

PAIN ETHOGRAM MAPPING: A MULTIDIMENSIONAL ANALYSIS OF BEHAVIORAL CHANGES IN CATTLE INFECTED WITH FOOT-AND-MOUTH DISEASE USING A VISUAL ANALOGUE SCALE

Pemetaan Etogram Nyeri: Analisis Multidimensi Perubahan Perilaku Sapi Terinfeksi Penyakit Mulut dan Kuku (PMK) Menggunakan *Visual Analogue Scale*

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Abstract

Foot-and-mouth disease (FMD) is a highly contagious viral disease that causes severe pain and compromises cattle welfare. Objective pain assessment is challenging but essential for effective therapeutic management. This study aimed to comprehensively characterize the pain profile in FMD-infected cattle by validating the use of the visual analog scale (VAS) through a multidimensional analysis of pain behavioral manifestations. To ensure robustness, the validation process included inter-rater reliability assessments and a comparison with established pain indicators, addressing concerns about the VAS's reproducibility. This qualitative descriptive study was conducted on 15 FMD-infected cattle in Makassar City and Gowa Regency. Pain intensity was evaluated using the VAS based on direct observation of a series of behavioral parameters. The results indicated heterogeneity in pain intensity across parameters. Locomotor deficits, such as lameness and slowness, as well as agitation (restlessness), consistently correlated with moderate pain levels. Conversely, interactive responses, such as aggression and most postural changes, were identified in the mild pain category. It was concluded that the VAS is a valid and reliable instrument for multidimensional pain assessment in FMD-infected cattle, with mobility and agitation being the most significant markers for the early detection of moderate pain.

Keywords: Animal Welfare, Foot and Mouth Disease (FMD), Locomotor Deficit, Pain Ethogram, Visual Analog Scale (VAS)

Abstrak

Penyakit Mulut dan Kuku (PMK) adalah penyakit virus yang sangat menular yang menyebabkan rasa sakit yang parah dan mengganggu kesejahteraan ternak. Penilaian nyeri secara objektif merupakan tantangan tetapi penting untuk manajemen terapeutik yang efektif. Studi ini bertujuan untuk mengkarakterisasi secara komprehensif profil nyeri pada sapi yang terinfeksi PMK dengan memvalidasi penggunaan Skala Analog Visual (VAS) melalui analisis multidimensional dari manifestasi perilaku nyeri. Untuk memastikan kekokohan, proses validasi mencakup penilaian reliabilitas antar penilai dan perbandingan dengan indikator nyeri yang telah ditetapkan, untuk mengatasi kekhawatiran tentang reproduktivitas VAS. Studi deskriptif kualitatif ini dilakukan pada 15 sapi yang terinfeksi PK di Kota Makassar dan Kabupaten Gowa. Intensitas nyeri dievaluasi menggunakan VAS berdasarkan pengamatan langsung dari serangkaian parameter perilaku. Hasil menunjukkan heterogenitas intensitas nyeri di seluruh parameter. Defisit lokomotor, seperti pincang dan lambat, serta agitasi (kegelisahan), secara konsisten berkorelasi dengan tingkat nyeri sedang. Sebaliknya, respons interaktif seperti agresi dan sebagian besar perubahan postural diidentifikasi dalam kategori nyeri ringan. Disimpulkan bahwa VAS merupakan instrumen yang valid dan andal untuk penilaian nyeri multidimensional pada sapi yang terinfeksi penyakit mulut dan kuku (PMK), dengan mobilitas dan agitasi sebagai penanda paling signifikan untuk deteksi dini nyeri sedang.

Kata kunci: Defisit Lokomotor, Etogram Nyeri, Kesejahteraan Hewan, Penyakit Mulut dan Kuku (PMK), *Visual Analogue Scale* (VAS)

INTRODUCTION

Animal welfare is a fundamental pillar of modern livestock systems; however, it is often compromised by infectious disease outbreaks (Papakonstantinou *et al.*, 2024). One of the most significant global threats in this context is foot-and-mouth disease (FMD), a highly contagious viral infection in cattle and other cloven-hoofed animals (Purba *et al.*, 2024). With morbidity rates approaching 100%, FMD not only causes massive economic losses due to reduced productivity but also poses serious welfare issues because of the acute pain response experienced by animals (Abd-Ellatieff *et al.*, 2023). Clinical manifestations in the form of vesicular lesions on the oral mucosa and hoof area cause intense pain that directly affects essential behaviors, such as movement, posture, and feed intake (Ismail *et al.*, 2023).

Although the impact of FMD on behavior is well known (Wolf *et al.*, 2020), objective quantification of pain intensity in cattle in the field remains a major challenge owing to the masking effect phenomenon, whereby cattle evolutionarily hide signs of pain (Zoltick *et al.*, 2024). This often leads to inaccurate pain assessment (underestimation) and hinders appropriate therapeutic intervention (Marino & Allen, 2017). Therefore, a solution is needed in the form of a valid non-invasive assessment instrument. The visual analog scale (VAS) has been widely recognized as a reliable tool for measuring pain intensity in clinical research (Cavagnari *et al.*, 2024). However, the effectiveness of VAS is highly dependent on the selection of relevant behavioral parameters (De Grauw & Van Loon, 2016). Unfortunately, the application of VAS to holistically characterize FMD pain profiles by simultaneously integrating various behavioral domains has not been widely explored, as previous studies have tended to focus on only one behavioral dimension (Møller *et al.*, 2024; Bufalari *et al.*, 2007).

Given the urgency of this issue, this study aimed to conduct a comprehensive evaluation of pain in cattle infected with FMD by testing the application of VAS through multidimensional analysis. This study specifically characterized the behavioral manifestations of pain, including locomotor deficits (lameness and/or sluggishness), changes in posture and activity (hunching and/or restlessness), and interactive responses (aggression and/or fear). This approach is

expected to build a more complete and reliable pain profile to improve animal welfare-based therapy management.

RESEARCH METHOD

Animal Ethics

All procedures for handling and observing animals in this study were performed in accordance with animal welfare principles and were approved by the Animal Research Ethics Committee of the Faculty of Medicine, Hasanuddin University (number: 00035/UN4.1.30.1.1.4/DI.05.01/2026).

Research Object

The research subjects consisted of 15 Bali cattle (*Bos javanicus*) located at several smallholder farms in Makassar City and Gowa Regency, South Sulawesi. Subject selection was conducted using purposive sampling based on clinical inclusion criteria, namely, (1) diagnosed with FMD by a veterinarian, (2) showing active lesions on the oral mucosa and/or interdigital area of the hooves, and (3) no history of comorbidities or other physical injuries that could interfere with behavioral assessment. The sample included a variety of genders and ages (ranging from 8 months to 6 years) to represent a diverse population.

To minimize environmental bias in the assessment of pain behavior, the selected subjects had relatively homogeneous management characteristics. The management applied to all subjects was traditional, using tethering. Cattle were placed in grazing areas or rice fields with natural environmental exposure and stood on natural ground (soil/grass). The cattle did not use nose rings to avoid facial pain bias and were tied with loose neck ropes. During the acute phase of infection observation, the subjects were confirmed not to have received analgesic/anti-inflammatory therapy (NSAIDs) that could affect the expression of natural pain. Feed management for all subjects was controlled by providing fresh forage (elephant grass) and water ad libitum consistently before and during the period of illness.

Research Design

This study employed a descriptive observational design with a cross-sectional approach. This design was chosen to capture the clinical profile and quantify the intensity of pain in cattle infected with foot-and-mouth disease (FMD) during the active phase of the infection. Data were collected at a single time point through a systematic assessment of the behavioral manifestations of pain and changes in body posture.

Research Variables

The independent variable observed in this study was the clinical manifestation of foot-and-mouth disease (FMD) infection in the form of active vesicular lesions. The dependent variable measured was pain intensity assessed using the visual analog scale (VAS) method based on locomotor behavior, posture, and interactive response parameters. To maintain data validity, control variables were applied to the type of livestock (Bali cattle), husbandry management (tethered system on a dirt floor), and treatment status (nonanalgesic) to eliminate confounding factors that could influence the expression of pain behavior.

Data Collection Methods

Data were collected using a noninvasive observational approach combined with limited clinical examinations. Data collection was carried out in situ (at each animal's maintenance/mooring location) to ensure that the observed behavior was the animal's natural response to pain, without being influenced by stress due to transportation or a new environment. The data collection

stages included clinical examination and diagnosis confirmation, behavioral observation, quantitative pain assessment, research instruments (ethogram and VAS scale validation), and observation bias control.

Clinical Examination and Diagnosis Confirmation

Before behavioral observation began, a physical examination was performed by a veterinarian to confirm the clinical diagnosis of FMD. The examination included inspection of the oral mucosa (mouth) to identify the presence of vesicles, erosions, or ulcers, as well as inspection of the interdigital and coronary areas of the hooves to identify active lesions. At this stage, the cattle are also checked to ensure that they do not have other diseases that could be confounding variables.

Behavioral Observation

The behavioral data collection method uses the Focal Animal Sampling technique, in which each individual cow is observed intensively over a specific period of time. Observations were conducted for a total of 24 h per subject to capture variations in circadian rhythms (daily cycles). The observation time was divided into four 5-hour sessions interspersed with breaks, covering the active phase (daytime) and the rest phase (nighttime). Observers remained at a safe distance (at least 5-10 meters) so as not to intimidate the animals or trigger the observer effect, which can cause animals to hide signs of pain. All observation sessions were recorded using high-resolution (1080p) video cameras mounted on static tripods. These recordings were used for the verification of data.

Quantitative Pain Assessment (Scoring)

Qualitative behavioral data were converted into quantitative data using the Visual Analog Scale (VAS) instrument. The assessment is carried out based on a pre-compiled etogram (behavior catalog), covering three main domains: (1) the locomotor-postural domain by observing imbalance, slowness of movement, and abnormal posture (such as hunching/kyphosis). (2) Activity domain by observing agitation, changes in standing/lying patterns, and isolative behavior. (3) The interactive domain was assessed by observing responses when approached (aggression/fear) and attention to the wound area (licking/rubbing).

Research Instruments: Validation Of Etogram and VAS Scale

The main instrument used was the Visual Analog Scale (VAS), which was adapted for this study to assess pain. The VAS consists of a 10 cm horizontal line with anchor descriptors of “no pain” (score 0) and “worst pain” (score 10). Scoring is based on a pain etogram (behavior catalog) developed by synthesizing parameters from three main domains: locomotor-postural, activity-attitude, and interactive-responsive. The detailed operational definitions for each behavioral parameter assessed are presented in Table 1.

Observer bias control (Inter-observer Reliability)

To maintain consistency in the assessment and minimize subjectivity, the entire VAS scoring process was performed by a single trained observer (single-blinded observer) who was unaware of the detailed history of lesion severity prior to scoring behavior.

Data Analysis

The data processing process began with the data tabulation stage, where all raw visual analog scale (VAS) scores from manual measurements were converted into a digital format using spreadsheet software (Microsoft Excel). At this stage, data cleaning and grouping based on

behavioral parameter variables (locomotor, activity, interactive) and demographic variables (age and gender) were performed to facilitate further analysis.

The analytical method used in this study was descriptive statistics. This approach was chosen because the main objective of the study was to characterize pain profiles and identify dominant behavior patterns rather than to test comparative hypotheses between experimental treatments. The specific statistical tests performed included the following: (1) Mean calculation: Used to determine the central tendency value of pain intensity for each behavioral parameter. This value represents the average pain level experienced by the sample population for a particular symptom. (2) Calculation of Standard Deviation (SD): Used to measure the variability or distribution of pain score data. A high SD value indicates heterogeneity in pain responses between individual cows, whereas a low value indicates uniform responses. (3) Frequency distribution (percentage): Used to classify the severity of pain into ordinal categories based on predetermined cut-off points: mild pain (score 1–3.4), moderate pain (3.5–7.4), and severe pain (7.5–10). This analysis aimed to map the proportion of the population experiencing a certain degree of pain.

The results of the data analysis are presented in two main forms. First, in the form of summary tables, we present detailed numerical data (mean \pm SD) that allow readers to see the exact values of each parameter. Second, graphical visualizations in the form of bar charts or heatmaps can be used to clarify the patterns of comparison between parameters and facilitate an intuitive interpretation of pain profiles.

RESULTS AND DISCUSSION

Results

Subject Characteristics and Clinical Manifestations

The clinical symptoms observed in all subjects included ulcerative lesions on the oral mucosa and interdigital nail areas, accompanied by hypersalivation and decreased appetite, which formed the basis for pain evaluation in this study. The clinical manifestations and key behavioral responses in FMD-infected cattle are shown in Figure 1. Clinically, the infection is characterized by the presence of ulcerative lesions on the oral mucosa (Figure 1A) and lesions on the interdigital areas of the hooves (Figure 1B), which are identified as the main causes of pain in infected animals. Animal responses to this pathological condition varied; locomotor deficits, such as a hunched posture (kyphosis), were observed as indicators of moderate pain (Figure 1C). Meanwhile, adaptive behaviors, such as curling up while lying down, were documented as responses associated with mild pain (Figure 1D).

Pain Profile Based on Multidimensional Ethogram

Pain intensity was evaluated using the VAS based on the behavioral parameters defined in Table 1 (see the Methods section). The results of the quantitative assessment using the VAS revealed heterogeneity in the distribution of pain intensity across various behavioral parameters, as summarized in Table 2 and visualized in Figure 2. In general, pain responses were polarized into two main intensity categories: moderate and mild pain.

Parameters related to locomotor activity and function dominated the moderate pain category (mean score > 3.5). Changes in standing patterns recorded the highest mean score (4.22 ± 0.999), closely followed by restlessness/agitation (4.17 ± 1.162) and depressed mood (3.82 ± 1.338). Specific locomotor deficits, namely lameness and slow movement, were also consistently within this range with identical scores (3.70), indicating that mobility impairment is the most clinically significant manifestation of pain in cattle infected with FMD. Conversely, the parameters included in the interactive and responsive domains tended to fall into the mild

pain category (mean score < 3.5). Aggressive and fearful responses had mean scores of 2.72 ± 0.812 and 2.30 ± 0.788 , respectively. An interesting finding was observed in *nosocial* behavior (reaction to the painful area), where licking the wound (1.53 ± 0.674) and curling up (1.38 ± 0.700) showed the lowest scores among all parameters evaluated.

Comparative Analysis Based on Demographic Factors

Further analysis was conducted to explore the influence of demographic factors on pain expression variability (Figure 3). The heatmap visualization presents a comparison of pain profiles, where darker colors in the cells represent higher average VAS scores, facilitating the identification of dominant patterns between the subgroups. The findings showed significant divergence in responses; older cattle (3–6 years) recorded higher scores on the locomotor deficit parameter, whereas younger cattle (<3 years) were identified as being more emotionally reactive. In addition, evaluation based on sex revealed that male cattle consistently showed higher scores for stress indicator parameters than female cattle.

Discussion

This study maps the complex pain profile in FMD-infected cattle, highlighting fundamental diagnostic challenges, where interactive and adaptive behavioral manifestations tend to appear in the mild pain category. The most notable finding of this study was the identification of a clear dichotomy between “honest signals” that are difficult to suppress, such as locomotor deficits and agitation, and other behaviors that are masked by the masking effect (Zoltick *et al.*, 2024). This polarized pattern offers a new perspective compared to previous studies, such as those evaluating postsurgical or purely musculoskeletal pain, which often show uniform increases in VAS scores across all behavioral domains. Furthermore, these results expand on the findings of Møller *et al.* (2024), who focused on the respiratory dimension, by demonstrating that in FMD cases, mobility (locomotor) indicators have higher diagnostic sensitivity than interactive indicators. The following discussion outlines the implications of these findings and formulates more precise clinical strategies.

Dominance of Locomotor Deficit and Agitation as “Honest Signals” of Pain

The most consistent and significant finding of this study was the high pain scores for parameters related to motor function and emotional status. The parameters of imbalance (mean score 3.70), slowness (3.70), restlessness/agitation (4.17), and changes in standing patterns (4.22) formed a cluster of indicators with the highest intensity scores. High scores on these parameters indicate their potential as more reliable “honest signals” of pain. Theoretically, these manifestations are thought to be related to functional and autonomic responses that are more difficult for animals to consciously modulate than interactive responses, although further validation using physiological biomarkers is needed to confirm the underlying neurobiological mechanisms (Gouzoules & Gouzoules, 2002). Locomotor deficits, for example, are a direct biomechanical consequence of painful lesions on the hoof; animals are physiologically forced to alter their gait to avoid the painful stimulus, a response that cannot be easily concealed (Kata *et al.*, 2014). Similarly, agitation (restlessness) is often an external manifestation of autonomic nervous system activation in response to internal stressors (pain), which is also difficult for animals to control consciously (Gerken, 2023).

High scores on the agitation parameter can be interpreted as an affective-emotional component of the pain experience. Persistent pain is not only a physical sensation but also a powerful psychological stressor. This condition can activate the sympathetic nervous system and the hypothalamic-pituitary-adrenal (HPA) axis, triggering the release of stress hormones, such as cortisol and catecholamines (DeMorrow, 2018). This increase in physiological and

psychological arousal manifests as agitation, hypervigilance, and an inability to rest normally (Sic *et al.*, 2025). Thus, locomotor deficits and agitation can be considered “honest signals” of pain, as both are physiological and mechanical responses that are difficult for animals to conceal and are directly related to the pathological mechanisms and stress responses.

The Mild Pain Response Paradox: Interpretation of the Masking Effect and Nocifensive Behavior

On the other hand, the paradox arises from the prevalence of mild pain responses in other behavioral domains, particularly in interactive and adaptive responses such as aggression (average score of 2.72), fear (2.30), and curling up (1.38). This phenomenon can be explained by the concept of the masking effect, a well-documented adaptive behavioral strategy in prey species. To avoid perceived vulnerability to predators or dominant herd members, cattle can instinctively suppress conspicuous manifestations of pain behavior (Zoltick *et al.*, 2024).

In their natural environment, explicitly showing signs of weakness or pain can increase the risk of predation by other animals. Consequently, cattle have evolved to suppress conspicuous manifestations of pain behavior to avoid perceived vulnerability. According to Steagall *et al.* (2021), pain assessment in prey animals is often complicated by this innate tendency, which can lead to inaccurate assessments (underestimation) if validated ethograms are not used to assess pain. Therefore, low scores on parameters such as aggression and fear may not indicate the absence of pain but rather represent suppressed responses to maintain an alert appearance and not appear weak.

Low scores on nocifensive behavior (behavior aimed at reducing harmful stimuli), such as licking or lifting the leg, are also interesting. Although seemingly contradictory, this can be interpreted as a coping strategy to avoid the exacerbation of pain. Ulcerative FMD lesions are highly sensitive. Therefore, animals may actively avoid physical contact with the area to prevent further pain (Weary *et al.*, 2006). The infectious phase during observation (approximately seven days) may have also passed the peak of the hyperacute inflammatory phase, during which reflexive nociceptive responses may be more dominant. In the subacute phase, the observed behavior may reflect chronic pain management rather than an acute response (Purba *et al.*, 2024).

The Influence of Demographic Factors and Clinical Implications

A comparative analysis (Figure 3) showed that age and sex modulated pain expression. Older cows had higher lameness scores, possibly because greater body weight exacerbates pain in hoof lesions. Conversely, younger cattle showed higher aggression and fear scores, which may reflect greater emotional reactivity in animals with an immature nervous system (Grandin & Shivley, 2015). Sex-based differences, in which male cattle showed higher scores on stress parameters such as restlessness and depression, were likely influenced by hormonal factors. Hormones, such as testosterone, can increase reactivity and defensive-aggressive behavior in male mammals under stress or pain (Broom & Fraser, 2015).

The clinical implications of these findings are significant and are summarized in Table 4. This study confirms that pain assessment in cattle with FMD requires a multidimensional approach. Veterinary practitioners can focus their observations on locomotor deficits and agitated behavior as the most reliable indicators for detecting moderate animal pain. The use of a structured ethogram (Table 1) can be a valuable diagnostic tool in the field to objectify assessments, guide therapeutic decisions (e.g., analgesic dosage and frequency), and evaluate treatment effectiveness over time.

It is important to acknowledge several methodological limitations of this study to ensure

scientific transparency. First, although a single observer was used to maintain consistency in the assessment, this still leaves the potential for subjective bias that cannot be cross-validated through inter-observer reliability testing. Second, conducting the study in situ on smallholder farms presented the challenge of complex environmental controls. External variables, such as temperature fluctuations, environmental noise, and human presence around the mooring area, are external stressors that are difficult to isolate completely and have the potential to bias animal behavioral responses. Third, the relatively small sample size and observation restrictions in the subacute infection phase limit the generalizability of the findings to a wider population or a different spectrum of disease phases.

These limitations underscore the need for further research with a more robust design, including a larger sample size, involvement of multiple observers, and integration with physiological stress biomarkers for objective validation. As suggested by Tschoner *et al.* (2024), a combination of several assessment methods (a multimodal approach) is always superior to a single method. Despite these limitations, this study makes an essential contribution to the scientific literature by providing an initial ethological framework and practical tools for improving animal welfare standards during outbreaks of painful diseases, such as FMD.

CONCLUSIONS AND SUGGESTIONS

Conclusions

The multidimensional ethogram-based visual analog scale (VAS) is a valid instrument for assessing pain in cattle infected with FMD. Locomotor deficits (lameness and sluggishness) and agitation (restlessness) were identified as the most reliable indicators of moderate pain. Other responses that tend to indicate mild pain suggest the possibility of a masking effect, emphasizing the importance of a multidimensional approach for accurate pain assessment.

Suggestions

Practitioners are advised to focus FMD pain assessment on locomotor deficits and agitation as the primary indicators for therapeutic intervention. Further research is warranted with larger samples, longitudinal designs, and integration with physiological biomarkers for further validation. The results of this study also have the potential to be developed as educational material for standardizing animal welfare-based pain management.

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Tables

Table 1. Multidimensional Pain Ethogram for Assessment in Cattle Infected with FMD

Behavioral Domain	Parameter	Brief Operational Description
Locomotor and Postural	Lameness	Asymmetry of gait, shortened weight-bearing phase, or reluctance to bear weight on one limb.
	Sluggishness	Significant reduction in movement speed and increased latency to initiate movement.
	Arching	Increased abnormal curvature of the back (kyphosis) when standing or walking.
	Stiffness	Restricted joint movement or loss of movement fluidity, particularly after a period of inactivity.
Activity and Attitude	Altered Standing Pattern	Abnormal changes in the duration or frequency of standing, often accompanied by a rigid or restless posture.
	Agitation (Restlessness)	Increased frequency of purposeless movements (e.g., stepping in place, repeated head movements).
	Isolative Behavior	Actively separating from the herd, showing inactivity and reduced social interaction.
Interactive and Responsive	Depressed Posture	Head position lowered below the line of the back, vacant gaze, and reduced responsiveness to environmental stimuli.
	Defensive Aggression	Hostile responses when approached (threatening, butting, kicking) as a defensive mechanism.
	Avoidance Behavior	Active attempts to maintain distance or flee from the observer, indicating extreme vigilance.
	Attention to Wounded Area	Activity focused on the lesion area, such as licking, biting, or rubbing the painful site.

Table 2. Summary of Multidimensional Pain Assessment Results in Cattle Infected with Foot-and-Mouth Disease (n = 15)

Parameter	Mean VAS Score (Mean ± SD)	Dominant Category	Dominant Frequency (%)
Standing	4.22 ± 0.999	Moderate	86.67
Agitation (Restlessness)	4.17 ± 1.162	Moderate	80.00
Depressed	3.82 ± 1.338	Moderate	73.33
Lameness	3.70 ± 1.743	Moderate	66.66
Sluggishness	3.70 ± 1.268	Moderate	66.66
Aggressive	2.72 ± 0.812	Mild	80.00
Arching	2.45 ± 1.115	Mild	80.00
Fearful	2.30 ± 0.788	Mild	87.00
Stiffness	2.03 ± 1.329	Mild	93.33
Lifting the Leg	1.92 ± 1.034	Mild	93.33
Licking the Wound	1.53 ± 0.674	Mild	100
Curling Up	1.38 ± 0.700	Mild	100

Table 3. Clinical Implications and Recommendations for Field Assessment of Pain in Foot-and-Mouth Disease (FMD)

Priority Level	Key Indicators (Behavioral Parameters)	Clinical Interpretation & Recommended Actions
High Priority (Significant Pain Signals)	Abnormal Standing, Agitation (Restlessness), Depressed Posture, Lameness, Sluggishness	Interpretation: These are “red flag” signals strongly correlated with moderate to severe pain and are difficult for animals to conceal. Recommendation: These indicators must be the primary focus during the initial observation. Cattle with high scores on these parameters should be considered to experience significant pain and require immediate consideration of analgesic intervention.
Moderate Priority (Contextual Indicators)	Aggressive Behavior, Fearful Behavior, Stiffness, Arching	Interpretation: These may indicate pain but are also strongly influenced by individual temperament, environmental stress, or disease stage. Recommendation: Evaluate together with high-priority indicators. Changes from the animal’s baseline behavior are critical. For example, a normally calm cow becoming aggressive is a significant finding.
Low Priority (Adaptive/Subtle Indicators)	Curling Up, Licking the Wound, Lifting the Leg	Interpretation: These are subtler signs of pain, often associated with adaptive behavior or chronic pain management by the animal itself (masking effect). Recommendation: Less sensitive for detecting acute pain. They are more useful for long-term recovery monitoring and general welfare evaluation rather than as primary indicators for emergency therapeutic decisions.

Figures

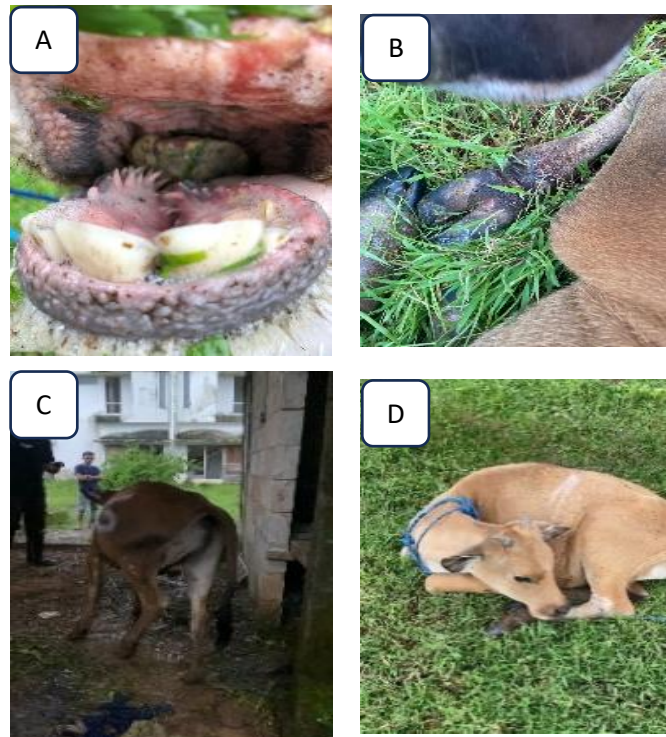


Figure 1. Clinical manifestations and key behaviors in FMD-infected cattle. (A) Ulcerative lesions on the oral mucosa. (B) Lesions in the interdigital area of the hooves, which are the main cause of pain. (C) Locomotor deficits, such as a hunched posture, which is an indicator of moderate pain. (D) Adaptive behavior, such as curling up when lying down, a response associated with mild pain.

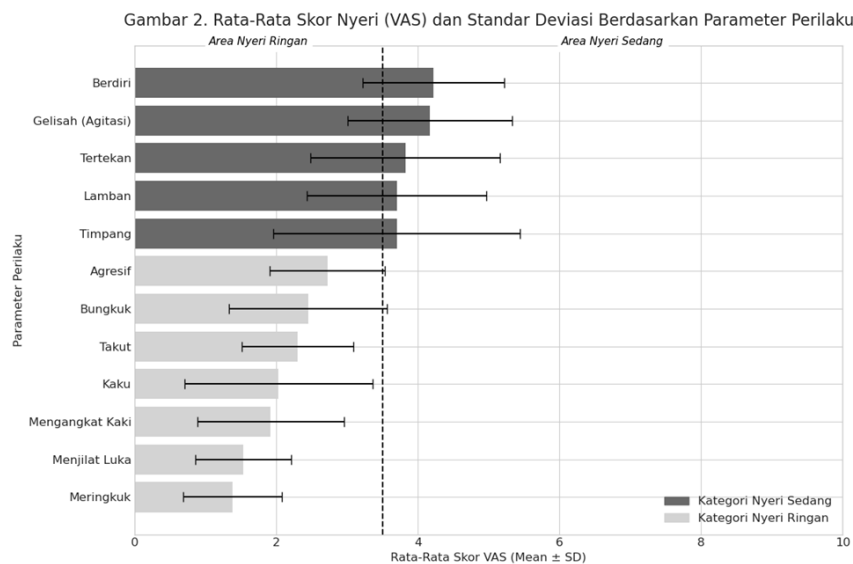


Figure 2. Average pain score (VAS) and standard deviation based on behavioral parameters. Description: This visualization summarizes the main quantitative findings, presenting a comparison of average pain scores (mean) and standard deviations (SD) represented by error bars. The graph is sorted from highest to lowest scores to highlight the most significant pain indicators. The dotted vertical line at a score of 3.5 marks the threshold between mild and moderate pain categories.

Gambar 3. Heatmap Profil Nyeri Komparatif Berdasarkan Faktor Demografis

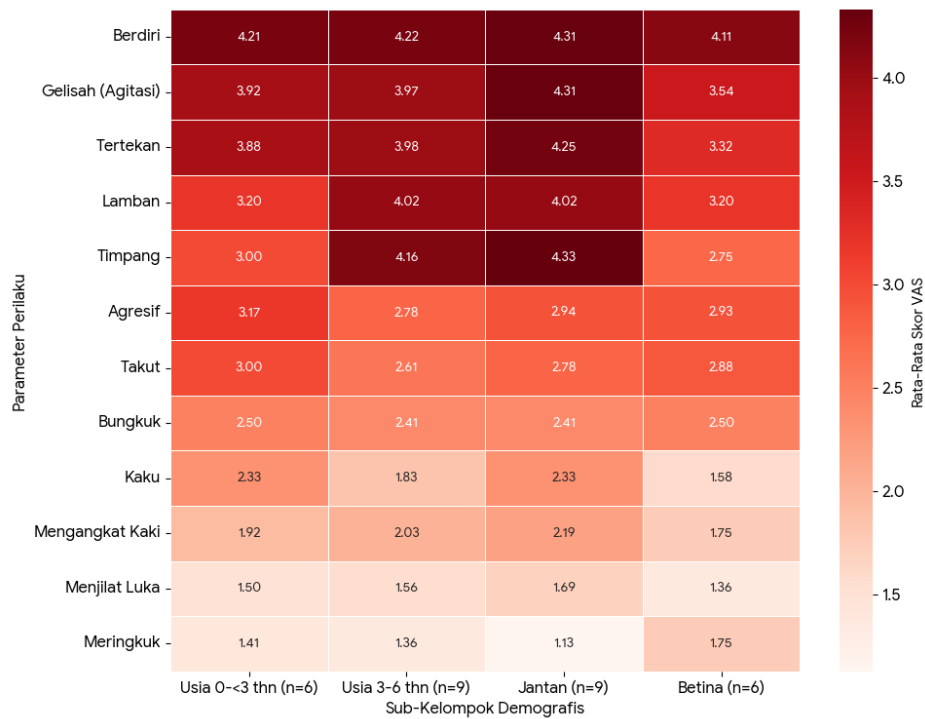


Figure 3. Comparative pain profile heatmap based on demographic factors. Description: This heatmap presents a comparative visualization of pain profiles, in which each cell represents the average VAS score with darker colors indicating higher pain scores. This visualization allows for quick pattern identification, highlighting the parameters most affected by age and sex factors.