UNDERSTANDING THE INFECTION CHAIN™ AND CONTROL STRATEGIES FOR FOUR PREVALENT PATHOGENS
INTRODUCING THE INFECTION CHAIN™

The Infection Chain™ connects epidemiological events between six different production phases, and identifies opportunities for a systematic approach to disease control strategies. The goal is to identify and understand potential causes of disease transmission at each stage of production as part of a whole-herd approach to health management.

Disease management across the production system

Rather than segment information, control, and measurement, the Infection Chain™ applies new and existing knowledge to logical chain thinking. The results are multiphase intervention strategies that align with the production system, starting with replacement gilt and semen introduction through output to market. This comprehensive approach helps to focus on the entire population and determine the underlying cause of problems.

The six tabs of this brochure provide more detail on the control strategy and considerations for four of the most common respiratory pathogens—Porcine reproductive and respiratory syndrome (PRRS), Mycoplasma hyopneumoniae (Mhp), Porcine circovirus type 2 (PCV2), and influenza A virus in swine (IAV-S).

Included in the Infection Chain™ are the following epidemiological events:
- Persistence of infection
- Shedding patterns
- Vertical transmission
- Horizontal transmission
- Lateral infection

*First proposed by Dr. Eduardo Fano, Dr. Brian Payne, and Dr. Edgar Diaz in the United States to address both Mycoplasma hyopneumoniae (Mhp) and porcine reproductive and respiratory syndrome (PRRS) control.

Vertical Infection Chain vs. Horizontal Infection Chain:
Systemic pathogens may be passed through the placenta from sow to fetus by vertical infection. Non-systemic pathogens are transmitted horizontally through direct contact or the environment.
A WHOLE-HERD APPROACH

To successfully control disease, it is necessary to maximize immunity and minimize exposure. Knowing when, where, and how to implement disease management strategies is critical, so an approach that looks at the impact of disease on the entire production chain can lead to the best results.

Control strategies can be divided into three categories that apply to each phase of the Infection Chain™:

1. **MINIMIZE EXPOSURE**
   Adhering to the protocols of every stage ensures continued minimal exposure through subsequent stages.

2. **MAXIMIZE IMMUNITY**
   Maintenance of uniform immunity will reduce/eliminate resident pathogen circulation for maintenance of stability.

3. **MEASURE (DX)**
   Auditing internal and external protocols, monitoring for changes within the population, and regular testing provide the insight required to develop and implement the right solutions.

Introduction to the 5-Step Process

Boehringer Ingelheim has developed a systematic platform, known as the 5-Step Process, that effectively meets the challenges of pathogen control in any production system. The 5-Step Process allows veterinarians and producers to coordinate and optimize the use of multiple management tools, and by doing so, makes ongoing control simpler and more effective.

For long-term control, the 5-Step Process should be repeated until all goals are achieved.

Internal Biosecurity vs. External Biosecurity:
Biosecurity includes understanding and managing transmission risks internally within the farm (i.e. sanitation of people and shared equipment, movement within the population), and external threats outside the farm (i.e. replacement animals, transportation).
MINIMIZE EXPOSURE
- Maintain open communication with genetic provider to know/understand current infection status of gilt and semen source at all times
- Know and understand the health history, current management, and biosecurity protocols in place at genetic provider
  - A standard farm-focused prevention plan should be in place with attention to minimizing transmission between rooms/barns by fomites, pigs, or people

MAXIMIZE IMMUNITY
- Know and understand the vaccination protocols of the replacement source
- Create a plan to align replacement gilt vaccination status with your own protocols

MEASURE (DX)
- Know and understand the diagnostic protocol the genetic provider has in place to understand and validate the disease status of both the gilt and semen source
- Test upon arrival and after isolation to verify status prior to entry

Goal: Purchase/procure and introduce PRRSv negative genetic replacement gilts and semen
- Maintain open communication with genetic provider to know/understand current PRRSv status of gilt and semen source at all times
- Know and understand biosecurity protocols in place at genetic provider
- Know and understand the PRRSv diagnostic protocol the genetic provider has in place to validate PRRSv negative status of gilt and semen source

Goal: Maintain open and recurrent communication with multiplier or genetic provider to know current Mhp status of source farm
- Know and understand biosecurity protocols in place at genetic provider
- Know the Mhp diagnostic protocol the multiplier has in place to assess Mhp status

Goal: Maintain open and recurrent communication with multiplier or genetic provider to know current porcine circovirus associated disease (PCVAD) clinical status of source farm
- Know and understand biosecurity protocols in place at genetic provider

Goal: Know the IAV status of replacement animals and prevent introduction of IAV into the recipient herd
- Confirm knowledge of IAV status (ideally from recent diagnostics) from source/incoming animals
- Prevent IAV entry into GDU or commercial herd using isolation
REPLACEMENT GILT DEVELOPMENT

**MINIMIZE EXPOSURE**
- Utilize dedicated gilt development-acclimation flow for replacement gilts
  - All-in/all-out flow is preferable
  - Minimize frequency of replacement animal entry
  - Flows that accommodate acclimation and isolation are preferable
  - Implement biosecurity protocols that are focused on external biosecurity to prevent introduction of wild-type virus and maintenance of non-infectious status of the replacement gilt
  - Standard farm-focused prevention plan with attention to minimizing transmission between rooms/barns by fomites, pigs, or people

**MAXIMIZE IMMUNITY**
- Purchase or internally produce non-infectious gilts to use as replacement gilts
- Vaccinate replacement gilts prior to entry to the breeding herd

**MEASURE (DX)**
- Monitor for changes in disease status throughout the growing period
- Verify disease status prior to GDU exit/sow herd entry
  - Tissue, serum, nasal swab, and/or oral fluid sampling and testing

**PRRS**
**Goal:** Purchase or internally produce PRRSv-negative gilts to use as replacement gilts
- Vaccinate replacement gilts with Ingelvac PRRS® at least two times prior to entry to the breeding herd
- Validate PRRSv negative status at entry to the GDU
  - Serum and/or oral fluid sampling and PRRS PCR testing
- Validate PRRSv negative status at exit of the GDU and prior to entry to the breeding herd
  - Serum and/or oral fluid sampling and PRRS PCR testing

**Mhp**
**Goal:** To prepare/develop immune and non-shedding gilts
- Gilts should start the acclimation process as early as 50 days of age, if possible, allowing ample time for safe and effective exposure and recovery from disease and shedding prior to the first farrowing (at 350 days of age)
- Vaccination with Ingelvac MycoFLEX® around weaning; re-vaccination with Ingelvac MycoFLEX® at 100–150 days of age
- Strategic usage of antibiotics, target 150–230 days of age or when exposure of the gilt pool has been confirmed
- Understand the base line status before exposure
  - Laryngeal or deep tracheal sampling, n=60, pooling of 3, PCR testing
- Validate successful exposure of the gilt pool no later than 120 days of age
  - Laryngeal or deep tracheal sampling, n=60, pooling of 3, PCR testing

**PCV2**
**Goal:** To prepare/develop immune and non-clinical gilts
- Vaccination with Ingelvac CircoFLEX® around weaning
- Re-vaccination with Ingelvac CircoFLEX® at 100–150 days of age (selection age)
- Implement biosecurity protocols that are focused on external biosecurity to prevent introduction of other pathogens (co-infections)

**IAV-S**
**Goal:** To prepare/develop immune and non-infectious gilts to the breeding herd
- If IAV shedding is found at entry to or anticipated exit of GDU, sequence the virus for epidemiologic use
- Replacement gilts should not be shedding IAV for at least 2 weeks prior to movement into sow farm (ie, 2 IAV OF negative PCR test results, 2 weeks apart)
- Vaccinate all gilts (regardless of age or shedding status) with Ingelvac Provenza®
- A booster vaccination of gilts prior to sow farm entry may be considered prior to movement to the sow farm
- Continue to recommend human IAV vaccination for all animal caregivers and discourage anyone with influenza-like illness from entering farms
- Minimize potential for IAV transmission from humans to pigs
Goal: Implement a PRRS control protocol/strategy to achieve and maintain PRRS stable status
- Mass vaccinate breeding herd quarterly with Ingelvac PRRS® to maintain PRRS-stable status, or semi-annual/seasonal mass vaccination protocol. Protocol dependent on specific needs/caps risks of the breeding herd
  - Maintenance of uniform population breeding herd immunity will reduce/eliminate resident virus circulation and will protect and mitigate consequences of external introduction of non-resident heterologous PRRSv should it occur
  - Diagnostically monitor PRRSv status of breeding herd/gestation herd
  - Refer to monitoring guidelines of the farrowing unit

Goal: Positive “stable/low prevalence” sow herd
- Semi-annual or annual sow herd mass vaccination with Ingelvac MycoFLEX® to maintain uniform population breeding herd immunity
  - If the sow herd immune management is expected to be a medium- to long-term strategy (6–12 months), sow medication can be considered as a short-term tactic
  - Collect cross-sectional samples from sows and pigs at least every 4 months (two steps)
    - Sample 30 gilts prior farrowing. Collect laryngeal swabs for Mhp PCR and serum samples for serology
    - Sample 30 old sows (3–6 parity). Collect serum samples for serology

Goal: Immune “low vertical transmission” sow herd
- If reproductive PCVAD (porcine circovirus associated disease) is confirmed or expected, semi-annual or annual sow herd mass vaccination with Ingelvac CircoFLEX® to maintain low transplacental (vertical) transmission rate
  - Minimize co-infections and promote proper immune management in the gilt acclimation process
  - Sample fresh placental umbilical cord serum (PUCS) from placentas of newly farrowed dams over three time periods (3–4 weeks apart). No samples to be collected past 24 hours of farrowing. Chill immediately. Invert placenta, select four random umbilical cords, and milk them into a single blood tube. Chill and send overnight to diagnostic laboratory. Samples tested individually for PCV2 via qPCR.

Goal: Minimize new animal introductions to reduce IAV circulation at the sow level
- Minimize the frequency of new animal introduction to the sow herd
  - Enter gilts effectively immunized against IAV with Ingelvac Provenza®
  - KV of sow herd (or entering gilts/prebreeding) may be appropriate if sow farm routinely has a history of clinical signs (with diagnostics) due to IAV (fever, reduced conception, cough, etc.)
  - Minimize potential for IAV transmission from humans to pigs

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Goal: Implement a PRRS control protocol/strategy to achieve and maintain PRRS stable status
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  - Sample fresh placental umbilical cord serum (PUCS) from placentas of newly farrowed dams over three time periods (3–4 weeks apart). No samples to be collected past 24 hours of farrowing. Chill immediately. Invert placenta, select four random umbilical cords, and milk them into a single blood tube. Chill and send overnight to diagnostic laboratory. Samples tested individually for PCV2 via qPCR.

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- If reproductive PCVAD (porcine circovirus associated disease) is confirmed or expected, semi-annual or annual sow herd mass vaccination with Ingelvac CircoFLEX® to maintain low transplacental (vertical) transmission rate
  - Minimize co-infections and promote proper immune management in the gilt acclimation process
  - Sample fresh placental umbilical cord serum (PUCS) from placentas of newly farrowed dams over three time periods (3–4 weeks apart). No samples to be collected past 24 hours of farrowing. Chill immediately. Invert placenta, select four random umbilical cords, and milk them into a single blood tube. Chill and send overnight to diagnostic laboratory. Samples tested individually for PCV2 via qPCR.

Goal: Minimize new animal introductions to reduce IAV circulation at the sow level
- Minimize the frequency of new animal introduction to the sow herd
  - Enter gilts effectively immunized against IAV with Ingelvac Provenza®
  - KV of sow herd (or entering gilts/prebreeding) may be appropriate if sow farm routinely has a history of clinical signs (with diagnostics) due to IAV (fever, reduced conception, cough, etc.)
  - Minimize potential for IAV transmission from humans to pigs
**Sow Herd, Farrowing, and Suckling Pigs**

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**Replacement Source**

**Gilt Development**

**Sow Herd**

**Gestation**

**Farrowing**

**Suckling Pigs**

**Wean-to-Market**

**Goal:** Positive “stable/low prevalence” sow herd. No transmission, or low transmission, from sow to piglet.
- Generating piglets with a very low Mhp prevalence at weaning should be the outcome of a well-managed gilt acclimation program and this will bring a reduction of the sow to piglet transmission rate.
- If the sow herd immune management is expected to be a medium- to long-term strategy, sow medication during the lactation stage can be considered as a short-term tactic.

**Mhp**

**Goal:** Immune “low vertical transmission” sow herd.
- Vaccination with a full dose of Ingelvac CircoFLEX®, Ingelvac FLEXcombo®, or Ingelvac 3FLEX® around 21 days of age.
- Proper piglet management: Colostrum intake and cross fostering.

**Goal:** IAV control/elimination in suckling pigs, and protection of piglets through vaccination with Ingelvac Provenza™.
- Vaccinate piglets as early as day 1 with Ingelvac Provenza™.
- Perform diagnostics on piglets with clinical signs of IAV using nasal swabs, and sequence for appropriate epidemiological investigation.
- Minimize potential for IAV transmission from humans to pigs.

**Goal:** Implement a PRRS control protocol/strategy to achieve and maintain PRRS stable status.
- **Suckling Pigs:** For optimum PRRS control/protection, PRRS vaccination should occur 3–4 weeks prior to exposure to field virus.
  - Vaccinate with Ingelvac PRRS® or Ingelvac 3FLEX® pre-weaning if risk of PRRSv exposure is high during the early nursery phase of production in effort to appropriately place vaccine 3–4 weeks prior to exposure/infection.
  - **Farrowing Pigs:** Implement internal biosecurity protocols to minimize/eliminate virus transmission in farrowing phase of production.
  - Diagnostically monitor PRRSv status of breeding herd (includes farrowing and suckling pig phase of production).
  - Minimum protocol guideline: Serum test at least 30 “due-to-wean” piglets (DTW) for PRRS PCR in pools of 5 at least monthly.

**PRRS**

**MEASURE (DX)**

- Monitor for changes in disease status throughout the farrowing and suckling period.

**MAXIMIZE IMMUNITY**

- Adhere to vaccination protocols described for breeding herd/gestation and suckling pigs.

**MINIMIZE EXPOSURE**

- Implement and adhere to internal biosecurity protocols (i.e. McRebel protocols).
- Standard farm-focused prevention plan with attention to minimizing transmission between rooms/barns by fomites, pigs or people.
**Goal:** Maximize immunity in pigs that are at risk to PRRSv exposure/infection during the wean-to-market phase of production to mitigate the consequences of infection and improve health and performance

- Vaccination with a full dose of Ingelvac MycoFLEX®, Ingelvac FLEXcombo®, or Ingelvac 3FLEX® at 21 days of age
- Practice all-in/all-out pig flow with dedicated breeding herd sources of PRDC pathogens
- Monitor with laryngeal or deep tracheal swabs at 6–8 weeks of age. If > 20% of prevalence go back to gilt and sow herd links (root cause philosophy)

**MEASURE (DX)**

- Monitor for changes in disease status throughout the weaning period

**MINIMIZE EXPOSURE**

- Implement internal and external biosecurity protocols to minimize/prevent internal circulation of pathogens and introduction of external field pathogens
- Standard farm-focused prevention plan with attention to minimizing transmission between rooms/barns by fomites, pigs or people
- Practice all-in/all-out pig flow with dedicated breeding herd sources of known disease status

**MAXIMIZE IMMUNITY**

- In areas of high swine density, if pigs arrive at a growout unvaccinated, consider vaccination prior to or at arrival to prevent disease impact throughout the growout

**PRRS**

- Vaccination with a full dose of Ingelvac Provenza™ immunizes against both H1 and H3 subtypes of IAV
- Perform diagnostics in growing pigs if evidence of clinical cough at any age.
- Sequence if IAV is identified, for proper epidemiologic investigation
- Monitor for additional incursion of IAV using IAV PCR via oral fluids at key phases of wean-to-market flow
  - 8–10 weeks of age (nursery exit) / 12–14 weeks of age / 16–18 weeks of age

**IAV-S**

- Piglets should be immunized against IAV prior to time of exposure, and use of Ingelvac Provenza™ Immunizes against both H1 and H3 subtypes of IAV
  - Perform diagnostics in growing pigs if evidence of clinical cough at any age.
  - Sequence if IAV is identified, for proper epidemiologic investigation
  - Monitor for additional incursion of IAV using IAV PCR via oral fluids at key phases
  - If IAV is found, request subtyping on screen positive samples, and sequence if an epidemiologic investigation is of interest
  - Minimize potential for IAV transmission from humans to pigs

**PCV2**

- Vaccination with a full dose of Ingelvac CircoFLEX®, Ingelvac FLEXcombo®, or Ingelvac 3FLEX® around 21 days of age
- Practice all-in/all-out pig flow with dedicated breeding herd sources of PRDC pathogens

**Mhp**

- Monitor with laryngeal or deep tracheal swabs at 6–8 weeks of age. If > 20% of prevalence go back to gilt and sow herd links (root cause philosophy)
MARKET

MINIMIZE EXPOSURE
- Implement external biosecurity protocols to minimize/prevent contamination of people, fomites, equipment and transportation from market back to farm

MAXIMIZE IMMUNITY
- It is not advisable to vaccinate at this stage; maximum immunity has been achieved by the control strategies of the previous stages

MEASURE (DX)
- Audit external biosecurity protocols

Goal: Minimize/prevent exposure to virus returning to farm
- Implement and adhere to biosecurity protocols targeted at the prevention of virus transmission from market to farm – ie, people, fomites, and transport biosecurity
- Audit external biosecurity protocols

Goal: Minimize/prevent exposure to PRDC pathogens returning to farm
- Implement external biosecurity protocols to minimize/prevent contamination of people, fomites, equipment, and transportation of PRDC pathogens from market back to farm
- Audit external biosecurity protocols

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- Implement external biosecurity protocols to minimize/prevent contamination of people, fomites, equipment, and transportation of PRDC pathogens from market back to farm
- Audit external biosecurity protocols

Goal: Minimize exposure as per general guidelines
- Minimize potential for IAV transmission from humans to pigs
- Audit external biosecurity protocols

IAV-S

PCV2

Mhp

PRRS
Review of the Infection Chain™ by pathogen.

**PRRS**
- Purchase/Procure and introduce PRRSv negative genetic replacement gilts and semen
- Prepare/develop and introduce immune & non-infectious gilts to the breeding herd
- Implement a PRRS control protocol/strategy to achieve and maintain PRRS stable status, including a vaccination schedule with Ingelvac PRRS® and Ingelvac 3FLEX® for uniform immunity
- Maximize immunity in pigs that are at risk of PRRSv exposure/infection during the wean-to-market phase of production to mitigate the consequences of infection and improve health and performance
- Minimize/prevent exposure to virus from market back to farm

- Maintain open and recurrent communication with multiplier or genetic provider to know current PCVAD clinical status of source farm
- To prepare/develop immune and non-clinical gilts: Vaccination around weaning and re-vaccination at selection age
- If reproductive PCVAD is confirmed or expected, biannual or annual sow herd vaccination (mass vaccination) to maintain low transplacental (vertical) transmission rate
- Vaccination full dose of Ingelvac CircoFLEX®, Ingelvac FLEXcombo®, or Ingelvac 3FLEX® around 21 days of age
- For full expression of the immunological program, implement proper internal and external biosecurity protocols and practice all-in/all-out pig flow

**Mhp**
- Maintain open and recurrent communication with multiplier or genetic provider to know current Mhp status of source farm
- Effective (validated) early gilt exposure allowing ample time for recovery from shedding prior to the first farrowing
- Biannual or annual sow herd vaccination to maintain a uniform population breeding herd immunity

- Reduced sow to piglet transmission rate is the outcome of a well-managed gilt acclimation program and a low infection pressure sow herd
- Vaccination with a full dose of Ingelvac MycoFLEX®, Ingelvac FLEXcombo®, or Ingelvac 3FLEX® at 21 days of age
- Minimize/prevent exposure to PRDC pathogens from market back to farm

**IAV-S**
- Know the IAV status of replacement animals and prevent introduction of IAV into the recipient herd
- Prepare/develop and introduce IAV immunized and non-infectious gilts to the breeding herd
- UV control/elimination in suckling pigs, and protection of piglets through vaccination with Ingelvac Provenza™
- Piglets should be immunized against IAV prior to time of exposure, and use of Ingelvac Provenza™ immunizes against both H1 and H3 subtypes of IAV
- Minimize the potential for IAV transmission from humans to pigs by promoting human IAV vaccination and supporting sick employee policies
- Be attentive to the risk of IAV transmission from wild waterfowl or local domestic poultry
Understanding the Infection Chain™ and implementing ongoing control strategies across the entire system will help you get the most from your vaccination protocols.

Strengthen your whole-herd approach to maximum immunity with Boehringer Ingelheim vaccines.

For more information on building a prevention program, contact your Boehringer Ingelheim representative.