Development and application of a novel approach to scoring ear tag wounds in dairy calves

Megan L. Harmon,1 Blair C. Downey,1,2* Alycia M. Drwencke,1,2 and Cassandra B. Tucker1†
1Center for Animal Welfare, Department of Animal Science, University of California, Davis 95616
2Animal Behavior Graduate Group, University of California, Davis 95616

ABSTRACT

Application of ear tags in cattle is a common husbandry practice for identification purposes. Although it is known that ear tag application causes damage, little is known about the duration and process of wound healing associated with this procedure. Our objective was to develop a detailed scoring system and use it to quantify wound healing in dairy calves with plastic identification tags. Calves (n = 33) were ear tagged at 2 d of age, and wound photos were taken weekly until 9 to 22 wk of age. This approach generated 10 to 22 observations per calf that were analyzed using a novel wound scoring system. We developed this system to score the presence or absence of external tissue types related to piercing trauma or mechanical irritation along the top of the tag (impressions, crust, and desquamation) and around the piercing (exudate, crust, tissue growth, and desquamation). Ears were scored as “piercing only” when tissue around the ear tag was intact. We found that impressions, crust, tissue growth, and desquamation were still seen in many calves by 12 wk of age. This suggests that extrinsic factors, such as mechanical disturbance and irritation, may have contributed to prolonged wound healing. Indeed, impressions along the top of the tag, likely caused by rubbing against the ear, were observed for nearly the full duration of the study. Further research is warranted to understand ways to improve the ear-tagging process.

Key words: ear tags, wound healing, animal welfare

INTRODUCTION

Ear tagging is a common livestock management procedure in which a piercing tip is punctured through the ear. Tags utilized in livestock production vary in design and material, ranging from visual tags made of metal or plastic to electronic radiofrequency ID (RFID) tags. These tags have widespread use (e.g., up to 80% of US dairy farms, USDA, 2016; required under European Union legislation, European Parliament, 2000) and are applied at many stages of life to serve different purposes, including identification, behavioral monitoring, insecticide application, record keeping, and disease tracking (e.g., Williams et al., 1981; USDA, 2016; Pereira et al., 2018). However, farm animals, including dairy cattle, exhibit behavioral responses during ear tagging procedures indicative of pain or stress (e.g., increased heart rate, respiratory rate, and tail flicking: Stewart et al., 2013). Tagging can also lead to traumatic wounds that may be slow to heal (Hayer et al., 2022). However, there is limited research on the occurrence of tissue alterations and healing progression associated with ear tagging.

Trauma, such as that induced by castration, nose flap application, or ear tagging, can lead to wounds (e.g., lacerations, contusions, and abrasions: Leaper and Harding, 2006), as can friction (e.g., chafing: Purim and Leite, 2014; rubbing: Valente et al., 2022) and pressure (e.g., pressure ulcers: Salcido et al., 2007; Bisang et al., 2022). Ear tagging creates a traumatic wound, but little is known about the healing progression that follows. Acute wounds often heal through a chronological, interdependent progression of 4 main stages: hemostasis, inflammation, proliferation, and remodeling (e.g., Velnar et al., 2009; Demidova-Rice et al., 2012). During this progression, cellular processes (platelet aggregation, inflammation, epithelial proliferation, angiogenesis, and fibroplasia) form external tissue types, including clots, scabs, granulation, and new epithelium, that are all associated with normal wound healing (Bertone, 1989), which can be quantified through visual assessment. Previous studies have observed limited clinical signs of lesions in ear tags, including hemorrhage, inflammation, scabbing, tissue deformation, ulceration, and purulent discharge in beef and dairy cattle (Johnston and Edwards, 1996; Hayer...
et al., 2022) and in sheep (Edwards and Johnston, 1999; Edwards et al., 2001), but some external tissue types that are generated during normal wound healing (e.g., granulation and new epithelium) were not measured or reported. Wound healing is expected to progress through the 4 main stages within 3 wk for minor acute wounds (e.g., abrasions, scrapes, and superficial burns in humans: Korting et al., 2011). The healing process of ear tag wounds has been continuously quantified for up to 6 wk (Hayer et al., 2022), but tissue alteration (reddening, pus, incrustation) was still present at this point. Measurements over a longer period of time, document- ing a comprehensive description of tissue alterations after ear tagging, are required to better understand the healing progression. Wound healing can be disrupted by both local (microenvironment, hygiene, infection, mechanical disturbance) and systemic (age, stress, disease) factors (Bertone, 1989; Guo and Dipietro, 2010). Infection, a wound healing impediment caused by increased microbial invasion of tissue, presents with attributes such as excessive exudate (e.g., purulent discharge or blood), prolonged inflammation, and swelling (Grey et al., 2006). In humans, infection onset after an initial surgical wound often occurs within the first 30 d post-operation (Young and Khadaroo, 2014). Similar infection timelines are seen in more avascular tissue wounds, such as ear cartilage piercings in humans (Meltzer, 2005). Proper management for ear tag wounds is often focused on initial infection. Recommended care by ear tag guides involves disinfecting instruments and skin before application to decrease infection risk and allow normal healing (Allflex, 2021). Likewise, sterile earrings and instruments are recommended to prevent infection in human ear piercings (Tweeten and Rickman, 1998).

Mechanical disturbances, such as skin movement or distortion, may also pose a concern. This irritation can occur at any point during wound healing and has the potential to disturb the organizing cells of the wound bed and to spread or exacerbate infection (Bertone, 1989). In human piercings, piercing handling or friction irritation from tight clothing can disturb the wound bed and prolong healing (ear piercings: Tweeten and Rickman, 1998; navel piercings: Meltzer, 2005). Rubbing of ear tags on objects has also been observed in animals, suggesting that these wounds are at risk for irritation as well (e.g., swine: Sherwin, 1990). Ear tagging in calves may thus encounter both initial infection risk and later irritation complications that would prolong the healing process.

The objective of this study was to develop a novel scoring system to describe the external tissue alterations present during the healing process of dairy calf ear tag wounds.

MATERIALS AND METHODS

Animals

This experiment was conducted from July to December 2021 at the University of California, Davis Dairy Facility. All procedures were approved by the University of California, Davis Institutional Animal Care and Use Committee (protocol #21601). Data (https://doi.org/10.25338/B8BS8J), supplemental figures (https://doi.org/10.5281/zenodo.7251062), and RMarkdown files (https://doi.org/10.5281/zenodo.7251060) for all figures are available online in the Dryad repository (Harmon et al., 2023).

We monitored all healthy female Holstein and Jersey calves born between July and October 2021, for a total of 33 heifers (24 Holsteins, 9 Jerseys) in this study. Heifers were followed for a variable number of weeks (9–22 wk of age; sample sizes reflected in all figures); data collection ceased in December due to a lack of continued assistance in monitoring calves. From birth to 64 to 69 d of age, heifers were housed individually in outdoor plastic hutches (2 × 1.5 × 1.4 m, length × width × height) surrounded by wire panels (2 × 1.5 × 0.9 m, length × width × height). Hutches were bedded with rice hulls (~15–20 cm depth), and fresh bedding was added every 2 wk. Calves were fed grain (Starter Calf Feed 901033, Associated Feed and Supply Co.) and water ad libitum in a bucket. Calves were fed colostrum twice daily (0900 and 1600 h; 1.4 or 1.9 L/feeding for Jerseys and Holsteins, respectively) from 0 to 5 d of age, then a diet of rehydrated milk replacer (26% CP, 16% fat, 15% total solids, mixed as indicated at a rate of 142 g/L of hot water; Calva Products Inc.) via a bottle until 35 to 38 d of age, then a bucket. Milk was fed to 10% of BW, according to farm protocol (Jerseys and Holsteins were fed 1.4 and 1.9 L, respectively). Milk provision increased by 0.5 L per feeding at 8, 18, and 32 d of age. Calves were gradually weaned starting at d 50 by removing 1 feeding, and were fully weaned at d 60 and provided with a TMR. During the milk-fed period, electrolytes were fed to 14 calves for 1 to 3 feedings each. Of the 14 calves, 8 were treated with Sustain III (Bimed Inc.) 1× each, as a precaution if loose manure or lack of appetite persisted after 1 feeding of electrolytes. All calves were disbudded via caustic paste at 3 d of age (13 Holstein, 5 Jersey) or via an electric cauterity iron at 6 wk of age (11 Holstein, 4 Jersey) as part of a separate experiment, balanced based on birth weight and breed.

At 64 to 70 d of age (mean = 66 d), weaned heifers were moved to an outdoor, covered group pen (5.7 × 4.1 m) bedded with rice hulls. Pens housed 8 similarly aged heifers. At 70 to 139 d of age (mean = 105 d), heif-
ers moved to an outdoor group pen (43.3 × 7.2 m) of 30 similarly aged animals. This pen was partially covered with a roof and had rice hull bedding in one half. At 100 to 206 d of age (mean = 161 d), heifers moved to a new group pen similar in structure to the previous pen. In all group pens, heifers were fed a mix of grain and alfalfa behind head gates.

**Ear Tag Application and Measurement**

Calves were tagged at 2 d of age in both ears with farm identification tags (Global Maxi Female GXF/GSM on the front and Global Large Male GLM on the back, 16.7 g; Allflex). Tags were applied with pliers by farm employees (Universal Total Tagger Applicator APP-UTT, Allflex); both ears were disinfected with chlorohexidine 2% before application, as per standard farm practice. Applied tags could move and twist freely within the piercing site. Target tag placement was between the ridges, within the proximal one-third of the ear (Supplemental Figure S1,DOI:10.5281/zenodo.7251062; Harmon et al., 2023). Post-hoc ear tag placement measurements were taken on the same day when calves were 83 ± 26 d (mean ± SD; 150 mm MC1630EWRI Digital Caliper, Mahr GmbH; Table 1), due to labor constraints. Tag placement measurements collected for each ear were distance from tag to head, distance from tag to end of ear, and thickness of ear. Distance from tag to head and distance from tag to end of ear were used to calculate tag location as a proportion of total ear length. Ear tag placement in relation to the ear ridge was qualitatively measured as “on” or “between” the ear ridges for both ears. Calves were also ear tagged in the left ear (with the exception of 1 calf tagged in the right ear) with an RFID tag (High Performance Half Duplex HDX Ultra EID Tag, 8 g, Allflex) at 4 to 7 d of age. Distance from the RFID tag to the head was also measured. Jersey heifers received an identifying tattoo in the left ear, and all calves had a tissue sample removed from the ear for genetic testing at 61 ± 25 d, as per farm protocol.

**Digital Photography of Wounds**

Photographs were taken of calf ears between July and December 2021 (DSLR camera D3600, Nikon). Researchers were trained on photography using a task-based standard operating procedure that detailed required photo angles and distance from calf. All photos were taken using a ring light (RL100 Macro LED Ring Flash, ProMaster) to ensure consistent quality. Following an initial photo taken on d 4 of life (hereafter referred to as “wk 0”), photos were taken once per week for each calf starting in wk 1. Photos were taken for both ears at 4 different locations: front of ear tag, under tag (front), back of ear tag, under tag (back). The tag was lifted for both “under tag” photos.

**Wound Scoring System**

We developed a novel scoring system to evaluate ear tag wounds. Based on initial observations, the presence or absence of 7 different external tissue types along the top of the tag (impressions, crust, desquamation) and around the piercing (exudate, crust, tissue growth, and desquamation) were evaluated at all 4 photo locations for each ear (Figure 1). We also scored if no visible wound-related tissue types were present beyond the piercing. All tissue types were scored from both the front and back angles of the ear, except impressions, impression crust, and impression desquamation, which were only present at the front of the tag. Some tissue types were modeled after Adcock and Tucker (2018; exudate, crust), whereas others were specific to ear tag wounds (e.g., “desquamation” and “impressions”). Weekly photos were scored by 1 observer who was trained to reliability ≥76% on all tissue types against 2 qualified researchers (Cohen’s kappa; irr package version 0.84.1, Gamer et al., 2019; R version 4.2.2, R Core Team, 2022; RStudio version 2022.12.0+353, R Studio Team, 2022). Piercing crust reliability was ≥76%, whereas all other tissue type reliabilities were ≥80%. This reliability was assessed using an 80-photo
Placement of Tags

Tags were placed slightly further out in the ear than one-third the distance from the head (left: 0.42 ± 0.01, right: 0.44 ± 0.01 mm, median proportion of the total length of the ear ± SE; Table 1). Most tags were placed between the ridges, but 21% were placed on the ridge (Table 1). Of the 21% of tags placed on the ridge, 86% were in the left ear. It is possible that this laterality was due to the tagger’s handedness, but this has previously been found to be nonsignificant, albeit with a mostly right-handed population (Hayer et al., 2022). Non-optimal tagging is not uncommon and is recorded in up to 40% of ear tags on farms (Hayer et al., 2022). Tag placement may influence pain or wound healing, as the density of nerves and larger blood vessels is higher in up to 40% of ear tags on farms (Hayer et al., 2022). Tag placement may influence pain or wound healing, as the density of nerves and larger blood vessels is higher along the ridges (Rashid et al., 1987). Manufacturers commonly recommend application between the ridges (Allflex, 2021), and others have found associations with tagging on the ridge and wound lesions (Hayer et al., 2022). However, there was no clear difference in wound tissue type progression between left and right ears (Supplemental Figures S2 to S5) or for tags on or between the ridges (Supplemental Figures S6 to S9, https://doi.org/10.5281/zenodo.7251062; Harmon et al., 2023), based on visual inspection. Tagging on the rib or between the ridges appears to cause similar external wounds, but whether pain during tagging or the healing process differs by location is not yet known. All tags were free to rotate within the piercing site, which is anecdotally suggested to improve healing but may also contribute to mechanical wound disturbance, a known factor in slowed wound healing (Bertone, 1989).

RESULTS AND DISCUSSION

Wound tissue types are presented separately for the front (Figure 2) and back (Figure 3) of the ear. Left and right ears were combined in these results as they did not differ based on visual inspection (Supplemental Figures S2 to S5, https://doi.org/10.5281/zenodo.7251062; Harmon et al., 2023).

Placement of Tags

Almost all calves in our study had long-lasting ear tag wounds. Very few ears were scored as “piercing only” at wk 0 (front: 2%, Figure 2; back: 9%, Figure 3), indicating that ear tag application causes immediate damage, including impressions, crust, tissue growth, and desquamation, beyond the hole itself. Tissues associated with the healing process were present for up to 12 wk, with only 10% of calves scored as “piercing only” at this point (Figures 2 and 3). Sample size varied over time, but many calves still had impressions, exudate, crust, tissue growth, or desquamation present at the end of their data collection period (9–22 wk of age, Figures 2 and 3). Evaluation of the 1 calf who had data in wk 22 found that desquamation was still present at this point. Ear tag wounds have previously only been followed continuously for up to 6 wk post-application (Hayer et al., 2022) but have been suggested to have similar healing durations as other standard procedures for cattle (e.g., castration: up to 9 wk, Norring et al., 2017; hot-iron disbudding: up to 13 wk, Adecock and Tucker, 2018). Our results indicate that the healing process can be substantially longer than that reported for other painful procedures, suggesting an effect of extrinsic factors in healing of ear tag wounds.

Piercing crust was common throughout data collection. Crust was already present in 88% of ears viewed from the back at wk 0, with the highest prevalence occurring within the first 2 wk (front: 94% in wk 1; back: 100% in wk 2). This is consistent with other findings, where incrustations were common and found at the highest frequency 1 to 3 wk after piercing (85% to 69%, respectively; Hayer et al., 2022). This initial incrustation may be the resulting tissue type of hemostasis, in which a blood clot is formed to stop hemorrhage after the initial trauma (Gale, 2011). However, by wk 6, piercing crust was still present in 74% of ears from the front and 89% from the back, in contrast to Hayer et al. (2022)’s findings of incrustation in only 36% of calves at 6 wk. Piercing crust varied in both color and amount across time scored (Figure 4), possibly associated with different stages of healing, although we did not score the severity of crust. Human wounds have been scored using the Red-Yellow-Black (RYB) classification system, which uses exudate color and quantity as indicators of healing complications, ulti-
<table>
<thead>
<tr>
<th>Examples</th>
<th>Tissue</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piercing only</td>
<td>No visible wound-related tissue types present beyond the piercing.</td>
<td></td>
</tr>
<tr>
<td>Impressions</td>
<td>Tissue outside the area of the piercing is sunken or a distinct line of discoloration compared to the surrounding area is present. Crust can also be present.</td>
<td></td>
</tr>
<tr>
<td>Impression crust</td>
<td>Raised dried tissue of any size that is tan, yellow, red, black, or pink. This is scored outside the area of the tag.</td>
<td></td>
</tr>
<tr>
<td>Impression desquamation</td>
<td>Tissue outside the area of the piercing has dry patches of epithelium lifting away or detaching from the ear. This category is mutually exclusive.</td>
<td></td>
</tr>
<tr>
<td>Exudate</td>
<td>Moisture that is either bright red, yellow, cream, or white is present.</td>
<td></td>
</tr>
<tr>
<td>Piercing crust</td>
<td>Raised dried tissue of any size that is tan, yellow, red, black, or pink. This is scored in connection to the piercing.</td>
<td></td>
</tr>
<tr>
<td>Tissue growth</td>
<td>Smooth pink or black tissue surrounding the ear tag or piercing and extending beyond the undamaged ear so that the tissue is not level with the piercing.</td>
<td></td>
</tr>
<tr>
<td>Piercing desquamation</td>
<td>Dry patches of epithelium lift away or detach from the ear surrounding the piercing. This category is mutually exclusive.</td>
<td></td>
</tr>
</tbody>
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**Figure 1.** Wound scoring system for dairy calves following ear tagging. The impressions, impression crust, and impression desquamation tissue types were scored from the front top angle only.
Figure 2. Proportion of tissue types present at the front of the ear at each week of age (0–22 wk). Calves were ear tagged at 2 d of age and ear tag wounds were scored weekly, beginning on d 4 of life (wk 0). Brighter colors indicate a higher proportion of ears (left and right ears for all calves included in that week's sample, noted across the top) had that tissue type present at that week, whereas darker colors indicate a lower proportion of ears.
Figure 3. Proportion of tissue types present at the back of the ear at each week of age (0–22 wk). Calves were ear tagged at 2 d of age and ear tag wounds were scored weekly, beginning on d 4 of life (wk 0). Brighter colors indicate a higher proportion of ears (left and right ears for all calves included in that week's sample, noted across the top) that that tissue type was present at that week, whereas darker colors indicate a lower proportion of ears.
mately guiding appropriate wound treatment (Stotts, 1990; Vermeulen et al., 2007). Given the observed variability in quantity, color, and presentation of crust in our study, incorporating a similar classification system may allow for more refined assessment of healing in ear tag wounds, facilitating better discrimination between crust associated with acute trauma and later healing complications.

Tissue growth and exudate were common but consistently more prevalent at the front of the ear compared with the back. At the maximum prevalence, tissue growth was seen in 91% of calves from the front (wk 4) but 67% from the back (wk 6). Similarly, exudate was documented in 86% of calves from the front (wk 7) and 59% from the back (wk 7). Across species, epidermal heterogeneity is often seen on ventral and dorsal surfaces (Duverger and Morasso, 2009). In calves, we see fewer hair follicles on the front of the ear than on the back, which may lessen the physical barrier between the ear tag and the wound. This could lead to more irritation at the front of the ear, leading to persistence of wound types reflective of fresh lesions, such as exudate.
and tissue growth. A similar pattern has been documented in mice, with wounds on hairless skin showing delayed healing compared with those on hair (Langton et al., 2008).

Frontal tissue growth, exudate, and piercing crust were still present in many ears by 12 wk (52, 35, and 38%, respectively) with only 10% of both front and back ears showing “piercing only” at this point. All 3 tissue types were still present at 20 to 21 wk post-tagging in both the front and back of the ear, although sample size was lower at these time points (Figures 2 and 3, n = 7 and 4 calves, respectively). In comparison, Hayer et al. (2022) found the presence of incrustation, pus, and blood discharge in only 19.6% of calves older than 10 wk. In studies on hot-iron disbudding wounds, exudate, granulation, and crust have been observed at their greatest prevalence 2 to 6 wk after disbudding (dairy calves in Adcock and Tucker, 2018, and Reedman et al., 2022; goat kids in Alvarez et al., 2019), with crust present at a maximum of 8 to 10 wk after disbudding (dairy calves: Adcock and Tucker, 2018; goat kids: Alvarez et al., 2019). Although initial healing for ear tag wounds appears similar to that in studies examining both this and other standard painful procedures, tissue types associated with healing persisted for longer than has previously been reported. This poses clear welfare concerns, because the pain sensitivity of similar unhealed wound types has been shown to be greater than that of healed tissue (e.g., disbudded calves; Adcock and Tucker, 2018).

**Environmental Factors**

The long healing time and persistence of tissue types seen in our study could be associated with environmental factors. Routine human handling could have led to mechanical wound disturbance (i.e., friction) against the ear, which is known to slow healing (Bertone, 1989) and lead to complications (e.g., human ear piercing: Meltzer, 2005; Tweeten and Rickman, 1998; pigs: Sherwin, 1990). Healing may also have been disturbed by calves interacting with penmates after grouping (e.g., Hayer et al., 2022) or rubbing against their enclosures, similar to pigs (Sherwin, 1990). Wound healing can also be slowed by poor hygiene, which can cause infection (e.g., mice; Karner et al., 2020) and is associated with increased inflammation, incrustation, and bleeding in calves (Hayer et al., 2022). Poor bedding hygiene may also increase fly load, leading to head throws, kicking, and skin twitches (Mullens et al., 2006) that may further agitate ear wounds due to friction. In addition, our calves were fed restricted quantities of milk (10% of BW/d), which is known to lead to slower wound healing compared with calves fed a biologically normal amount of milk (e.g., after disbudding; Reedman et al., 2022). Our calves likely had reduced energy available to allocate to healing, contributing to long-lasting wounds.

**Ear Tag Type**

Our study involved the application of 2-piece plastic Allflex tags weighing 16.7 g. Wounds have also been observed from a variety of different tag types in different settings, including 1-piece ATag Feedlot Allflex tags in pasture-based beef cattle and 2-piece MSD Animal Health Intelligence accelerometers in dairy calves and feedlot cattle (B. C. Downey, R. E. Coon, M. L. Creamer, University of California–Davis, CA; personal communication). These tags varied in weight (11.3 g vs. 28.9 g, respectively) and application method (pierced through the front vs. back, respectively) and were applied at different ages. Evidence of wounds across tag types, including plastic and metal materials, has also been documented in sheep (Edwards and Johnston, 1999). Taken together, this suggests that long-lasting wounds could be widespread across a diverse range of tag designs.
Implications for Scientific Applications

Wounds and potential pain resulting from the ear tag healing process may limit conclusions drawn in other studies. For example, ear tag accelerometers are used both on farm and in research settings to track behavior and health (e.g., Hill et al., 2017; Gardaloud et al., 2022), but it is not yet known whether wounds affect these measurements, particularly if ear movement is reduced or altered due to pain, or if crust build-up prevents the tag from moving normally in the ear. In addition, pain associated with procedures like disbudding is often evaluated using behavioral changes in response to analgesics (e.g., McMeekan et al., 1999; Ede et al., 2019), which provide systemic relief, but this may be conflated with pain associated with wound tag healing.

CONCLUSIONS

Using our novel wound scoring system, we showed that ear tags led to long-lasting presence of tissue types associated with healing. These tissue types persisted for at least 12 wk in many calves. Piercing trauma was also accompanied by friction wounds from the tag itself, suggesting that both infection and irritation may play a role in slow healing. Alternate identification methods that either do not cause long-lasting wounds or promote healing should be explored.

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REFERENCES


ORCIDs

Megan L. Harmon https://orcid.org/0000-0001-5294-5231
Blair C. Downey https://orcid.org/0000-0003-3747-0164
Alycia M. Drwencke https://orcid.org/0000-0001-8201-5764
Cassandra B. Tucker https://orcid.org/0000-0002-6014-441X