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Source: Journal of Wildlife Diseases, 55(2) : 298-303

Published By: Wildlife Disease Association

URL: https://doi.org/10.7589/2018-01-008

DOI: 10.7589/2018-01-008

Journal of Wildlife Diseases, 55(2), 2019, pp. 298–303

OUTCOMES OF SNARE-RELATED INJURIES TO ENDANGERED MOUNTAIN GORILLAS (*GORILLA BERINGEI BERINGEI*) IN RWANDA

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ABSTRACT: Mountain gorillas (*Gorilla beringei beringei*) are one of the most critically endangered great apes in the world. The most common cause of mountain gorilla morbidity and mortality is trauma (e.g., injury from conspecifics or snare entrapment). We conducted a retrospective case-control study of free-ranging, human-habituated mountain gorillas to evaluate factors associated with snare entrapment and the results of clinical intervention. Data were collected from clinical records on all clinical intervention cases (n=132) in Volcanoes National Park, Rwanda, conducted between 1995–2015. Wildlife veterinarians treated 37 gorillas entrapped in snares and 95 gorillas for other clinical conditions (including trauma and respiratory illness). Multivariate statistical analyses revealed that young gorillas (<8 yr old) were more likely than older gorillas to become snared; that comorbidities delayed times to intervention (≥3 d); and that severity of wounds at the time of intervention were associated with increased risk of lasting impairment (including loss of limb or limb function, or death) within 1 mo after intervention. Our results may influence decisions for gorilla health monitoring and treatment to most effectively conserve this critically endangered species.

Key words: Conservation medicine, *Gorilla beringei beringei*, mountain gorilla, Rwanda, snares.

INTRODUCTION

Mountain gorillas (*Gorilla beringei beringei*) are one of the most critically endangered great ape subspecies in the world, with only two isolated populations remaining: one in Bwindi Impenetrable National Park, Uganda and one in the Virunga Massif spanning the borders of Rwanda, the Democratic Republic of Congo (DRC), and Uganda (Robbins et al. 2001; International Union for Conservation of Nature 2006). Gorillas face a variety of threats to their sustainability including habitat encroachment due to subsistence farming, political instability in the region, potential exposure to human and livestock pathogens, and trauma from snares set for other wildlife (Schaller 2000; Robbins et al. 2009; Grueter et al. 2013).

By the early 1980s, only 250 mountain gorillas remained (Cranfield and Minnis 2007). In order to protect the remaining mountain gorillas, the governments of Rwanda, Uganda, and the DRC, in partnership with a number of nongovernmental organizations, implemented a comprehensive conservation effort (Rainer et al. 2003; Robbins et al. 2011). Agencies and organizations have worked together to initiate and promote ecotourism, create and deliver local conservation education programs, reform poachers, establish ranger-based monitoring, increase law enforcement within parks, and establish a wildlife veterinary intervention program (Gray and Kalpers 2005). In part as a result of these efforts, the total mountain gorilla population increased and is currently at 1,004 animals (Hickey et al. 2018).

Wildlife veterinarians in Rwanda, Uganda, and the DRC provides veterinary care to wild, human-habituated mountain and Grauer's gorillas (*Gorilla beringei graueri*). Two of the most-common causes of gorilla mortality include traumatic injury (e.g., injury from snare entrapment) and respiratory disease (Spelman et al. 2013).

In order to better understand the epidemiology of snare injuries in wild mountain gorillas in Rwanda, we conducted a 20-yr

retrospective case-control study aiming to evaluate 1) factors associated with snare entrapment of mountain gorillas; and 2) whether clinical intervention and the characteristics of the injury affected gorilla survival in the first month after snare removal. We hypothesized that factors including age, sex, season, and comorbidity (a concurrent disease process) were associated with ensnarement. Secondly, we hypothesized that following ensnarement, comorbidity, type of snare (rope or wire), time to intervention, wound treatment, and wound severity influenced a gorilla's likelihood of chronic or permanent physical impairment or death in the first month following intervention.

MATERIALS AND METHODS

Factors associated with snare entrapment

To assess factors associated with ensnarement in mountain gorillas, demographic and clinical data were analyzed from gorillas (n=132) receiving clinical interventions between 1995–2015 in Volcanoes National Park, Rwanda. Data were obtained from the wildlife veterinarians' computerized clinical database as well as from paper-based field observation records. The case definition was any mountain gorilla observed with an ensnarement between 1995–2015 (n=37), with 30 of the 37 ensnarement cases requiring anesthesia to remove the snare. The definition for a control gorilla (n=95) was a mountain gorilla from the same geographic region and treated during the same time period that had a clinical intervention for a health problem other than a snare. Non-snare health interventions were defined as administration of anesthesia or therapeutic drugs to a mountain gorilla. This control group was utilized because no population-based health data existed for the purposes of serving as controls for our study. In our case-study group, one gorilla was snared twice and was treated as a separate case each time due to the extensive time period between snare incidents. Case and control gorillas were not matched on any specific predictor variables during analysis. Of the 132 gorillas that underwent health interventions, the ratio of controls to cases was 2:5, which increased the power of the analysis as compared to having evenly sized case and control groups.

Potential factors associated with ensnarement (yes/no), including sex, age, season, and comorbidity, were evaluated using univariable and then multivariable logistic regression approaches. Each variable was coded categorically for analysis. Sex compared males to females and age compared young (<8 yr old) to old (≥8 yr old); biologically, these categories differentiated sexually mature from immature individuals (Watts 1991). Season compared the rainy (September to November, and March to May) to dry (June to August, and December to February) seasons, and comorbidity compared gorillas that had one or more concurrent disease processes at the time of intervention (e.g., respiratory disease, diarrhea) to those that did not. We used STATA™ software (StataCorp, College Station, Texas, USA) to test for statistical significance for defined variables at α=0.05, and we ran logistic regression separately for each factor to evaluate the strength of association between each variable and the likelihood of ensnarement. If multiple factors were significant during univariable logistic regression analysis, they were then combined into a multivariable model to examine the simultaneous effects of factors on the outcome of gorilla ensnarement.

Clinical intervention factors affecting survival status

Trained trackers record abnormalities of seven key health indicators (body condition, activity, respiratory rate and character, integument, discharge from the head, other discharge, and fecal output) during daily observations of every habituated gorilla (Gray and Kalpers 2005; Cranfield and Minnis 2007). If abnormalities were observed, a veterinarian conducted a second, more detailed health assessment. If the veterinary assessment determined that the illness or injury was human-induced or life-threatening, veterinarians in consultation with park authorities decided whether or not to conduct an in situ clinical intervention to treat the injured or ill gorilla. Clinical interventions involved snare removal with or without anesthesia, wound cleaning, and administration of therapeutic drugs (e.g. antimicrobials, anti-inflammatories). To understand the potential influence of these clinical interventions on the 1-mo survival status of ensnared gorillas (n=37), we conducted a retrospective case-control study and utilized a logistic regression analysis approach. Snared individuals were classified as either impaired (including loss of limb or limb function or death) 1 mo after clinical intervention or alive and fully recovered at 1 mo after snare removal.

Factors including comorbidity, type of snare, time to intervention, use of anesthesia and treatment, and wound severity were analyzed categorically. Comorbidity was defined as the presence (yes/no) of concurrent disease. Type of snare compared rope and wire. Time to veterinary intervention compared prompt (<3 d) to delayed

TABLE 1. Factors associated with snare entrapment among mountain gorilla (*Gorilla beringei beringei*) in Volcanoes National Park, Rwanda, 1995–2015.[a]

Risk factor	Total cases	Frequency (prevalence %)		Odds ratio	*P* value	95% Confidence interval	
		Snared cases	Non-snared controls			Lower	Upper
Age							
Old (≥8 yr old)	71	5 (7)	66 (93)	1	—	—	—
Young (<8 yr old)	56	31 (55)	25 (45)	16.4	<0.010[b]	5.72	46.81
Sex							
Female	65	19 (29)	46 (71)	1	—	—	—
Male	67	18 (27)	49 (73)	0.9	0.762	0.42	1.9
Season							
Dry[c]	71	22 (31)	49 (69)	1	—	—	—
Wet[d]	61	15 (25)	46 (75)	0.7	0.416	0.33	1.56
Comorbidity							
No	108	34 (31)	74 (69)	1	—	—	—
Yes	16	3 (19)	13 (81)	0.5	0.306	0.13	1.88

[a] — = reference category for odds ratio comparison.

[b] Significantly different than reference category based on *P* values <0.05 in univariate logistic regression analysis.

[c] June–August; December–February.

[d] September–November; March–May.

(≥3 d) medical attention. Anesthesia and treatment assessed whether the intervention utilized either procedure (yes/no) in order to remove and treat the snare effectively. Wound severity compared no or mild injury (i.e., superficial wounds with or without mild swelling) to severe injury (i.e., restriction of blood flow, ischemia, necrosis, and/or purulent discharge). Factors found to be statistically significant ($P<0.05$) in bivariate analyses were then evaluated using a multivariable logistic regression model to evaluate the strength of association of factors with being impaired (or dead) or fully recovered at 1 mo following intervention.

RESULTS

Factors associated with snare entrapment

Between 1995–2015, wildlife veterinarians conducted 132 clinical interventions in Volcanoes National Park, Rwanda. Snared gorilla cases accounted for 37 of the interventions. Control group gorillas ($n=95$) included interventions for clinical presentations such as respiratory illness ($n=40$), wounds unrelated to ensnarement ($n=28$), dermatologic conditions ($n=10$), lethargy ($n=4$), abscesses ($n=4$), infections ($n=3$), ulcers ($n=2$), and other less common conditions ($n=4$). Gorillas without age group information available (one snare case and four control cases) were excluded from regression analyses, yielding 36 gorillas in the snared group and 91 gorillas in the control group.

Of the factors analyzed, age was a statistically significant factor for ensnarement ($P=0.010$) while sex ($P=0.762$), season ($P=0.416$), and comorbidity ($P=0.306$) were not statistically significant factors for ensnarement (Table 1). The age range of snared gorillas spanned 1 d to 24 yr old. Within the intervention population, young (<8 yr old) gorillas had 16 times greater odds of ensnarement compared to older (≥8 yr old) gorillas ($P<0.010$: 95% confidence interval 6–47), and young gorillas comprised 86% of all snare cases in the study. In contrast, the age range of control group gorillas was 1 d to 42 yr old, with just 27% of the control group composed of young gorillas.

Clinical intervention factors affecting survival status

Of the 37 snare interventions performed, 86% of gorillas made full recoveries within 1

TABLE 2. Clinical intervention and wound factors associated with decreased 1-mo survival status postsnare removal for mountain gorillas (*Gorilla beringei beringei*) in Volcanoes National Park, Rwanda, 1995–2015.[a]

Intervention factor	Total snared cases	One-month survival status (%)		Odds ratio	*P* value	95% Confidence interval	
		Alive	Impaired			Lower	Upper
Comorbidity							
No	34	31 (91)	3 (9)	1	—	—	—
Yes	3	1 (33)	2 (66)	20.7	0.027[b]	1.42	300.54
Type of snare							
Rope	23	21 (91)	2 (9)	1	—	—	—
Wire	8	7 (88)	1 (12)	1.5	0.755	0.12	19.17
Time to intervention							
Rapid	28	27 (96)	1 (4)	1	—	—	—
Delayed	8	5 (63)	3 (37)	16.2	0.026[b]	1.39	188.88
Anesthesia							
Yes	25	22 (88)	3 (12)	1	—	—	—
No	11	10 (91)	1 (9)	0.7	0.799	0.07	7.95
Treatment							
Yes	16	11 (69)	5 (31)	1	—	—	—
No	21	21 (100)	0 (0)	0.1	0.084	0.01	1.32
Severity							
None/mild	27	25 (93)	2 (7)	1	—	—	—
Severe	6	3 (50)	3 (50)	12.5	0.021[b]	1.45	107.63

[a] — = reference category for odds ratio comparison.

[b] Significantly different than reference category based on *P* values <0.05 in univariate logistic regression analysis.

mo following snare removal. Factors associated with physical impairment or death of snared gorillas within 1 mo of intervention (Table 2) included comorbidity (P=0.027), delayed (≥3 d) interventions (P=0.026), and severity of wounds (P=0.021). Other factors associated with clinical interventions (administration of anesthesia and wound treatment) as well as factors associated with the wound itself (including type of snare) did not significantly impact the 1-mo survival status. Cases exhibiting comorbidity (8%, 3/37) of snared gorillas were 21 times more likely to show a poor survival outcome (impairment or death). Comorbidities included residual wounds from a previous ensnarement (which occurred months prior for the single gorilla that was snared twice), a swollen eye (an incidental finding), and a septic open humeral fracture (not involving the snared limb). While a majority (78%, 28/36) of interventions occurred within 2 d of the initial observation, interventions that took three or more days from the time of initial observation of the snare to execution of the intervention were 16 times more likely to result in physical impairment or death. Of the 36 snare interventions with timeline data available, 22% (8/36) were conducted three or more days after the ensnarement was first observed. The longest intervention delay was 3 wk. Severe wounds with ischemia and necrosis of tissues were 13 times more likely to result in permanent injury or death (Fig. 1). Of the 33 snare cases with wound severity data available, six gorillas (18%, 6/33) sustained severe injuries from ensnarement while 27 (82%, 27/33) sustained minimal to no observable wounds. Collinearity between independent variables prevented multivariable logistic regression modeling.

DISCUSSION

This was the first retrospective case-control study to examine factors and clinical implica-

FIGURE 1. Snare-related injuries in mountain gorillas (*Gorilla beringei beringei*) in Volcanoes National Park, Rwanda: A rope snare (A) and a wire snare (B); a snare causing mild injury (C), and one causing severe wounds (D).

tions for snare-related trauma in endangered mountain gorillas and to discern specific factors associated with poor outcomes (e.g., lasting physical impairment or death) in snared gorillas. Of the 32 snare-related interventions in Rwanda, all but five individuals recovered completely within 1 mo of clinical intervention (an 86% success rate). We determined that the primary factor associated with ensnarement was age (<8 yr old) with over 86% of cases occurring in gorillas less than 8 yr old (Table 1). Our results also showed that gorillas were more vulnerable to suffering impairment or death by 1 mo after intervention if they had a comorbidity, if the intervention took more than 3 d to occur (was delayed), or if the inciting wound was severe (Table 2).

Our results suggested that prompt veterinary intervention improved the likelihood of recovery for injured or ill mountain gorillas. For this reason, veterinary care is an important component of effective conservation management of this endangered species. Clinical interventions to treat ill and injured individuals have likely contributed significantly to the recovery of mountain gorillas, making it the only great ape whose numbers are increasing in the wild; the habituated mountain gorilla population in the Virunga Massif has increased by 4% annually, with half of that population growth rate attributable to provision of veterinary care (Robbins et al. 2011). In our study population (n=132), all but 19 individuals recovered completely: an 86% success rate.

We utilized a case-control study design because it was efficient and low-cost to conduct, and there was an abundance of case-control material with which to work. Other strengths of the study included the unique dataset studying a free-ranging wildlife species and the robust sample size (n=132). The study was limited by focusing solely on the intervention population of animals: a case-control study of the general population would

further evaluate the role and impacts of veterinary interventions, but would require making decisions not to treat snared gorillas, which would be problematic from a conservation and ethical standpoint. While we believe our results can be extrapolated to the general mountain gorilla population, future studies should work to understand the long-term impacts of ensnarement on survival status and reproductive success and evaluate the importance of factors in the general population. Based on the knowledge gained from this research, we suggest remaining focused on monitoring efforts, especially of the most at-risk subpopulation, young gorillas, and always advocating for shorter response times, conditions permitting.

ACKNOWLEDGMENTS

The authors would like to thank Joost Philippa for his assistance throughout the study. Data for this study were the result of the tireless work of many wildlife veterinarians and support staff and of many gorilla trackers working for the Rwanda Development Board and the Dian Fossey Gorilla Fund International who perform daily monitoring of human-habituated gorillas in Volcanoes National Park. The Students Training in Advanced Research (STAR) Program and the International Summer Externship Travel Award through the University of California at Davis School of Veterinary Medicine Endowment Fund, as well as the Office for Global Programs and Karen C. Drayer Wildlife Health Center, provided financial support for this project.

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Submitted for publication 10 January 2018.
Accepted 21 August 2018.