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Original article

Induction of parturition in the sow and incidence of splayleg syndrome in the newborn piglet

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Abstract — The relationship between gestation length and incidence of the splayleg condition in newborn piglets (two or, much more rarely, four splayed limbs) was investigated in natural or artificially induced farrowings of sows from two breeds, Large White and Piétrain. Records on 2 070 first- or second-parity litters and 19 312 piglets born alive were collected on one experimental farm over a 12-year period. The treatment used for inducing parturition consisted of an intramuscular injection of an analogue of prostaglandin $F_{2\alpha}$ on days 110 to 114 of pregnancy. Incidence of splayleg was much higher in male than in female piglets, and in piglets born from Piétrain dams than in those born from Large White dams. Moreover, the incidence of splayleg was strongly influenced by gestation length both for natural and artificially induced farrowings. The adverse influence of shorter gestation lengths was breed-dependent, with this influence being of greater extent in Piétrain than in Large White dams. The unfavourable effect of larger litter size at birth on the incidence of splayleg is thought to partly operate through shortened gestation length in natural farrowings of large litters. On practical grounds, the significant difference in average gestation length between the two breeds under study (114.2 and 115.3 days for naturally farrowing Large White and Piétrain dams, respectively) is to be taken into account for defining the most suitable way of using artificial induction of parturition. (© Elsevier / Inra)

pig / splayleg syndrome / gestation length / induction of parturition

Résumé — Induction de la mise bas chez la truie et incidence du syndrome d'abduction des membres chez le porcelet nouveau-né. La relation entre la durée de gestation et l'incidence du syndrome d'abduction des membres (*splayleg*) chez le porcelet nouveau-né (avec les deux membres postérieurs ou, beaucoup plus rarement, les quatre membres affectés) a été étudiée lors de mises bas naturelles ou artificiellement provoquées chez des truies Large White et Piétrain. Des données concernant 2 070 portées (de rang 1 ou 2) et 19 312 porcelets nés vivants ont été recueillies dans un troupeau expérimental sur une période de 12 ans. Le traitement utilisé pour provoquer artificiellement la mise bas consistait en une injection intramusculaire d'un analogue de la prostaglandine $F_{2\alpha}$ entre

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le 110^e et le 114^e jour de gestation. La fréquence d'apparition du syndrome *splayleg* a été nettement plus élevée chez les porcelets mâles que chez les porcelets femelles et chez les porcelets nés de mères Piétrain que chez les porcelets nés de mères Large White. Par ailleurs, l'incidence du syndrome *splayleg* a été fortement influencée par la durée de gestation tant pour les mises bas naturelles que pour les mises bas provoquées. L'ampleur de l'effet défavorable des durées de gestation plus courtes a été fonction de la race de la mère, avec un effet plus marqué chez les mères Piétrain que chez les mères Large White. Quant à l'effet défavorable des tailles de portée à la naissance plus élevées sur l'incidence du syndrome *splayleg*, on peut supposer qu'il est dû en partie au raccourcissement de la durée de gestation dans le cas des mises bas naturelles de portées de grande taille. Sur le plan pratique, la différence significative de durée moyenne de gestation entre les deux races étudiées ici (respectivement 114,2 et 115,3 jours pour les mères Large White et Piétrain mettant bas naturellement) est à prendre en compte pour définir le meilleur protocole d'utilisation de l'induction artificielle de la parturition chez la truie. (© Elsevier / Inra)

porc / syndrome d'abduction des membres / durée de gestation / mise bas provoquée

1. INTRODUCTION

For the last two decades, the use of prostaglandin $F_{2\alpha}$ analogues during late pregnancy for induction of parturition (e.g. [2, 9, 11]) has become a prominent feature of practical management of neonates in the pig industry. This technique makes it possible to obtain synchronized farrowings within normal daytime working hours, and greatly facilitates the supervision of the delivery process and the effective care of newborn piglets. On the other hand, the occurrence of congenital or very early onset splayleg syndrome, first described by Gilbert et al. [14] as myofibrillar hypoplasia, is known to depend upon several genetic, nutritional or environmental factors as reviewed by Ward [36, 37]. This clinical condition characteristically consists of postural collapse with a failure of adduction of hind and, more rarely, fore limbs. The functional ability to suck and to avoid accidental overlaying by the sow is severely limited, resulting in a mortality rate of the order of 50 % in affected piglets [36]. Splayleg can be a major cause of preweaning mortality of piglets in some herds and/or at certain periods [7, 22, 32]. Incidence of splayleg has been shown to be higher for gestations of shorter length. The gestation length for splayleg-affected litters was significantly shorter (113.6 vs. 114.5 days) than that for non-affected contemporary litters in the study of Sellier and Ollivier [26], and the corresponding difference was of 0.4 days in the study of van der Heyde et al. [32]. This finding supports the earlier suggestion that a developmental disorder of the neuromuscular system caused by 'physiological immaturity' is implied in the aetiology of the splayleg abnormality [37]. On this basis, the artificial control of the time of farrowing which leads to a shortened gestation compared to natural farrowing might therefore favour the occurrence of splayleg in the newborn piglet.

The aim of this article is to report some results dealing with the relationship of gestation length with incidence of splayleg in natural or artificially induced farrowings of sows from two breeds (Large White and Piétrain).

2. MATERIALS AND METHODS

2.1. Animals and management

Records collected over a 12-year period on an Inra experimental farm (Bourges-Avord, Cher, France) were available on a total of 2 070 first- or second-parity litters from Large White and Piétrain dams. The Large White sows were from either the control (LWC) or the selected line (LWS) involved in a long-term selection experiment for increased litter size [8]. The Piétrain sows were from two closed lines (PA and PB) which were contemporaneously subjected to two different selection regimes for seven generations [25, 27]. The Large White sows were mated to Large White and Piétrain boars for producing their first- and second-parity litters, respectively. All litters from Piétrain gilts and sows were purebred litters. The numbers of litters were 142, 118, 702, 558, 330 and 220 for LWC × LWC, PA or PB × LWC, LWS, PA or PB × LWS, PA × PA and PB × PB line combinations, respectively. The corresponding numbers of piglets born alive were 1 310, 1 119, 6 775, 5 705, 2 670 and 1 733, respectively.

During pregnancy, breeding females were housed indoor and tethered in stalls, and received 2.5–2.7 kg of commercial feed per day. They were moved into farrowing facilities at least 3 days before they were expected to farrow. Parturition, either natural or artificially induced (see later), took place in individual farrowing pens. Numbers of fully formed piglets at farrowing (born alive and stillborn) were recorded. Dams were fed ad libitum over the whole lactation period. Piglets received iron injection at 3 or 4 days of age. Creep feed was made available to piglets at about 10 days of age. Male piglets were kept entire in first-parity replacement litters whereas they were castrated at about 3 weeks of age in second-parity litters. Piglets were weaned during their 6th week of life, i.e. on average at 38 days of age, and preweaning survival rates were recorded.

2.2. Type of farrowing

As indicated in *table I*, there were three successive periods of time regarding the type of farrowing (natural or induced). In the earlier period, covering 4 years, 624 litters were all issued from natural farrowings. In the following period (2 years), 462 litters were issued from either natural or artificially induced farrowings. The treatment used for inducing parturition consisted of a single intramuscular injection of 150 μg of a synthetic analogue of prostaglandin $F_{2\alpha}$ (cloprostenol, compound ICI no. 80996) made in the neck region at 07.30 a.m., so that parturition mostly occurs within the working hours on the following day (the average time from injection of cloprostenol to delivery of the first piglet was 27 h). In the latter period (6 years), artificial induction of parturition was routinely practised for 984 litters. About two-thirds of the artificially induced farrowings resulted from injection of cloprostenol at the 111th or 112th day of gestation (*table I*).

2.3. Assessment of splayleg

All the piglets born alive (n = 19312) were ear-notched and individually examined for occurrence of splayleg on the day of farrowing and on the day after. The most frequent form of this abnormality consisted of the sideward and forward splaying of the hind limbs. A more severe form of the abnormality, with the four limbs splayed, occurred in about 15 % of the affected piglets. These two forms of the splayleg condition were pooled together in the present study.

2.4. Statistical analysis

For analyzing the traits expressed as proportions (percentage of splaylegged piglets among piglets born alive, stillbirth rate and survival rate from birth to weaning), the angular transformation as well as the corrections suggested by

Table I. Distribution of litters (with numbers of piglets recorded in parentheses) per period of time and farrowing type.

Farrowing type	Period of time [1] 1 (n = 4)	2 (n = 2)	3 (n = 6)	Total
Natural farrowing	624 (5 578)	253 (2 269)	–	877 (7 847)
Artificially induced farrowing [2]	–	209 (1 772)	984 (9 693)	1 193 (11 465)

[1] n: number of years of data collection; [2] numbers of litters obtained by cloprostenol treatment at the 110th, 111th, 112th, 113th and 114th day of gestation were 164, 350, 465, 184 and 30, respectively.

Bartlett [4] for 0 and 100 % proportions were used. A series of analyses of variance were performed on different data subsets, i.e. data from natural farrowings (n = 877), data from artificially induced farrowings (n = 1193) and data from contemporary natural and induced farrowings (n = 462), using the general linear models (GLM) procedure of the SAS package [23]. For analyzing records from either natural or induced farrowings, the fixed effects included in the model consisted of year-season (11 or 16 levels, respectively), dam breed (two levels), dam parity (two levels), gestation length (eight or five levels, respectively), and dam breed × dam parity and dam breed × gestation length interactions. Subsequent analyses of these two data subsets were made with gestation length taken as a covariate (instead of being a main effect), in order to fit the within-dam breed curvilinear regression (second-degree polynomial) of splayleg frequency on gestation length. For analyzing records from the 462 contemporary natural and induced farrowings taking place in the period 2, the following fixed effects were included in the model: year-season (four levels), dam breed (two levels), dam parity (two levels), farrowing type (two levels) and all two-way interactions among the three latter main effects.

3. RESULTS

As reported in *table II*, the overall incidence of splayleg was markedly higher ($P < 0.001$) in male than in female piglets. It was also much higher ($P < 0.001$) in Piétrain than in Large White purebred litters. The Piétrain × Large White crossbred litters showed an intermediate incidence of splayleg, and significantly differed from both Piétrain ($P < 0.001$) and Large White ($P < 0.05$) purebred litters. In the following analyses, the sex of the piglet was ignored for simplicity as the sex ratio (on average, 51.0 % of males among piglets born alive) was found to be unaffected by year-season, dam breed, dam parity and gestation length (results not shown).

The difference among dam breeds in gestation length for natural farrowings amounted to slightly more than 1 day, i.e. two-thirds of the standard deviation of the trait (*table III*). Large White sows displayed a shorter gestation length than Piétrain sows ($P < 0.001$): 114.2 days for LW purebred litters and 114.1 days for P × LW litters vs. 115.3 days for P purebred litters. In addition, the within-dam breed relationship between gestation length and litter size at birth did not deviate from linearity and was highly significant ($P < 0.001$), with shorter gestation lengths associated with higher numbers of piglets born. The linear regression of gestation length on litter size at birth was found to be –0.14 ± 0.02 days and was of the same magnitude for both dam breeds.

The analysis of records collected in the 2-year period in which natural and induced farrowings occurred contemporaneously (*table IV*) showed a highly significant dam breed by farrowing type interaction for gestation length ($P < 0.001$). Due to the breed difference in 'natural' gestation length, induction of farrowing caused a reduction

Table II. Overall incidence of splayleg (%) according to sex and genetic type of piglets.

Genetic type[1]		Parity of dam	No. of litters	Sex[2]		
Sire	Dam			F	M	F + M
LW	LW	1	844	2.0	2.7	2.4 ± 0.3[3]
P	LW	2	676	2.2	4.8	3.5 ± 0.4
P	P	1, 2	550	6.1	9.8	8.0 ± 0.4
All genetic types		–	2 070	3.4 ± 0.3	5.8 ± 0.3	4.6 ± 0.2

[1] LW: Large White; P: Piétrain; [2] F: female; M: male; [3] mean percentage ± standard error.

Table III. Incidence of splayleg and average gestation length and litter size at birth according to genetic type (877 natural farrowings).

Genetic type[1]		Parity of dam	No. of litters	Splayleg (%)	Gestation length (days)	Total born per litter
Sire	Dam					
LW	LW	1	302	1.8 ± 0.4^{a2}	114.2 ± 0.1^{a}	9.7 ± 0.2^{b}
P	LW	2	315	3.7 ± 0.4^{b}	114.1 ± 0.1^{a}	10.2 ± 0.2^{b}
P	P	1, 2	260	4.9 ± 0.4^{c}	115.3 ± 0.1^{b}	8.9 ± 0.2^{a}

[1] LW: Large White; P: Piétrain; [2] means (± standard error) bearing different superscript letters differ at the $P < 0.05$ level.

Table IV. Effect of induction of farrowing on incidence of splayleg, gestation length, stillbirth and preweaning survival for each dam breed (253 natural and 209 artificially induced contemporary farrowings).

Dam breed[1]	No. of litters	Difference (induced – natural) ± SE			
		Splayleg (%)	Gestation length (days)	Stillbirth (%)	Preweaning survival (%)
LW	292	–1.1 ± 1.2 ns	–0.8 ± 0.2***	–0.2 ± 1.3 ns	6.6 ± 2.8*
P	170	1.8 ± 1.6 ns	–2.6 ± 0.3***	–3.1 ± 1.8 ns	–4.4 ± 3.5 ns
Significance of dam breed by farrowing type interaction[2]		ns	***	ns	*

[1] LW: Large White; P: Piétrain; [2] ns : $P > 0.05$; *: $P < 0.05$; *** : $P < 0.001$.

of 2.6 days in gestation length of Piétrain sows, whereas the reduction was only of 0.8 days for Large White sows. Artificially induced farrowings compared to natural farrowings resulted in a significant increase of 6.6 % ($P < 0.05$) in preweaning survival rate for litters from Large White dams, whereas it resulted in some decrease of the same trait in litters from Piétrain dams. This decrease is partly due to the slightly higher incidence of splayleg for induced farrowings of Piétrains sows. As for the augmentation of preweaning survival rate found for induced farrowings of Large White sows, it is probably associated with the better human care of piglets, which is made possible by the timing of almost all parturitions during the working hours of the day.

Table V reports the general pattern of statistical significance of main effects and interactions for splayleg incidence and preweaning survival rate in natural farrowings on the one hand and in artificially induced farrowings on the other hand. Effect of dam parity was confounded with the effect of genetic type of piglets for litters from Large White dams. That the dam breed by dam parity interaction was significant for splayleg incidence ($P < 0.01$) in artificially induced litters results from a higher splayleg incidence in second-parity crossbred litters compared to first-parity purebred litters from Large White dams, whereas there was no noticeable effect of dam parity for Piétrain dams which produced only purebred litters. However, this interaction was not significant in natural farrowings.

Table V. Results of analysis of variance (*F*-tests) for incidence of splayleg and preweaning survival rate in each farrowing type.[1]

Source of variation	Natural farrowing (877 litters)			Artificially induced farrowing (1 193 litters)		
	d.f.	Splayleg	Preweaning survival	d.f.	Splayleg	Preweaning survival
Year-season	10	ns	ns	15	**	**
Dam breed (B)	1	***	ns	1	***	***
Dam parity (P)	1	*	ns	1	*	ns
B × P	1	ns	ns	1	**	*
Gestation length (G)	7	***	***	4	***	**
B × G	5	***	ns	4	***	ns

[1] ns: $P > 0.05$; *: $P < 0.05$; **: $P < 0.01$; *** $P < 0.001$. d.f.: degrees of freedom.

The effects of dam breed, gestation length and dam breed by gestation length interaction were highly significant ($P < 0.001$) for incidence of splayleg whatever the farrowing type. This is illustrated graphically in *figure 1*, which shows the fitted curves relating incidence of splayleg to gestation length for the four dam breed by farrowing type combinations. In both natural and artificially induced farrowings, incidence of splayleg sharply rose as gestation length decreased in litters from Piétrain dams. The influence of gestation length was much smaller in litters from Large White dams, especially when parturition was artificially induced.

4. DISCUSSION

Though the overall prevalence of the splayleg syndrome in newborn piglets appears to be fairly low (around 0.6 %) in the present-day pig industry [5, 22, 29, 30], its actual economic impact is not negligible when con-

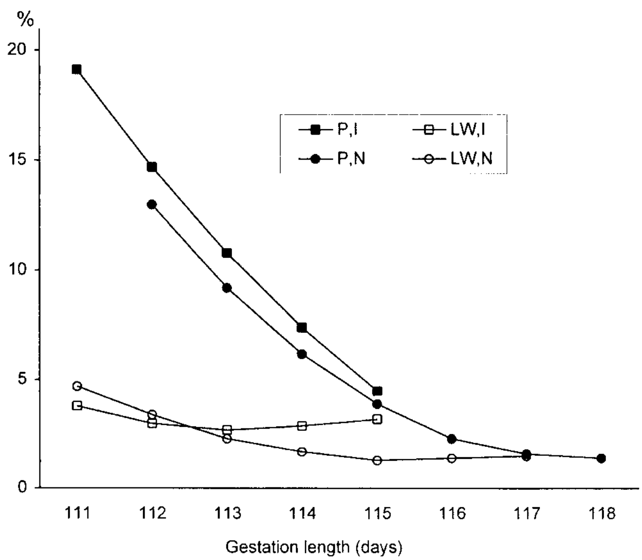

Figure 1. Fitted curves relating the percentage of splaylegged newborn piglets to gestation length for natural (N) or artificially induced (I) farrowings of Large White (LW) and Piétrain (P) dams.

sidering the severely impaired motor and postural ability and consequently the high mortality rate of affected piglets [17, 20, 26, 36].

The splayleg condition results from a developmental disorder of skeletal muscles. The immaturity of muscle fibres is probably not caused by altered motor innervation. A reduction of the myofibrillar equipment of muscle cells (termed as myofibrillar hypoplasia) and an increased deposit of glycogen granules in large extramyofibrillar spaces (possibly due to a low rate of mobilization of glycogen store) are among the most thoroughly described features of abnormal muscle ultrastructure in splay-legged individuals [1, 10, 12, 16, 18, 37].

The current study confirms that incidence of splayleg is markedly higher in male than in female piglets [24, 26, 28, 32, 34, 36]. It should, however, be noted that some authors reported no effect at all or only a marginal effect of sex on incidence of splayleg [15, 20, 31]. The hypothesis of a sex-linked monogenic inheritance of splayleg was put forward in the early 1970s by Lax [19]. In contrast, postulating an underlying continuous variable (the liability) and one threshold value above which splayleg occurs, Sellier and Ollivier [26] found that the genetic basis of splayleg is of an additive polygenic nature, with an heritability close to 0.50 for the liability. The mode of inheritance was similar in both sexes as like-sexed relatives did not resemble each other more than unlike-sexed ones. These authors concluded that splayleg, though sex-influenced, is not to be considered as a sex-linked genetic defect, and it appears to be governed polygenically with environmental factors also playing a role in its development. Recently, the mode of inheritance of splayleg was investigated using complex segregation analysis methods [29, 30]. Stigler et al. [29] concluded that a two-locus model enabled to fit their data in a satisfactory manner, in spite of fairly low estimated penetrance values. Thaller et al. [30] showed that the best-fitting model consisted of a mixed inheritance involving one major gene acting together with polygenic effects, with the dominance status at the major locus possibly being breed-dependent.

The liability to splayleg is considerably greater in the heavily muscled and halothane-sensitive Piétrain than in the Large White breed, as previously shown by Sellier and Ollivier [26]. There could exist a link between the stress susceptibility displayed by most Piétrain sows and the more frequent occurrence of splayleg in their offspring. It was indeed suggested earlier [18] that increased glucocorticoid hormone levels in stress-susceptible pregnant sows could influence the pathological development of fetal muscles. Regarding breed differences in incidence of splayleg, the most often mentioned result in the literature is the greater liability of the Landrace compared to the Large White or the Duroc [34, 36]. To our knowledge, only one direct comparison between the Piétrain and the Landrace is available in this respect [30], and the incidence of splayleg appears to be similar in the progeny of Piétrain and German Landrace boars.

A noticeable seasonal variation in incidence of splayleg was observed in the two experimental herds studied by van der Heyde et al. [32]. Some effects of year-season were found in the present study, but there was no evidence for a consistent influence of season across years both for natural and artificially induced farrowings.

Earlier studies showed that splayleg occurs more frequently in litters of larger size, with the size of affected litters exceeding that of unaffected litters by more than one piglet at birth [17, 20, 24, 26, 32]. It is worthy to note that this positive relationship of incidence of splayleg with litter size exists within breed but not between breeds, as indicated by the respective levels of Large White and Piétrain for these two traits. However, our study indicates that there exists a negative within-breed correlation of –0.22

between litter size at birth and gestation length as far as natural farrowings are concerned. This negative correlation was previously reported in several pig breeds [3, 13, 21, 33]. It may therefore be hypothesized that the effect of litter size on incidence of splayleg partly operates through gestation length. Artificial induction of parturition makes it possible to make gestation length and litter size unrelated to each other. In that situation, the average difference in litter size between affected and non-affected litters was of smaller magnitude than that mentioned earlier. Gestation length per se is likely to be a more important environmental source of variation in incidence of splayleg than litter size at birth.

The large dam breed difference in gestation length for natural farrowings is in line with the general association of gestation length with litter size. The average value found here for the gestation length of Large White sows falls within the range of values (114.1–114.8 days) reported in the literature for this breed. That Piétrain sows display a comparatively longer gestation was also reported by Vanstalle et al. [33], with average values of 116.5 and 115.7 days in Piétrain and Belgian Landrace sows, respectively.

Very few studies have specifically dealt with the effect of induction of parturition on incidence of splayleg. No noticeable effect was found by Walker [35] for treated and control sows whose gestation length was 114.0 and 116.3 days, respectively. However, Bölcskei et al. [6] reported that the number of splaylegged piglets was significantly larger for farrowings induced by a treatment on day 112 of pregnancy compared to farrowings induced by a treatment on days 113 or 114 of pregnancy and to control (natural) farrowings. In the present study, the way in which the induction of parturition affected the incidence of splayleg was dependent on the breed of dam and the day of cloprostrenol treatment. Piétrain sows compared to Large White sows revealed to be much more sensitive to the effect of the day of pregnancy on which the induction treatment took place. The closer association between gestation length and incidence of splayleg shown by Piétrain sows was also found in natural farrowings.

5. CONCLUSION

This investigation brings about a number of confirmations pertaining to the large effects of sex of piglet, breed of dam and gestation length on incidence of splayleg. The extent of the adverse influence of shorter gestation lengths was, however, breed-dependent both for natural and artificially induced farrowings, and was markedly greater in Piétrain than in Large White dams. On practical grounds, the significant breed differences in gestation length deserve being taken into account when defining the most suitable way of using artificial induction of parturition.

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