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Efficacy of a novel cervical dislocation tool for humane euthanasia of broilers and broiler breeders

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ABSTRACT Euthanasia is an essential task performed daily on commercial poultry farms around the world to safeguard animal welfare. Manual cervical dislocation (**MCD**) is the most common euthanasia method but can be challenging to perform given the physical strength required to implement this technique. Therefore, the objective of this study was to evaluate the efficacy of a novel cervical dislocation tool (**NCDT**) compared to MCD. A total of 60 Ross 308 chickens (6-wk old) and 60 Ross 706 parent stock breeders (21-wk old) were enrolled in the study. Birds were sexed, blocked by body weight, and allocated to 1 of 2 treatments: 1) MCD and 2) NCDT. Immediately following euthanasia application, insensibility, and death were monitored. Once death was confirmed, gross evaluation, radiograph, and macroscopic/microscopic scoring were performed. Both euthanasia methods were 100% effective in achieving insensibility followed by cardiac and respiratory arrest in both age groups. In 6-wk-old broilers, there were no differences in insensibility measures or location and severity of the dislocation site by treatment. The NCDT treatment group showed an increased frequency of fractures located at the tooth-like process that projects from the cranial aspect of the centrum of the axis (dens) but had no impact on bird insensibility. For parent stock, differences in nictitating membrane reflex (**NMR**) and laceration scores for birds euthanized with NCDT were found and likely associated with additional force exerted with the tool. The NCDT is a promising replacement for MCD and future work should address the development of free and accessible training materials for on-farm use.

Key words: broiler breeder, broiler, euthanasia, cervical dislocation, animal welfare

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INTRODUCTION

Humane euthanasia is the process of ending the life of an animal in a way that minimizes pain and distress (American Veterinary Medical Association, 2020; Boyal et al., 2022). This requires rapid loss of consciousness followed by irreversible impairment of respiratory, cardiac, and brain functions (AVMA, 2020). In the poultry industry, implementing timely and humane euthanasia is an ethical obligation conducted daily to safeguard the welfare of compromised birds in our care (Jacobs et al., 2019; Nielsen et al., 2019). To successfully conduct euthanasia in a commercial poultry operation, farm workers must be appropriately trained with approved euthanasia methods that they feel confident in performing consistently (Bandara et al., 2019; Linares et al., 2018). Several euthanasia methods are approved for poultry, but by far, the most common method implemented in the United States broiler industry is manual cervical dislocation (**MCD**) (Jacobs et al., 2019).

Manual cervical dislocation is considered an acceptable euthanasia method with conditions under the euthanasia guidelines of AVMA (2020). It is also considered a preferred or permitted method by the AVMA and the American Association of Avian Pathologists (**AAAP**) if used in scenarios for depopulation (Center For Food Animal Well Being, 2014; AVMA, 2019). Insensibility and death from MCD are achieved by the separation of the spinal cord between the base of the skull and the first cervical vertebrae (C1), thus eliminating blood supply and neuronal connectivity to the brain (Jacobs et al., 2019).

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The AVMA (2020) guidelines for euthanasia do not provide requirements or limitations pertaining to bird weight or age when performing MCD, but the method is most effective for smaller (i.e., < 2.3 kg) and younger birds As birds age and become larger, greater physical strength is required by the person performing MCD to effectively separate the skull from C1. Physical fatigue may become a common challenge faced by caretakers euthanizing birds, particularly when the birds are heavier/older or multiple birds require euthanasia in one setting (Martin et al., 2018). Thus, identifying methods or providing tools to facilitate the cervical dislocation process is needed.

A physical tool may be used to make cervical dislocation easier for the operator, but the method must meet criteria to ensure good animal welfare (i.e., rapid loss of consciousness followed by cardiac and respiratory arrest; AVMA, 2020). In rabbits, an assisted euthanasia device mounted to a wall has been used to assist in the dislocation process by minimizing ergonomic stressors experienced by individuals euthanizing heavy rabbits (≥ 150 g body weight) (Euthanasia Guide for Ontario Commercial Meat Rabbit Producers, 2016). A commercial broiler breeder company adapted this novel cervical dislocation tool (**NCDT**) to aid with on-farm poultry euthanasia. This device allows the caretaker to position the bird's neck within the device and gently pull upward, using additional body strength (i.e., both arms and back) as compared to only one arm pulling with MCD. Additionally, the arm span and/or height of the person is not a relevant factor for successfully performing euthanasia with NCDT and this tool may be particularly helpful with larger birds or when conducting euthanasia on multiple birds. Anecdotal experience with the tool on commercial farms suggests that NCDT is as effective in euthanizing birds as MCD. However, no formal studies to date have evaluated the efficacy of this device. Therefore, the objective of this study was to compare the euthanasia efficacy between NCDT and MCD in broilers aged 6 and 21 wk. We hypothesized that animal welfare outcomes related to insensibility and death would not differ between NCDT and MCD and that macroscopic or microscopic trauma associated with each technique would not differ between treatments.

MATERIALS AND METHODS

The protocol was approved by North Carolina State University Institutional Animal Care and Use Committee (no. 22-482) and in accordance with the Guide for the Care and Use of Agricultural Animals in Research and Teaching (Tucker et al., 2020). Considering there was no data available at the time to perform a power analysis specific to NCDT efficacy, the sample size was determined using a combination of ethical and financial considerations.

This was a 2-stage study evaluating the efficacy of a NCDT in achieving humane euthanasia in commercial broilers at 6 and 21 wk of age.

Study Animals and Housing

Six-Week-Old Birds Sixty commercial Ross 308 roosters (n = 30; weight: 1.7 ± 0.4 kg) and hens (n = 30; weight: 1.6 ± 0.4 kg) were transferred from a terminal university teaching protocol and utilized for this study. Broilers were housed in a pen composed of wire panels according to Ag Guide standards and had free choice access to feed and water. Wood shavings were provided as litter and replaced as needed and additional environmental enrichment, including rubber balls, were provided daily. Upon initiation of the trial, individual birds were removed from the pen and carried in sternal recumbency with the keel supported and wings restrained to an experimental room where the trial was completed.

Twenty-One-Week-Old Birds Sixty 21-wk-old commercial Ross 706 parent stock roosters (n = 30; weight: 2.5 ± 0.8 kg) and hens (n = 30; weight: 2.3 ± 0.7 kg) were provided by a commercial poultry breeder company. All birds were housed on commercial farms that met standard industry practices outlined in the National Chicken Council Animal Welfare Guidelines (National Chicken Council, 2022). Birds were transported by plastic carrier crates (35 in x 23.5 in x 10.25 in, 5 birds per crate) on a truck for 45 min to the research facility. Upon initiation of the trial, individual birds were removed from the crates and carried in a similar manner to the 6-wk-old birds to a room where the trial was completed.

Euthanasia Procedure

One trained investigator (R.C.) with over 20 yr of experience performing poultry euthanasia conducted all euthanasia events on 6-wk-old birds while euthanasia of 21-wk-old birds was performed by 1 trained investigator (S.R.) with over 12 yr of euthanasia experience. Given the individual performing the euthanasia were different, age groups were not statistically compared.

On the day of the trial, broilers were individually weighed, blocked by sex, and randomly allocated to 1 of 2 euthanasia treatments:

1. **MCD:** Birds were euthanized by manual cervical dislocation as described previously.
2. **NCDT:** Birds were euthanized using a novel cervical dislocation tool. The NCDT was mounted approximately 40 cm above the floor. In a sequential process, the bird's head was placed dorsally in between 2 metal arms of the device at the base of the C1 vertebra. Once the head was secure, an upward traction at a 45-degree angle was applied by the individual until a loss of resistance indicating separation of the vertebrae was detected (Figure 1).

Evaluation of Treatment Efficacy

Insensibility and Death Immediately following euthanasia, insensibility was evaluated using 5 measures described in Table 1. Death was confirmed at the time of

Figure 1. Novel cervical dislocation tool in use.

cardiac arrest (s), determined by auscultation via stethoscope.

Radiographs Following confirmation of death, carcasses were radiographed to determine location and degree of cervical dislocation severity, and presence of fractures in the dens or crushed vertebral bodies using a portable X-ray unit (MasterRad A6 Handheld Portable High Frequency X-Ray Generator, Medicatech Inc., Irvine, CA; Wireless Flat Panel Detector, Pinnacle X-Ray Inc., Suwanee, GA; Acquisition and Processing Software, Voyance, Irvine, CA). One lateral image was taken of the entire head and cervical spine at a film-focus distance of 76 cm and a radiographic technique of 60 kVp/3 mAs. Radiographs were downloaded as DICOM files (n = 120 radiographs), then scored by one board-certified veterinary radiologist (N.N.) using a scoring rubric modified from Bandara et al. (2019) (Tables 2 and 3).

Macroscopic and Microscopic Evaluation Following radiography, a gross visual assessment of the dislocation site was performed on all birds by a poultry veterinarian (E.R.) as described in Table 4.

For further evaluation, histopathology was conducted on 12 randomly selected male and female 6-wk-old broilers (n = 24 total birds) by a double board-certified poultry pathologist (S.C.). Tissue was sectioned and immediately fixed in 4% neutral buffered formalin for at least 1 wk. All lesions, including fractures of the skull, vertebral dislocation, and cervical vertebral fractures, were recorded. Additionally, the anatomic integrity of cervical structures, including the jugular veins, vagal nerves, trachea, esophagus, cervical muscles, as well as the location and degree of hemorrhages and lacerations of the nervous tissue (cervical spinal cord and brain) were noted. Heads, spinal cords, and surrounding soft tissues were decalcified for at least 4 wk in 10% EDTA solution (pH 7.4) at room temperature (25°C). Afterward, formalin-fixed, and decalcified heads and necks were cut rostro-caudally in 3 to 5 coronal or sagittal sections of 0.5 cm thickness. For each cross-section of the head, the extent of subdural and parenchymal hemorrhage was assessed using a 5-point scoring system quantifying the total area impacted by hemorrhage (Score 0: 0%, Score 1: up to 25%, Score 2: up to 50%, Score 3: up to 75% and Score 4: up to 100% of the area affected). Due to inappropriate tissue collection technique, tissue samples collected from 12-wk-old birds resulted in pathological artifacts rendering the accuracy of the results unreliable. Therefore, these samples were not included in the results.

Following hemorrhage assessment, 2 sections of the spinal column were processed for routine histopathology: one longitudinal from the dislocated edge of the vertebra and 1 transversal section at the 0.5 cm distance from the dislocated edge. Sections of spinal columns, muscles, trachea, and subcutis were routinely processed, embedded in paraffin, cut into 3.5-μm sections, and stained with hematoxylin and eosin following standard procedures. For each tissue section, the location and extent of hemorrhage (subcutaneous, parenchymal, and subdural), demyelination, vertebral fractures, tracheal lesions, and edema were assessed using a 4-point scoring system quantifying total area impacted by each measure (Score 0: 0%, Score 1: up to 20%, Score 2: up to 50%, Score 3: up to 100% of the area affected.

Table 1. Insensibility and death measures, descriptions, and procedures. Adapted from Bandara et al. 2019.

Measure	Description	Procedure
Nictitating membrane reflex (NMR) cessation	Transient closure of the nictitating membrane in response to mechanical stimulation	The medial canthus of the eye or the cornea was lightly touched with a fingertip. Reflex cessation (i.e., time in which last NMR was present) was recorded in seconds
Pupillary light reflex (PLR) cessation	Constriction of the pupil in response to light	Light was directed into the eye with a flashlight. Pupil constriction cessation (i.e., time in which last pupil constriction was present) was recorded in seconds
Clonic and tonic convulsion (CT) cessation	Rapid, uncoordinated movement of the body and wings (clonic) or muscle rigidity with the legs and wings outstretched (tonic)	Visual observation of rapid wing flapping and foot paddling or legs and neck outstretched. Clonic/tonic convulsion cessation (i.e., time in which last convulsion was observed) was recorded in seconds
Feather erection onset	Sudden erection of feathers, not in response to external stimuli	Visual observation of first occurrence of F was recorded in seconds
Cloacal relaxation onset	Cloacal opening and relaxation	Visual observation of first cloacal opening was recorded in seconds

Table 2. Location and degree of cervical dislocation (modified from Bandara et al., 2019).

Location	Definition
Occipital	Separation occurs between base of skull (occipital bone) and C1 vertebrae, where no vertebrae are attached to the occipital bone
C1 (Atlas)	Separation occurs between C1 and C2 vertebrae, where C1 remains attached to the occipital bone
C2 (Axis)	Separation occurs between C2 and C3 vertebrae, where C1 and C2 remain attached to the occipital bone
C3	Separation occurs between C3 and C4 vertebrae, where C1, C2, and C3 remain attached to the occipital bone
C4	Separation occurs between C4 and C5 vertebrae, where C1−C4 remain attached to the occipital bone
Degree	Definition
Luxation	Complete dislocation of 2 vertebrae (or C1 and occipital bone) at the articular process joints
Subluxation	Partial (incomplete) dislocation of 2 vertebrae at the articular process joints

Table 3. Location and description of fractures by type (modified from Bandara et al. 2019).

Location	Definition
Dens	Fracture of the dens (tooth-like process that projects from the cranial aspect of the centrum of the axis (C2) to articulate with the atlas (C1)).
Crushed vertebral bodies	Multiple fractures of a vertebra that cannot be classified as a fragment, articular process, or dens fracture

Table 4. Scoring system for gross evaluation measurements assessed at dislocation site.

Measurement	Scoring system
Laceration and external bleeding	0 = no laceration of the skin 1 = laceration of the skin with no external bleeding 2 = laceration of the skin with external bleeding
Subcutaneous hemorrhage (SCH) at cervical dislocation site	0 = none 1 = <25% of surface area
Damage to trachea	2 = 26−50% of surface area
Transection of spinal cord	3 = 51−75% of surface area 4 = 76−100% of surface area

Statistical Analysis

Data were analyzed using R software within the integrated RStudio environment (Version 4.1.0; 2021-06-29; RStudio, Inc., Boston, MA). The functions and packages used were presented in the format 'package::function' corresponding to the computer programming language in R. For all tests, a significance of 5% was considered. All figures were created with a color palette distinguishable by colorblind people (ggplot2::scale_colour_viridis_d). All analyses were conducted separately for each age dataset (6 and 21-wk-old birds). R's packages and functions conducted in the current study can be found in the supplementary material (Table S1).

Insensibility and Death Individual linear models (stats::lm) were used to compare euthanasia treatment effect on bird weight, insensibility measures (NMR, PLR, CL convulsions, feather erection, and cloacal relaxation), and cardiac arrest. Variables assumed normal distribution as defined by Cramer-Von Mises (nortest::cvm.test) after Box-Cox transformation (car::powerTransform). For all models, euthanasia treatment and sex (covariable) were used as fixed effects. Bonferroni was used to adjust multiple comparisons to the post-hoc test (lsmeans::lsmeans and multcomp::cld) and the Wilcoxon test (stats::wilcox.test) was used to compare the treatments for variables presenting as not normally distributed even after transformations (weight, NMR, PLR for 6-wk old birds, and cloacal relaxation for 21-wk-old birds).

Radiographs Location and degree of cervical dislocation severity and presence of additional fractures (i.e., dens fractures or crushed vertebral bodies) was analyzed using a logistic regression model (stats::glm). Euthanasia treatment and sex (covariable) were used as fixed effects. Bonferroni was used to adjust multiple comparisons to the post-hoc test (lsmeans::lsmeans and multcomp::cld).

Macroscopic and Microscopic Evaluation For both ages, only descriptive statistical analysis was performed for the following gross evaluation measurements: subcutaneous hemorrhage at the dislocation site, damage to trachea, and transection of the spinal cord, given each score presented no variation. Laceration score was analyzed using a generalized linear model adjusted by Poisson distribution (stats::glm) with euthanasia treatment and sex (covariable) used as fixed effects. For microscopic pathological scoring of head and spinal column, Wilcoxon test (stats::wilcox.test) was used to compare treatments in 6-wk-old birds, respectively.

RESULTS

Insensibility and Death

Six-Week-Old Birds No differences were found in any of the insensibility measurements between euthanasia treatments and cardiac arrest was achieved on average at 222 ± 61 and 184 ± 57 s for MCD and NCDT birds ($P > 0.05$). There was no influence on weight or sex on insensibility and death parameters ($P > 0.05$; Table S2).

Twenty-One-Week-Old Birds Birds euthanized with MCD displayed a longer NMR duration than NCDT birds (Figure 2). There was a sex effect within this age group. Male birds weighed more ($\beta = 0.233$; $P = 0.016$) and exhibited a longer feather erection duration onset ($\beta = 0.264$; $P = 0.049$) compared to females. No differences were found in any of the remaining insensibility measures and cardiac arrest was achieved on average at 92 ± 31 and 100 ± 38 s for MCD and NCDT birds ($P > 0.05$; Table S2).

Radiographs Location and cervical dislocation severity for both age groups were not different between euthanasia treatments. The presence of den fractures was greater in the NCDT treatment group compared to the MCD group in 6-wk birds only (Figures 3 and 4). No other differences in dislocation severity or fractures were found and there was no sex effect (Table S3).

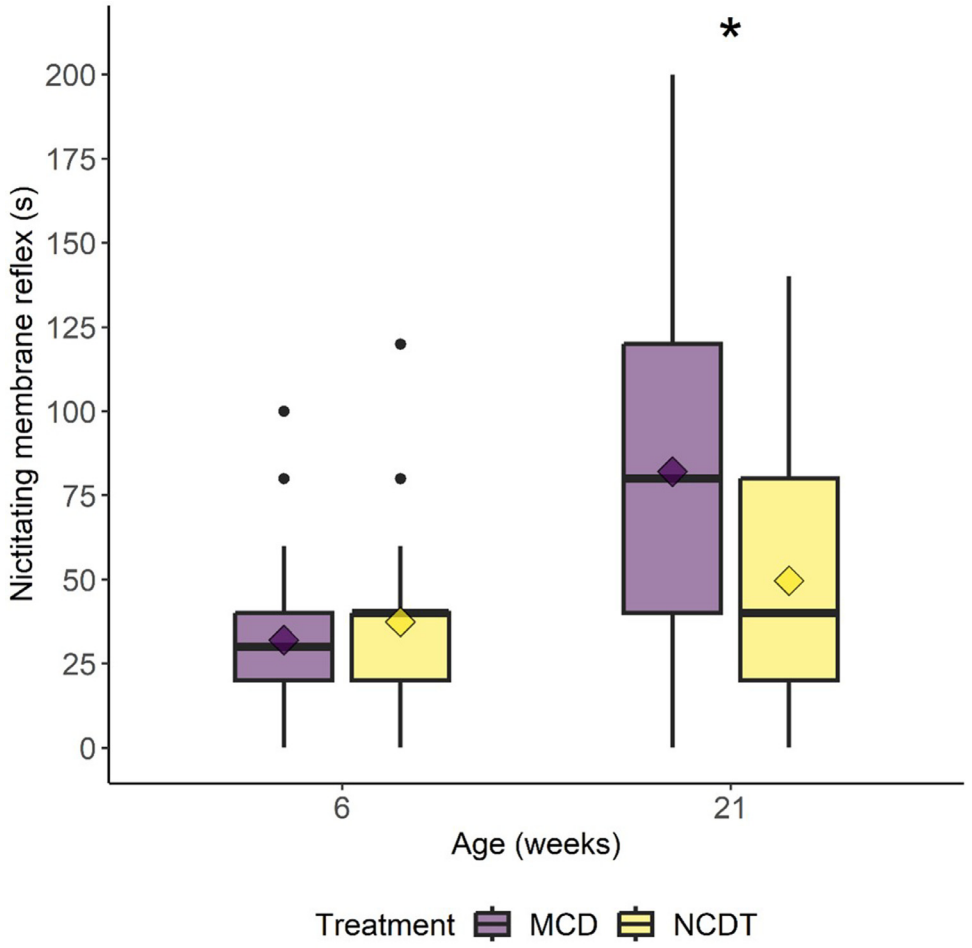

Figure 2. Boxplot of time to cessation of nictitating membrane reflex (s) for 6-wk-old broilers and 21-wk-old broiler breeders (the diamond indicates the mean; the black circle indicates the outlier; and * indicates a significant difference).

Macroscopic and Microscopic Evaluation Birds for each age group presented with the same gross evaluation score for SCH, damage to trachea, and spinal cord transection (SCH: score 4, trachea: score 0, and spinal cord transection: score 4). Laceration scores were greater in the NCDT treatment group compared to MCD in 21-wk-old birds only (Figure 5) and 21-wk-old male birds presented with a more severe laceration score

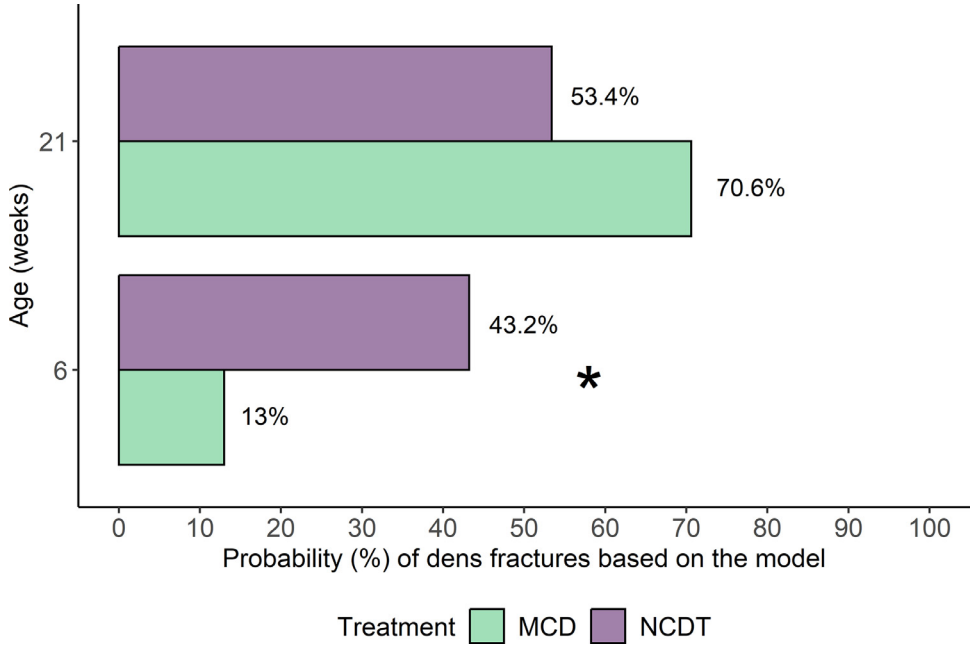

Figure 3. Bar plot of dens fractures (presence or absence) for 6-wk-old broilers and 21-wk-old broiler breeders (* indicates a significant difference).

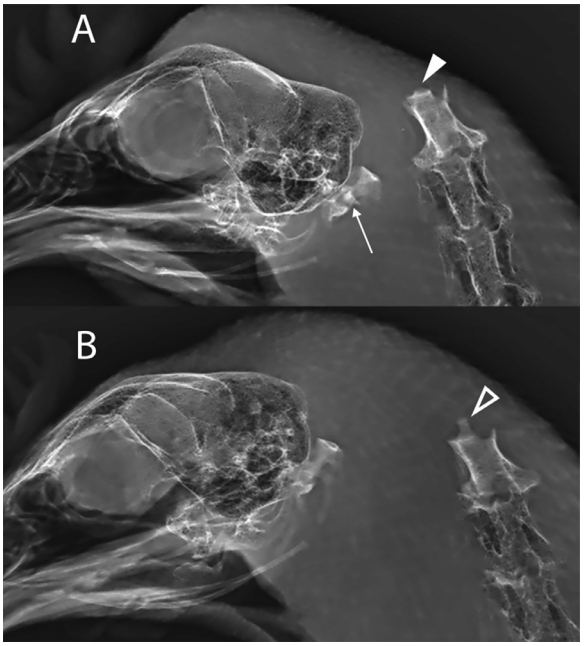

Figure 4. Lateral radiographs of a chicken with (A) and without (B) den fractures. In the chicken with the dens fracture, the dens (arrow) is superimposed with C1 and not seen on the cranial margin of C2 (closed arrow). In comparison, in the chicken without a fracture, the dens (open arrowhead) is seen on C2.

($\beta = 1.791$; $P = 0.019$) compared to females. No pathological (macroscopic and microscopic) differences were noted across age groups and between treatment groups (Figures 6 and 7, Table S4).

DISCUSSION

Euthanasia is an essential welfare task performed daily on commercial poultry farms around the world. Ending the animal's life in a way that minimizes pain and distress is an ethical obligation for all individuals working directly with compromised birds. Manual cervical dislocation is the most common method used to perform euthanasia on farm but can be challenging given the ergonomic demands (i.e., physical strength, arm span) required to euthanize. Various tools, such as the Koechner euthanizing device (**KED**) or captive bolt stunner, are occasionally used to aid euthanasia of larger-sized birds. However, the KED can crush the vertebra and spinal cord (Baker-Cook et al., 2021) and the captive bolt may fail because the comb can prevent placing the device in the proper position (Boyal et al., 2022). Alternative tools like the NCDT may have the potential to improve euthanasia efficacy and minimize worker

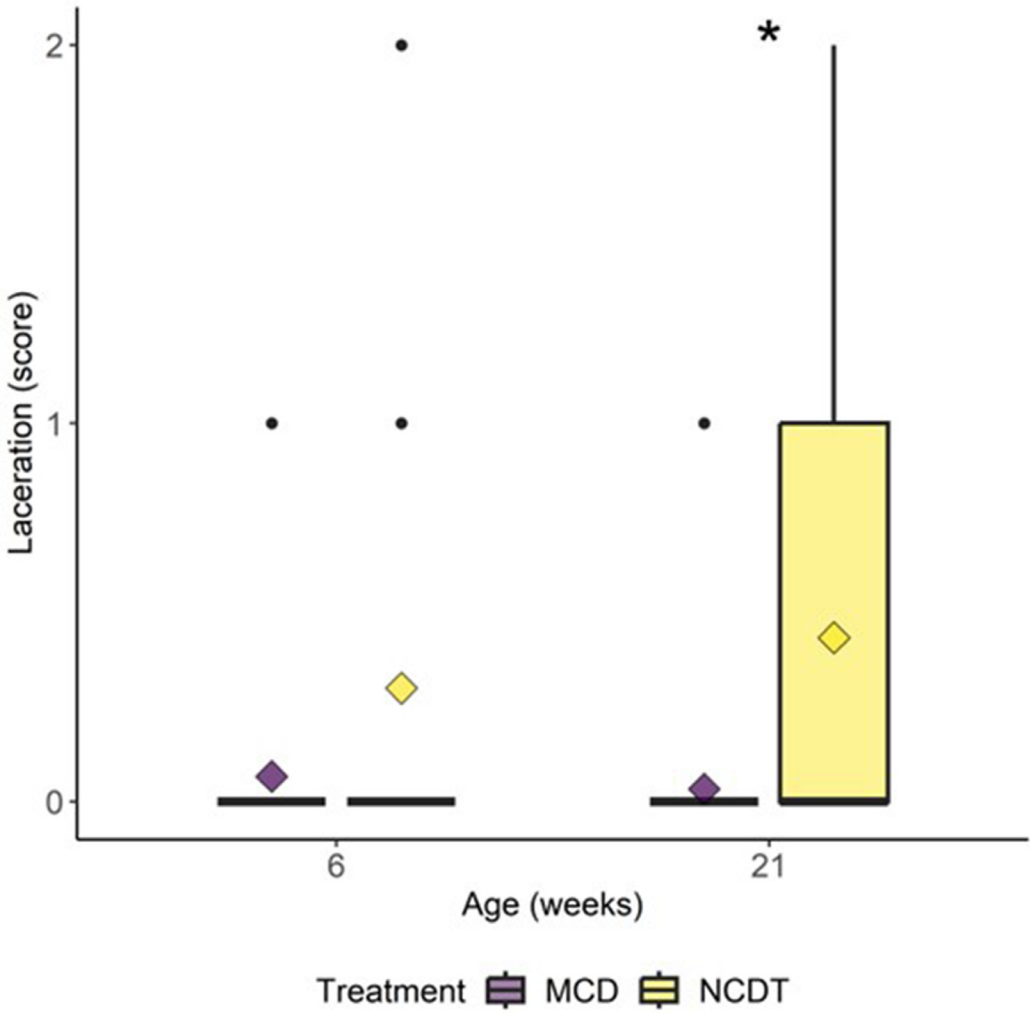

Figure 5. Boxplot of laceration scores between the treatments for 6-wk-old broilers and 21-wk-old broiler breeders (the diamond indicates the mean; the black circle indicates the outlier; and * indicates a significant difference).

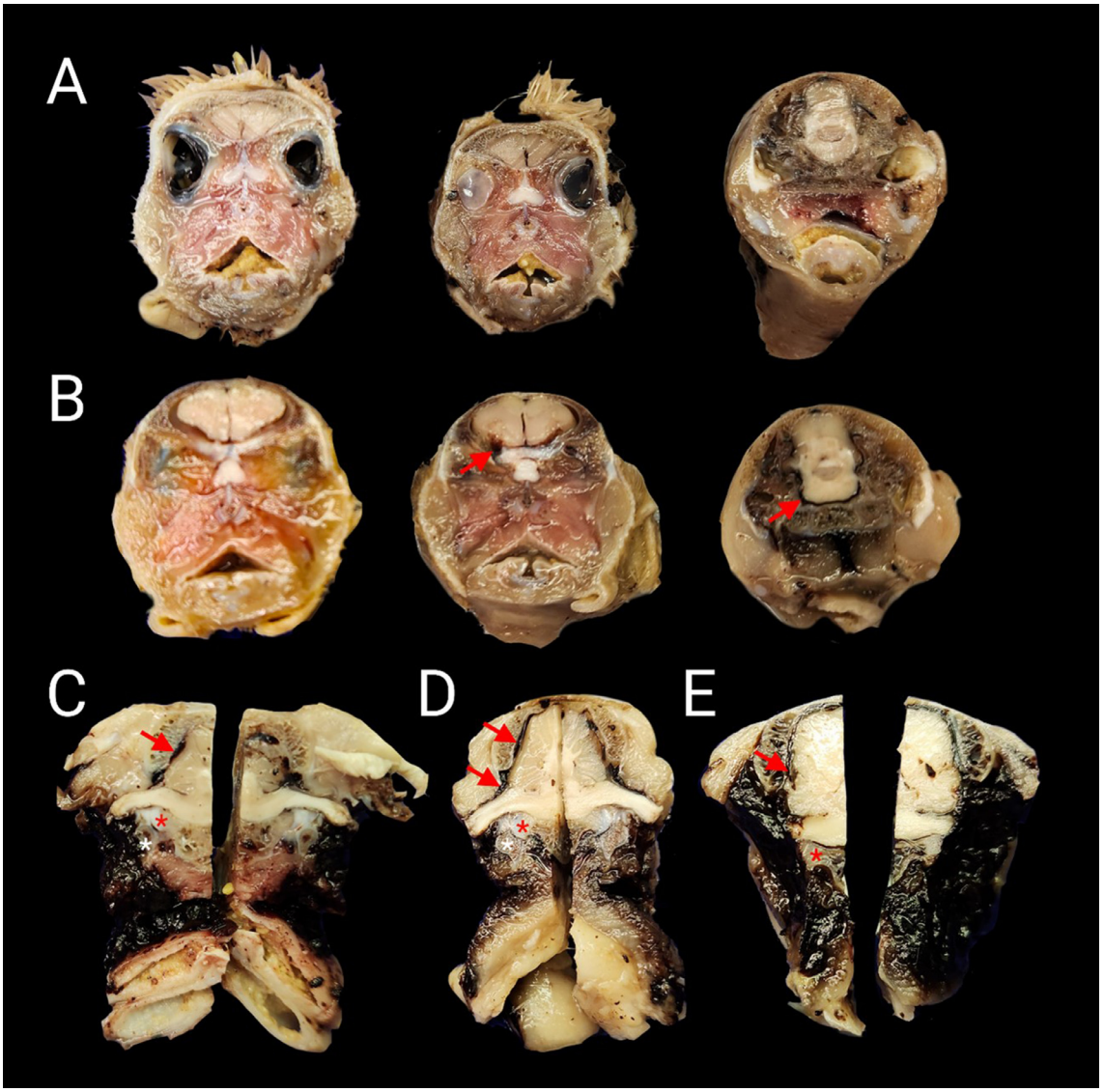

Figure 6. Macroscopic findings in the 6-wk-old chicken groups. (A and B) From left to right are progressive rostral to caudal transversal dissections of the same bird head. (A) No macroscopic evident subdural hematomas (score = 0). (B) The subdural hematoma reaches the rostro-ventral area of the cranium (red arrows) (score = 2). (C and D) Longitudinal sections of the aboral cranium and occiput. All sections present subdural hematomas encircling the cerebellum and medulla oblungata. (C) The occipital condyle was intact (red asterisk) and articulating with a fractured first vertebral articular process (white asterisk). (D) The occipital condyle was intact (red asterisk) and articulating with an intact first vertebral articular process (white asterisk). (E) The occipital condyle was fractured (red asterisk). The gross panel was assembled in Biorender.com (Agreement number: IE25TWJU2N).

fatigue associated with the euthanasia process. Therefore, the objective of this study was to evaluate the efficacy of a NCDT in 6- and 21-wk-old broilers when compared to MCD.

Both MCD and NCDT euthanasia methods were 100% effective in rendering all birds unconscious following the application of the treatment. Birds across age groups achieved death (defined by cardiac and respiratory arrest) within 90 to 220 s. This work is in agreement with previous broiler MCD studies demonstrating average cessation of a heartbeat at 155 s (Bandara et al., 2019). This work reinforces that MCD is a consistent and reliable euthanasia method that renders birds immediately insensible and results in death. Moreover, the results from this study demonstrate that utilizing the NCDT is an equally effective method and supports previous literature demonstrating alternative euthanasia device efficacy in poultry (Martin et al., 2016, Bandara et al., 2019).

Although time to achieve cardiac arrest was not different among treatments or age groups, 21-wk-old birds euthanized with the NCDT demonstrated shorter time to NMR loss. Nictitating membrane reflex is used as an indicator of consciousness and is typically lost following brainstem damage or death (Sandercock et al., 2014; Sparrey et al., 2014). There was approximately a 5-s difference in NMR loss between MCD and NCDT treatment groups (MCD: 32 ±22.6 vs. NCDT: 37.4 ±28.6). Nictating membrane reflex loss in this study was in fact shorter than NMR loss times in birds euthanized with sodium pentobarbital (44 s; Sandercock et al., 2014).

Average time to NMR loss in this study differed from previous work in broiler euthanasia (Jacobs et al., 2019; Baker-Cook et al., 2021). Jacobs et al. (2019) reported

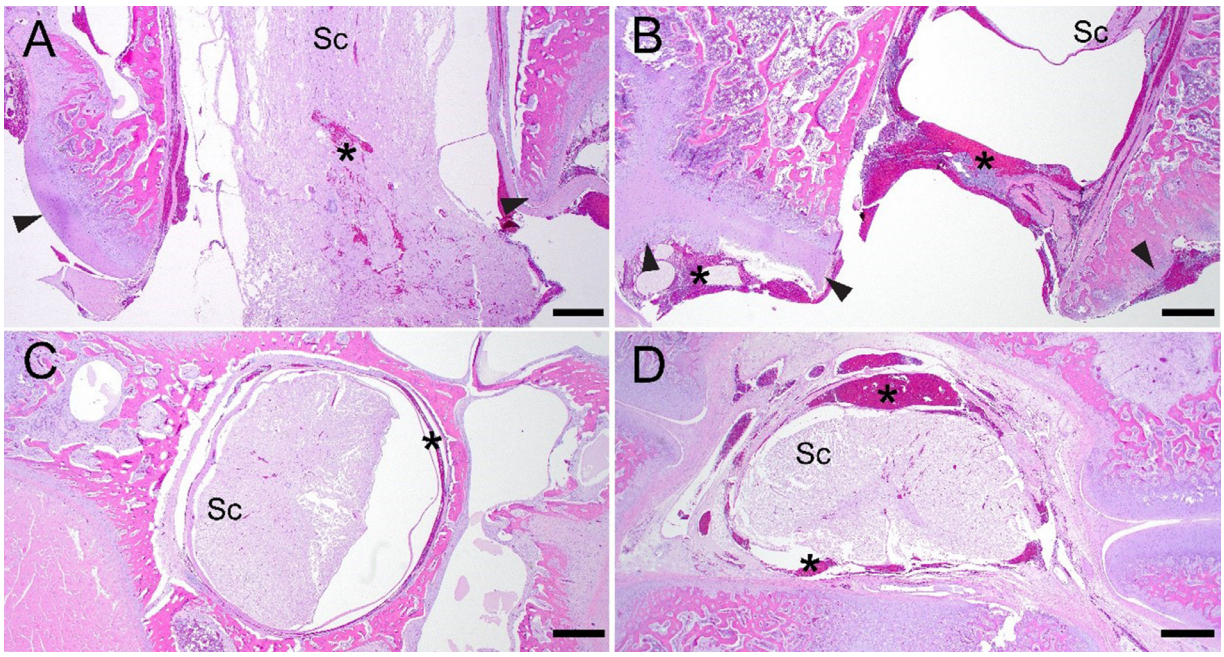

Figure 7. Microscopic observations in the 6-wk-old group. (A and B) Longitudinal sections of the dislocated end of the spinal column with spinal cord. (A) The articular surface of the vertebra was intact (black arrowhead, score = 0), subdural, subarachnoid, and parenchymal hemorrhages were moderate (back asterisk, score = 2). Spinal cord (**Sc**) was rarefied and fragmented near the site of dislocation. (B) Multiple fractures were effacing the vertebral edges (black arrowhead, score = 3), severe hemorrhage effaces meningeal compartment, and spinal canal (black asterisks, score = 3). The spinal cord (Sc) was fragmented and retracted into the canal. (C and D). Transversal sections of spinal column at 0.5 cm from the dislocated edge. (C) Mild subdural hemorrhage was present (black asterisk, score = 1). The spinal cord was mildly rarefied (score =1). (D) Presence of severe subdural and subarachnoidal hemorrhage (score = 3) which extends to the adjacent connective tissue. These were accompanied by moderate demyelination and rarefaction of the spinal cord. All scale bars (right bottom corner) are 500 um. Histopathological samples were assembled in Adobe Acrobat.

that NMR loss was longer in duration for birds euthanized with an alternative euthanasia device (KED). In this 2019 study, NMR loss times were longer in birds euthanized with KED compared to MCD, with NMR loss times lasting on average 100 s following euthanasia application. Work conducted by Baker-Cook et al. (2021) also demonstrated that the KED device resulted in the longest time to achieve insensibility via NMR loss, although these results were presented as frequency (present/absent) and not duration.

Decreased time to NMR loss in the NCDT treatment group is typically attributed to achieving greater brain stem damage and trauma, although histopathological findings were not different between treatment groups. The biological and animal welfare relevance of this finding should be considered. Given no additional insensibility measures were different between treatment groups and no birds regained consciousness, caution in interpreting the superiority of NCDT over MCD should be taken.

From a radiographic perspective, the location and degree of cervical dislocation severity were not different between treatments or among age groups. However, an increased frequency of dens fractures was found in the NCDT group among young birds (6-wk) only. Vertebral fractures can occur during euthanasia when excessive force is used to separate the vertebrae resulting in crushing (not severing) of the spinal cord and surrounding vertebrae (Gregory and Wotton, 1990; Martin et al., 2016).

This incidence of crushing is more likely to occur when mechanical devices, like KEDs, are used to perform cervical dislocation (Baker-Cook et al., 2021). The results from our study suggest that the force delivered to the vertebrae may be excessive when euthanizing young birds given younger birds have smaller and less developed vertebrae compared to more mature birds (Lilburn, 1994). From an animal welfare standpoint this is not a concern, given all birds were rendered immediately insensible with the NCDT and there was no evidence of spinal cord crushing. From a logistical standpoint, on-farm training should emphasize that excessive force does not need to be used when utilizing the NCDT, particularly when euthanizing smaller birds with the device.

Gross evaluation of the head and neck of euthanized birds revealed that older male broilers demonstrated greater laceration scores (defined as tearing of the skin with or without external bleeding). Previous work has demonstrated similar results with euthanasia devices such as the KED and Turkey Euthanasia Device (**TED**; Baker-Cook et al., 2021) resulting in more physical trauma to skin and bone. This is likely associated with the physical weight of the birds and mechanical forces pulling on the skin. Given there were no negative differences in insensibility measures for the NCDT when compared to the MCD, skin laceration may be considered more of an aesthetic/public appearance concern, than a welfare concern.

Aesthetics are an important factor to take into consideration when choosing a euthanasia method on-farm for

livestock workers. For example, firearms and captive bolts are considered aesthetically and emotionally disturbing for those working with cattle (Shearer, 2018) thus impacting the choice in euthanasia method used on farms. In addition, individuals may postpone or avoid performing euthanasia if they are uncomfortable with the euthanasia technique or tool (Rault et al., 2017). Familiarity and comfort may also play a role in caretakers' confidence to perform euthanasia. A recent study by Clarkson et al. (2023) found that poultry caretakers preferred MCD over other euthanasia methods, partly due to their familiarity with and practicality of the method and the lack of training and educational materials on other devices/techniques (Clarkson et al., 2023).

CONCLUSION

The use of a NCDT is a promising replacement for MCD in euthanasia of broilers and broiler breeders, particularly for older birds that are more ergonomically challenging to euthanize with MCD. In 6-wk-old broilers, there were no differences in insensibility or death parameters or location and severity of the dislocation site by treatment. The NCDT treatment group showed an increased frequency of dens fractures but does not have significant welfare impacts, given all birds were effectively rendered unconscious. For older broilers (21-wk), NCDT and MCD were 100% effective in rendering birds' unconscious followed by death. Differences in NMR and laceration scores for older birds euthanized with NCDT are likely attributed to additional physical external trauma caused by the tool itself. Additional factors influencing these results also include bird sex and weight. Future work should address the development of free and accessible training materials to prepare on-farm caretakers with the skillset and confidence to effectively perform euthanasia using this alternative tool.

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DISCLOSURES

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.psj.2024.103449.

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