Proper development of replacement females can be critical to the productivity and profitability of a beef operation. Replacement females are the future of any given beef cow herd and they are the mechanism by which genetic progress is made in a cow herd. It has been estimated that the development costs for preparing a heifer to calve at 24 months age average about 31% of her total lifetime expenses. Veterinary practitioners can provide an invaluable service to their clients by providing assistance to develop and implement a comprehensive heifer development program.

One of the primary goals of a heifer development program is to get a high proportion of the heifers to conceive early in the breeding season. Heifers that become pregnant early in their first season tend to breed early as cows and have greater longevity in the herd. Becoming pregnant early in the breeding season has several advantages that will be discussed later. In order to accomplish that goal, heifers need to reach puberty prior to or at the beginning of the breeding season. Heifers are more fertile on their third estrus cycle compared to their first estrus cycle so reaching puberty prior to the breeding season increases the chances of the heifer becoming pregnant early. Some producers will also breed heifers to calve prior to the mature cows. By placing these points on a timeline, it is easy to see the importance of heifer age and growth.

A heifer development program should include several key areas. These areas are selection, health, growth and nutrition, breeding, calving, and rebreeding. Each of these areas will be discussed in more detail below.

Selection
Most commercial producers are going to select replacements from heifers born on the operation. Having a planned program to produce potential replacements can offer significant advantages. The application of artificial insemination in the commercial cow herd gives the producer the opportunity to select bulls that rank high for maternal traits with the specific intent of producing heifers that will serve as future replacements for the herd. Using sexed or gender sorted semen can increase the proportion of heifers born from matings specifically intended to produce replacements.

The selection process for replacement heifers can begin at birth. Performance records of both the sire and dam should be evaluated if possible. Heifers sired by bulls with larger scrotal circumference measurements will reach puberty at an earlier age. Heifers born to dams with poor feet and leg confirmation, excessive size, poor disposition, or poor udder conformation should not be considered as future potential replacements. Dams of potential replacement heifers should thrive in their environment while requiring minimum additional inputs.

Several authors have recommended that potential replacement heifers should not receive growth promoting implants. Some authors have reported that implants interfere with development of the reproductive tract or result in decreased fertility while others have reported that implants have minimal to no impact on overall reproductive performance.

Selecting heifers that are born early in the calving season offers several important advantages. Early born heifers were conceived early and, therefore, may be from more fertile dams and will have heavier weaning weights, reach puberty earlier and have higher pregnancy rates than heifers born later in the calving season. There is growing evidence that nutritional and environmental factors during gestation can program the growth and reproductive performance of progeny heifers. Protein restriction during late gestation can affect age at puberty and reproductive efficiency of heifer progeny. Replacements should be selected from dams that were properly managed during gestation.

At weaning, heifers should be evaluated for growth potential and conformational soundness. Simply selecting the biggest heifers as replacements may not be optimum because this is likely to lead to a gradual increase in mature cow size. For seedstock producers, Expected Progeny Differences (EPD’s) are a useful tool for comparing animals based on their predicted production capabilities.

At approximately one year of age individual growth performance and confirmation should be reevaluated. Pelvic area measurement is a tool that is used in an effort to reduce the incidence of dystocia but there is some controversy concerning its use. The average pelvic area of the herd can be increased over time by using pelvic measurements but, as pelvic area increases, so does mature cow size and, potentially, calf birth weight. Also, differences in pelvic area observed in yearlings are not always present when those heifers reach two years of age. The current recommendation for using pelvic area measurements is to eliminate heifers that do not meet a minimum pelvic area measurement.

Reproductive tract scoring (RTS) is a tool used to subjectively classify pubertal status through evaluation of the reproductive tract via rectal palpation. The technique is typically applied a few months before the start of the breeding season. Briefly, heifers are assigned a score of 1-5 based on the size and tone of the uterus and the presence of palpable structures on the ovaries. Having a high percentage of heifers with RTS of 4 or 5 indicates that majority of the heifers have reached puberty. If a high percentage of heifers have scores lower than 4, nutritional adjustments must be made or heifers with low RTS can be culled.
Health
A solid preventive health program is a critical component of a heifer development program. A preventive health program should be tailored to each operation and should be focused on providing maximal immunity to the most important reproductive pathogens on that ranch. For most operations, these pathogens include bovine viral diarrhea virus (BVDV), bovine herpes virus-1, leptospirosis, vibriosis, and possibly trichomoniasis. Brucellosis vaccination may be considered if heifers as sold as replacements as some state still require brucellosis vaccination as part of entry requirements. Regardless of the vaccine program used, the primary goal should be to maximize immunity to important reproductive pathogens prior to the start of the breeding season. Parasite control programs will vary depending on location, environment and rainfall. Diagnostic testing for specific diseases may be warranted depending on the biosecurity program for the operation. The veterinarian is uniquely suited to assist producers with developing herd health programs that are specifically tailored to a given operation.

Growth and nutrition
Prior to weaning, nutrition for the growing replacement heifer is provided by her mother. If creep feeding is used, care must be taken to not allow the calves to become too fat. Heifers that become overconditioned as calves may have reduced productivity as adults.6

The nutritional management of beef replacement heifers has been reviewed.16-18

Important targets have been established to guide the nutritional management of replacement heifers. The overriding goal is for heifers to reach desired weights and attain puberty prior to the breeding season with minimum supplementation. The topic of replacement heifer target weight has been reviewed.18 Heifers that require significant supplementation may not be suitable as replacements.

Most beef heifers will enter their first breeding season at around 15 months of age. Heifers should reach 60-65% of their expected mature body weight prior to breeding.18 Most heifers will have reached puberty by the time they have reached this weight. Research has shown that this weight gain does not have to be consistent over the entire weaning to breeding period.18 Research has also shown that the source of nutrients does not matter as long as desired levels of gain are achieved.19 This information allows considerable flexibility in heifer feeding programs. Recent research has investigated the impacts of feeding heifers to a lighter target weight of 50-55% of mature weight prior to the first breeding season.20,21 This body of work has demonstrated that, in some cases, developing heifers to a lighter target weight can reduce development costs without affecting reproductive efficiency. Although there was no difference in overall pregnancy rate, heifers developed to 50% of mature weight reached puberty later and therefore conceived later in the breeding season.22

Once heifers are confirmed pregnant, average daily gain should be adjusted to insure that heifers reach 85% of expected mature weight prior to calving and calve in a body condition score (BCS) of 6. Reaching 85% of mature weight reduces the risk of dystocia and calving in a BCS of 6 gives the heifer needed energy reserves to return to estrus cyclicity in a timely manner. The ration should be adjusted to provide for rapid fetal growth during the last trimester of gestation.

Breeding
Several important milestones should have been met prior to the start of the breeding season. Heifers should have reached desired target weights and reached puberty prior to breeding. Some producers elect to breed heifers to calve 3-4 weeks ahead of the mature cows to allow closer observation of the heifers and to give the heifers more time to return to cycling for their second breeding season. This gives calves born to replacement heifers an advantage as well since they will be older at weaning.

Breeding replacement heifers is an excellent time to take advantage of artificial insemination. Estrus synchronization facilitates the use of artificial insemination and may give heifers an extra opportunity to become pregnant during the breeding season. Numerous estrus synchronization protocols are effective in heifers. If a significant proportion of the heifers are not cycling, use of a progestin based synchronization protocol may help induce puberty in some animals.

One of the most critical components of a successful heifer breeding program is bull selection. Artificial insemination is a great tool for breeding replacement heifers and improving the genetics of the herd. Proper bull selection is also one of the most effective dystocia prevention tools available to producers. Calving ease bulls with balanced EPDs exist in most breeds and careful evaluation of EPD’s can identify these bulls. Use proven sires with high EPD accuracy for breeding heifers.

The first breeding season is a great time to apply selection pressure for fertility. Restricting heifers to a confined, shortened breeding season ensures that only the most fertile heifers have the chance to remain in the herd as cows. The typical recommended breeding season length for heifers is 2 estrus cycles or 42 days. If estrus synchronization is used, this 42 day period may include 3 estrus cycles. Early diagnosis of pregnancy permits producers to select heifers that conceived early in the breeding season. As mentioned previously, heifers that become pregnant early in their first breeding season tend to become pregnant early in the breeding season as cows and have increased longevity in the herd.2 Retaining only those heifers that conceived early in the breeding season should increase the reproductive efficiency of the herd over time.
Calving

Heifers should calve at approximately 85% of their expected mature weight in a body condition score of 6.23 At 85% of mature weight, heifers have attained enough size to minimize the occurrence of dystocia provided they are bred to appropriate bulls. Calving in a body condition score of 6 helps insure adequate energy reserves to resume estrus activity in a timely manner following calving.

Heifers are at increased risk of dystocia compared to mature cows and therefore should be observed closely and often during the calving season. Keeping heifers confined for ease of observation must be balanced with the risk of disease in the calves if the animals are too crowded. The ideal calving area in most climates is a clean grassy pasture with shelter from harsh weather and easy access to facilities so that assistance can be provided when needed. Keeping other cattle out of the calving area prior to the calving season may help reduce the risk of infectious disease in the calves.

Calving assistance should be provided in a timely manner to minimize the effects of dystocia on both the calving heifer and the calf. Providing prompt assistance, when needed, improves return to cyclicity in heifers.22 If a heifer has been in active labor for more than 90 minutes without making progress, assistance should be provided.

Rebreeding

Achieving a female’s second pregnancy is often the most difficult of her life. The nutritional demands of lactation stacked on the demands for maintenance and growth may prevent some heifers from returning to estrus activity soon enough to get pregnant during the next breeding season. Developing heifers that reach puberty early, conceive early in the breeding season, reach target weight and BCS goals prior to calving and calve without dystocia have the best chance of remaining productive within the herd.

Resources

Readers who desire more in-depth information regarding heifer management are referred to the November 2013 edition of the Veterinary Clinics of North America: Food Animal Practice. The entire issue is devoted to beef heifer management and offers several excellent reviews on the subject. Another very recent review of heifer development has been published by Larson and colleagues.24

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Diagnosing and Managing Vagal Indigestion Syndrome
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Vagal indigestion syndrome is an umbrella term used to describe a variety of disease conditions that present with a relatively consistent set of clinical signs. Interference with the vagus nerve at various locations can lead to development of the various forms of vagal indigestion. However, many, if not most, clinical cases have no direct involvement of the vagus nerve. Many of the conditions resulting in signs consistent with vagal indigestion are difficult to differentiate based on clinical findings alone. Understanding the pathogenesis and conducting a careful clinical investigation will usually lead to an accurate diagnosis. This paper presents the author’s approach to diagnosis and management of vagal indigestion syndrome.

Types of vagal indigestion
Free gas bloat (type I)
Type I vagal indigestion is characterized by chronic, sometimes intermittent, accumulation of free gas within the dorsal sac of the rumen. The bloat is usually mild to moderate in severity but can become life-threatening.

Omasal transport failure (type II)
Type II vagal indigestion is characterized by the accumulation of ingesta within the reticulorumen while the omasum and abomasum remain relatively empty.

Pyloric outflow obstruction (type III)
Type III vagal indigestion is characterized by accumulation of fluid ingesta in the abomasum with backflow of ingesta into the omasum and reticulorumen leading to distention of these organs as well.

Indigestion of late pregnancy (type IV)
Type IV vagal indigestion is very similar to type III except that it is thought to be caused by a large gravid uterus interfering with normal abomasal emptying.

Clinical presentation
Free gas bloat (type I)
- Mild to moderate distention of the upper left quadrant on the abdomen with free gas (bloat)
- Normal stratification of rumen contents may be palpable if bloat is not too severe
- Bloat is usually chronic and may be intermittent
- Decreased appetite and lethargy may be present
- Evidence of other systemic disease (respiratory disease, TRP) may be present
- Respiratory difficulty may be present depending on severity of bloat

Omasal transport failure (type II)
- Decreased appetite, weight loss and decreased milk yield may be noted
- Moderate to marked distention of the left side of the abdomen in early cases. As condition progresses, abdomen will take on a “papple” shape with distention of the upper and lower left quadrants and lower right quadrant
- Rumen motility is often increased due to activation of the low threshold tension receptors in the reticular wall
- Rumen contents lose the normal stratification and develop a frothy consistency
- Mild dehydration may be present
- Enlarged “L” shaped rumen is palpable upon rectal examination
- Decreased fecal volume with longer than normal fiber length. Feces may have a greasy or pasty appearance
- Significant bloodwork abnormalities are not usually evident

Pyloric outflow obstruction (type III)
- Decreased appetite, lethargy, weight loss and milk yield may be noted
- Abdomen usually takes on “papple” appearance
- Rumen motility is usually decreased due to more severe distention leading to activation of high threshold tension receptors
- Rumen contents lose normal stratification and become watery
- Dehydration is usually evident and may be severe
- Varying degrees of depression may be evident
- Spontaneous reflux occasionally occurs in severe cases
- Enlarged “L” shaped rumen is palpable upon rectal examination
- Fecal volume is decreased more than with Type II and may have longer than normal fibers
- Hypokalemic, hypochloremic metabolic acidosis is usually evident on blood work
Indigestion of late pregnancy (type IV)

- Clinical appearance is very similar to Pyloric Outflow Obstruction
- Large gravid uterus is evident upon rectal examination and may obscure evaluation of the rumen

Differential diagnoses

Free gas bloat (type I)

- Injury to vagal nerve leading to functional deficits of the reticulum and/or cardia
  - TRP, liver abscess, peritonitis
- Functional interference with normal reticulorumenal motility patterns
  - Adhesions from TRP, liver abscess, neoplasia
- Esophageal obstruction
  - Intraluminal foreign body – hedge apple, potato etc
  - Extraluminal mass – enlarged mediastinal lymph node, abscess
- Dietary changes

Omasal transport failure (type II)

- Injury to vagal nerve leading to functional deficits of the reticular groove, reticuloomasal orifice, or omasum
  - TRP, liver abscess, peritonitis
- Functional interference with function of the reticuloomasal orifice
  - Adhesions, abscess, peritonitis
- Neoplasia involving reticular groove or reticuloomasal orifice
  - Papilloma
- Foreign body obstruction of the reticuloomasal orifice
  - Placenta, plastic bag, baling twine

Pyloric outflow obstruction (type III)

- Injury to vagal nerve leading to motility deficits of the abomasum
  - TRP, peritonitis
- Abomasal volvulus
  - Stretching of the abomasal wall may injure nerve and/or muscle leading to altered motility patterns
- Lymphosarcoma involving the pylorus
- Abomasal impaction
  - Poor quality roughage diets
- Foreign body obstruction of the pylorus
  - Trichobezoar (young calves)

Indigestion of late pregnancy (type IV)

- Clinically indistinguishable from pyloric outflow obstruction
- Only occurs in with late term pregnancy

Diagnosis/differentiation of types

Free gas bloat (type I)

- Pass orogastric tube to rule out intraluminal obstruction
  - Extraluminal mass may still allow passage of tube
- Rule out dietary causes as much as possible
  - Evaluate rumen fluid for microbial activity
- Ultrasound examination of the cranioventral abdomen may provide evidence of TRP or adhesions
- Ultrasound examination of the thorax may reveal evidence of pleural or pulmonary disease consistent with pneumonia
  - Mediastinal disease cannot be assessed with ultrasound
- Thoracic radiography in smaller animals may reveal evidence of intrathoracic masses

Omasal transport failure (type II)

- “Papple” shaped abdomen is the classic clinical sign
- Rumen motility is usually increased but may be more quiet than normal due to frothy nature of rumen contents
- Frothy rumen contents
- Enlarged “L” shaped rumen noted on rectal examination
- Ultrasound examination of the cranioventral abdomen may provide evidence of TRP or adhesions
- Relatively empty abomasum when visualized with ultrasound
- Minimal abnormalities noted on bloodwork
Concurrent disease may cause bloodwork changes
- Normal ruminal fluid chloride level (<30 mEq/L)

**Pyloric outflow obstruction (type III)**
- “Papple” shaped abdomen is the classic clinical sign
- Dehydration is generally more severe than with Type II
- Rumen motility is generally decreased
- Fluid rumen contents
- Ultrasound examination of the cranioventral abdomen may provide evidence of TRP or adhesions
- Abomasum may be distended with fluid contents when visualized with ultrasound
- Ultrasound examination of the pyloric region may provide evidence of lymphosarcoma
- Hypokalemic, hypochloremic metabolic acidosis evident on bloodwork
- Elevated ruminal fluid chloride level (>30 mEq/L)
  - May approximate serum chloride level in severe cases
  - May develop 2-3 days following abomasal volvulus correction
- Right flank exploratory laparotomy

**Indigestion of late pregnancy (type IV)**
- Rule out other causes of Pyloric Outflow Obstruction
- Large gravid uterus may obscure palpation of enlarged rumen

**Treatment**

**Free gas bloat (type I)**
- Treat underlying disease condition
  - TRP, pneumonia
- Screw-in rumen trocar or surgical rumenostomy may be needed
  - Normal function may return with time if bloat can be controlled

**Omasal transport failure (type II)**
- Treat underlying disease
- Decompress rumen via large bore orogastric tube
- Transfaunation
- Left flank exploratory laparotomy with rumenotomy
  - Remove penetrating foreign bodies by pulling back into reticulum
  - Drain abscess back into reticulum if firmly adhered to reticular wall
  - Remove foreign body/material from reticulorumen

**Pyloric outflow obstruction (type III)**
- Treat underlying disease
- Decompress rumen via large bore orogastric tube
- Correct dehydration, metabolic and acid-base abnormalities
  - IV fluid therapy
- Gastric motility modulation
  - Erythromycin
- Right flank exploratory laparotomy
  - Lymphosarcoma – euthanasia
- Left flank exploratory laparotomy with rumenotomy
  - Treat TRP/abscess as described above
  - Feed orogastric tube into abomasum via hand in the rumen
    - Administer DSS to help relieve abomasal impaction
    - Massage abomasum through rumen wall
- Abomasotomy to remove foreign bodies

**Indigestion of late pregnancy (type IV)**
- Induce parturition or caesarian section
- Repeated rumen decompression and supportive care until calving
Several infectious pathogens have the ability to cause infertility and/or abortion in cattle. The pathogens that commonly cause reproductive loss in cattle include bovine viral diarrhea virus (BVDV), bovine herpes virus-1 (BHV-1, also known as Infectious Bovine Rhinotracheitis or IBR), Leptospirosis, Campylobacter fetus subsp. venerealis, Tritrichomonas foetus, and Neospora caninum. Controlling and minimizing the effects of these pathogens requires sound herd biosecurity programs, one component of which is vaccination. The purpose of this paper is to briefly review the efficacy and safety of vaccination against reproductive pathogens in cattle.

**BVDV and BHV-1**

**Do vaccines provide a benefit**

Bovine viral diarrhea virus can effect reproduction in a variety of ways including alterations in ovarian function, early embryonic death, abortion, congenital defects, and the development of immunotolerant persistently infected (PI) calves. The most common reproductive effects of BHV-1 are alterations in ovarian function and mid to late-term abortion. The efficacy of vaccination to reduce the reproductive impact of these pathogens has been recently reviewed. This review found that vaccination against BVDV and BHV-1 consistently provided protection of the fetus from virulent challenge even though the protection is not 100% in all cases. In a recent meta-analysis of the published literature regarding vaccination against BVDV, Newcomer et al found a decrease in abortion rate of nearly 45% and a decrease in fetal infection of nearly 85% in vaccinated cattle versus non-vaccinated cohorts. The meta-analysis included 46 studies reported in 41 separate papers. In a large study involving four different experiments utilizing Brazilian cow-calf operations, Aono et al reported that vaccination against BVDV, BHV-1 and leptospirosis resulted in reduced pregnancy loss and/or increased pregnancy rate in vaccinates versus non vaccinated controls. Results varied between the different experiments included in the report. In a similar study, Pereira et al reported reduced pregnancy loss or increased pregnancy rate (depending on the experiment) in vaccinated versus non vaccinated Brazilian dairy cattle.

**Efficacy of modified live versus killed vaccines**

Among the many choices that producers and veterinarians must make when establishing a reproductive vaccine program is the choice of whether to use modified live virus (MLV) or inactivated/killed viral (KV) vaccines. There is general agreement the MLV vaccines provide a more robust and longer lasting immune response. Modified live vaccines also typically generate a stronger cell-mediated immune response. In contrast, KV vaccines are generally considered to have a wider margin of safety, especially in pregnant cattle.

Both types of vaccines can be efficacious when used correctly. Inactivated BHV-1 vaccine has been shown to provide protection against BHV-1 challenge. In this study, 3 of 21 vaccinates and 14 of 14 non-vaccinated controls aborted when challenged with virulent BHV-1 at approximately 180 days of gestation. Inactivated BVDV vaccine has been shown to provide fetal protection when pregnant heifers were commingled with BVDV persistently infected cows during gestation. Fetuses were harvested via caesarian at approximately 150 days of gestation. BVDV was isolated from 4 of 15 vaccinated heifers and 14 of 14 control heifers.

A single dose of MLV BHV-1 vaccine given at either 13 or 8 months prior to challenge has been shown to be effective. Abortion occurred in 1 of 13 heifers vaccinated 13 months prior to challenge, 3 of 19 heifers vaccinated 8 months prior to challenge, and 18 of 19 non-vaccinated controls. A single dose of MLV vaccine has been shown to protect fetuses from the development of BVDV persistent infection. In this study, 0 of 39 calves born to vaccinated heifers were PI while 18 of 19 calves born to control heifers were PI.

Administration of two doses of MLV vaccine containing both BVDV and BHV-1 prior to breeding has been shown to be protective against challenge via exposure to PI cattle and cattle acutely infected with BVDV-1. No vaccinated heifers aborted following BHV-1 challenge compared 4 of 10 controls. None of 19 calves from vaccinated heifers were BVDV PI compared to 10 of 10 fetuses or calves from control heifers.

Rodning et al compared two MLV vaccines and one KV vaccine for ability to prevent BVDV persistent infection. All heifers received four doses of the respective vaccine prior to breeding and were subsequently challenged by exposure to PI animals. Two of 18 calves produced by KV vaccinates were PI compared to 0 of 19 and 0 of 18 calves produced by the two MLV vaccinate groups. Ten of 10 calves produced by non-vaccinated control heifers were PI.

The previously mentioned meta-analysis published by Newcomer et al demonstrated that vaccination against BVDV reduced abortions by nearly 45% and fetal infection by nearly 85% compared to non-vaccinated controls. While both types of products provided better protection than no vaccination, the use of MLV vaccines was more effective at reducing the risk of abortion and fetal infection compared to the use of KV vaccines.
Bovine viral diarrhea virus exists in two distinct genotypes described as BVDV1 and BVDV2. While the genotypes are clinically indistinguishable, antigenic differences do exist. Effective cross protection between genotypes is variable. The use of vaccines containing both genotypes has been shown to be superior and is recommended. Fortunately, most currently available commercial vaccines contain both genotypes.

**Safety of modified live vaccines**

Vaccines against reproductive diseases are most commonly administered to beef cattle prior to breeding or during gestation when females are checked for pregnancy. There are advantages and disadvantages to each approach. Prebreeding vaccines provide peak immunity during conception and early pregnancy when most reproductive loss occurs but often require extra handling of the cattle in order to administer the vaccines. Administering vaccines at pregnancy diagnosis is more convenient since cattle are already being handled but the timing may not provide optimal immunity at the time of greatest risk. Regardless of the timing of administration of MLV vaccines, there are some safety concerns that should be considered.

Necrotic oophoritis has been reported following intravenous administration of MLV BHV-1 vaccines. Chiang et al reported decreased first service conception rates when heifers were given MLV BHV-1 vaccines at estrus compared with non-vaccinated controls. It is important to note the differences in conception rate reported in this study were numerically different but not statistically different. The difference in overall calving rate was statistically significant.

Infection of ovarian tissue by BVDV following administration of MLV vaccine has been demonstrated. Infection with BVDV following estrus has been shown to effect ovarian follicular dynamics. Perry et al investigated the effects of vaccination with either MLV or KV vaccines containing both BVDV and BHV-1 when naïve heifers were vaccinated at the start of synchronization for fixed time artificial insemination (FTAI). Heifers that received the MLV vaccine had reduced pregnancy rate and an increased number of abnormal estrus cycles compared to heifers receiving KV vaccine or non-vaccinated controls. It is important to note that the heifers in this study were naïve at the time of vaccination and that administering the vaccine at the start of synchronization for FTAI is an extra-label use of the vaccine. Label instructions for most MLV vaccines indicate that prebreeding vaccination should not occur within 28 days of breeding.

In more recent work, Walz et al found no difference in serum progesterone concentrations or pregnancy rates when primiparous, previously vaccinated, dairy cows were vaccinated 17 days prior to the start of an estrus synchronization-FTAI protocol. The reproductive effects of MLV vaccine administration prior to estrus synchronization in previously vaccinated heifers have been investigated. Revaccination was performed 10 or 31 days prior to synchronized natural breeding. No differences in duration of interestrus intervals, proportion exhibiting estrus within 5 days of synchronization, serum progesterone concentrations, pregnancy rates, and pregnancies within the first 5 days were observed. No BVDV or BHV-1 was isolated from luteal, ovarian, or fetal tissues harvested between 44 and 62 days of gestation.

Safety of MLV vaccines administered during pregnancy is a current topic of debate. Currently several products are labeled for use in pregnant cows. Label instructions indicate the females must receive at least one dose of the same MLV vaccine prior to breeding and have been vaccinated within the preceding year before receiving MLV vaccine during pregnancy. When label instructions are followed, vaccination with MLV vaccines during pregnancy has been shown to be safe. In one study, heifers vaccinated with KV vaccines twice as calves received MLV vaccine, KV vaccine or no vaccine at pregnancy check. Heifers were 60-120 days pregnant at the time of vaccination. One abortion occurred within each treatment group. Ellsworth et al reported the results of a large safety trial in which previously vaccinated heifers were vaccinated during pregnancy with 10 times the normal vaccine dose of MLV BVDV and BHV-1. Six of 11 BHV-1 seronegative controls (had not received prebreeding vaccine) aborted. Nine of 12 calves born to BVDV seronegative controls had precolostral antibody titers indicating inutero exposure to BVDV. ALL 59 previously vaccinated heifers delivered live healthy calves, 58 of which were negative for precolostral antibody titers (one calf nursed prior to sampling). The same report details the findings of three field trials in which previously vaccinated pregnant cows or heifers received MLV vaccine containing both BHV-1 and BVDV during the first, second, and third trimesters. No difference in abortion rate between vaccinates and controls were observed in any of the three trials.

Both BVDV and BHV-1 are important reproductive pathogens in cattle. When used correctly, vaccines can be an effective part of an effective biosecurity program. Both MLV and KV vaccines are effective although MLV vaccines are preferred. Administration of MLV vaccines prebreeding or during pregnancy appears to be safe as long as the animals have been previously vaccinated according to label directions.

**Leptospirosis**

Leptospirosis is an important bacterial disease of cattle. Reproductive consequences of Leptospira infections include abortions, stillbirths, early embryonic death and infertility. Non-reproductive manifestations of Leptospira infection include septicemia and nephritis. Leptospirosis is also an important zoonotic pathogen. Leptospira taxonomy is extremely complex and confusing. Leptospira are divided based on genetic sequencing with at least 16 genomespecies identified. Approximately 200 serovars of Leptospira have been identified. Leptospira serovars are typically associated with one or more maintenance hosts and prevalence.
varies with geography. Leptospira serovars host adapted to cattle include \textit{Leptospira interrogans} serovar hardjo (type hardjoprajitno) and \textit{Leptospira borgpetersenii} serovar hardjo (type hardjo-bovis). Serovar hardjo type hardjo-bovis is found in cattle throughout the world and serovar hardjo type hardjoprajitno is typically found in cattle in the United Kingdom. Other serovars commonly associated with disease in cattle include pomona and grippotyphosa. Serovar hardjo is host adapted to cattle causing chronic infections of the renal and reproductive systems. Results of reproductive infection generally include infertility, early embryonic death and sporadic abortions. Serovar hardo type hardjo-bovis is the most common cause of Leptospirosis in cattle in the United States. Infections with other serovars such as pomona tend to cause late term abortions occasionally occurring in abortion storms.

Traditional pentavalent leptospira vaccines used in cattle in the United States include hardjo (type hardjoprajitno), pomona, canicola, grippotyphosa, and icterohaemorrhagiae. These vaccines can provide good protection against serovars contained within the vaccine other than hardjo but traditionally have not provided adequate protection against hardjo. However, one recent study demonstrated that administration of pentavalent vaccine containing hardjo type hardjoprajitno was effective at protecting 6 month old heifers from experimental challenge with hardjo type hardjo-bovis. Leptospira vaccines are bacterins and therefore require appropriate boosters when initially administered. Once the initial series of vaccines has been properly administered, once yearly boosters are usually adequate although more frequent boosters may be required in some areas.

Monovalent vaccines specifically targeting serovar hardjo type hardjo-bovis are available. These vaccines produce a strong cell mediated immune response and have been shown to be effective at preventing colonization of the renal and reproductive systems in experimentally challenged animals. Vaccination of calves as young as 4 weeks old has been shown to be protective against experimental challenge when challenge occurs up to 12 months after vaccination. Multiple vaccines containing serovar hardjo type hard-bovis are currently available in monovalent forms or in combination with pentavalent leptospira vaccines.

Although several studies have shown that vaccines containing serovar hardjo type hardjo-bovis are effective against experimental challenge, efficacy in field trials remains questionable. In a large study of beef cow-calf herds, administration of a monovalent hardjo-bovis vaccine along with oxytetracycline did not significantly improve reproductive performance. Similarly, a large study conducted in a commercial dairy in California failed to demonstrate an improvement in reproductive efficiency or a reduction in urine shedding when cows received two doses of a monovalent hardjo-bovis vaccine along with oxytetracycline.

Leptospirosis remains an important reproductive disease of cattle with \textit{L. borgpetersenii} serovar hardjo type hardjo-bovis being the most important Leptospira pathogen of cattle in the United States. Vaccines containing serovar hardjo type hardjo-bovis have been shown to be highly effective at protecting cattle against experimental challenge but efficacy in field trial settings remains questionable. At least one pentavalent vaccine containing serovar hardjo type hardjoprajitno has been shown to protect cattle against experimental challenge with type hardjo-bovis.

**Campylobacter fetus subsp. venerealis (Vibrio)**

Vibriosis is a venereally transmitted disease of cattle causing transient infertility, early embryonic death or abortion. Infection generally does not produce any outward signs of infection in bulls and the only signs in cows are related to decreased reproductive efficiency. Vaccines targeting \textit{C. fetus} subsp. \textit{venerealis} are available in oil adjuvanted and aluminum hydroxide absorbed types. Oil adjuvanted vaccines are considered more effective particularly if only one dose is administered. Vaccination is generally effective if administered prior to breeding and appropriate boosters are given when an animal is first vaccinated. The response to vaccination against \textit{C. fetus} subsp. \textit{Venerealis} has been recently reviewed. It has been recommended that bulls receive 2.5 times the normal dose of oil adjuvanted vaccine prior to breeding to produce protective immunity. There is some evidence that vaccination is effective in the treatment of infected bulls.

**Tritrichomonas foetus**

\textit{T. foetus} is a protozoal pathogen responsible for infertility, early embryonic death and abortion in cattle. Transmission is venereal. Infected bulls serve as the reservoir in most situations. Diagnosis and management of \textit{T. foetus} infection is somewhat complicated and has been recently reviewed. There is currently one commercially available vaccine for \textit{T. foetus} in the United States. The vaccine is labeled for use in cows and claims to reducing shedding of the organism. Vaccination against \textit{T. foetus} has been described in recent reviews as being effective for prevention of infection and treatment of infection in bulls. However, a recent meta-analysis of the published literature concluded that the quantity and quality of the published literature was insufficient to make conclusions regarding the efficacy of the vaccine. Vaccination against \textit{T. foetus} appears to be most useful when working to clear up an infected herd or when other risk factors for \textit{T. foetus} transmission cannot be fully controlled.

**Neospora caninum**

\textit{Neospora caninum} is a protozoal pathogen that can cause abortion in cattle. Cattle are incidental hosts and become infected when feed is contaminated with canine feces. Vertical transmission via transplacental infection can also occur in cattle. The diagnosis and control of Neosporosis in cattle has been recently reviewed. A vaccine for \textit{N. caninum} was previously available but it was not effective and is no longer on the market. Currently there are no effective vaccines for \textit{N. caninum} available in the United States.


Preputial injuries are common in bulls and can have a serious impact on the overall productivity of a cow herd. In single sire settings, preputial injury may have a significant impact on pregnancy rates if a bull is no longer able to breed cows successfully and a replacement is not provided quickly enough. Producers often make considerable investments in bulls as a primary way to improve the genetics of a herd and significant economic loss can be incurred due to serious preputial injury.

Preputial injury occurs most commonly in pasture breeding situations but can also occur in bulls housed in artificial insemination studs. Injury may occur during the breeding process or may result from habitual prolapse and subsequent trauma. Bos indicus influenced breeds are more likely to experience preputial injury due to their tendency for habitual prolapse. Anatomic factors such as a pendulous sheath, a longer prepuce and a larger preputial orifice lead to habitual prolapse in these bulls. Although less frequent, Bos taurus breeds commonly experience preputial injury. Polled bulls tend to have poorly developed preputial retractor muscles making them more prone to habitual prolapse. Breeding accidents can occur in bulls of any breed.

If the bull is able to retract the prepuce into the sheath following injury, the injury may not be noticed for several days. It is typical for these injuries to be several days old when they are presented for veterinary care. The types of injuries include laceration, avulsions, and abscess formation. Any of these injuries may be complicated by significant edema and/or infection. Preputial injury in bulls has been reviewed.1,2

Preputial laceration
Laceration is probably the most common type of preputial injury. Lacerations may occur as a direct breeding injury or may occur secondary to preputial prolapse. Most lacerations occur on the ventral aspect of the prepuce. Most lacerations are not discovered acutely and are usually complicated by edema and infection. As the prepuce swells, prolapse tends to occur making the injury easier to see. If the swelling continues, paraphimosis may develop and the bull will not be able to retract the prepuce back into the sheath. This sets up a vicious cycle as the edema worsens due to gravity and further injury may occur. In cold climates, the prolapsed prepuce is highly susceptible to frostbite. If a preputial laceration occurs during the breeding season, the bull must be replaced because he will not be available for the current breeding season regardless of what treatment he undergoes.

The primary goals of initial treatment of this type of injury are to control infection and edema and get the prepuce placed back into the sheath where it will be protected. In many cases the prepuce is markedly swollen and dirty. To facilitate adequate examination, soaking the prepuce in warm water with a mild disinfectant may be useful. This will help remove scabs and other debris making examination easier. Warm water hydrotherapy for 20-30 minutes and massage may help reduce edema enough to get the prepuce back into the sheath. If the prepuce cannot be placed back into the sheath, it must be protected with a bandage. Support from some type of sling may also be useful by holding the prepuce close to the ventral abdominal wall to reduce the development of dependent edema. A soft plastic tube should be inserted into the preputial lumen to facilitate urination. The tube should be soft and flexible to prevent iatrogenic injury but must be rigid enough to maintain patency under a pressure bandage. A section of nasogastric tube or milking unit tubing will work well. The cut edges should be smoothed and adding multiple fenestrations to one end will facilitate urine flow. In addition to providing for urine flow, the tube can serve as a rigid structure to facilitate the placement of a pressure bandage. Bandaging the prepuce under moderate pressure will help reduce the edema more quickly. Prior to placing the bandage, a disinfecting ointment or emollient should be massaged into the prepuce taking care not to get the ointment on the hair. A mixture of anhydrous lanolin, scarlet oil and oxytetracycline works well. The bandage should be changed and the prepuce massaged daily until it can be placed back into the sheath. Broad spectrum antibiotics and anti-inflammatory therapy should be provided as needed.

Once the prepuce is back in the sheath, it should be retained there and allowed to heal for several days. The easiest method of retaining the prepuce is with a bandage. A tube is placed in the preputial lumen as previously described. Ideally, the tube should extend past the proximal aspect of the laceration to minimize urine contamination. Elastikon® is applied to the tube while the tube is clean and dry. The tube is then lubricated with ointment and placed in the preputial lumen. The tube should be inserted up to the previously applied Elastikon®. The Elastikon® is then wrapped onto the haired skin to hold the tube in place. For protection, the bandage is then covered with white athletic tape. It is critical not to get any of the ointment on the haired skin so that the tape will stick. If necessary, the top edge of the bandage can be sutured to the skin with a few interrupted sutures. The bandage is left in place for 7-10 days to give the prepuce a chance to heal. As an alternative to a bandage, a purse-string suture may be placed in the preputial orifice. The skin should be thoroughly cleaned to help prevent infection.

After 7-10 days, the prepuce should remain retracted into the sheath. If it does not, the bandage or purse-string should be replaced. If the prepuce is damaged too badly to save or if the owner elects to salvage the bull, amputation of the prepuce is a good option. A rigid plastic tube is placed in the preputial lumen and a rubber ring is placed around the prepuce proximal to the affected area. A
The prognosis for return to breeding soundness is generally good. Preputial fornix. The swelling is similar in appearance to that seen with a penile hematoma but it is located more distally. Significant occurs with lacerations or other injuries that occur near the fornix. Most affected bulls have a characteristic swelling at the level of the preputial tissue. If infection remains or healing is not complete, surgical intervention should be delayed. Preputial length becomes an issue for some bulls. In order to have the highest chance of returning to breeding soundness, the length of healthy prepuce remaining after surgery should be at least twice the length of the free end of the glans. Proximity of the injury to the hairline is also important. There should be at least 4-5 cm of healthy prepuce between the hair line and the site of the injury. If not, there is a greater chance of post surgical complications. Once a bull has been deemed a good surgical candidate, the surgical procedure must be chosen. Surgical options include circumcision and preputial resection and anastomosis or reefing. Both surgical options can be performed under heavy sedation and local anesthesia or on a rotating chute with local anesthesia but general anesthesia is preferred. Circumcision is quicker and easier to perform, is less expensive, and can potentially be performed before the lesion is completely healed. However, the risk of postoperative stricture is greater with circumcision than resection. Circumcision is performed with the penis retracted within the sheath. A rigid plastic tube is placed in the preputial lumen. Two rows of absorbable overlapping horizontal mattress sutures are placed through both layers of preputial mucosa. The sutures are placed around the full circumference of the prepuce. All sutures may be placed prior to cutting or the surgeon may proceed in a “cut and sew” fashion. The prepuce is then transected distal to the rows of suture. The exposed edges of preputial mucosa are then apposed using a simple continuous pattern. Topical antibiotic is applied and a bandage or purse-string suture is placed to prevent prolapse. Preputial resection and anastomosis, also called reefing, is the preferred option in most cases. The prognosis for return to breeding soundness is higher following reefing than with circumcision. Preputial resection is performed with the penis extended. After aseptic preparation, a circumferential incision is made both distal and proximal to the affected area. Marker sutures should be placed both distal and proximal to the affected area to ensure proper alignment during the anastomosis. Care should be taken to insure, as much as possible, that adequate length of healthy prepuce is left. Incisions are extended through the preputial mucosa to the superficial layers of elastic tissue. A third longitudinal incision is made connecting first two incisions. The lesion and associated fibrous tissue are then removed. The mucosa is then apposed using absorbable suture in a simple interrupted or horizontal mattress pattern. A Penrose drain is then sutured over the tip of the glans to protect the incision from urine. Topical antibiotic is applied to the incision and the penis is allowed to retract back into the sheath. A bandage or purse-string suture is placed to prevent prolapse. A scar revision surgical technique has recently been described. It is reported that this technique may be better suited to bulls that have a limited length of healthy prepuce tissue remaining. In short, an elliptical incision is made around the scar and the scar removed. The defect is then closed longitudinally using a bootlace suture pattern. Postoperative care is similar regardless of the surgical technique used. Systemic antibiotics are provided for 5-7 days along with appropriate anti-inflammatory therapy. The bandage or purse-string can usually be removed in a few days as long as prolapse does not occur. Complete sexual rest is required for at least 6-8 weeks, at which time the bull should be evaluated for breeding soundness. The prognosis for return to breeding soundness is generally good.

Preputial avulsion
Preputial avulsion is a breeding injury that occurs most commonly during semen collection with an artificial vagina. If the prepuce sticks to the inside of the AV when the bull thrusts during ejaculation, the prepuce may tear at the fornix. Occasionally the tear may encompass the full circumference of the prepuce. These injuries are usually noticed immediately. Primary closure following cleaning and debridement is usually an option for these injuries. If the injury is too old for primary closure, treatment is similar to that described for a preputial laceration. If left untreated, a preputial abscess may develop. Prognosis is generally good following primary closure and 3-4 weeks of sexual rest.

Preputial abscess
Abscessation may develop any time the injured prepuce is retracted into the sheath and the injury is not noticed. This most commonly occurs with lacerations or other injuries that occur near the fornix. Most affected bulls have a characteristic swelling at the level of the preputial fornix. The swelling is similar in appearance to that seen with a penile hematoma but it is located more distally. Significant

Callicrate® bander or similar instrument works well. This effectively strangulates the distal portion of the prepuce causing it to slough. Bulls treated in this manner will likely develop a stricture at the amputation site. If needed, a preputial resection can be performed at a later date. Amputation can also be used to improve the salvage value of a bull that is going to be sold.

The bull should be reevaluated in 4-6 weeks to assess the condition of the prepuce. At this time, the determination can be made as to whether surgery will be required. More than 50% of bulls with significant lacerations will heal and not require surgery when given appropriate medical treatment and enough time. If the penis will extend normally, the bull is likely to be functional without undergoing surgery. There will likely be some scar tissue present at the laceration site. The owner should be cautioned that there is an increased risk of a second laceration because this fibrous tissue is less elastic than normal preputial tissue.

Indications for surgical intervention include persistent prolapse, preputial stricture, and phimosis. Occasionally an owner will request prophylactic surgery for a bull that is not injured but might be at high risk for preputial injury. Presurgical evaluation should include an assessment of tissue health, prepuce length, and proximity of the injury to the hairline. Surgery should be performed on healthy tissue. If infection remains or healing is not complete, surgical intervention should be delayed. Prepuce length becomes an issue for some bulls. In order to have the highest chance of returning to breeding soundness, the length of healthy prepuce remaining after surgery should be at least twice the length of the free end of the glans. Proximity of the injury to the hairline is also important. There should be at least 4-5 cm of healthy prepuce between the hair line and the site of the injury. If not, there is a greater chance of post surgical complications. Once a bull has been deemed a good surgical candidate, the surgical procedure must be chosen. Surgical options include circumcision and preputial resection and anastomosis or reefing. Both surgical options can be performed under heavy sedation and local anesthesia or on a rotating chute with local anesthesia but general anesthesia is preferred.

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cellulitis may be present. Drainage through the prepuce may be attempted by passing a rigid pipette through the preputial orifice to the fornix and penetrating into the abscess. Even though the abscess is subcutaneous, drainage through the skin is unlikely to be successful because adhesions will develop that will prevent extension of the penis. Antibiotics and anti-inflammatory therapy are indicated. Prognosis for return to breeding soundness is generally poor due to adhesion formation and immediate salvage may be the best option if severe cellulitis is not present. Recovered bulls could be used for semen collection for artificial insemination.

References
Effective management of pain resulting from husbandry practices or disease is a major challenge for food animal practitioners. The challenge is exacerbated by growing concern among consumers of food animal products about pain experienced by livestock animals. That concern is most notable regarding pain caused by routine husbandry practices such as castration and dehorning. In response to growing concern among consumers, producers, and veterinarians about pain experienced by livestock animals, considerable research has been conducted on the topic of pain alleviation over the past several years. A complete review of the published literature regarding pain in livestock is beyond the scope of this document. However, readers are referred to the March 2013 issue of the Veterinary Clinics of North America: Food Animal Practice for a very thorough review of the literature relative to this topic. That issue can be accessed online at http://www.vetfood.theclinics.com/issue/S0749-0720(13)X0002-7.

Challenges to effective analgesia
One of the biggest challenges to providing effective analgesia to food animals is the lack of Food and Drug Administration (FDA) approved medications for pain relief for food animals. Currently there are no medications labeled for analgesia in food animals in the United States.1 Flunixin meglumine is labeled for use in cattle for treatment of inflammation due to a variety of disease processes but it is not labeled for analgesia. Since there are no medications approved for analgesia in food animals, administration of any medication for the purpose of analgesia requires Extra-Label Drug Use (ELDU). In order for ELDU use to be legal, it must occur by or on the order of a veterinarian within the confines of a valid Veterinary Client Patient Relationship (VCPR). Readers are referred to the practice act for their respective state for clarification of what constitutes a VCPR. Food animal veterinarians perform ELDU routinely, if not daily, so this should not prevent veterinarians from prescribing medications for the purpose of analgesia.

A primary reason that there are no medications approved for analgesia in food animals is that there is no consistent, reliable, repeatable way to measure pain in livestock species. Researchers have used a variety of methods to assess pain. Measurement of serum cortisol has been the traditional method used to assess pain response. Cortisol increases in response to pain but the response can be variable and other stimuli can affect the cortisol response. Other techniques for assessing pain in food animals include measurement of acute phase proteins such as substance P and haptoglobin, assessment of behavioral changes, heart rate or heart rate variability, assessment of feed intake and average daily gain, and even measurement of skin temperature. Techniques for assessing pain are being refined and new ones are being developed. Methods of assessing pain in food animals are discussed in detail in several recent review articles.2-4

Cost is cited as another common reason that analgesic drugs are not used in food animals. Costs can be measured in terms of actual costs of the medications or in terms the time required to appropriately administer analgesic medications. Many producers perform common husbandry practices such as castration and dehorning themselves. Involving a veterinarian to meet the requirements of ELDU can result in additional costs as well.

The idea that pain reduces animal performance is well documented in the literature. It is logical that providing analgesia should improve animal performance thereby offsetting at least some of the costs of providing the analgesia. While few studies have been able to document a significant improvement in performance attributable to the provision of analgesia for practices such as castration and dehorning, recent studies have shown improvements in health and average daily gain (ADG) when analgesia is provided at the time of castration.5,6 In a very recent abstract, Roberts et al2 investigated castration, castration + meloxicam and no castration (controls) in 3 month old beef calves. Calves castrated with meloxicam had decreased ADG for 2 weeks post castration compared to castrated calves receiving meloxicam and non-castrated controls.

Motivations for providing analgesia
Veterinarians and producers may have different motivations for providing analgesia to food animals. Possible motivations include improving animal performance, improving animal health, and improving animal welfare. As mentioned above, the evidence for improved performance or health attributable to analgesia is limited. The primary force driving consumer concerns about pain in food animals is concern about the impacts of pain on animal welfare. Improving animal welfare should be a motivating force for veterinarians and producers as well. Even in the absence of improved performance, improving welfare is justification for the adoption of analgesic practices in food animal production. In fact, providing analgesia for painful practices may become simply a cost of doing business in order to maintain access to markets and to maintain consumer demand for food animal products. Producers and veterinarians should be proactive in the adoption of practical analgesic practices in an effort to improve the welfare of livestock animals.
Preemptive analgesia
Preemptive analgesia is the concept of providing analgesia prior to the onset of a painful stimulus. Preemptive analgesia is often more effective than analgesia occurring after pain is perceived. While preemptive analgesia is not always possible, it can be effectively provided for procedures such as dehorning, castration and other elective or planned surgical procedures.

Multimodal analgesia
Multimodal analgesia is the application of multiple analgesic treatments, typically with different mechanisms of action. Multimodal analgesia is generally more effective than single analgesic treatments and is discussed in more detail later in this document.

Commonly used analgesic drugs
Food animal veterinarians have access to numerous drugs that have analgesic properties. These drugs include local anesthetics, non-steroidal anti-inflammatory drugs (NSAIDs), opioids, α2-agonists, and N-methyl-D-aspartate receptor antagonists (Ketamine). Gabapentin is another drug that may be useful for analgesia in some situations. Excellent reviews of the analgesic drugs available for use in food animals have been recently published. Table 1 at the end of this document lists commonly used analgesic drugs along with doses, routes of administration and withdrawal times.

Application of analgesia in food animal practice
The following provides a brief discussion of practical ways to provide analgesia in common food animal practice situations.

Castration
Studies investigating analgesia for castration are numerous and an excellent review of the topic has been recently published. Readers are referred to this review for a detailed review of the published literature.

Local anesthesia for castration can be provided in multiple ways. Lidocaine can be injected directly into the testicle or into the spermatic cord. The dose for intratesticular injection varies depending on the size of the testicle. The author typically injects 2-10 mls directly into each testicle. There is a notable increase in injection pressure and an increase in firmness of the testicle as the tunics fill with lidocaine. The author stops the injection once the testicle feels full. Injection of 5-10 mls of lidocaine directly into each spermatic cord can also be effective. Injection into the spermatic cord has the advantage of blocking the cremaster muscle which is not blocked with intratesticular injection. Subcutaneous infiltration of lidocaine into the distal aspect of the scrotum can be helpful for anesthetizing the skin at the site of the scrotal incision.

Local anesthesia has been shown to reduce the acute cortisol response associated with castration but the overall area under the curve for cortisol concentration was only modestly reduced. This suggests that the effects of local anesthesia are short lived. Administration of an NSAID has been shown to be beneficial for alleviating pain associated with castration. Administration of an NSAID prior to castration does not abolish the acute cortisol response but the total area under the curve is reduced to a greater extent than that seen with local anesthetics alone. Unfortunately, many study protocols resulted in the NSAID being administered 20 minutes or more prior to the castration procedure which makes application of those study findings difficult.

The combination of local anesthesia and NSAID resulted in the greatest reduction in the total area under the curve for cortisol concentration post castration suggesting that multimodal therapy is more effective than either therapy administered alone. More recent studies support this finding as well.

It is often recommended that calves be castrated as early as possible to reduce the negative effects of castration. Powell et al recently demonstrated the benefits of early castration on average daily gain at weaning. Calves castrated at birth had higher post weaning ADG than calves castrated at weaning. When calves castrated at weaning were given a single dose of meloxicam, ADG was improved compared to calves not receiving meloxicam. Additionally, calves castrated at weaning demonstrated altered immune function. Meloxicam administered at weaning reduced haptoglobin concentrations compared to calves that did not receive meloxicam. These findings are consistent with those published by Coetzee et al demonstrating a decrease in the incidence of respiratory disease when calves received meloxicam prior to castration when entering the feedlot.

Dehorning
Studies investigating the effects of various analgesic treatments for alleviation of pain associated with dehorning are numerous. For a detailed review of the literature, readers are referred to an excellent recent review by Stock and colleagues.

Unlike castration, a simple nerve block can provide complete anesthesia of the horn in young calves. Local anesthesia has been shown to alleviate the initial rise in cortisol concentrations observed when calves are dehorned without anesthesia. The cornual nerve block is performed by injecting 5-10 mls of lidocaine subcutaneously just ventral to the temporal ridge of the frontal bone at a point halfway between the lateral canthus of the eye and the horn. With larger horns, a partial ring block may need to be performed on the caudal aspect of the horn to achieve complete anesthesia. A successful cornual nerve block alleviates the pain associated with the dehorning procedure and also makes the procedure easier for the operator.

Provision of an NSAID has been shown to be useful to help alleviate the pain associated with dehorning once the effects of the cornual nerve block wear off. Several studies have demonstrated a delayed rise in cortisol once the effects of local anesthesia have
subsided. This delayed cortisol peak can be attenuated by administration of an NSAID. As with castration, many study protocols administer the NSAID 20 minutes prior to dehorning making application of the results difficult. More recent work with meloxicam administered at the time of dehorning has demonstrated a positive effect.14

Sedation may also be useful for providing analgesia during dehorning. Whenever possible a multimodal approach to analgesia including local anesthesia, NSAIDs and sedation (if possible) is recommended.13

Lameness

The provision of analgesia for lameness has been recently reviewed.15 Providing effective analgesia for lameness is challenging because lameness is often chronic by the time the animal is presented for veterinary care. Chronic pain is less responsive to analgesic compounds due to central sensitization and wind up.8 Alleviation of the inciting cause of lameness is critical for alleviation pain. Corrective claw trimming and the application of claw blocks are useful in the alleviation of pain in many causes of lameness.15

Local anesthesia of the distal limb via regional intravenous anesthesia is a simple and effective method for providing analgesia during painful claw procedures or digital surgery. Briefly, a tourniquet is placed proximal to the area to be anesthetized, most commonly over the middle of the metacarpus or metatarsus. Lidocaine (20-30 mls) is then infused into any accessible vein distal to the tourniquet. The dorsal common digital vein is used most commonly but the abaxial sesamoid veins can be used as well. The procedure will provide complete anesthesia of the limb distal to the tourniquet. The author has left tourniquets in place for 30-45 minutes with no adverse effects.

Published reports of studies investigating analgesia for lameness are scarce. Listed below are a few studies demonstrating beneficial effects of analgesia for lameness in cattle.

**Chapinal N et al. J Dair Sci, 93 2010 pp. 3039-3046**16
- Flunixin meglumine (2.2 mg/kg IV) administered immediately before corrective hoof trimming and 24 hours later
- No difference in gait scores but untreated cows spent more time lying down compared to treated cows

- Induced lameness model using intraarticular amphotericin B
- Flunixin meglumine (1 mg/kg IV) at the time of lameness induction and 12 hours later
- Treated calves had improved lameness scores and reduced recumbency compared to untreated controls

**Coetzee JF et al. J Anim Sci, 92 2014 pp. 816-829**18
- Induced lameness model using intraarticular amphotericin B
- Treatments included placebo, meloxicam (0.5 mg/kg PO), or meloxicam + gabapentin (15mg/kg PO) administered 4 hours after lameness induction and repeated once daily for 4 days.
- Meloxicam alone or with gabapentin reduced lameness severity in the experimental model

**Surgical Pain**

Whenever possible preemptive analgesia should be employed to manage pain associated with surgery.8 Since most bovine surgery is performed with the animal awake, clinicians must have a good grasp of local and regional anesthetic techniques. Reviewing these techniques is beyond the scope of this paper but an excellent review of common techniques has been recently published.8 Local anesthetics and NSAIDs are commonly used to provide intra- and post-operative analgesia. Opioids such as morphine or butorphanol are commonly used for post-op analgesia in the author’s clinic.

**Obstetrical Pain**

Published studies investigating the use of analgesia are scarce. It seems plausible that providing analgesia, particularly following a difficult dystocia, would be beneficial to the cow but data on which to base those decisions is lacking. In a recent review on the topic, Laven et al.22 concluded that available data on the use of NSAIDs post calving was insufficient to allow formulation of recommendations regarding NSAID use. The authors concluded that more research on the subject was needed. Also, there is some evidence that periparturient administration of NSAIDs may lead to an increased incidence of retained placenta. The studies listed below demonstrate some of the recent work investigating the periparturient use of NSAIDs.

**Newby NC et al. J of Dair Sci, 96(6) 2013 pp. 3682-3688**20
- Meloxicam administered 24 hours post calving (0.5 mg/kg of body weight)
- No difference in dry matter intake, milk production, blood metabolites, or health events
- Meloxicam increased feeding time and the frequency of bunk visits for 24 following injection

- No difference in the incidence of retained placenta in meloxicam treated versus untreated controls

**Stilwell G et al. J Dair Sci, 97 2014 pp. 888-891**22
- Carprofen (1.4 mg/kg IV) administered immediately after calving
- Treated cows spent more time eating in the 24 hours after calving
- 305 day milk yield was higher in primiparous cows treated with carprofen
- Carprofen treatment increased the time from calving to conception
References

In order to improve productivity and profitability of a beef cow enterprise, an assessment of productivity based on production records must be performed. According to the 2007-2008 National Animal Health Monitoring System Beef Cow-Calf Report, over 83% of all beef cow/calf operations maintained some form of production records. In herds with more than 100 cows, the percentage increased to 90%. Just keeping records is of little value to the beef producer. For records to be useful, the data must be summarized and analyzed to aid in making management decisions that will affect the overall productivity of the operation. Analysis and interpretation of production records is a valuable service veterinary practitioners can provide to their clients.

Analysis of beef cow/calf production records does not have to be complex to be useful. Numerous record keeping software systems are commercially available. Most of these programs will conduct routine analysis procedures and provide a report to the user. Additionally, simple spreadsheet program can be used to conduct most of the useful calculations.

Production records analysis has two broad goals. The first is to evaluate the productivity of the cow/calf operation as a whole. This is done in an effort to identify areas where the operation is doing well and, more importantly, areas where changes might be made to increase the productivity of the herd. The second goal is to evaluate the performance of individuals within the herd to aid in selection and culling decisions. Selection and culling decisions are often based on visual appraisal which may not provide an accurate assessment of an animal’s true productive capacity.

The goal of this paper is to review the process of production records analysis for parameters that have a significant effect on the productivity of an operation. It will not include a complete discussion of all possible analysis techniques but will focus on those that are easy to obtain and use. For additional information, the reader is referred to a recently published review on this topic. Beef cow/calf production records are typically divided into three categories: breeding, calving, and weaning.

Evaluation of breeding records
Breeding and pregnancy performance is measured by several indices. The denominator used in calculation of most of these indices is the number of cows exposed to a breeding opportunity. It is important to accurately determine this number prior to calculating performance indices. In order to insure accuracy, a few adjustments may have to be made to arrive at the actual number of females exposed to a breeding opportunity. Any exposed pregnant females sold or transferred out of the herd prior to pregnancy diagnosis should be subtracted. Any exposed females or pairs purchased prior to pregnancy diagnosis should be included. Exposed females that die prior to pregnancy diagnosis should be included. Any exposed females that are intended to be sold but remain in the exposed female herd are subtracted from the number exposed when they are sold.

Pregnancy percentage
- Calculated as the number of exposed females diagnosed as pregnant divided by the number of exposed females X 100
- May also be measured by strata of interest such as cow age, body condition score, service sire, etc.
- Key points
  - Year-to-year variation will occur due to environmental stresses
  - This value should only be used in comparisons with similar operations
  - A low value may indicate a problem but it does not identify the cause of the problem
- Targets: 90-95% for cows with a 60 day breeding season, 80-85% for heifers with a 45 day breeding season

Time to conception
- Determines how quickly cows become pregnant after being exposed to a breeding opportunity
- Requires accurate estimation of gestational age at pregnancy diagnosis in natural service herds.
- Determined using the beginning exposure date and the days pregnant on the day of examination
- Allows creation of a pregnancy rate distribution

Pregnancy rate distribution
- Visualized using a simple histogram
- Distribution interval determined by evaluator (1 week, 2 week, etc)
- Most common to break the breeding season into 21 day periods
- May be stratified according to parameter of interest
- Ideal distribution is strongly left skewed indicating that a high proportion of cows became pregnant early in the breeding season
- Should expect 60-65% of the herd to become pregnant in the first 21 days if cows and bulls are fertile at the beginning of the breeding season
Flat or right skewed distribution may indicate delayed estrus or the presence of an infectious disease causing early embryonic death.

An excellent review of interpretation of pregnancy rate distribution has recently been published.2

**Pregnancy loss percentage or abortion percentage**
- Calculated as the number of cows that are diagnosed pregnant but fail to calve divided by the number of cows diagnosed as pregnant X 100
- May be stratified according to parameters of interest (cow age, body condition score, management group)
- Target: Less than 2%2

**Evaluation of calving records**
The denominator for many of the gestation and calving performance indices is the number of cows exposed to a breeding opportunity. To insure accuracy, this number should be carefully derived as described above.

**Calving percentage**
- Calculated as the number of females calving divided by the number of females exposed X 100
- Is a good measure of breeding performance and gestational management
- Directly related to pregnancy percentage and pregnancy loss percentage
- Key points
  - May indicate that a problem exists but does not identify the cause
  - Year-to-year variation should be expected
  - Does not describe the calving distribution
- Target: 80-85%, National average reported as 91.5% in NAHMS 07-08 Beef Report.

**Pregnancy loss percentage or abortion percentage**
- See description above

**Calving distribution**
- Cumulative number of calves born by 21, 42, 63, and >63 days of the calving season divided by the total number of calves born X 100
- Beginning of the calving season is 285 days after bulls were first introduced or the date on which the 3rd mature cow calves
- Should closely mirror the pregnancy rate distribution with the ideal distribution being strongly skewed to the left indicating that a high proportion of calves were born early in the calving season
- Viewed a simple histogram
- Targets: 60-65% born in 1st 21 days, 85-90% born by 42 days, 100% born by 63 days
- May be stratified according to parameters of interest

**Calf death loss**
- Based on cows exposed: calculated as number of calves that died divided by the number of cows exposed X 100
- Based on calves born: Calculated as number of calves that died divided by the number of calves that were born X 100
- May indicate deficiencies in herd health, calving environment, nutrition, or breeding program
- Includes all calf deaths from birth to weaning
- Does not distinguish between calf deaths at birth versus during the suckling period

**Calving interval**
- Period from the birth of one calf until the birth of the next calf
- Target: 12 months

**Evaluation of weaning records**

**Calf crop or weaning percentage**
- Calculated as the number of calves weaned divided by the number of cows exposed X 100
- Encompasses breeding, gestation, birth, and rearing the calf
- Any calves purchased prior to weaning should not be included
- Target: >75%

**Measures of calf weight**
- Actual weaning weight
  - Calculated as total weight of weaned calves divided by the number of weaned calves
  - Usually stratified by contemporary group (bulls, steers, heifers)
  - Not standardized for a given age
  - Not useful for comparisons between operations due to differences in environment and management
Target: 40% of cow’s mature weight

- National average reported as 559 lbs for bulls and steers and 515 lbs for heifers

- Weight per day of age
  - Calculated as calf’s weaning weight minus the birth weight divided by age in days at weaning
  - Allows standardized comparisons between calves of different ages

- Adjusted 205 day weaning weight
  - Calculated by multiplying weight per day of age by 205 and adding birth weight
  - Allows standardized comparisons between calves of different ages

- Each of these measures are typically evaluated as averages for a given contemporary group

### Calf death loss

- See calculation described above
- May be stratified as time of death relative to calf age

### Overall measure of herd performance

#### Pounds of calf weaned per cow exposed

- Calculated as total pounds of calf weaned divided by the number of cows exposed
- Non-specific single index of performance of the cow herd
- May provide a single year-to-year index of herd performance
- Some year-to-year variation should be expected

### Measures of individual animal performance

The indices described above evaluate performance of the cow herd as a whole. Objective evaluation of individuals within the herd is also necessary for the purposes of selecting animals as replacements, making breeding decisions, and making culling decisions.

Comparisons of individual animals within their contemporary groups are usually made by the use of ratios. Ratios provide an evaluation of an individual’s performance relative to the average performance of their contemporary group. For example, adjusted weaning weight ratio is calculated as an individual’s adjusted 205 day weaning weight divided by the average adjusted 205 day weight of the contemporary group and the result is multiplied by 100. A calf with a weaning weight ratio of 100 is average for the group. A ratio of 110 indicates that that calf’s performance was 10% better than the average for his contemporaries.

### Most probable producing ability

- Measure that allows accurate comparison of future production potential for cows with different numbers of progeny
- Can be calculated for various traits
- Calculated according to the following equation (weaning weight example):
  \[ MPPA = H + \left[ \frac{NR}{1 + (N-1)R} \right] \times (C-H) \]

- Where: \( H \) = herd average weaning weight ratio
- \( N \) = number of calves included in the cow’s average
- \( R \) = 0.4, the repeatability factor for weaning weight ratio
- \( C \) = average weaning weight ratio for all calves the cow has produced
- Value is calculated by most cow/calf records keeping programs
- Cows can be ranked within a herd by MPPA for adjusted 205 day weaning weight
- Should be used to evaluate cows within contemporary groups
- Interpreted as a ratio
  - MPPA of 100 is average
  - MPPA of 110 indicates production 10% above average for the group
  - MPPA of 95 indicates production 5% below average for the group

### References

Research Update on Physical Methods of Bovine Euthanasia

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Cattle veterinarians and producers are frequently faced with the need to humanely euthanize animals due to illness or injury. Based on the Guidelines for Euthanasia of Animals published in 2013 by the American Veterinary Medical Association, cattle can be euthanized by injection of a barbiturate overdose or by physical disruption of the brain via gunshot or captive bolt device. While barbiturate overdose is usually the most aesthetically pleasing method of euthanasia, it is impractical for use in most on-farm euthanasia situations. Barbiturate overdose can only be performed by veterinarians due to the controlled nature of the medication, it is expensive and it leaves a potentially dangerous carcass/environmental residue if carcasses are not disposed of properly. That leaves producers and veterinarians with physical disruption of the brain as the only approved method of euthanizing livestock in most on-farm situations. Although gunshot and captive bolt devices have been around for many years, recent work over the last few years has aimed to improve the effectiveness and humaneness of these euthanasia methods.

Effects of captive bolt or gunshot on brain function
The correct application of a captive bolt or gunshot to the brain of an animal during euthanasia results in instantaneous loss of consciousness followed by death. It is believed that the concussive forces of the bolt or projectile striking the skull are responsible for the immediate loss of consciousness. Physical disruption and/or destruction of brain tissue then occur as a result of penetration of the bullet or bolt into the brain. This direct penetration of the brain causes a rapid increase in intracranial pressure, intracranial hemorrhage, and displacement of brain tissue. Additionally, cavitation, shockwaves and rotational forces applied to the brain result in further destruction of brain tissue. As a free bullet penetrates the skull and brain, it tends to expand causing more severe cavitation injury than what is typically seen with a penetrating captive bolt since the shape of the bolt doesn’t change.

Anatomic landmarks for captive bolt euthanasia
Traditional descriptions of the preferred landmarks for captive bolt euthanasia describe shooting at the intersection of two imaginary lines drawn from the medial canthus of each eye to the opposite horn or top of the opposite ear. Recent research has shown that this position is too far rostral resulting in failure to physically disrupt the brainstem and in some types of cattle results in missing the brain altogether. More recent guidelines from the AVMA and the American Association of Bovine Practitioners describe placing the shot at the intersection of two lines drawn from the lateral canthus to the opposite horn or top of the opposite ear. This position is also consistent with the recommendations of the World Organization for Animal Health. Based on further recent investigations into captive bolt shot placement, the author recommends placing the captive bolt on midline halfway between the top of the poll and an imaginary line drawn between the lateral canthus of each eye. (Figure 1) This position more accurately places the captive bolt directly over the brainstem in a variety cattle types and head shapes.

Application of the penetrating captive bolt
Due to the limited penetration depth of captive bolt devices, euthanasia via captive bolt requires precise shot placement and requires that the muzzle of the captive bolt device be pressed firmly against the animal’s head at the time of the shot. The device should also be held as close to perpendicular as possible relative to the animal’s head. Placing the shot correctly requires good restraint since the device must be in contact with the head. In recumbent animals the author prefers the use a halter to tie the head around to the animal’s hind limb. The author prefers to sedate ambulatory animals with a heavy dose of xylazine and allow them to become recumbent prior to euthanasia. Sedation is not required and animals may be euthanized while restrained in a chute but removing them from the chute post-euthanasia can be problematic.

Behavioral responses of the animal are used to confirm loss of consciousness following captive bolt shot. An animal that is standing when shot should collapse immediately. The eye should be centered within the orbit and display a dilated pupil with lack of a corneal reflex when the eye is touched. The lack of a corneal reflex is the most sensitive indicator of unconsciousness. Additionally, there should be immediate loss of coordinated respiration and no coordinated vocalization. Limb movement is common following captive bolt shot and is not a sign of returning sensibility. In some cases limb movement can be quite dramatic and care should be taken to avoid being injured by flailing limbs.
Because a penetrating captive bolt creates less brain trauma than the typical free bullet, it is recommended that the captive bolt shot be followed with a secondary step to insure death once loss of consciousness in confirmed based on the reflexes described above. Possible secondary steps include exsanguination, pithing, or intravenous injection of a saturated salt solution such as potassium chloride (KCL). Pithing can be performed by inserting a metal rod or similar device into the hole created by the bolt. The rod is inserted into the brainstem and possible into the proximal spinal cord creating additional damage to the brain tissue. Potassium chloride solution can be created by dissolving KCL into warm water until the solution becomes saturated. Sixty to 120 mls injected intravenously will readily stop the heart of most cattle. Potassium chloride should never be injected into a conscious animal because it induces cardiac arrest but does not induce unconsciousness.

Euthanasia via gunshot

Although gunshot has been used as a euthanasia method for many years, there is relatively little published research regarding the topic. There is a tremendous number of possible combinations of firearm type, caliber, and bullet type. This variety coupled with limited research makes it difficult to make recommendations regarding the ideal equipment for gunshot euthanasia of cattle. A recent study conducted at Kansas State University investigated the effectiveness of a variety of firearms for euthanasia of feedlot cattle. This study included rifles, handguns, and shotguns. The authors concluded that all of the firearm/bullet combinations tested were effective for euthanasia of feedlot cattle except for the .22 caliber hollow-point and the 9mm pistol firing a full metal jacket bullet.

In the absence of data to make specific recommendations regarding caliber and bullet type, some general recommendations should be made. Caliber selection should be balanced with the goal of having enough power to penetrate the skull and brain without having a significant risk of the projectile exiting the target animal thereby increasing the safety risk to other animals or people. Selection of an appropriate bullet type is critically important. Soft nosed lead bullets are preferred over hollow-points or bullets with a full metal jacket. Some hollow-points will fragment prior to penetrating the skull. The distortion of the shape of the bullet transfers energy into the brain and creates the profound cavitation effect that makes gunshot so effective. Bullets with a full metal jacket retain their shape and transfer less kinetic energy into the brain. These bullets also increase the risk of over penetration allowing the bullet to exit the target animal. Shotguns firing birdshot are very effective at close range and have minimal risk of overpenetration.

In most cases, shot placement for firearm euthanasia is similar to that described above for captive bolt. Just as with captive bolt, the goal is to disrupt the cerebral cortex and brainstem. However, one advantage of firearm euthanasia is that it does not require close contact with the animal. In some cases, the point of entry of the bullet may need to be adjusted to get the bullet to reach to target area of the brainstem. The brainstem lies on midline on the floor of the calvarium. Imagining a line drawn between the ear holes and shooting for the point where that line crosses midline will result in the bullet penetrating the brainstem. If the animal is at some distance from the person conducting the euthanasia with its head raised the entry point of the bullet will need to be lower on the head in order to reach to brainstem.

The behavioral responses of the animal following gunshot are virtually the same as those described above for captive bolt. If the caliber and bullet type have been selected appropriately, a secondary step to ensure death is usually not needed following gunshot delivered to the brain.

Conclusion

Both gunshot and captive bolt euthanasia are effective and can be readily applied in on-farm situations where cattle require euthanasia. When performed correctly, both methods result in immediate loss of consciousness followed shortly by death.

References