidity on infected farms is often nearly 100%, although mortality is usually very low. The infection is often mild, resulting in low direct losses from the disease (Er et al., 2014), although serious losses can happen when SIV simultaneously infects pigs with other pathogens or when infection occurs in sows during late pregnancy (Fablet et al., 2012). Wesley (2004) reported 22% stillbirths in naturally infected gilts after infection with H3N2 SIV at 80 to 82 days of gestation. Abortions can also occur when sows are infected with new strains of SIV (Choi et al., 2002). Swine influenza is also a potential threat to human health (Ito et al., 1998).

Swine influenza is one of the most ubiquitous diseases circulating in the global pig population. Corzo et al. (2013a) reported a 90.6% herd prevalence in USA using a real-time reverse transcription polymerase chain test and a cross-sectional study in northern Mexico reported that more than 50% of pigs from commercial farms were seropositive to H1 or H3 subtype SIV (Lopez-Robles et al., 2014). Swine influenza is also widespread in Europe. An analysis of historical surveillance data in Norway showed that the national herd seroprevalence of influenza A(H1N1)pdm09 virus was around 43%, and the individual pig seroprevalence of pandemic H1N1 on infected farms was more than 60% (Er et al., 2016a). Another study in 2009 reported almost 100% herd-seroprevalence against SIV in 98 randomly selected piggeries in Spain, with 62.3% of individual animals seropositive (Simon-Grife et al., 2011). In England, a 52% herd prevalence was reported by Mastin et al. (2011) with the highest individual seroprevalence being 33% in sows.

Swine influenza is endemic in the Chinese pig population, with many subtypes contemporaneously circulating in pig farms. Serological evidence of H1, H3, H4, H5, and H9 influenza viruses has been found in the Chinese pig population (Ninomiya et al., 2002; Yu et al., 2011). Liu et al. (2011a) reviewed the data from 10 years of publications and concluded that the average individual pig seroprevalence to subtypes H1, H3, H5, H7 and H9 were 31.1, 28.6, 1.3, 0 and 2.4%, respectively. Song et al. (2010) reported an individual pig seroprevalence of more than 50% for H1 and H3 in commercial farms in Fujian Province. However, no antibody against H5N1 was detected in pigs in Fujian, and while H9 infection was detected it was only at a very low seroprevalence (1% in 2004 and 2.6% in 2007). In Tibet, 52 and 16.9% of pigs were seropositive to H1N1 and H3N2, respectively (Liu et al., 2014). Infection with more than one subtype of SIV often occurs in the Chinese pig population. For example, 8.8 and 24% of the pigs tested in Fujian Province and Tibet, respectively were seropositive for H1 and H3 (Song et al., 2010; Liu et al., 2014).

China, particularly south China, is considered by some as "the epicenter of influenza"

(Liu et al., 2011b), because of the unique ecosystem containing vast wetlands, live animal markets, and one of the largest human and pig populations in the world. Other studies have shown that SI is not evenly distributed in China and is more prevalent in south China (Yu et al., 2009). Unfortunately, husbandry, management and biosecurity practices adopted on pig farms in China are rarely described and no information is available on potential risk factors for SI infection in pig farms in China. The objectives of this study were to describe: the herd level prevalence in pig farms reporting SI infection; the distribution of infection; the husbandry, management and biosecurity practices adopted on the surveyed pig farms; and the putative risk factors for SI in Guangdong Province.

2. Materials and methods

2.1. Sample strategy

The study was conducted in Guangdong Province in July and August 2015. The sampling frame was the client lists of 10 private consultants who were offering veterinary services to pig farms in all 21 prefectures within the province. The average number of clients (piggeries) per prefecture for the consultants was 80. The veterinary consultants used a random number process to randomly select piggeries from their complete client lists for sampling. On average 7 farms were randomly selected from each of the 21 prefectures in the province (total of 153 pig farms surveyed) (Fig. 1). Four of the consultants provided details on the number of farms serviced and the number of pigs on these farms in 15 prefectures.

2.2. Data collection

A questionnaire was designed and administered to collect information about husbandry, management, trade and biosecurity practices, and interfaces between pigs and other animal species, including humans. The farmers were asked if a swine flu-like syndrome, such as coughing, nasal discharges or sneezing, had been seen in their pigs in the six months prior to the questionnaire being administered. Data were collected on when this event occurred, its duration, mortality levels, and whether it was confirmed by diagnostic tests and/or by a veterinarian. The questionnaire was pretested on 12 farms and subsequently revised. The final questionnaire contained 84 questions and the average response time to complete was 30 minutes. The questionnaires were administered to piggery owners/managers by the consultants in a face-to-face setting. The consultants were trained in delivering the questionnaire by the authors before administering the survey. The questionnaire and its delivery had been approved by the South China Agriculture University Human Ethics Committee.

2.3. Data analyses

Using information collected from the piggery and from the consultants, a case was defined as a farm that had contained pigs with SI-like clinical signs, including coughing and/or labored breathing, in the six-months preceding the questionnaire administration and which also met at least one of the following criteria:

- The outbreak lasted less than 30 days on the farm;
- The morbidity was higher than 10%;
- The case fatality rate was less than 5%;
- The outbreak was diagnosed as SI infection by a veterinarian or from laboratory samples.

70 farms that met the criteria were defined as case farms. Among these, 19 had the epidemic diagnosed by a professional (12 by a on–farm veterinarian and 7 by a diagnostic laboratory). The remaining 51 case farms all had SI-like clinical signs in pigs and met at least 1 of the first 3 criteria (19 farms met 1 of the criteria; 29 met 2 of the criteria; and 3 case farms met all of the first 3 criteria).

The herd prevalence was estimated only in the 15 prefectures with a known sampling frame by weighting in each stratum (prefecture) in Microsoft Excel (Redmond, WA, USA) using the method of Dohoo, Martin et al. (page 35-37, 2010). Maps were developed with ArcGIS 9.3 (ESRI Inc., Redlands, CA, USA) to show the location of the affected and non-affected piggeries. Statistical descriptions of the husbandry, management, trading and biosecurity practices were conducted with Microsoft Excel (Redmond, WA, USA) and R software (version 3.0.2). The total number of cases per month was calculated and the number of cases in each month was illustrated by constructing a histogram using Microsoft Excel.

Data collected from the 153 pig farms were used to identify putative risk factors for SIV infection in the 6 months preceding the administration of the questionnaire. Univariable and multivariable logistic regression analyses were done using SPSS (SPSS Inc., IBM Corporation, Somers, NY) version 19 to identify risk factors for farmer' reported SI infection in their piggery. Ten risk factors were excluded from the multivariable logistic regression analysis due to collinearity and two risk factors were excluded due to similarity to other risk factors. Factors (12) with P-values < 0.2 in the univariable logistic regression analyses were offered to a multivariable model. A stepwise backward method was used to generate a final model with variables retained when the P-value of the likelihood ratio test was < 0.05. Interactions between factors in the final model were examined for statistical significance. The goodness of fit of the final model was tested using the Hosmer-Lemeshow test (Hosmer, 2013). Area under the curve (AUC) was also calculated with SPSS.

3. Results

3.1. Herd prevalence

Of 153 surveyed farms, 70 (46%) were defined as cases. Using the data from the 15 prefectures where the total number of farms in the sampling list was known, the herd prevalence of farmer' reported SI infection in the preceding 6 months was 58% (95% CI: 48 - 68%), after adjusting for the sample weights in each stratum.

3.2. Temporal distribution of SI infection

Fifty-nine of the 70 case farms reported the onset dates or months of the SI-like infection. For the data collected (January to August, 2015) the most cases of SI-like infection were observed from March to May (Fig. 2).

Demographic, management and husbandry practices of pig farms

The demographic profile of farms participating in the study and the on-farm husbandry and management practices are summarized in Table 1.

The majority (86%) of the farms involved in this study were farrow to finish pig farms (breed, grow and fatten pigs and then send them to a slaughterhouse), 11% were farrow to wean farms (sell gilts or weaners to other farms for breeding or fattening purposes), and 3% of the surveyed farms were fattening farms (purchased weaners to fatten). Approximately half (46%) were categorized as small farms (< 2000 head). Farrow to wean farms had larger populations than farrow to finish and fattening farms and were more likely to record production information and employ a veterinarian as a full-time worker on the farm.

3.2. Practices for introduction and selling of pigs

The practices for the introduction and selling of pigs on surveyed farms are presented in Table 2. Fattening farms introduced more pigs and at more frequent intervals (6.5 times per year with about 1200 head in total) than farrow to finish farms (1.8 times per year with about 140 head) and breeding farms (1.5 times per year with about 70 head); farrow to wean farms sold more pigs more frequently (a total of 27600 head sold 210 times per year) than farrow to finish farms (5327 pigs sold 46 times per year) and fattening farms (800 pigs sold 6 times per year). Of the interviewed owners/managers, 89% would contact farrow to wean farms directly when they needed new stock, but 5% of them would use agents ("middle-men") and 1% of them would attend a live pig market for replacement stock. When selling pigs, less than half of the farms (42%) would sell all the pigs in a pen at one time. On 30% of the visited farms, buyers would participate in selecting pigs for purchase and their subsequent loading onto trucks.

3.2. Biosecurity management practices on farms

The biosecurity practices of farms participating in the study are presented in Table 3. In general, breeders adopted better biosecurity management practices than fattening and farrow to finish farms, and similarly, larger farms had better biosecurity than smaller ones. However, on average, only about 70% farms had a vehicle disinfection drive-through tyre wash at the front-gate, only about half of the surveyed farms required all vehicles from outside to be disinfected. Dogs, cats and poultry were commonly present (more than 50%) on pig farms. In 46% of the farms with dogs/cats, the dogs/cats could contact pigs directly. Of the 86 farms which also kept some poultry, 69% of them purchased poultry from live bird markets and 67% of farms had the same worker feed both the pigs and the poultry. Approximately 90% of the farms (141) had a pond on their farms, with 18% of them using the pond water for flushing waste from their piggeries and two used pond-water as pig drinking water. Swill was fed to pigs in only 3.9% (6) of the surveyed farms.

3.2. Risk factor analysis

Among the 84 questions, 52 factors were analyzed and 24 factors were significantly associated ($p < 0.20$) with farmer' reported SI infection in the univariable logistic regression analyses (Table 4). The results of the multivariable logistic regression analysis are presented in Table 5. In the final multivariable logistic regression model, piggeries that did not prevent the entry of wild birds, raised poultry or did not have a disinfection pool at the piggery entrance were more likely to have an outbreak of SI in the 6 month period preceding the administration of the questionnaire (OR = 2.50, 95%CI: 1.01-6.16; OR = 3.24, 95%CI: 1.52-6.94; OR = 2.65, 95%CI: 1.04-6.78; respectively) (Table 5). The Hosmer–Lemeshow test of goodness of fit (p = 0.73) and the AUC (0.73; 95%CI: 0.65-0.81) indicated that the model fitted the data well and had a medium predictive ability.

4. Discussion

A high seropositivity of SI at the individual animal level has been reported in previous studies in the Chinese pig population (Song et al., 2010; Liu et al., 2011a; Strelioff et al., 2013). However, the herd prevalence of SIV infection in China has rarely been reported and it is likely that the individual animal prevalence is biased through the sampling methodology used. This study found a high farmer-reported herd prevalence (almost 60%) in pig farms in Guangdong Province from January to August 2015. To our knowledge, this is the first study describing husbandry, management and biosecurity practices adopted in Chinese pig farms and identifying risk factors for SI infection in pig farms in China.

This study had several strengths and limitations. Due to the unwillingness of many farmers to allow collection of serum samples from their pigs, we used farmer reported SI infection when analyzing potential risk factors. The clinical signs of SI infection in pigs are similar to other respiratory diseases, including porcine reproductive and respiratory syndrome and infection with *Mycoplasma hyopneumoniae*, however the low mortality, short duration and recovery without therapy help in differentiating SI from other respiratory diseases (Detmer et al., 2013; Kong et al., 2014). In this study, the dependent variable, (SI), relied partly upon the farm owners/managers' knowledge of the disease and partly on epidemiological features or diagnosis of the disease. It is believed that the farmers surveyed should be familiar with SI as it is a commonly seen disease in local pig farms and 93% of farmers visited claimed they knew about SI. Nearly half of the surveyed farms claimed that they had participated in training on swine diseases offered by local official veterinary stations in the preceding year (data not shown). The temporal distribution of farmer reported SI outbreaks highlighted a peak of infection during March to May, which fits well with the SI surveillance results with serum tested by the provincial university laboratory (personal communication with the head of the laboratory). Although a case was identified using a variety of disease effects, it is worth investigating the association between farmer-reported SI infection and the results of laboratory diagnostic tests in future studies. Although the accuracy of farmers' perception on SI epidemic in a herd hasn't been evaluated in China, several studies conducted internationally have indicated that pig farmers have a good knowledge on SI (Hernandez-Jover et al., 2012; Rabinowitz et al., 2013). Data on farmer' reported SI outbreaks also relies heavily on the willingness of farmers to cooperate in the study, consequently we used the services of veterinary consultants who offer technical support to the local farmers, to increase the response rate. All surveys were administered by the consultants, and none of the randomly selected farmers/managers refused to be involved in the study. Recall bias could be another obstacle for a syndrome survey (O'Neill et al., 2014); however in this study 80% of the interviewed farms had detailed production records documenting the specific onset date (44/70) or month (59/70) of the SI outbreaks experienced.

The univariable logistic regression analysis indicates that there were many (16) significant variables that may be reflective of poor biosecurity. These and the three significant variables from the multivariable logistic regression analysis demonstrate implementation of poor biosecurity practices on many local pig farms. The husbandry and biosecurity practices adopted by local farms indicate several potential pathways for the introduction of SI into the surveyed farms. For example, live pig movement between pig farms is considered a high-risk practice (Brown, 2000; Almeida et al., 2017) with 57% of the visited farms having introduced live pigs in the year preceding the survey. Approximately one-third (35%) of the farms that introduced pigs in the preceding year did not always quarantine these introduced stock, and of those who did adopt some form of quarantine, half of them only used visual inspection for signs of clinical disease. Due to the common subclinical infection status of SI in individual pigs (Er et al., 2014; Er et al., 2016b), visual inspection could be ineffective in detecting disease in introduced pigs. About 6% of the visited farms purchased pigs from traders (middle men) or from live pig markets, where pigs from different farms are mixed. Mixing of pigs and contact of pigs from different sources can facilitate SI spread

(Bowman et al., 2014a; Bowman et al., 2014b; Lauterbach et al., 2018). Contact between pigs and infected buyers can be another risk factor for SI introduction (Grontvedt et al., 2013; Nelson and Vincent, 2015). Less than half of the surveyed farms sold the whole pen each time. Others have reported the association of SI infection with a lack of all-in all-out management in the fattening room (OR 2.4, 95% CI: 1.0–5.8) (Fablet et al., 2013). When selecting and loading pigs, on 30% of the farms buyers would participate in the activity. However, many of the surveyed farms did not ask the buyers to change their clothes (58%) or boots (72%) before entering the piggeries. Buyers sometimes purchase pigs from different farms to make up a consignment, with 11% of surveyed farmers reporting seeing trucks collecting their pigs already containing pigs from other farms. Since SIV can be transmitted through aerosols (Corzo et al., 2013b; Hemmink et al., 2016), the close proximity of pigs from other farms present on these trucks could introduce SIV via aerosols, or they could contaminate clothes or boots of people involved in the loading (Lauterbach et al., 2018).

Pigs can contract influenza A viruses from other species, especially from humans and birds (Karasin et al., 2000; Grontvedt et al., 2013; Nelson and Vincent, 2015). Avian influenza viruses have been isolated from pigs in many places. In Canada, H4N6 influenza A viruses were isolated from pigs with pneumonia on a commercial swine farm (Karasin et al., 2000). Human source influenza A infection in pigs has also been widely reported. For example, a study in the Czech Republic reported that antibodies against human influenza virus isolated during the 1995 epidemic were present in the local pig population. It is possible that the human virus was introduced to the pig herds by infected animal attendants, in whom antibodies against this virus were also found (Pospisil et al., 2001). In China, former prevailing human H1N1 strains have been shown to be circulating in the pig population (Yu et al., 2007; Yu et al., 2009). The authors concluded that more than 40 outbreaks of human-origin H1N1 viruses in swine had been reported in the 5 years after H1N1pdm09 was first detected in humans (Nelson and Vincent, 2015).

South China, especially Guangdong Province, is considered an epicenter for influenza (Ninomiya et al., 2002). Understanding the complexity of the interface between pigs and other species, including humans, is key to understanding the ecology of influenza in this area. The high proportion of farms with other species on farm, including cats/dogs (75%) and poultry (57%) in this study, can provide opportunities for potential cross-species transmission of influenza within this area. Similar to the findings of this study, in a small study (85 farms) conducted in Spain by Simon-Grife et al. (2011) the presence of other species on a farm increased the risk of infection with SI in fattening pigs (OR = 2.3). In contrast, Takemae et al. (2016) found that the presence of other animals on a farm was protective for influenza A infection in pig farms in Vietnam (OR = 0.26). The conflicting results may be due to different ecosystems and husbandry practices adopted between studies. In the current study the presence of backyard poultry increased the risk of farmer-reported SI. Our survey found that 69% of farms with poultry introduced live poultry from local live bird markets, where high prevalences of avian influenza have been reported (Yuan et al., 2015). Compared to H5 and H7 subtype avian influenza, H9 subtype is the most common avian-sourced influenza infection in pigs. In China, 28 swine H9N2 viruses were isolated from 1998 to 2007 (Karasin et al., 2000; Yu et al., 2011). Furthermore wild birds, particularly wild ducks, can be involved in the transmission of influenza viruses to pigs through contaminating pond water, and as SIV can also be transmitted to poultry, the possibility of SIV transmitting to wild birds cannot be ruled out (Karasin et al., 2000; Karasin et al., 2004; Kuntz-Simon and Madec, 2009). Of the visited farms 89% had ponds, and 18% of them used the pond water to flush piggeries. Furthermore wild waterfowl are commonly seen on these ponds during the bird migratory seasons (personal communication with some interviewed pig farmers). Avian influenza virus can remain infective for more than 40 days in water at temperatures ≤ 23 ℃, thus contaminated pond water could potentially introduce avian influenza virus to pigs through aerosolization during flushing (Lebarbenchon et al., 2011; Lebarbenchon et al., 2012).

The findings of this study can help reduce the risk of SI on pig farms and mitigate against the risk of a potential influenza pandemic. The study highlights the need for improved biosecurity in piggeries, particularly with respect to the introduction and sale of pigs. Local veterinary authorities should educate farmers on better biosecurity management to reduce the risk of SI and the findings from this study should be included in educational material for local farmers. For example, farmers should follow an all-in all-out practice for batches/pens and should not let buyers enter piggeries. Farmers should particularly be aware that backyard poultry and wild birds on farm do have a potential negative impact to their pigs. As well as influenza virus, other pathogens, including *Brachyspira pilosicoli* and atrophic rhinitis pathogenic *Pasteurella multocida* (Dejong, 1991; Smith, 2005), can be transmitted from poultry to pigs. Active surveillance for SI is currently undertaken in south China by the National Reference Laboratory for Animal Influenza, and this is designed to monitor gene mutations of circulating SIVs and the early detection of new strains with potential pandemic threat (Chen et al., 2013; Yang et al., 2016). To be more efficient, sampling should be conducted in early spring in Guangdong, and farms with poor biosecurity and particularly those with poultry, wild birds and other animals with access to the pigs should be specifically targeted for sampling.

5. Conclusions

This study has revealed several potential pathways for SI transmission among pig farms in Guangdong Province. Access by humans, poultry, wild birds and other animals on pig farms can increase the risk of SI infection in pig farms. The findings of this study highlight the importance of understanding the local pig industry and the practices adopted when developing control measures to reduce the risk of SI to local pig farms. It is concluded that biosecurity needs to be improved significantly to reduce the risks from SI in southern China.

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Figures and tables

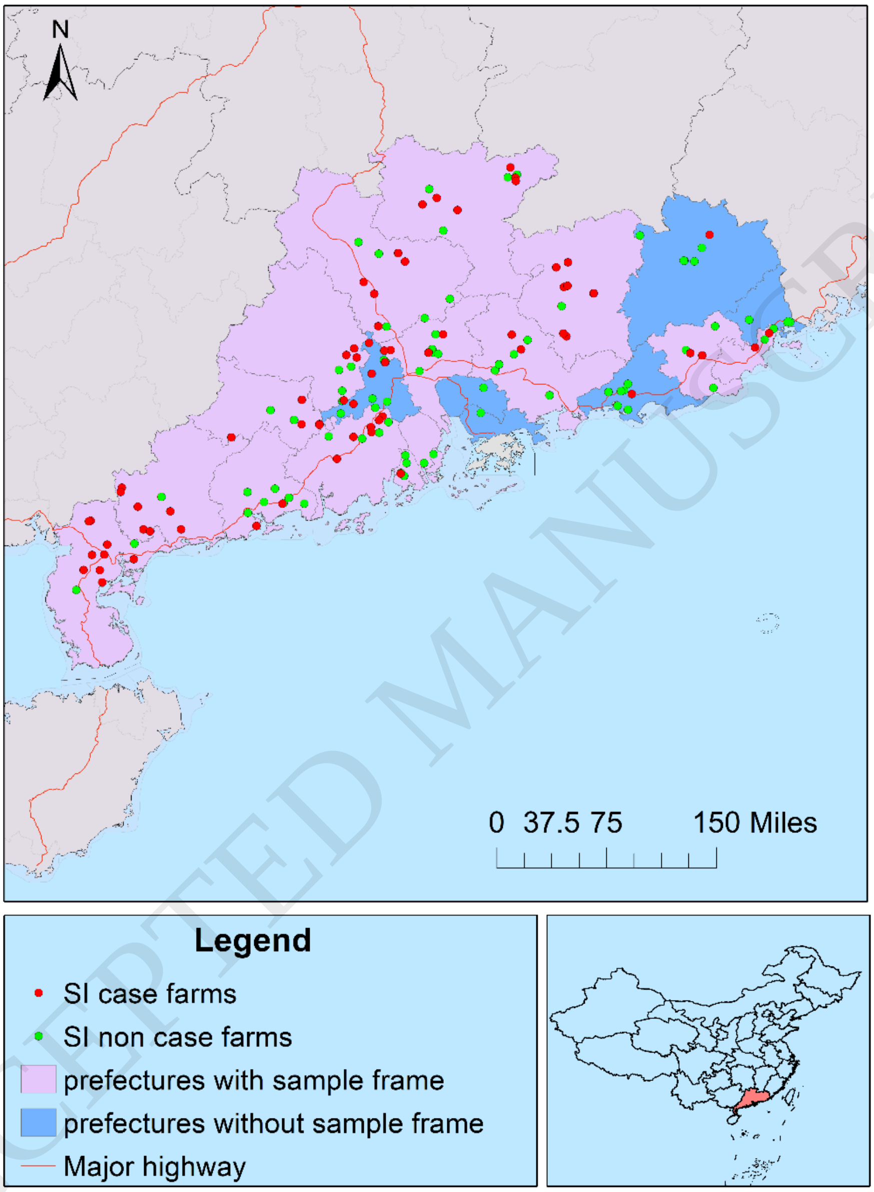

Fig. 1. Sampled pig farms in Guangdong Province

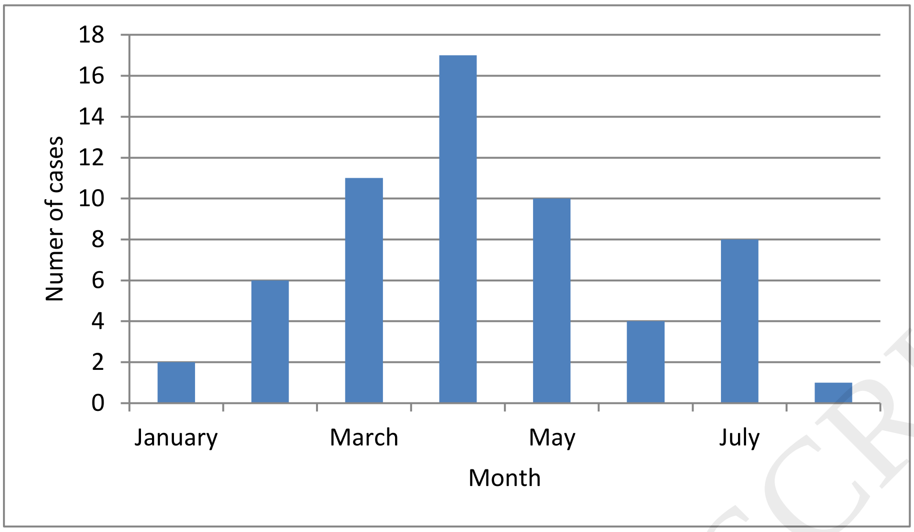

Fig. 2. Temporal distribution of farmer-perceived SI cases between January and August 2015 in Guangdong province

Table 1 Demographic profile and husbandry practices of the 153 pig farms participating in the study categorized by herd size and farm type

Explanatory variable	Level	farm type			farm size (head)		Total
		farrow to finish	farrow to wean	fattening	< 2000	≥ 2000	
N (%)		131 (86%)	18 (11%)	4 (3%)	71 (46%)	82 (54%)	
Total pig population (mean ± SD)		2810 ± 2690	12511 ± 17029	1260 ± 424	1098 ± 970	6347 ± 17673	
Duration of operation (Years)	=< 10	76%	83%	100%	76%	78%	77%
	> 10	24%	17%		24%	22%	23%
Keep production records	Yes	76%	100%	75%	72%	85%	79%
	No	24%		25%	28%	15%	21%
Total employees (mean ± SD)		12.0 ± 15.0	54.9 ± 63.8	3.8 ± 1.0	5.3 ± 5	26.8 ± 73.8	
Full-time veterinarian employed on farm	Yes	47%	94%	25%	34%	68%	52%
	No	53%	6%	75%	66%	32%	48%
Employees live on the farm	Yes	93%	94%	100%	90%	96%	93%
	No	2%	6%		3%	1%	2%
	Not always	5%			7%	2%	5%
Accommodation area for staff adjacent (< 10 meters) to buildings housing pigs	Yes	31%	11%	25%	39%	20%	29%
	No	69%	89%	75%	61%	80%	71%

Table 2 The introduction of live pigs and selling practices of farms participating in the study

Explanatory variable	Level	farm type			farm size (head)		Total
		farrow to finish	farrow to wean	fattening	< 2000	≥ 2000	
Introduced pigs in the year preceding the survey	Yes	61%	28%	50%	66%	50%	57%
	No	39%	72%	50%	34%	50%	43%
Source of introduced pigs	Breeding farms	88%	100%	100%	90%	89%	89%
	Middle men	6%			6%	5%	5%
	Live pig market	1%				2%	1%
	Others	5%			4%	5%	4%
New pigs are quarantined when introduced	Yes all the time	62%	100%	50%	45%	85%	65%
	Sometimes	14%	0%	0%	18%	6%	12%
	Never	24%	0%	50%	37%	8%	23%
Measures undertaking during quarantine in farms which adopted quarantine practices	Observe for signs of illness only	52%	14%	50%	61%	38%	50%
	Observe pigs and do diagnostic tests	37%	86%	0%	24%	55%	40%
	Observe pigs and occasionally collect samples for testing	11%	0%	50%	15%	6%	11%
Sell all the finishing pigs in an individual pen	Yes all the time	43%	33%	50%	32%	51%	42%
	Sometimes	30%	33%	50%	28%	33%	31%

Explanatory variable	Level	farm type			farm size (head)		Total
		farrow to finish	farrow to wean	fattening	< 2000	≥ 2000	
	Never	27%	33%		39%	16%	27%
Who selects and loads pigs for sale	Workers from the farm only	68%	94%	50%	66%	74%	70%
	Buyers only	11%			15%	5%	10%
	Both	21%	6%	50%	18%	21%	20%
People loading pigs change their clothes before entering the piggery to select and load pigs	Yes	46%	6%	75%	61%	26%	42%
	No	54%	94%	25%	39%	74%	58%
People loading pigs change their boots before entering the piggeries to select and load pigs	Yes	30%	6%	50%	37%	21%	28%
	No	70%	94%	50%	63%	79%	72%
Ever seen half loaded truck (presence of other farm pigs on truck) before loading	Yes	13%			18%	5%	11%
	No	77%	100%	75%	65%	93%	80%
	Not sure	10%		25%	17%	2%	9%
Number of times pigs were introduced in the year preceding the survey (mean ± SD)		1.8 ± 1.2	1.8 ± 0.8	6.5 ± 7.8	1.8 ± 3.4	1.9 ± 2.8	

Explanatory variable	Level	farm type			farm size (head)		Total
		farrow to finish	farrow to wean	fattening	< 2000	≥ 2000	
Number of pigs introduced in the year preceding the survey (mean ± SD)		138 ± 366	70 ± 19	1211 ± 1682	104 ± 712	216 ± 974	
Number of times pigs were sold during the year preceding the survey (mean ± SD)		45 ± 70	201 ± 301	5.5 ± 6.4	21 ± 63	96 ± 328	
Number of pigs sold during the year preceding the survey (mean ± SD)		5228 ± 10413	25999 ± 32120	800 ± 1131	1959 ± 5069	12109 ± 40335	

Table 3 Biosecurity practices adopted in the participating farms

Explanatory variable	Level	farm type			farm size (head)		Total
		farrow to finish	farrow to wean	fattening	< 2000	≥ 2000	
Disinfection pool for trucks at the farm entrance	Yes	69%	94%	75%	59%	83%	72%
	No	31%	6%	25%	41%	17%	28%
Disinfection of vehicles from outside	Yes, always	50%	89%	50%	37%	71%	55%
	No or sometimes	50%	11%	50%	63%	29%	45%
Not allow visitors to enter the piggery	Yes	73%	89%	25%	69%	77%	73%
	No	27%	11%	75%	31%	23%	27%
Dogs/cats present on farm	Yes	77%	50%	100%	82%	68%	75%
	No	23%	50%		18%	32%	25%
Dogs/cats can have direct contact with pigs [a]	Yes	46%	44%	50%	49%	43%	46%
	No	54%	56%	50%	51%	57%	54%
Dogs/cats can have direct contact with pig feed or drinking water [a]	Yes	38%	38%	25%	38%	36%	37%
	No	62%	62%	75%	62%	64%	63%
Feed raw poultry meat or pork to dogs/cats [a]	Yes	29%	12%	50%	38%	18%	28%
	No	71%	88%	50%	62%	82%	72%

Explanatory variable	Level	farm type			farm size (head)		Total
		farrow to finish	farrow to wean	fattening	< 2000	≥ 2000	
Poultry present on farm	Yes	59%	33%	100%	75%	41%	57%
	No	41%	67%		25%	59%	43%
The same person(s) feeds both pigs and poultry [b]	Yes	68%	67%	50%	69%	64%	67%
	No	32%	33%	50%	31%	36%	33%
Source of poultry [b]	Live bird markets	71%	67%	25%	75%	59%	69%
	Nearby villages	11%		25%	8%	15%	10%
	Breeder poultry farms	10%	17%	25%	10%	15%	12%
	Breed themselves	8%	17%	25%	8%	12%	9%
Pond present on farm	Yes	88%	100%	75%	81%	97%	89%
	No	12%		25%	19%	3%	11%
Pond water used as a source of drinking water for pigs [c]	Yes	1%	6%			3%	1%
	No	99%	94%	100%	100%	98%	99%
Pond water used to flush piggeries [c]	Yes	17%	22%		20%	16%	18%
	No	83%	78%	100%	80%	84%	82%
Netting used to prevent access of birds to piggery	Yes	10%	24%	25%	7%	17%	12%
	No	90%	76%	75%	93%	83%	88%

Explanatory variable	Level	farm type			farm size (head)		Total
		farrow to finish	farrow to wean	fattening	< 2000	≥ 2000	
Wild birds able to enter piggery	Yes	45%	47%	50%	55%	36%	45%
	No	23%	41%		16%	32%	25%
	Not sure	32%	12%	50%	28%	31%	30%
Is swill fed to pigs?	Yes	4%		25%	6%	2%	4%
	No	96%	100%	75%	94%	98%	96%

[a] Only conducted with the farms having dogs/cats present on the farm.

[b] Only conducted with farms keeping poultry on farm.

[c] Only conducted with the farms having a pond on the farm.

Table 4 Results of the analysis by univariable logistic regression for owner reported Swine Influenza infection in piggeries

ID	Risk factors	P-value	OR (95%CI)
1	Less than 10 years of operation	0.056	2.18 (0.98, 4.85)
2	Less than 2000 head inventory	0.006	2.5 (1.3, 4.8)
3	No quarantine implemented	0.084	1.78 (0.93, 3.43)
4	Don't sell all finishing pigs in one pen every time	0.121	1.68 (0.88, 3.21)
5	People loading pigs do not change clothes before entering piggery	0.001	3.28 (1.68, 6.41)
6	People loading pigs do not change boots before entering piggery	0.056	2.26 (0.98, 4.1)
7	Workers loading pigs do not conduct spray disinfection to their clothes/boots after loading trucks	0.006	2.72 (1.34, 5.5)
8	No production records kept	0.013	2.81 (1.24, 6.34)
9	No veterinarians among employees	0.002	2.81 (1.46, 5.43)
10	Workers occasionally work in different piggeries	0.001	3.08 (1.58, 6.01)
11	No disinfection of workers before entering the piggery	0.001	4.29 (1.83, 10.04)
12	Without scheduled disinfection of pig pens	0.081	1.86 (0.93, 3.74)
13	Process feed in the piggery	0.115	2.15 (0.83, 5.57)
14	Not separate living area of employees from piggery area	0.083	1.87 (0.92, 3.8)
15	Visitors are allowed to enter the piggery	0.009	2.68 (1.28, 5.62)
16	Dogs/cats on the farm	0.032	2.33 (1.08, 5.05)
17	Poultry on the farm	<0.001	3.96 (1.99, 7.9)
18	Wild birds able to gain entry to the piggery	0.002	4.22 (1.71, 10.4)
19	Wild birds have potential contact with drinking water of pigs	0.006	4.18 (1.5, 11.65)
20	Eat poultry meat on farm	0.017	6.41 (1.39, 29.46)
21	Purchase live poultry to cook on farm	0.024	2.25 (1.11, 4.53)
22	Not using mouth mask/gloves when treating sick pigs	0.005	2.69 (1.35, 5.34)
23	No college graduates employed on the farm	<0.001	5.19 (2.28, 11.83)

ID	Risk factors	P-value	OR (95%CI)
24	Introduced pigs in the year preceding the questionnaire	0.196	1.54 (0.8, 2.94)

Table 5 Results of the analysis by multivariable logistic regression for owner reported Swine Influenza infection in piggeries

	β	Sig.	OR	95% CI for OR	
				Lower	Upper
Wild birds able to enter piggery	0.92	0.047	2.50	1.01	6.16
Poultry present on the farm	1.18	0.002	3.24	1.52	6.94
The workers are not required to undertake any biosecurity measures, such as changing clothes/boots, having a shower or disinfecting their boots, before they enter the piggery	0.97	0.042	2.65	1.04	6.78
Constant	-1.71				