Chapter

Tools and Protocols for Managing Hyperprolific Sows at Parturition: Optimizing Piglet Survival and Sows' Reproductive Health

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Abstract

Genetic selection for higher prolificacy is one of the major causes for a decrease in piglet survival and reproductive health of the sow. Large litters increase farrowing duration and decrease piglet birth weight and therefore have an impact on piglet vitality, colostrum uptake, and piglet survival. Large litters also increase the incidence of postpartum dysgalactia syndrome (PDS) and the probability of the sow to be removed from the herd because of reproductive failure. Therefore, hyperprolificacy challenges the performance of the sow in terms of parturition, colostrum production, neonatal survival, and fertility. In this review, we discuss the tools and protocols for management of parturition, colostrum, and sows' reproductive health. We provide checklists for the prevention of birth complications and PDS as well as for improvement of mammary gland development and colostrum production.

Keywords: sow, large litter, parturition, postpartum dysgalactia syndrome, piglet survival, colostrum, risk factors, management

1. Introduction

1.1 Parturition and birth complications

About 10 years ago, a duration of 300 min was the upper limit for a physiological parturition [1]. Since then, litter size and farrowing duration increased steadily [1]. Nowadays, sows are hyperprolific (average litter size > 16) with an average farrowing duration of longer than 300 min [1–7]. This means that more than half of all parturitions are longer than physiologically. This rapid increase is concerning and leads to a high incidence of dystocia with subsequent negative consequences on piglet survival and sows' fertility and longevity [1–7]. An older survey showed that dystocia was mostly of maternal origin [8], whereas a newer survey identified that dystocia is nowadays almost exclusively due to maternal causes; with uterine inertia being the most common cause [9]. Primary uterine inertia, which is the reduction or complete absence of contractility of the myometrium already at the beginning of parturition, is due to hormonal abnormalities such as increased progesterone, and/or deficiencies of oxytocin and prostaglandin secretion and/or the presence of their receptors. Stress, e.g., caused by the inability of sows to express normal nest-building behavior, is an important cause of primary uterine inertia [10]. Other causes are nutritional factors, e.g., diets low in fiber and high in energy leading to constipation and obesity [11]. Secondary uterine inertia is more common than primary inertia, usually occurring because of a prolonged farrowing particularly associated with a large litter size [12]. Idiopathic dystocia may occur because of the use of prostaglandin F2α and oxytocin to induce or control parturition [12].

Thus, in order to prevent birth complications, the needs of the sow must be fulfilled, stress must be avoided, and nutrition must be optimized. If not, hormonal imbalance will result into weak uterine contraction and subsequently dystocia. Therefore, active birth management starts before birth in order to prevent this and continues during birth when proper response to hormonal imbalance is needed.

1.2 Colostrum and piglet survival

Sufficient mammary gland development is important for optimal colostrum production and therefore prevention of piglet mortality [13]. Pre-weaning piglet mortality rate was 7.1% (reference value: <11%), when piglets ingested more than 200 g of colostrum, and increased to 43.4% when intake was less than 200 g [14]. Thus, piglets need at least 200 g of good quality (>50 mg IgG/ml) colostrum. Unfortunately, colostrum yield is highly variable, averaging 3.5 kg and ranging between 1.5 and 6.0 kg [15, 16]. This means that some sows will not produce enough colostrum for their piglets. Further, even though the average yield might be enough for a litter of average size (about 17–18 piglets), it can be difficult for many sows to adequately nurse more than 10–11 piglets without human assistance (such as assisted suckling, cross fostering, movement to a nurse sow, split or suckling assistance) [17]. Thus, factors affecting mammary gland development and colostrum production need to be identified and optimized [13]. One of these factors is the hormonal status of the sow, which can be because of stress, suboptimal feeding, and husbandry during the week(s) before parturition.

Besides the production of a sufficient amount of good quality colostrum, there are further challenges. One of them is the length of the colostral phase. Colostrum is produced only during the first day after the start of parturition. Already after the first 6 h, the IgG content in colostrum is halved [18]. Since large litters can easily extend farrowing beyond 6 h [1], many piglet are born too late in order to get an appropriate amount of good quality colostrum. Therefore, the goal at each parturition is not only to optimize colostrum production by the sow but also the colostrum uptake by neonate piglets. Neonate piglets must acquire a sufficient amount of immunoglobulins from ingested colostrum for energy and passive immune protection [19]. The concentration of immunoglobulins in the plasma of piglets shortly after birth correlates positively with their survival rate [20]. Thus, it is necessary to assess colostrum quality and colostrum intake by piglets throughout parturition in order to reduce piglet pre-weaning mortality. This is especially important if mammary gland development is low and/or parturition is prolonged.

1.3 Postpartum dysgalactia syndrome and sows' fertility

PDS is the most important puerperal disease and is characterized by insufficient colostrum and milk production by the sow during the first days of lactation [21]. As consequence, colostrum and milk intake by piglets is reduced, and therefore their mortality increased [21]. Further, PDS negatively affects subsequent reproductive health of the sow [4]. Unspecific symptoms for PDS include fever (>40°C), loss of appetite, and lethargy [21]. Specific symptoms are dysgalactia and vulvar discharge syndrome [21]. Causes of the vulvar discharge syndrome are vaginitis, endometritis, and cystitis [22].

An increasing incidence for PDS of up to 34% was recently reported [23], which is connected with the increase in litter size and farrowing duration [3]. In one study, the percentage of sows with fever during the first 24 h postpartum increased from 40 to 100%, when the farrowing duration increased from less than 2 to more than 4 h [24]. Furthermore, until the third day postpartum, the percentage of sows with reduced appetite was higher in sows with a farrowing duration of more than 4 h than in sows with less than 4 h [24]. In another study, 85.9% of sows with puerperal disease had farrowing durations of more than 6 h, whereas 78.8% of healthy sows completed parturition in less than 3 h [25].

Both prolonged farrowing and PDS share mutual risk factors [11, 21]. Further, both are connected with a decrease in subsequent fertility [4, 5, 26]. Thus, prevention of birth complications and proper birth management will also prevent postpartum disease and therefore optimize subsequent reproductive performance.

2. Tools and protocols before parturition

Proper management of hyperprolific sows in order to optimize piglet survival and sow's reproductive health starts before parturition. The aim is to improve mammary gland development and colostrum production as well as to prevent birth complications and puerperal diseases. In order to do so, optimizing environment, management, and nutrition is highly important. **Table 1** provides a checklist for preventive measures.

Factor	Recommendation	Reference
Nutrition		
Constipation score	≥ 2	[11, 21, 41, 83]
Body condition	16 – 20 mm	[11, 21, 38, 57]
Feed intake	Restricted; 18-24 MJ NEa/kg ka	[44-49]
Feeding frequency	≥ 4x/day	[51]
Fiber content in the feed	≥ 7%	[43, 50]
Water intake	≥ 25L/day	[43]
Management		
Ambient temperature	18 – 22 °C	[21, 37, 38]
Drinkers – water flow rate	4L/min	[43]
Hygiene – farrowing unit	Wash, dry& disinfect	[21, 34, 35, 36]
Hygiene – sow	Wash before entering unit	[21, 34, 35, 36]
Moving sows from pregnancy to farrowing unit	5 – 7 days before expected farrowing	[21, 38, 49]
Space allowance	Crates with ≥ 67 cm width; open crate; no crate	[10, 27, 28, 32]
Nestbuilding material	2 kg straw with daily refilling	[10, 27, 28, 32]
Prepartum assessment mammary gland	Number of functional teats and the degree of edema	[52-55]

Table 1.
Checklist for prevention of birth complications and puerperal diseases as well as for improving mammary gland development and colostrum production.

2.1 Environment and stress

Modern housing and production systems have promoted the confinement of sows in crates during farrowing. In crates, the sow's movement is severely restricted, and bedding and rooting material is often limited. Consequently, nest-building behavior is reduced or does not occur at all. The lack of space and absence of nest-building materials and behavior are important stressors in sows [27]. This promotes the release of opioids and results into decreased oxytocin secretion and reduced uterine contractility [10, 28]. Thus, the lack of space and bedding material can prolong parturition due to uterine inertia. Considering that a large litter itself can prolong parturition [1, 12], hyperprolific sows need access to space and rooting material in order to prevent birth complications. Allowing the sow to move freely before and during farrowing reduces the duration of farrowing by an average of 100 min, thereby reducing the risk of stillborn piglets and birth of piglets with low vitality [12].

Besides an increase in oxytocin secretion, proper nest-building behavior increases prolactin [29], which is essential for colostrum production. The prepartum decrease in progesterone leads to an increase in prolactin [30]. Delays in progesterone decrease and in prolactin increase relative to the onset of parturition were associated with a strongly reduced yield of colostrum [31]. Thus, as with farrowing duration and prevention of birth complications, studies have found a positive effect of provision of space and nest-building material on oxytocin and prolactin release and therefore colostrum production and maternal nursing behavior [32].

2.2 Management and hygiene

Proper management, especially hygiene, is highly important for the prevention of PDS and therefore piglet mortality and decreased fertility in sows [21]. The current hypothesis is that interactions between endotoxins produced by Gram-negative bacteria in the gut, mammary gland, and/or urogenital tract and alterations in the immune and endocrine functions play a central role in the development of PDS [21]. This is supported by a study where periparturient sows were challenged with lipopolysaccharide (LPS) endotoxin of *E. coli*, in which sows generated symptoms similar to PDS [33]. *E. coli* originates from the environment or can already be present in the urogenital tract of prepartum sows or enter during or after parturition. Predominantly, *E. coli* followed by *Staphylococcus* spp. and *Streptococcus* spp. are isolated from the urogenital tract in case of cystitis, endometritis, and mastitis [34, 35]. Considering that these are unspecific bacteria originating from feces and environment, it is important to keep hygiene before and during parturition at a high level [36]. Risk factors for PDS are the use of unslatted floor, no washing of sows and no use of disinfectants in the farrowing rooms [36].

Besides hygiene, alterations in the immune and endocrine functions play a central role in the development of PDS [21]. Considering that parturition itself decreases immunity and causes significant inflammatory changes [23], all other factors affecting immunity and endocrinology need to be kept at a minimum level. The most important factor is stress, as described above. Stress needs to be reduced as much as possible. Stress due to restricted space in farrowing crates and lack of nest-building material is discussed above [21]. Other stressors are high ambient temperature and abrupt change from group housing during gestation to restraint in crates a few days before farrowing [37, 38].

2.3 Nutrition and body condition

Nutrition and body condition are important to prepare the sow for farrowing and the production of colostrum and milk. The sow should have an optimal body condition around parturition. Obesity needs to be avoided [11]. The fatter the sow, the longer the duration of parturition. It is possible that the fat deposition stores lipid-soluble steroids such as progesterone. In this case, the prepartum decline in progesterone may be delayed which in turn affects oxytocin receptor activation [10, 12]. Low concentration of oxytocin receptors will result in weak uterine contractions and colostrum let-down. Higher backfat and progesterone lead also to lower colostrum quality and production [39, 40]. If possible, backfat should be between 16 and 20 mm [11].

Besides body condition, there is a negative correlation between constipation and farrowing duration [11]. The more constipated the sow, the longer the duration of parturition. One reason may be that constipation can cause a physical obstruction to the passage of the piglets [12]. Another reason may be that constipation may result in higher concentrations of LPS. LPS can be absorbed from the gut and affect normal endocrine changes associated with farrowing [41]. A third explanation may be that the discomfort and pain associated with constipation affect hormonal changes associated with parturition [12]. Studies have found that pain releases opioids, which inhibit oxytocin secretion during parturition [28, 42]. Therefore, pain due to prolonged constipation, or any other source of pain, can reduce myometrial contractions and therefore cause birth complications. Constipation can be evaluated using a constipation index [43]. Constipation index should be two or higher, i.e., feces should be present, pellet-shaped, and not dry [11].

In order to prevent constipation and obesity, ad libitum feeding in the last third, especially in the last week, of gestation should be avoided. Restricted feeding supports the birth process, mammary gland development, and colostrum production [44]. There were positive associations between colostrum yield and plasma concentrations of urea, creatinine, and free fatty acids [45]. Further, there was a positive association between backfat loss in the last third of gestation and colostrum yield [46]. These results show that feed restriction with protein and fat mobilization for metabolism has positive effects on colostrum production [30]. Nevertheless, this can probably only be recommended for sows that have reached a good body condition (>18 mm) at the end of gestation. Unfortunately, sows usually receive high-energy concentrated diet low in fiber during late gestation [47]. Such diets can promote obesity and constipation, leading to poor mammary gland development [30], low colostrum quality [48], birth complication [11], and PDS [21, 49]. Late pregnancy diets should contain at least up to 7–10% fiber [43]. A good fiber source can also be provided by offering different types of roughage, e.g., straw or hay, or adding any other feedstuffs with high levels of fiber such as sugar beet pulp [50].

Besides amount and composition of feed, the feeding intervals are important. A short time-lapse between the last meal prior to the onset of the expulsion stage and the onset considerably shortens the duration of farrowing [51]. Farrowing duration, odds for farrowing assistance, and odds for stillbirth were low, intermediate, and high when the time between the last meal and onset of parturition was less than 3, 3–6, and more than 6 h, respectively [51].

2.4 Prepartum assessment of mammary gland

In addition to improving mammary gland development by means of management, environment, and nutrition, the mammary gland needs to be evaluated before each parturition. It is important to assess the number and morphology of functional teats and the degree of edema. The number of functional teats available per piglet is positively associated with piglet survival [52]. If piglets had access to less than one functional teat, mortality increased to more than 14% [52]. If more than one teat was available, mortality was reduced to below 8% [52]. Besides the number of

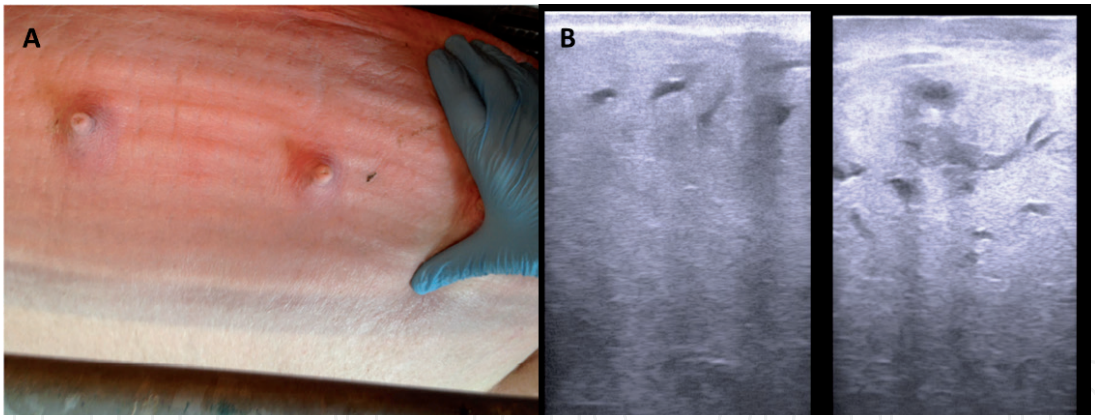

Figure 1.
Severe prepartum edema of the mammary gland. Visual inspection (A) reveals dimpled skin with persistent marks of the floor, swollen teats, and indistinguishable gland complexes. Ultrasonographic image (B) shows shadowing, thickened dermal tissue, hyperechoic lobuloalveolar tissue, and enlarged blood vessels, lymphatic ducts, and milk ducts. Images taken by Stefan Björkman.

functional teats, also the morphology is important. Piglets tend to suck first from teats that are close to the abdominal midline and have longer inter-teat distances [53]. Thus, a functional teat with short inter-teat distance and/or long distance between teat base and abdominal midline may be unusable for the piglet [54].

Furthermore, severe edema of the mammary gland before parturition will have a negative impact on teat accessibility, reduce colostrum quality, and increase the risk of PDS [48, 49]. The degree of mammary gland edema can be graded visually or via ultrasound [48, 49, 55]. At visual inspection, sows with severe udder edema have dimpled skin with persistent marks of the floor (**Figure 1A**). Further, teats are swollen and mammary glands are indistinct (**Figure 1A**) [48, 49]. Ultrasound of the mammary glands shows thickened dermal and subdermal tissues, hyperechoic lobuloalveolar tissue with enlarged blood vessels, and severe shadowing (**Figure 1B**) [48, 49, 55]. Also at the end of lactation, the assessment of the mammary gland, as described above, is crucial and should be used for the decision of removing the sow from the herd.

3. Tools and protocols during parturition

During parturition, it is important to recognize birth complications and treat accordingly. Further, evaluation of colostrum quality is necessary in order to know whether the sow has good quality colostrum or if piglets need additional colostrum from another sow. Also, the vitality and colostrum uptake of the piglets need to be assessed. Piglets with low vitality and low colostrum uptake are at risk of starving and hypothermia. Both increase piglet mortality, especially due to crushing by the sow. **Tables 2** and **3** provide protocols for diagnosis and treatment of birth complications. **Tables 4** and **5** provide guidelines for the assessment of colostrum quality and piglet vitality.

3.1 Diagnosis of birth complications

Appropriate and prompt treatment of a sow with birth complications is important to avoid still- or weak-born piglets and to increase piglets' health and survival. This can be achieved through continuous farrowing supervision [56]. Farrowing supervision is also necessary for reducing the risk of puerperal disease [38]. Already before parturition, it is important to spot those sows that may be at risk of dystocia. These sows are usually gilts or old sows (≥6 parity), thin (≤14 mm) or fat (≥23 mm) sows, constipated sows (<2), and sows with history of birth complications and birth of still and weak piglets [11, 57]. These sows need an obstetrical examination if more than 30 min have passed since the last piglet was expelled (**Table 2**) [12]. This applies also to sows that are restless and have strong abdominal contractions during parturition

Factor	Recommendation	Reference
Parity	1, ≥ 6	[57]
Constipation score	< 2	[11]
Body condition	≤ 14 mm, ≥ 23 mm	[11]
Last parturition	Birth complication, birth of dead and weak born piglets	[57]
Current parturition	Prolonged, restlessness, strong abdominal contractions; dead and still born piglets	[12]

Table 2.
Risk factors for birth complications. Farrowing supervision should occur every 30 min when sow is at risk. Otherwise, farrowing supervision once an hour.

Guideline for diagnosis and treatment of birth complications
Rectalize the sow, remove feces and palpate the birth canal in order to determine whether a piglet is within birth canal
➢ Piglet within birth canal
➢ Wash vulva 3x with warm water & iodine soap, dry with paper towels
➢ Apply rectal glove and plentiful of lubricant
➢ Remove piglet gently by hand
➢ No piglet within birth canal (or any other kind of obstruction)
➢ If at the beginning of parturition: Manual induction of the Ferguson reflex, massaging the udder of the sow, and/or physical exercise
➢ If during or at the end of parturition: Inject oxytocin – low dose of 5 - 10 IU intramuscular

Table 3.
Guidelines for diagnosis and treatment of birth complications [12, 61–69].

Brix %	ELISA IgG (mg/ml) mean ± SEM	IgG quality category
< 20	14.5 ± 1.8	Poor
20-24	43.8 ± 2.3	Borderline
25-29	50.7 ± 2.1	Adequate
≥ 30	78.6 ± 8.4	Very good

Table 4.
Guideline for evaluating colostrum quality (colostrum collected from several anterior teats within 0–3 h from the start of farrowing) using Brix refractometer [70].

Indicator	Critical value	Reference
Crown-rump length	< 26 cm	[2, 72]
Body weight	< 1200 g	[2, 72]
Body temperature	< 37 °C	[2, 72, 73]
Skin temperature	< 30 °C	[53, 74]
Meconium staining	Severe	[63]
Latency to moving	> 15 seconds	[2, 63]
Latency to standing	> 5 minutes	[2, 63]
Latency to teat	> 25 minutes	[2, 72]
Latency to suckle	> 30 minutes	[2, 72]

Table 5.
Behavioral and physiological indicators of low colostrum intake and neonatal mortality.

or to sows with prolonged parturition (>300 min) [12]. Obstetric intervention is usually not indicated before 1–15 h has passed since the last piglet was born in sows without risk for dystocia, which are at the beginning of parturition (<300 min since the expulsion of the first piglet) and show no signs of strong abdominal straining or restlessness [11, 12, 57]. Restlessness can occur if stress and pain are present [58]. For instance, increased stress induces higher frequency of postural changes and longer duration of standing position of sows during the expulsion stage of parturition [58].

Whenever the abovementioned criteria are fulfilled, an obstetrical examination needs to be performed. An obstetric examination includes palpation and ultrasonography of the birth canal [12, 59]. Palpation of the birth canal should always occur through the rectum and not through the vagina. Vaginal palpation can lead to an increased risk of subsequent dystocia, stillborn piglets, and PDS [3, 7, 12, 57]. Rectal palpation is necessary to determine the exact cause of dystocia before any intervention is undertaken. When no piglet is felt within the birth canal, then the cause of dystocia is uterine inertia [8, 9, 12]. Other causes are, e.g., obstruction of the birth canal due to ventral deviation of the uterine horns or fetal malposition [8, 9, 12]. After these obstructive causes are ruled out, treatment for uterine inertia can be applied [12].

Ultrasonography can be used to determine whether farrowing is over or if the sow has retained piglets [59] or placentae [60] (**Figure 2**).

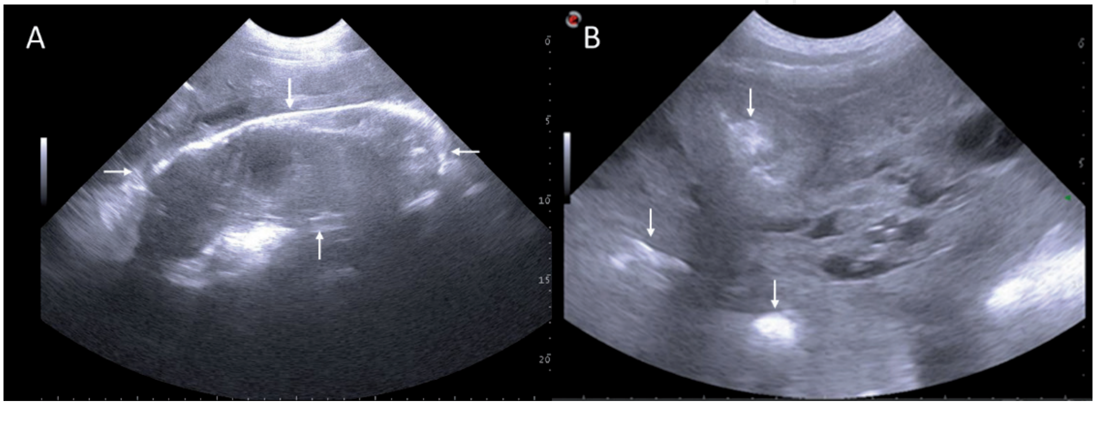

Figure 2.
Transabdominal ultrasonographic image of a non-expelled piglet (A; arrows indicate vertical and horizontal dimension) and placentae (B; arrows indicate placentae). Scale bars on right margins in 1 cm steps. Images taken by Alexander Grahofer (A) and Stefan Björkman (B).

3.2 Treatment of birth complications

Oxytocin, an uterotonic agent, is used during farrowing to treat dystocia by provoking uterine contractions [61]. If primary uterine inertia occurs, before administration of any exogenous oxytocin, we recommend trying means of releasing endogenous oxytocin, e.g., manual induction of the Ferguson reflex and massaging the udder of the sow [8]. Furthermore, movement and physical exercise of the sow have positive effects on the farrowing duration, especially if the sow is still at the beginning of the second phase [12]. If that does not help, we recommend waiting for at least 30 min. Often progesterone has not fully declined and oxytocin receptors are not fully expressed [62], which makes oxytocin administration contraindicated. In this case, possible stressors and sources of pain should be investigated, and provision of nest-building material or application of pain medication may be indicated. If the sow is constipated, removing feces from the rectum by hand is beneficial.

Immediate application of exogenous oxytocin is indicated if secondary uterine inertia is diagnosed towards the end of the second phase of parturition [12]. Several studies were conducted to prove the effect of oxytocin on the birth process and piglet survivability and to evaluate the proper dosage of oxytocin in dystotic sows [63–65]. An intramuscular administration of 10 IU of oxytocin did not cause any side effects. However, higher dosages led to an increase in stillborn piglets, changes in the umbilical cord, and higher meconium scoring [63–65]. Furthermore, the improper use of oxytocin can lead to unwanted side effects. These side effects are increased uterine inertia and manual assistance [66, 67] as well as ruptured or damaged umbilical cord [68] and decreased placental blood flow [69]. Hence, we recommend administering oxytocin only restrictively, e.g., 5–10 IU one to two times during parturition [12].

3.3 Colostrum collection and quality assessment

It is possible to easily collect colostrum during parturition due to the almost continuous (every 5–40 min) milk ejections [29]. A brix refractometer can be used for quality assessment. Brix refractometer can be an inexpensive, rapid, and satisfactorily accurate method for estimating IgG concentration on farm [70, 71]. We recommend collecting a colostrum from several anterior teats within 0–3 h from the start of farrowing when the IgG level peaks [70]. If this is done early during parturition, sows with low-quality colostrum can be spotted and more support to her litter, e.g., assisted nursing and split suckling, can be provided. Nevertheless, it is possible to determine colostrum quality at any stage of parturition. This may be indicated if piglets are born late (farrowing duration > 12 h). Differentiation between good and poor IgG content of colostrum is possible interpreting the results with the categories proposed in **Table 3**. Colostrum with an IgG level of 50 mg IgG/ml is considered of good quality [14]. When Brix values are <20%, they reflect very low levels of IgG, while values from 25% upwards are considered to correspond to good or very good concentration of IgG in colostrum. Results between 20 and 24% are defined as borderline [70]. With borderline results, we suggest taking another sample within 1–2 h to determine whether the development of the estimated IgG content is stable, increasing, or decreasing from the initial value.

Colostrum can also be stored and used later for piglets with low colostrum intake or for litters of sows with low colostrum quality. Colostrum can be stored in a fridge for 1–2 days or in the freezer for 3–6 months. Only sows with high colostrum quantity and quality should be selected. The collected colostrum can be administered to piglets using a feeding bottle with a suitable nipple or using a syringe.

3.4 Assessment of colostrum uptake

Certain behavioral and physiological indicators can be used to identify piglets with low vitality and low colostrum uptake [72]. Piglets with low vitality may need assistance with colostrum uptake in order to prevent starvation, hypothermia, and crushing by the sow [2]. **Table 5** provides an overview of these indicators. Besides birth weight and crown-rump length, piglet's survival chance correlates with body temperature, vitality score, rooting response, and latency to teat and suckle [72]. Whenever the following criteria are met, the piglet needs assistance with colostrum uptake: vitality score of less than two (no movements within 15 s of birth), latency to teat and therefore to suckle of more than 30 min, and a body temperature of less than 37°C during the first hour after birth. In order to spot these piglets in time, we suggest looking at them every 30 min during parturition.

However, this may be difficult to implement into practice. It may be helpful to make use of thermal images to overcome these difficulties [53]. Similar to body temperature, skin temperature is linked to birth weight, vitality, and colostrum ingestion and can be used to see whether a piglet has reached the teat and suckled and ingested colostrum within 30 min of birth [73, 74]. As a piglet begins to suck and ingest colostrum, energy and warmth are produced, increasing body and therefore skin temperature [53]. If skin temperature drops below 30°C, the piglet has not been successful [53] and needs to be assisted to suckle and ingest colostrum.

3.5 Assistance of colostrum uptake

It is important to ensure that each piglet in the whole litter has a sufficient intake of good quality colostrum (more than 200 g) within 12–16 h from the beginning of parturition [14, 75]. When possible, piglets with low colostrum uptake should be assisted to suckle, by helping them to attach to the smallest functioning teats. This procedure should be repeated three to four times within the first few hours. Additionally, weakly piglets can be hand-fed with colostrum collected from their own mother or other sows.

Assisted suckling and hand-feeding are appropriate in small or normal size litters where only one or two piglets require help. In large litters or when more piglets require assistance, split suckling is more effective. In order to minimize the sibling competition for colostrum intake, the litter is split into two groups. The heavier and stronger piglets are kept in the creep area or in a separate box, allowing the smaller piglets to suckle for 60–90 min, and then the groups are switched. When separating the piglets, both groups should always have free access to a warm creep area. This can be easily achieved by using a box with an additional heat lamp for the separated group, which leaves the creep area accessible for the remaining group to suckle. Assisted suckling should be combined with split suckling if some small piglets are still unable to successfully suckle.

Another strategy is to prolong the colostral phase. Piglets ingest colostrum usually until 24 h after the onset of parturition [75]. The composition of colostrum is affected by the status of tight junctions between mammary epithelial cells, and the ability to manipulate mammary tight junctions in the late colostral phase could allow Ig concentrations to be maintained at higher levels for a longer period. Injecting a supraphysiological dose of oxytocin to sows on day 2 of lactation (i.e., between 12 and 20 h after birth of the last piglet) increased the concentrations of IGF-I, IgG, and IgA in milk collected 8h after the injection [76]. The injection of oxytocin in the early postpartum period therefore delayed the occurrence of tightening of mammary tight junctions and prolonged the colostral phase, thereby having beneficial effects on the composition of early milk.

4. Tools and protocols after parturition

After parturition, it is important to investigate whether the sow is at risk or suffers from puerperal disease. Sows at risk are, e.g., sows that had constipation or stress, are obese, had a prolonged parturition, experienced birth help, and gave birth to more than one stillborn piglets (**Table 6**) [3, 21, 35]. These sows need to be checked within 3 days after parturition whether the animals shows general symptoms or other clinical signs of PDS [77, 78]. Underlying causes for PDS can be constipation, endometritis/metritis, cystitis, and mastitis [12, 62]. The underlying cause needs to be diagnosed and immediately treated.

4.1 General symptoms

General symptoms include fever, reduced appetite, lethargy, and vaginal discharge [41]. Body temperature is the most frequently used to evaluate the health status of a sow in the puerperal period [78]. Reference values range from 39 [24] to 40°C [38]. Though body temperature is a sign of inflammation, it can also be affected by several other parameters such as the circadian rhythm [79], parity [79], variation in repeated measurements [80], and positioning of the thermometer in the rectum [81]. Vulvar discharge occurs also in healthy and diseased animals [82, 83] with the highest incidence between days 2 and 4 postpartum [78, 84]. Further, the color, consistency, and quantity of vaginal discharge vary regardless of whether the vaginal discharge is physiological or pathological [85]. The color can vary from clear, whitish, yellowish to reddish (**Figure 3**). The consistency varies from watery to creamy with lumps, and the amount can be up to 500 ml [85, 86]. Increased volumes of vaginal discharge are associated with endometritis, but otherwise there does not seem to be strong correlations between other characteristics of vaginal discharge and PDS [86].

Indicator	Recommendation	Reference
Body temperature	≥ 40 °C	[24, 38]
Backfat	≥ 20 mm	[21, 35]
Constipation	≤ 1	[21, 35]
Appetite	Diminished; moderate or total anorexia	[21, 24]
Farrowing duration	Prolonged	[3]
Placenta expulsion	Impaired	[3]
Number of dead born piglets	≥ 2	[3]
Birth help	Yes	[3]
Vulvovaginal discharge	Moderate to large amounts	[78, 86]
Milk production	Hypogalactia, dysgalactia, agalactia	[21, 35]

Table 6.
Indicators, based on clinical history and clinical symptoms, for postpartum dysgalactia syndrome.

Figure 3.
Puerperal vaginal discharge with different colors. 0 = clear, 1 = reddish, 2 = yellowish, and 3 = whitish. The color of vaginal discharge varies regardless of whether the vaginal discharge is physiological or pathological [85]. Increased volumes of vaginal discharge are associated with endometritis. Images taken by Alexander Grahofer.

In conclusion, body temperature, especially under 40.0°C; appetite; and vaginal discharge cannot be used alone and as the single criterion for PDS. Still, body temperature of more than 40.0°C together with other clinical symptoms such as general behavior and feed intake are associated with PDS and require further diagnostics [78, 79]. These symptoms can be normal or associated with an infection of the urogenital tract or the mammary gland and constipation.

4.2 Endometritis

Besides prolonged parturition, obstetrical intervention, and the birth of more than one dead piglet, also retained placentae is a risk factor for endometritis [3]. For both, endometritis and retained placentae, ultrasonography is considered the best tool for diagnosis [3, 59, 78, 87]. Examination of uterine structures currently utilizes three criteria: fluid echogenicity, echotexture, and size [59, 87]. Changes in echotexture are a reflection of changes in the endometrial edema. Increased echotexture and any fluid echogenicity must be considered abnormal and indicative of an exudative inflammation of an acute or acute-chronic type [59, 87]. Fluid echogenicity is often associated with uterine edema and therefore increased echotexture and size of uterine cross-sections [3]. Thus, all criteria, enlarged uterine size, hyperechoic fluid accumulation, and heterogeneous uterine wall, are interconnected and can be used as ultrasonographic parameters to ascertain uterine disorders (**Figure 4**) [3, 87, 88].

In contrast, chronic endometritis, representing the most common type of uterine inflammation in pigs and most common cause of reproductive failure, cannot be definitively diagnosed by ultrasonography or by any other tool [59, 87]. Therefore, it is essential to recognize acute endometritis in time. This can be done based on the

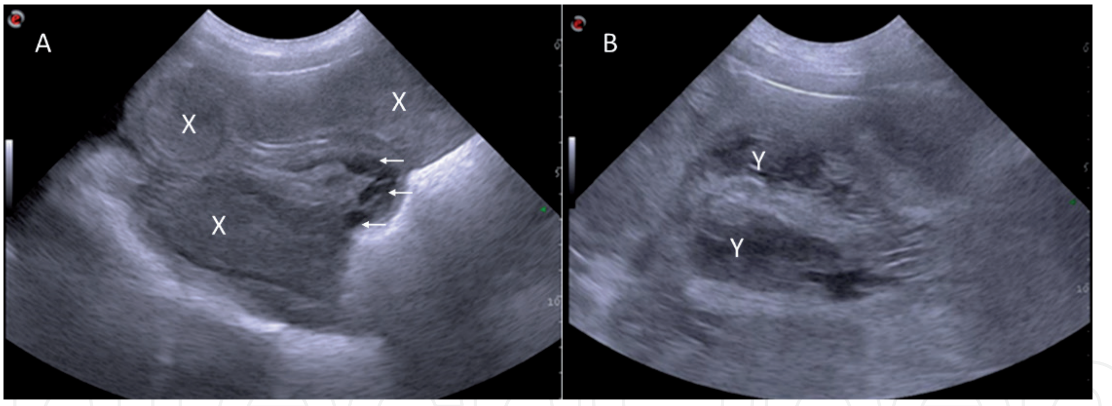

Figure 4.
Transabdominal ultrasonographic images of uterine cross-sections (X, Y) of sows assessed 3 days after parturition with enlarged and heterogeneous uterine wall (A) and hyperechoic fluid accumulation (B). Uterine vessels are prominently enlarged (examples marked with arrows). Scale bars on right margins in 1 cm steps. Images taken by Stefan Björkman.

criteria mentioned above, but it must be considered that fluid echogenicity, uterine edema, and increased uterine size during the first few days after parturition may be normal [3, 78, 88]. Furthermore, when interpreting uterine size, the age and parity of the sow as well as the number of postpartum days need to be considered [3, 59, 87].

4.3 Cystitis

Ultrasonography can also be used for the diagnosis of cystitis [89, 90]. Still, it is not as reliable as in the diagnosis of acute endometritis. Clear changes in the wall thickness and regularity and the mucosal wall surface are volume dependent [89, 90]. Overall, these measurements seem to be unreliable for diagnosis of cystitis. On the other hand, animals with cystitis have moderate to high amounts of sediment [89, 90]. Unfortunately, half of the sows without cystitis also show moderate to high amounts of sediment, which is mainly caused by the diet [89, 90]. Nevertheless, when none to mild amounts is present, the probability that the sow is suffering from no cystitis is high. When moderate to high amounts of sediment are present, other diagnostic tests need to be applied.

Another diagnostic test is urinalysis. It is preferred to collect spontaneous midstream urine in a transparent tube. The best time for collection is in the morning before feeding. On-farm urinalysis includes macroscopic urine evaluation and urine stix testing. During the macroscopic urine evaluation, the color, odor, and turbidity are evaluated [91, 92]. The color can vary between light yellow and dark yellow, depending on urinary concentration. The color should not be red or brown which indicates hematuria or myoglobinuria. The turbidity of the urine should be clear. Cloudy or turbid appearance indicates the presence of bacteria. The presence of bacteria can also increase ammonia in the urine and cause a putrid odor. Urine turbidity has a sensitivity of 0.74–0.80 and a specificity of 0.50–0.92 and 0.50 [93, 94]. Nevertheless, if urine is physiological, the probability that the sow is suffering from no cystitis is 0.85 [95]. Thus, because of low sensitivities of certain single markers, several markers need to be evaluated together. A macroscopic evaluation should always be combined with urine sticks testing. Urine sticks allow testing for protein, pH, nitrite, blood, and leukocytes. Parameters with low sensitivity are leukocytes, pH, and nitrite [93, 94]. Parameters with good sensitivity are blood and protein [95]. The normal pH is between 5.5 and 8, and an increase above 8 is indicative for the presence of bacteria. On the other hand, many other factors can increase the pH such as feeding, other diseases, and medication. Whenever the majority of these markers indicate cystitis, a urine sample should be sent for bacterial investigation.

4.4 Mastitis

Mammary gland, unlike the urogenital tract, is located outside the body and therefore easily accessible by hand. Thus, the diagnosis of mastitis can be done by palpation of the mammary gland. Mammary glands may appear swollen, firm, and warm [35]. In addition, skin color may be changed.

Other rapid mastitis tests as applied to cows are not available for sows. Diagnosis via cell count is not common and data on thresholds are rare [96]. A threshold of $>10^7$ cells per mL was proposed [35]. Further, a milk pH of more than 6.7 was reported [96]. If needed, ultrasonography can be used in the diagnosis. Affected mammary glands provide heterogeneous and hyperechoic images [97].

5. Conclusions

Hyper-prolificacy challenges the performance of the sow in terms of parturition, colostrum production, neonatal survival, and fertility. Birth complications, piglet mortality, and puerperal disease need to be prevented. Before parturition, we recommend that sows are allowed to move freely and that nest-building materials, e.g., straw, hay, sawdust, or paper sheets, are provided. Modifying the sow's late gestation diet in order to prevent constipation and high body condition will also have beneficial effects. During parturition, timely application of birth assistance is highly important. The exact cause of dystocia must be diagnosed and treated. Hyper-stimulation of the uterus with excessive oxytocin must be avoided. Close attention and assistance needs to be given to weak-born piglets, small piglets, and piglets without teats. New technologies, such as the use of Brix refractometer and infrared cameras, can help in the assessment of the status of colostrum and the newborn. After parturition, sows at risk of PDS need to be identified and checked within the first 3 days postpartum. Hungry and noisy piglets making vigorous nursing efforts indicates PDS. The exact cause of PDS should be determined for proper treatment. Acute endometritis is indicated by large amounts of vaginal discharge and diagnosed best using ultrasonography. Inspection and palpation of the mammary gland and evaluation of the sow's behavior best diagnose mastitis. Cystitis can be diagnosed by performing a macroscopic evaluation of urine and urine stix testing. If needed, samples of urine and vaginal discharge can be sent for bacteriological examination. If no signs of mastitis, cystitis, and endometritis around, the cause may be constipation.

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Conflict of interest

The authors declare no conflict of interest.

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