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Blood Serum Characteristics of Newborn Pigs: Comparison of Unaffected Pigs with Pigs Belonging to Five Mortality Groups

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Svendsen, L. S., B. R. Weström, J. Svendsen, A.-Ch. Olsson and B. W. Karlsson: Blood serum characteristics of newborn pigs: Comparison of unaffected pigs with pigs belonging to five mortality groups. Acta vet. scand. 1991, 32, 287-299. – The blood serum levels of glucose, hemoglobin, insulin, cortisol, albumin, alpha-fetoprotein, alpha$_2$-macroglobulin f and s, alpha$_2$-antitrypsin inhibitor and alpha$_1$-protease inhibitor were determined at birth in 5 clinically and morphologically identified mortality groups of pigs. These were compared with the levels observed in unaffected, apparently normal newborn unsuckled pigs. The blood serum profile of the pigs in the stillborn intra partum, weak, splayleg and trauma groups, respectively, as well as that of clinically normal splayleg littermates, differed significantly from that of the unaffected pigs. This was especially true for the levels of hemoglobin and the two macroglobulins. The importance of placental insufficiency causing chronic episodes of hypoxia which ultimately lead to a disturbance in organ development in the etiology of the mortality groups is discussed.

perinatal mortality; glucose; hemoglobin; insulin; cortisol; albumin; alpha-fetoprotein; alpha$_2$-macroglobulin; alpha$_2$-antitrypsin inhibitor; alpha$_1$-protease inhibitor; stillborn; weak; splayleg; trauma; hypoxia.

Introduction

The newborn pig is the survivor of an intrauterine battle in which fetal losses may approach 40% (*Pomeroy* 1960, *Wrathall* 1971). It has long been recognized that the pig at birth is neurologically relatively mature, but is physiologically immature (*Hakkarainen* 1975), especially with respect to systems involding gluco- and lipogenesis (see review by *Svendsen* 1982). During the first few days of life, the pig is still considerably at risk, since it is dependent on an external source of nutrition for development and growth, the colostrum and milk of the sow (*Bengtsson* 1971, *Hakkarainen* 1975). This is also reflected in the fact that the death losses of the pig from birth to the third day of life, the perinatal mortality, is so high - from 10-15% or even higher, in some herds. What is surprising, however, is that these figures tend to remain constant (*Bille et al.* 1974), in spite of the technological changes or development within pig production over the past few decades. Many of the death losses appear to be due to problems of adaptation and development, and thus to a great extent, are due to inherent factors or non-infectious causes. While infections may occasionally play a significant role in an individual herd, in general, these do not play a major role in

the incidence of perinatal deaths (*Svendsen et al.* 1986b).

The present investigation is part of a project studying perinatal mortality in pigs from the managemental, behavioural, pathological, physiological and biochemical aspects. The aim was to characterize blood serum constituents of apparently normal, unaffected pigs and of pigs belonging to several perinatal morbidity/mortality groups in order to help better understand the occurrence of such animals, and to obtain a good »indicator« of development at birth. Observations for some of the mortality groups have previously been reported (*Svendsen et al.* 1986c), but for a smaller material coming from the same herd. This report extends and expands previous observations.

Materials and methods

Animals

Newborn, unsuckled pigs were obtained from one pure breed Swedish Landrace sow herd in production. Complete management, health, and production data for the sows and for their piglets were maintained. For this investigation, sow number and age (number of litters), length of gestation (in days), length of parturition and number of pigs born were recorded and for each pig born, the birth order, time of birth, clinical condition at birth, birth weight (g), and the time of blood sampling (minutes after birth) were also noted (*Olsson & Svendsen* 1989).

As previously described (*Svendsen* 1982, *Björklund et al.* 1987a,b), newborn pigs were assigned to the *unaffected, stillborn* intra partum (i.p.), *weak, splayleg, splayweak* and *trauma* (morbidity/mortality) groups, with the following additions. The unaffected, stillborn i.p. and weak groups, respectively, were divided into two according to weight: pigs weighing at least 1.0 kg or more (normal weight) and pigs weighing less than 1.0 kg (underweight). The group of normal weight, unaffected pigs was further subdivided into three groups: those born in litters where no perinatal mortality or morbidity was present; those which had one or more littermates classified as belonging to a perinatal mortality group but not splayleg or splayweak; and those also having littermates which were splayleg and/or splayweak. Assignment of the pigs to the groups was not completed until the end of the perinatal period.

Serum analyses

Blood samples were obtained from the newborn, unsuckled pigs by puncture of the anterior vena cava. The serum levels of the different serum proteins were determined by electroimmunoassay (*Laurell* 1966) using specific antisera as previously described in detail: albumin (ALB) and alpha-fetoprotein (AFP), as mg/ml (*Karlsson* 1970; alpha$_2$-macroglobulin f (AMF), alpha$_2$-macroglobulin s (AMS), alpha$_2$-antitrypsin (AAT), and alpha$_1$-protease inhibitor (APT) as per cent of adult swine serum values (% adult SS) (*Weström et al.* 1982). The within and between assay reproducibility of these immunoprecipitation assays were 10-20%.

Serum glucose was determined as nmol/l using the glucosoxidase-peroxidase reaction (Reflocheck^R-Glucose, Boehringer Mannheim GmbH, Mannheim, Germany). Serum hemoglobin was determined as g/l using the rapid method described by *Larsson et al.* (1984).

Serum immunoreactive insulin (insulin) was determined as mIU/l using radioimmunoassay (*Thorell & Larson* 1978). Serum immunoreactive cortisol (cortisol) was determined as nmol/l using radioimmunoassay (Amerlex Cortisol RIA kit, Amersham International, Amersham, UK). For details regard-

ing the tracers, RIA protocols, reproducibility and specificity see the above references.

Statistical analyses

The statistical analyses were performed as previously decribed (*Svendsen* 1982), using the BMDP-Biomedical Computer Programs (*Dixon & Brown* 1983). Interrelationships between the various factors were determined using simple correlation analysis. The data for the different groups were compared using covariance analysis, with birth weight, gestation length, and litter size as the independent variables. For some constituents, the age of the pig at testing (No. minutes after birth) was also used as an independent variable. This type of analysis resulted in the removal of the linear effects of these common factors, and thus, to some extent, to a standardization of the pigs in the different groups. While no estimate of error has been made, it should be noted that the same method of analysis has been used previously for the comparison of the groups (*Svendsen* 1982, *Björklund et al.* 1987 a,b).

Results

The description of the groups in this study with respect to birth weight, gestation length, litter size and age at blood sampling after birth is given in Table 1 as means and standard deviations. The number of pigs represents the total number tested. Since not all pigs in a group may have been tested for a specific serum characteristic, the number of pigs tested in each group is given in every subsequent table.

Birth serum characteristics

The levels of the serum constituents at birth for the normal weight and the underweight unaffected pigs are reported as means and ranges in Table 2a.

Similar data is given for the mortality groups in Table 2b. Although absolute figures may vary with the breed of pig, it was considered

Table 1. Description of the unaffected and the perinatal mortality groups. Means and standard deviations.

	Unaffected			Stillborn intra partum		Weak		Splay-leg	Splay-weak	Trauma
	≥1 kg		<1 kg	≥1 kg	<1 kg	≥1 kg	<1 kg			
	Perinatal morb./mort. in litter: None				with		+ splay			
No. pigs	98	316	94	33	50	11	25	15	35	7	26
Birth weight (kg)	1.7	1.6	1.5	0.8	1.5	0.7	1.5	0.6	1.6	1.1	1.5
s.d.±	0.3	0.3	0.3	0.1	0.3	0.2	0.2	0.2	0.3	0.3	0.3
Gestation length (d)	115.5	115.2	114.8	115.3	115.1	114.6	115.0	114.7	115.3	114.1	115.2
s.d. ±	1.0	1.2	1.4	0.8	1.4	1.2	1.5	2.0	1.8	1.8	1.1
Litter size	9.5	11.6	12.0	12.2	11.7	13.7	10.8	12.7	11.2	11.7	11.7
s.d. ±	2.9	2.5	2.6	2.6	2.9	1.4	3.2	2.2	2.5	2.8	2.8
Test age (min)	31	24	43	36	10	10	29	159	128	384	113
s.d. ±	97	25	55	39	7	4	31	238	205	336	205

Table 2a. Blood serum characteristics of newborn unsuckled pigs. Means (±) and ranges. Units for the serum characteristics are given in the Materials and Methods. Unaffected pigs.

	Unaffected			
	≥1 kg			<1 kg
	Perninatal morbidity/mortality in litter:			
	none	with	+splay	
Glucose, $\bar{x}$	4.0	4.2	4.2	4.9
range	2.0-8.9	2.3-9.1	1.8-19.4	2.3-15.2
n	86	292	63	25
Hemoglobin, $\bar{x}$	129	127	117	121
range	93-162	79-168	82-142	88-166
n	71	269	46	22
Insulin, $\bar{x}$	12.9	11.2	15.6	10.6
range	0-38	0-121	1-68	0-35
n	19	101	22	25
Cortisol, $\bar{x}$	827	709	669	864
range	436-1573	215-1540	282-1049	271-1634
n	16	71	18	25
ALB, $\bar{x}$	3.5	3.1	3.2	2.2
range	1.4-6.8	1.0-8.3	1.3-5.7	1.0-5.6
n	33	104	54	33
AFP, $\bar{x}$	0.75	0.83	0.87	0.77
range	0.52-1.20	0.47-2.35	0.49-1.64	0.54-1.56
n	29	104	54	29
AMF, $\bar{x}$	20.2	21.6	16.9	19.1
range	7.5-29.0	9.5-46.0	7.7-26.9	11.5-40.0
n	3	104	54	33
AMS, $\bar{x}$	13.4	12.2	9.2	8.4
range	3.2-37.0	2.0-50.0	3.0-19.2	1.8-19.6
n	33	104	54	33
AAT, $\bar{x}$	534	577	486	496
range	0-880	355-1050	265-835	300-1380
n	32	102	54	33
APT, $\bar{x}$	337	330	350	302
range	85-576	36-500	225-738	155-546
n	32	102	54	33

that the relationship between the groups will remain the same. This relationship was investigated using covariance analysis with the levels obtained for the normal weight unaffected pigs coming from litters without perinatal morbidity and mortality as the control. The results for the other unaffected groups and for the mortality groups are presented in Table 3, where the direction of difference from the levels of the normal weight unaffected group was indicated, together with the significance levels. If significant differ-

Table 2b. Pigs in the perinatal mortality groups.

	Stillborn intra partum		Weak		Splay-leg	Splay-weak	Trauma
	≥1 kg	<1 kg	≥1 kg	<1 kg			
Glucose, $\bar{X}$	15.8	7.7	7.5	5.8	6.2	7.8	4.2
range	2.6-24.9	1.8-24.9	2.9-14.5	1.7-11.0	3.5-11.9	3.4-12.1	2.1-8.0
n	23	6	25	9	10	2	14
Hemoglobin, $\bar{X}$	111	103	112	106	104	131	127
range	71-157	85-117	81-134	78-137	83-134	130-132	110-140
n	13	5	17	8	8	2	13
Insulin, $\bar{X}$	17.8	9.7	14.5	12.9	23.2	11.5	15.1
range	0-45	0-21	0-45	0-28	5-66	11-12	0-35
n	21	6	18	8	9	2	10
Cortisol, $\bar{X}$	340	411	835	978	609	1034	672
range	50-828	216-700	179-1987	218-2263	254-1038	888-1180	265-1060
n	20	6	18	19	9	2	11
ALB, $\bar{X}$	3.1	1.7	3.1	1.1	3.4	2.6	2.9
range	1.5-6.4	0.5-7.8	1.5-6.7	0.4-5.8	0.0-6.3	1.2-6.0	1.4-4.6
n	49	11	22	13	34	7	24
AFP, $\bar{X}$	0.75	0.77	0.82	1.0	0.79	1.09	0.74
range	0.32-1.68	0.47-1.42	0.37-1.70	0.56-1.43	0.46-1.47	0.80-1.40	0.45-1.34
n	36	11	22	7	34	4	15
AMF, $\bar{X}$	14.2	13.6	20.3	12.6	15.3	12.3	16.2
range	5.5-30.8	6.0-32.4	12.6-26.3	8.5-24.2	8.5-24.5	6.3-18.9	5.0-26.3
n	49	11	22	13	34	7	24
AMS, $\bar{X}$	9.7	6.4	10.8	2.8	8.4	6.4	9.3
range	3.0-27.9	1.3-39.8	3.0-23.0	0.0-5.5	3.8-14.2	4.0-10.8	3.0-14.4
n	49	11	22	13	34	7	24
AAT, $\bar{X}$	468	578	558	564	574	486	496
range	150-850	390-790	335-1135	365-990	320-1015	225-685	150-760
n	49	11	22	13	27	5	20
APT, $\bar{X}$	236	256	331	222	323	242	289
range	73-484	198-408	238-432	103-332	44-533	110-370	95-498
n	49	11	22	13	27	5	24

ences for a group could only be detected when the effect of sex was evaluated, it was also indicated in Table 3. Since no significant differences in the serum constituents were found for the splayweak group, possibly due to the small material, it was not included in this table.

Significant differences in the levels of the serum consitituents were observed for many of the groups in comparison to those of the unaffected control. Of the mortality groups, the serum profile of the normal weight stillborn i.p. group appeared to deviate the most from that of the unaffected pigs, although differences were noted for most groups.

The serum constituents which appeared to be the most affected, that is, having values which consistently deviated significantly from that of the control levels, were hemoglobin, AMF, AMS and APT. The presence of lower levels of this last protease inhibitor in some of the groups was not evident until the effect of sex was determined (Table 3). In the normal weight unaffected group, the 13 females had significantly ($p = < 0.05$) higher levels of albumin and of APT than the 9 ma-

Table 3. Comparison of the blood serum characteristics of the pigs in the different mortality groups with those of newborn, unsuckled, normal weight unaffected pigs coming from litters with no perinatal mortality or morbidity. Determined by covariance analysis and indicated by significance levels where *** = $p < 0.001$, ** = $p < 0.01$ and * = $p < 0.05$, and if greater (>) or less < than the unaffected group means. When no significant difference was observed with a group, but was seen for one sex within that group, this was shown where m = male, f = female and n = No. pigs in the group/No. male or female pigs. Mean values ($\bar{x}$) are shown for the unaffected control group.

	Uanffected				Stillborn intra partum		Weak		Splayleg	Trauma
	≥1 kg			<1 kg	≥1 kg	<1 kg	≥1 kg	<1 kg		
	Perinatal morb./mort.:									
	none	with	with splay							
Glucose, $\bar{x}$	4.0				>***	>***	>***		m>**	
n									10/7	
Hemoglobin, $\bar{x}$	129		f<**	>*	<***		<***		<**	
n			46/26							
Insulin, $\bar{x}$	12.9									
Cortisol, $\bar{x}$	827				<***	<***				
ALB, $\bar{x}$	3.5							<**	m<*	
n									34/10	
AFP, $\bar{x}$	0.75									
AMF, $\bar{x}$	20.2		<**		<***	<***		<**	<***	<**
AMS, $\bar{x}$	13.4		<**		<**	<**		<***	<***	<*
AAT, $\bar{x}$	534		<*	m>**	<***					
n				33/6						
APT, $\bar{x}$	337	m>**			<***		m<**	m<**		<*
n		102/40					22/10	13/6		

les. No significant differences in mean serum levels of insulin or alpha-fetoprotein were observed between the control group and the other groups.

Relationships between birth characteristics

The relationships between the basic birth data for the pigs, birth weight, gestation length, litter size and age at blood sampling and the serum characteristics, are shown in Table 4 as simple correlation coefficients for the normal weight unaffected pigs. The interrelationships between the birth serum factors were also evaluated using simple correlation analysis, and these are presented for the normal weight unaffected group in Table 5.

The smaller animals in the normal weight unaffected group tended to show higher glucose levels and, interestingly, lower hemoglobin levels (Table 4). This fitted well with the weak negative relationship observed between glucose and hemoglobin levels in these animals (Table 5). However, the correlation between glucose and hemoglobin was consi-

Table 4. The relationship between birth weight, gestation length, litter size and age (min after birth) at taking blood sample and the serum characteristics in unsuckled, normal weight unaffected pigs, without perinatal mortality and morbidity in the litter, given as simple correlation coefficients (r).

	n	Birth weight	Gestation length	Litter size	Age at testing
Glucose	71	-0.27	0.22	0.16	0.27
Hemoglobin	71	0.41	0.23	-0.20	0.23
Insulin	19	-0.13	0.14	-0.72	0.23
Cortisol	16	-0.63	-0.13	0.23	-0.39
Albumin	33	0.14	0.30	-0.29	0.39
AFP	29	0.03	0.25	-0.53	0.49
AMF	33	0.28	0.33	-0.21	-0.61
AMS	33	0.21	0.37	-0.52	-0.39
AAT	32	0.26	0.14	0.21	-0.44
APT	33	0.51	-0.07	0.26	-0.63

derably higher for some of the other groups (indicated as r/No. pigs in group) (i.e., splayleg littermates, -0.37/46; underweight unaffected, -0.33/22; normal weight stillborn i.p., -0.52/13; normal weight weak, -0,.46/17). A very weak negative relationship between birth weight and insulin levels was seen for the unaffected group, whereas stronger positive correlations were noted for the mortality groups (i.e., underweight weak, 0.53/8; splayleg, 0.42/9). A very strong negative correlation between birth weight and cortisol levels was observed both for the unaffected pigs (Table 4), and for all the mortality groups. In general, the heavier the animal, the higher the albumin levels at birth (Table 5). Although only a weak positive correlation between albumin and birth weight was found for the unaffected pigs, a stronger relationship was generally found for the mortality groups (i.e., splayleg, 0.35/34).

Similarly, only a weak positive correlation between gestation length and insulin levels was noted for the unaffected controls (Table 4), but the shorter the gestation length, the higher the insulin levels for the splayleg pigs (splayleg littermates, -0.30/22; splayleg, -0.10/9) an the underweight ones (unaffected, -0.40/25; stillborn i.p., -0.13/6; weak, -0.07/8). Pigs with longer gestation lengths had higher albumin levels (Table 5), a tendency also observed for most of the mortality groups.

Probably the most interesting observation was the strong negative relationships between litter size and insulin, AFP and AMS levels, respectively, although weaker negative correlations were observed with hemoglobin, albumin and AMF levels, respectively (Table 4). This was observed for most mortality groups, and with respect to litter size and albumin, for all groups.

For the relationships between the birth serum characteristics (Table 5), positive correlations were observed between glucose and insulin, and between glucose and cortisol levels. However a positive relationship between glucose and cortisol was not observed for either the normal weight or underweight stillborn i.p. pigs (-0.48/20 and -0.38/6, respectively).

Table 5. The relationship between the serum characteristics at birth in unsuckled, normal weight unaffected pigs, without perinatal mortality and morbidity in the litter, given as simple correlation coefficients (r).

	n	Glucose	Hemo-globin	Insu-lin	Corti-sol	ALB	AFP	AMF	AMS	AAT	APT
Glucose	71-16		-0.14	0.30	0.40	0.13	0.45	0.53	0.44	-0.06	0.16
Hemoglobin	19-16			-0.02	0.03	0.47	0.29	0.66	0.39	0.11	0.28
Insulin	18-16				-0.26	0.14	0.35	0.30	0.24	-0.44	-0.30
Cortisol	16					-0.16	0.26	0.02	0.26	0.01	0.04
ALB	33-29						0.48	0.24	0.51	-0.11	-0.26
AFP	29							0.19	0.73	-0.08	0.05
AMF	33								0.46	0.28	0.42
AMS	33									0.22	0.08
AAT	32										0.36

Although hemoglobin levels showed no correlation with insulin levels in unaffected animals (Table 5), this differed for the mortality groups. The higher the insulin levels in splayleg littermates (-0.64/17), splayleg (-0.27/8), normal weight stillborn i.p. (-0.71/12) and underweight weak (-0.32/8) pigs, the lower the hemoglobin. A positive correlation between hemoglobin and insulin was observed for the underweight stillborn i.p. (0.67/5), normal weight weak (0.17/13) and trauma (0.37/10) groups. The correlation between hemoglobin levels and cortisol in these groups noted were the reverse of that with insulin (0.15/17, 0.28/8, 0.66/11, 0.73/8, -0.27/5, none, and -0.24/11, respectively).

Generally, good positive correlations were found between hemoglobin levels and those of the other serum proteins tested (Table 5). The higher the hemoglobin levels, the higher the AMF and AMS levels in most of the other groups.

Not unexpectedly, it was observed that insulin and cortisol levels were negatively correlated in all groups, except for the splayleg pigs. Although generally the relationship between insulin and albumin levels was positive (Table 5) (i.e., splayleg littermates, 0.37/19), there was a tendency for higher AFP, AMF and AMS levels to be related to lower insulin levels in the mortality groups. For the normal weight unaffected pigs, albumin levels showed a good positive correlation with AFP levels (Table 5). However, for all the underweight groups, AFP levels were negatively correlated with albumin: underweight unaffected (-0.25/29), underweight stillborn i.p. (-0.23/11), and underweight weak (-0.58/7). This negative relationship was also seen for the splayleg littermates (-0.43/53) and splayleg (-0.35/32) groups.

Discussion

Previous studies of a material similar to that reported here and coming from the same herd (*Svendsen* 1982, *Björklund et al.* 1987b), have indicated that the mortality groups were not separate entities, but represented a spectrum of reactions to an underlying syndrome. From the results of those studies, it was concluded that a major factor in the etiology of perinatal mortality and morbidity in pigs was litter size; how it ultimately affected the pig depended on the genetic constitution of the animal. The larger the litter the greater the possibility of the occurrence of placental insufficiency, and thus the greater the risk of the fetus being exposed to repeated incidents of hypoxia. *Meberg*

(1980) noted that in rats, a chronic hypoxic condition in utero due to placental dysfunction leads to lower body weight, an increase in the liver weight: body weight ratio and an increase in erythropoiesis. He speculated that an increased demand for erythropoiesis during long-term hypoxia may shunt common stem cells in the fetal liver in the direction of erythropoiesis at the expense of thrombopoiesis. Thus episodic fetal hypoxia will ultimately have an effect on liver development and growth.

As seen in the present study, the levels of many proteins of liver origin (*Stone* 1981, *Ohlsson et al.* 1986) in the different groups were significantly different, usually lower, than those in the control group, indicating that there had been a disturbance in fetal liver development in these animals. This was found especially for the levels for the alpha$_2$-macroglobulins and hemoglobin (Table 3), with the closeness of the relationship between hemoglobin and the macroglobulins being reflected by the strong positive correlations in their levels observed for most groups.

It has been suggested that the alpha$_2$-macroglobulins, by virtue of their broad specificity, may contribute to the defense of the organism by inactivating proteinases elaborated by invading pathogens and parasites (*Travis & Salvesen* 1983). Thus, the presence of lower alpha$_2$-macroglobulin levels in pigs surviving the perinatal period, i.e., splayleg pigs and pigs surviving traumatic injuries (*Svendsen et al.* 1986a, 1988), may contribute to an increased susceptibility to infection.

In addition, *Huang et al.* (1988) observed that human alpha$_2$-macroglobulin forms a complex with the platelet-derived transforming growth factor-β (TGF-β), which is involved in the stimulation of different cell types. It had been postulated (*Hill et al.* 1986) that TGF-β may have a physiological role in tissue growth and maturation during early mammalian development. Observations in the fetal pig (*Richardson et al.* 1989) indicated that TGF-β plays a role in the development of the blood vessels and capillary systems, and may also control lipid accumulation in subcutaneous adipose tissue development. This last function would be of especial importance in the postnatal survival of the pig. The intimate involvement of the human equivalent of porcine AMS with TGF-β indicates that this protein, and possibly other similar proteins, may have physiologically important roles to play in development.

Several of the mortality groups showed significantly lower levels of hemoglobin. The presence of anemia in fetal pigs will increase the risk of asphyxiation at birth (*Fagenholz et al.* 1979). Hyperglycemia is a feature of asphyxiation in the pig (*Randall* 1979) and in the present investigation, the stillborn i.p. pigs had high glucose levels and low hemoglobin levels (Tables 2b, 3). *Randall* (1972) suggested that some fetuses within a litter may be more susceptible to asphyxia than others, and the results of the present study indicated that this susceptibility may involve the presence of anemia.

In addition, the high glucose and low hemoglobin levels observed for normal weight weak pigs and splayleg pigs indicated that anemia may be a major contributing factor in the occurrence of these animals, possibly playing an important role in the full expression of the splayleg syndrome. While the results of this investigation showed no other significant differences between the normal weight weak group and that of the unaffected controls, histological observations (*Björklund et al.* 1987b) indicated that many weak pigs have also had a somewhat disturbed development. Thus this group probably contained 2 types, the normal animal that was caught in a blocked position and became

asphyxiated, and the pig affected to some extent by intrauterine problems so that it is sensitive to the extra stress of birth. With respect to the splayleg pigs, it was observed that only the males were anemic, an observation of interest since the proportion of males to females with clinical splayleg is about 70:30 (*Svendsen et al.* 1982). In this study, the clinically normal littermates had a blood serum profile similar to that of the clinically affected pigs. Therefore, the importance of factors such as placental insufficiency, sex and the presence of low hemoglobin levels in the development of the clinical symptoms of splayleg cannot be excluded. – Examination of the ranges for hemoglobin and glucose (Table 2b) for the unaffected underweight pigs indicated that some members of this group were also susceptible to and affected by birth asphyxia. The effect of asphyxia on the survival of these small animals cannot be evaluated, but its presence certainly would constitute an additional handicap.

Repeated episodes of hypoxia during gestation due to placental insufficiency will stress an animal and lead to problems such as the premature release of corticosteroids, which will adversely affect development. Normally, in the pig, fetal cortisol levels increase slightly after 100 days gestation, with a sharp increase observed at birth (*Dvorak* 1972, *Herbein et al.* 1977, *Brenner et al.* 1981). Adrenal hypertrophy (*Svendsen* 1982), lack of lipids in the adrenal cortex (*Björklund et al.* 1987b) and abnormal levels of cortisol (Tables 2b, 3) were not uncommon findings for many of the pigs in the mortality groups, and disturbances in adrenal function would impair the ability of the pig to survive birth and the perinatal period. Adrenal hypertrophy in pigs is associated with larger litter sizes (*Svendsen* 1982); the present study showed that for the unaffected group, and very often for the mortality groups, a larger litter size was associated not only with lower AMF, AMS and hemoglobin levels, respectively, but also with lower insulin and albumin levels, all of which are of vital importance for survival.

Insulin in unaffected pigs at birth is positively correlated with a greater capacity for macromolecular transmission, a capacity which appears to decrease with increasing maturation (*Svendsen et al.* 1990). Although no significant differences in birth insulin levels were found between the normal weight unaffected group and the other groups, the relationship between insulin levels and some of the other parameters appeared to be of some importance. The levels of this hormone were lower in heavier pigs and in pigs with a longer gestation length, confirming its association with the immature animal. However, the major finding was the correlation between low insulin levels at birth with larger litters; this may provide some of the answer to the occurrence of small pigs in such litters, with respect to the possible indirect effect of insulin on fetal growth. A positive correlation between insulin and albumin levels was also found in the present study, and there is some indication (*Lloyd et al.* 1987) that insulin regulates the synthesis of albumin at the level of gene transcription.

Conclusion

Since more underweight pigs occur in larger litters, and there was a negative correlation between the levels of many of the serum characteristics studied and litter size, it is likely that placental insufficiency plays a major role in the etiology of perinatal mortality and morbidity. There probably is a distinct chain of events, starting with placental insufficiency causing repeated episodes of hypoxia which may affect brain development. This in turn may lead to hormonal changes that ultimately disturb the development of the va-

rious other organs, espically the liver. Thus reducing the incidence of perinatal morbidity and mortality depends upon avoiding the development of such conditions. This may be accomplished by breeding for a sow that has sufficient uterine capacity for larger litters, i.e., sows that have large litters without the presence of perinatal morbidity and mortality.

While much remains to be elucidated, it is evident from the results of the present study that the development and subsequent survival of the newborn pig can be evaluated by determining the levels of hemoglobin, and of the two macroglobulins AMS and AMF in the blood serum at birth. While laboratory facilities are required for investigating macroglobulin levels, the determination of hemoglobin can (and has) been done in situ.

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Sammenfatning

Blod serum parametre hos nyfødte grise: En sammenligning mellem normale grise og grise fra 5 forskellige mortalitetsgrupper.

Blodserum koncentrationen af glukose, hæmoglobin, insulin, cortisol, albumin, alpha-fetoprotein, $alpha_2$-makroglobulin f og s, $alpha_2$-antitrypsin inhibitor og $alpha_1$-protease inhibitor blev bestemt ved fødslen i 5 kliniskt og morfologiskt forskellige mortalitetsgrupper, og sammenlignet med resultaterne fra nyfødte, tilsyneladende normale, udiede grise fra samme besætning. Blodserum billedet af grise som døde under fødslen, og af svagfødte grise, svømmere, og grise som blev trampet af soen, og af søskende til svømmere, var signifikant forskelligt fra normalgruppen, især med hensyn til koncentrationen af hæmoglobin og de to makroglobuliner. Resultaterne tyder på at mange af de grise som er syge/svage ved fødslen og/eller som dør under perinatal-perioden gentagne gange har været udsat for iltmangel under

fosterperioden. Dette kan bl.a. resultere i nedsat-/dårligt udviklet organfunktion. Nogle af de mulige årsager til iltmangel og nedsat næringstilførsel under fosterperioden diskuteres. Hæmoglobinkoncentration og indeholdet af alpha$_2$-makroglobulin f og s i blodserum er gode markører for nyfødte grises vitalitet.

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