RESEARCH ARTICLE

Clinical Response Decision Tree for the Mountain Gorilla (*Gorilla beringeii*) as a Model for Great Apes

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Disease is one of the main threats to the remaining great ape populations of the world. The decision to intervene in the health of the great apes for population sustainability is controversial. Humans' increasing negative influence on great ape health has mandated the reevaluation of current management policies. The Mountain Gorilla Veterinary Project (MGVP) has been making health intervention decisions since 1986. The decision to intervene has often been made subjectively due to poorly defined criteria that are often influenced by emotion. This paper provides a consistent framework for evidence-based health intervention decision-making. The decision tree is a five-tier process consisting of routine sentinel health observation, intensive follow-up veterinary health observation, outbreak assessment, risk assessment, and risk management. Although this paper focuses on the mountain gorillas, it serves as a basis for evidence-based decision-making in other species. *Am. J. Primatol.* 68:909–927, 2006. © 2006 Wiley-Liss, Inc.

Key words: mountain gorilla; evidence-based decision-making; health intervention

INTRODUCTION

The great apes, the orangutans (*Pongo pygmaeus*) of Borneo and Sumatra, and the chimpanzees (*Pan troglodytes*), bonobos (*Pan paniscus*), and gorillas (*Gorilla* sp.) of Africa are facing uncertain futures and their long-term sustainability is in question [Butynski, 2001]. The most prominent threat to their survival is habitat destruction/fragmentation from both logging and agricultural activities. The second most serious threat relates to the development of roads associated with logging. Such roads allow access and transport to and from remote areas, and provide an infrastructure for the commercial bush meat industry. Disease is usually considered the third most serious threat, and has

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risen in public awareness due to the highly publicized outbreaks of Ebola virus in western Africa that resulted in high mortality in chimpanzees and gorillas [Morell, 1995]. In protected areas (i.e., conservation areas and national parks) where deforestation and bush meat practices are a lesser threat, disease is rated as the primary threat.

In 1997 the Population Habitat Viability Assessment conducted by the Conservation Breeding Specialist Group (CBSG) in Uganda designated disease introduction as a major risk to the sustainability of the two populations of mountain gorillas (*Gorilla beringei*) in the protected areas of the Virunga Massif and Bwindi Impenetrable Forest [Werikhe et al., 1997]. These parks have sharp boundaries between the forest and the human communities, with few existing buffer zones. The human communities around the mountain gorilla parks have a density of 423–538 people per square kilometer (2002 Rwanda Census) and a population growth rate of approximately 3.7% per year [Butynski, 2001]. The mountain gorilla populations have the highest percentage of human-habituated individuals of any ape species and are subjected to intense research and ecotourism programs. These factors, which are compounded by agricultural practices at the boundaries of the park, promote contact between gorillas and humans and domestic animals, and thus increase the potential for the introduction and transmission of infectious diseases. Health care within the human and domestic animal populations around the parks is less than optimal and there is poor sanitation. Research has shown through genetic sequencing that the same enteric organisms (*Giardia*, *Microsporidea*, and *Cryptosporidea*) are circulating among humans, cattle, and gorillas in and around the park [Nizeyi et al., 1999, 2000, 2002]. The prevalence of antibiotic resistance to *Enterococcus* and *E. coli* in mountain gorillas has been found to be higher than expected for wild populations of animals, and has a pattern similar to that of human and cattle antibiotic resistance in the Bwindi area (Byarugaba, unpublished data). Gorillas share a >98% genetic similarity with humans [Hacia, 2001] and are susceptible to many human diseases, as well as zoonotic diseases associated with livestock.

Opportunistic blood samples have shown that gorillas lack antibodies and are probably naïve to many diseases that are endemic to the region (i.e., measles). If such diseases are introduced, they may cause high morbidity and mortality, which makes this a high-risk population for a serious epidemic [Hastings et al., 1991; Nutter et al., 2005]. The Mountain Gorilla Veterinary Project (MGVP), supported by the Morris Animal Foundation, was formed in 1986 at the request of Dian Fossey to provide emergency medicine and pathology services to the mountain gorilla population of Rwanda [Cranfield et al., 2002]. Because of the low numbers of gorillas in these populations and genetic studies showing that each animal's genetic input into the population's genome is important [Garner & Ryder 1996], the mountain gorillas are managed on an individual as well as a population basis with respect to veterinary care [Cranfield et al., 2002].

Veterinarians, trackers, guides, researchers, and other personnel from the MGVP, Ugandan Wildlife Authority, Office Rwandais du Tourisme et des Parcs Nationaux, Institut Congolais pour la Conservation de la Nature, Dian Fossey Gorilla Fund International, and Institute for Tropical Forest Conservation monitor the health of the gorilla populations. This is done by observation, noninvasive biological sampling, and postmortem examinations; however, historically the data have not been collected in a uniform fashion. The collection of important baseline medical data from invasive sampling of live animals was previously conducted on an infrequent, nonstandardized opportunistic basis. To

better understand the basic epidemiology of diseases within the ecosystem and monitor gorilla health, a standardized method of data collection and analysis was developed and implemented.

Any veterinary interaction (e.g., darting, treating, and anesthetizing) with a gorilla is considered an intervention. Interventions (with or without immobilization) are regulated by the protected-area authorities and veterinarians, and occur only in the presence of human-induced or life-threatening health problems. This intervention policy can be ambiguous, often subjective, and emotional.

During the process of developing a contingency plan, a method to standardize data collection was created that included the concerns of all stakeholders. As a byproduct, this led to the design of a clinical decision tree to standardize the intervention response to health-related issues. This decision tree is helping to ensure standardized data collection so that meaningful comparisons can be made to better assess risk and risk-management options.

MATERIALS AND METHODS

The development of the decision-tree process spanned two regional meetings of gorilla conservation organizations, which included nongovernmental organizations (NGOs) and the protected area managers of the Democratic Republic of Congo, Uganda, and Rwanda. The first iteration was created by several field and captive-primate veterinarians, and veterinary and human epidemiologists. After input and discussion by all stakeholders, it was edited by the Contingency Plan Team of the MGVP. This paper provides a summary of the final product.

To be useful and practical, a decision tree must be a dynamic document that is applicable to similar wildlife situations. Clinical decisions are reactionary in nature. However, clinical signs that are considered normal in one animal can portend an outbreak in another situation. A good decision-making process must help distinguish between these two situations and trigger a response only when necessary.

In many cases, clinical interventions are based on the presence of clinical signs alone. Because these are often nonspecific and therefore not associated with a definitive diagnosis, the severity of the observed signs may be the best indicator of risk for a timely response. To address this issue, a severity index of clinical signs was created and the terminology was standardized with the use of a data dictionary (Table I).

The MGVP's clinical-response decision tree was created for two purposes: The first was to standardize protocols for risk assessment in order to aid veterinarians and managers in making objective evidence-based intervention decisions that can be easily communicated and provide consistency in veterinary care among clinicians in the context of three different countries' management systems. The second was to categorize risk and thus act as a trigger to commence the actions outlined in a previously developed contingency plan for reducing the likelihood that a disease, once introduced, will cause a major outbreak or epidemic in the mountain gorilla population.

RESULTS

The decision-tree process consists of five hierarchical levels (Fig. 1):

Level 1: The collection and review of routine sentinel health monitoring data by trackers, guides, and/or behavioral researchers utilizing a basic standardized health observation form (paper-based or on a specially programmed personal data assistant (PDA)).

TABLE 1. The Data Dictionary of the Clinical Parameters and Signs With Severity Ratings for the Clinical decision tree of the Mountain Gorilla Veterinary Project

Parameter	Severity rating			
	Clinical sign definition	None or normal	Mildly or moderately abnormal	Highly abnormal
Body condition: The physical state of a gorilla distinguished from attitude and behavior	Weight: Body comparison in terms of muscle mass and body fat Abdomen: Part of the body, that lies between the throax and the pelvis General Attitude: The manner of acting	Unable to see the ribs and muscles appear normal Abdomen extends beyond the ribs (convex in appearance) Age and sex specific appropriate behaviors	Thin: a) estimated <10% loss of weight b) able to see the ribs c) notable muscle atrophy Flat (Abdomen and ribcage form continuous line) Behavior not like rest of the members at a particular time of day or in a particular context. E.g., lethargy, listless	Very thin: a) >10% loss of body weight b) ribs obviously pronounced c) atrophy of fat, muscles, sunken eyes Sunken: Abdomen sunken and concave Performing severely inappropriate behaviors in the context of the environment. e.g., still in the nest after 9 am or at one spot >1 hour with no body manipulation Unable to perform normal movements of any part(s) of one or more limbs, high degree of dysfunction present Severe Lameness: unable to keep up with the group, abnormal movements of 1 or more limbs Fast: When breathing is >25 minute/with/without audible sounds in a resting state
Activity: Quality of being active	Manipulation: Any manual movements with limbs. e.g., eating, grooming etc. Movement: The act of passing the whole body from place to place Breathing rate: Frequency of breathing, record as no. of breathes/minute	Normal movements with limbs of the body Normal movement of the whole body When the observer visualizes the nostrils and the chest and the animal appears comfortable and you barely visualize the movement of the chest and there are no audible sounds	Unable to perform normal movements of any part(s) of one or more limbs Lameness: abnormal movements of one or more limbs leading to the individual limping Slow: Breathing observed as <15 breathes/minute and audible sounds may/may not be heard	
Respiratory: Relating to respiration which is the talking in of oxygen and expiration of oxidation products	Breathing difficulty: A problem in exhalation and inhalation Coughing quality: Coughing is sudden explosive forcing of air through the glottis & larynx Coughing pattern: The sequence of coughing	No breathing difficulty shown No coughing Doesn't interrupt the activities of an individual	Labored: Visible respiratory effort by an individual without respiratory noise Dry: Harsh, grating, short sound with no mucus production Periodic: Intermittent interruption of coughing Periodic: Episodes of sneezing that are isolated events with periods of > 15 minutes between them	Extremely Labored: Visible respiratory effort by an individual with audible respiratory noise Productive: Moist sounding cough associated with exudates Continuous: Coughing >1 time in 5 minutes Continuous: > 1 episodes of sneezing within < 5 minutes
Integumentary: Includes the epidermis, dermis and all of their derivatives i.e., hair, nails, and mammary glands	Sneezing: Expelling air from the nose and mouth by involuntary spasmodic contraction of muscles of respiration Skin and hair: the tough membranous tissues that forms the external covering of the individual and may	One or fewer episodes of sneezing per observation Skin and hair as expected for the species	Sealy: Flakey, whitish looking pieces of epidermis sloughing off the body. Loss of hair: reduced density of hair Other skin/hair health problems:	Extensive or extreme variations of sealy, blisters, or other skin/hair problems with/without pruritis

TABLE I. Continued

Parameter	Severity rating		
	None or normal	Mildly or moderately abnormal	Highly abnormal
Gastrointestinal: Feces	have hair (includes visible mucous membranes)	rashes, redness, ulcers, erosions pustules, nodules maculae, scars, and thickenings Blisters: collection(s) of fluid under the epidermis or within the epidermis Cut: Superficial and limited to the skin surface Gash: More than just skin surface affected up to the muscle layer	Severe gash: More than skin affected and/or function of a system impaired
	Wounds: An injury to any part of the tissues of the body caused by trauma or disease	Intact integumentary system	
	Scratching: To rub to alleviate itching utilizing nails or other objects	No scratching or < 1 scratch per 30 minutes	Continuous: Scratching occurring > 1 time every 5 minutes or continuously for > 1 minute
	Swelling number: The number of swellings on the individual's body	None	Many: More than one swelling on the observed portion of the body
	Swelling size: The size of any abnormal enlargement on any part of the body		Large: (> 2.5 cm in diameter)
	Discharge: Substance that is emitted or evaluated as a secretion	None	Bloody, Other color: white, yellow, green, cloudy
	Defecation: The discharge of excrement from the rectum	Controlled elimination	Same as moderate but continuous
	Stool color: Color of the stool	Brown	Black: dark colored stool possibly indicating blood from the upper GI tract; blood red: reddish tinge or flecks of red in the feces indicating blood from the lower GI tract
	Stool consistency: The degree of texture or viscosity of the feces	Feces with the expected consistency and discrete lobes	Watery: Stools no longer retains any shape or consistency
	Other signs: Signs other than what is described above; e.g., CNS, reproductive	Normal movement and activity	Coma, paralysis, seizures
Other signs	Central nervous system	Not observed	Permanent prolapsed, swollen, maggots
	Prolapsed rectum	Not observed	Frequent vomiting
	Vomiting Dystocia	Not observed Not observed	No progression and female exhausted and showing signs of lethargy

Fig. 1. Flow chart of the clinical-response decision tree for mountain gorillas (*Gorilla beringei*). N/A: not applicable; ±: decision on individual case basis; reg: regional or in-country veterinarians can handle situation; inter: international help needed; PA: protected area authority; PD: MGVP project director; PH: public health official; SH: stakeholders; S: subsequent groups; Approp Inst: appropriate institution (e.g., NIH or CDC).

Level 2: Intense follow-up observations by trained health personnel using a more complex form focused on abnormalities from the basic observation data with a more detailed level of review.

Level 3: Outbreak assessment that places the scenario into either an outbreak or non-outbreak category according to the prevalence of clinical signs or a definite diagnosis.

Level 4: Assessment and categorization into low, medium, or high risk at the individual or population level.

Level 5: Risk management through implementation of the contingency plan.

Level One: Routine Health Monitoring and Review

Routine sentinel observational monitoring is the foundation of the health program for the mountain gorilla. Individual animals are observed for abnormalities that may indicate a health problem. Routine health observation data are gathered either by the trackers and guides or researchers on either a paper form or a PDA. Data are downloaded into an Internet-based data system (produced by the MGVP Database Team) called the Internet-Supported Management Program to Assist Conservation Technology (IMPACTTM). A strict data dictionary (Table I) in conjunction with thorough training ensures the consistency and accuracy of the data.

Utilizing the PDA, the observer identifies and enters the name of the group being observed, and the PDA automatically lists the names of the gorillas in the group. If the observer is utilizing the paper form, he picks the premade form that contains the names of the gorillas in the group being observed. The observer then records whether an individual animal was or was not observed (Fig. 2a). If an animal is marked as observed, the program asks which of the following parameters were observed: A) body condition, B) activity, C) respiratory system, D) skin/hair, E) discharge from head orifices, F) discharge from other areas of the body, G) stool, or H) other parameters (Table I). Each parameter is then recorded as normal or abnormal, and the observer has the ability to enter a text description for each abnormality noted (Fig. 2b).

Data collected on paper are entered into an Internet interface, while PDA data can be directly uploaded into IMPACTTM. Once the data are uploaded, reports are automatically generated by IMPACTTM as shown in Table II. In this example, no abnormalities were reported, so no further action would be indicated by the decision tree. The observation data are used to compile the normal prevalence rates of the parameters observed (see Fig. 1, level 1). Thus, IMPACTTM is a valuable tool for epidemiologically evaluating an outbreak in a uniform and statistically valid fashion. When level 1 routine observations indicate abnormal systems (Table III), the tool will direct the veterinarian or trained health personnel to complete a level 2 intensive follow-up observation for complex data collection and review (see Fig. 1, level 2).

Level 2: Intensive Follow-Up Observation, With More-Complex Data Collection and Review

The second level of data collected for input into the decision tree requires trained field health personnel to conduct a second observation of the group to confirm the accuracy of the basic data. This evaluation utilizes a more detailed and complex paper form or PDA observation module in the IMPACTTM program. This program is very similar in design, function, and use to the basic level program, but when a parameter with an abnormality is entered (Fig. 3a), a screen

Fig. 2. Screen capture of the IMPACTTM PDA data collection basic observation program showing (a) a list of individuals found in the observed group and (b) the observation of an individual gorilla, asking which parameters were seen and whether they were normal or abnormal.

appears with a list of strictly defined clinical signs to describe the abnormality in greater detail (Table I, Fig. 3b). If, as in the example of Table III, a routine basic observation report indicates abnormalities, and a subsequent intensive follow-up observation shows that the abnormalities are resolved (i.e., the animal stopped coughing and the wound is healing), no further action would be taken and data are stored in the database of epidemiological information. If the intensive follow-up observation shows abnormal clinical signs, as in Table IV, a decision has to be made as to whether the abnormality should be considered a non-outbreak or outbreak situation (see Fig. 1, level 3).

Level 3: Outbreak Assessment

An outbreak is defined as the occurrence of a disease or other health-related event in excess of what would be expected for the specific region and period of time. Although an outbreak may be defined by a single case, the term often implies that several individuals are affected. Important considerations in the investigation of an outbreak of infectious disease includes determining that an outbreak is in fact occurring and defining the extent of the population at risk. Given that data gaps in knowledge of the baseline prevalence of clinical signs and diseases in the mountain gorilla exist, outbreak assessment may initially prove to be the most challenging task. In the past, the identification of an outbreak was based on the collective experience and subjective judgment of the park manager and veterinarians. Currently, outbreaks are defined on the basis of past clinical

TABLE II. IMPACT Report from Level 1 Routine Observation with No Abnormal Parameters

Your data have been uploaded into IMPACT and analyzed		
Date of observation (s): 02/02/04		
Group Observed: Sabyinyo		
Number of individuals in the group observed		9 or 100%
Number of individuals in the group not observed		0 or 0%
Total group size		9
Number of dead gorillas observed		0
Number of non-group members observed		0
Total number of individuals observed		9
Number of abnormal parameters		0
Number of individual gorillas with abnormal parameters		0
Number of new abnormal parameters since		0
Yesterday		0
2-3 days		0
Last week		0
Tracker and guide detailed summary		
	Number of abnormalities by parameters:	
Parameters	Normals	Abnormals
Body condition	9	0
Activity	9	0
Respiratory	4	0
Skin/hair	4	0
Discharge-head	2	0
Discharge-other	0	0
Stool	0	0
Other system	0	0
Individuals observed with abnormalities: 0		
Name	Parameter (s) abnormal	
None	None	
Comments		
Gorilla	Comments	
None	None	
Action to be taken	None	

observations and the new data being amassed by IMPACT™, and the veterinarians and park managers can confirm or override the program at any point. One benefit of this system is that IMPACT™ records and updates the prevalence rates of clinical parameters and signs both spatially and temporally as it monitors for health. This was one of the faults of previous nonuniform health data collection methods, which frequently recorded data only from unhealthy animals.

As shown in Table III, if abnormal clinical signs are equal to or less than those expected (i.e., the coughing resolved, but the cut turned out to be a snare) it

TABLE III. IMPACT Report for Level 1 Routine Observation with Abnormal Parameters

Your data have been uploaded into IMPACT and analyzed		
Date of observation (s): 02/02/04		
Group Observed: Sabyinyo		
Number of individuals in the group observed		9 or 100%
Number of individuals in the group not observed		0 or 0%
Total group size		9
Number of dead gorillas observed:		0
Number of non-group members observed		0
Total number of individuals observed		9
Number of abnormal parameters		2
Number of individual gorillas with abnormal parameters		2
Number of new abnormal parameters since		
Yesterday		2
2-3 days		
Last week		2

Tracker and guide detailed summary		
	Number of abnormalities by parameters:	
Parameters	Normals	Abnormals
Body condition	9	0
Activity	9	0
Respiratory	4	1
Skin/hair	4	1
Discharge-head	2	0
Discharge-other	0	0
Stool	0	0
Other system	0	0

Individuals observed with abnormalities:	
Name	Parameter (s) abnormal
Kabatwa	Respiratory
Turiho	Skin/hair

Comments:	
Gorilla	Comments
Kabatwa	Coughing a lot
Turiho	Cut on left wrist
Action To Be Taken	Conduct intensified observation and more complex data collection and review

is considered a non-outbreak situation (see Fig. 1, level 4) and the data are stored. Non-outbreak assessments usually deal with individual welfare issues. If the prevalence of abnormal clinical signs is higher than expected, as we see in Table IV, the scenario would be assessed as an outbreak (see Fig. 1, level 4). Outbreak risk assessment would more likely involve population welfare.

Fig. 3. Screen capture of the IMPACTTM PDA data collection intensive observation program showing (a) the observation of an individual gorilla, asking which parameters were seen and whether they were normal or abnormal, and (b) the specific clinical signs for the body condition of the observed individual.

Level 4: Risk Assessment and Categorization As Low, Medium, or High Risk

Risk assessment is the process of estimating the implications of a disease/hazard introduction, and results in a final estimation or characterization of the risk. Risk assessment is a logical process by which risks are evaluated based on available scientific information. This standardized format for risk assessment supports veterinarians in making evidence-based decisions in the field. It also provides organization to vital communication efforts among field personnel, the park authority, veterinarians, and other NGO stakeholders. In order for the process to work and to ensure transparency, both the assumptions made and the factors that contribute to certainty in estimates of risk must be fully elucidated and documented.

In the vast majority of cases in the field, risk assessment is based on observational/clinical signs because of the limited availability of quantitative information. Therefore, the assessment is primarily qualitative in nature. Although qualitative risk assessment is not as desirable as quantitative assessment, it has been recognized as a valid tool by the World Trade Organization, the Food and Agricultural Organization of the United Nations, and the Organization of International Epizootics. This decision tree must function in the stochastic world of veterinary medicine in a field situation. Therefore, it must deviate from decision mechanisms used in human medicine. These deviations include dependency on observed clinical signs rather than verbal communication for patient assessment, the risk and difficulties of

TABLE IV. IMPACT Report from Intensified Observation as a Follow-Up to the Routine Observation of Sabinyo Group (Table 3) Where Two Individuals Were Observed With Abnormal Parameters That Have Not Resolved, and Additional Cases Were Observed Thereby Indicating an Outbreak Situation

Your data have been uploaded into IMPACT and analyzed	
Date of observation (s): 02/02/04	
Group Observed : Sabyinyo	
Number of individuals in the group observed	9 or 100%
Number of individuals in the group not observed	0 or 0%
Total group size	9
Number of dead gorillas observed	0
Number of dead gorillas with clinical signs of infection	0
Number of dead gorillas without clinical signs of infection	0
Number of non-group members observed	0
Total number of individuals observed	9
Number of abnormal parameters	
Number of abnormal clinical signs	5
Number of individual gorillas with abnormal clinical signs	3
Number of mild or moderate abnormalities	5
Number of mild or moderate infectious abnormalities	2
Number of mild or moderate noninfectious abnormalities	1
Number of mild or moderate undetermined (+/-) abnormalities	2
Number of severe abnormalities	0
Number of severe infectious abnormalities	0
Number of severe noninfectious abnormalities	0
Number of severe undetermined (+/-) abnormalities	0
Number of new abnormal clinical signs since	
Yesterday	1
2-3 days	2
Last week	3
Number of new mild or moderate abnormalities since	
Yesterday	1
2-3 days	2
Last week	3
Number of new severe abnormalities since	
Yesterday	0
2-3 days	0
Last week	0
Estimated Transmission Rate for this group	High
Estimated Mortality Rate for this group	Low
This group is probably in an outbreak.	
If it is in an outbreak the risk level for this group is medium.	
Action to be taken: Continue observation, alert protected area manager and project director	

Veterinarian detailed summary

Parameter	Number of abnormalities by parameter		
	Normal	Mild or Moderate	Severe
Body condition	9	0	0
Activity	9	0	0
Respiratory	7	2	0
Skin/hair	8	1	0
Discharge-head	7	2	0

TABLE IV. Continued

Discharge-other	9	0	0
Stool	2	0	0
Other system	0	0	0

Individuals observed with abnormalities	
Name	Parameter abnormal
Turiho	Skin/hair
Guhonda	Respiratory, discharge-head
Kabatwa	Respiratory, discharge-head

Comments:	
Gorilla	Comments
Turiho	Would healing well, using hand normally
Guhonda	Continuous productive coughing
Kabatwa	Continuous productive coughing

performing routine physical exams on gorillas, and the need, in the majority of cases, to anesthetize the animal for sample collection and treatment. Available human diagnostic tests may or may not be validated for gorillas, and thus have questionable diagnostic value. Although the risk-assessment decision-tree process is initiated by qualitative data, quantitative data should also be collected for confirmation or to reduce uncertainty in the characterization of risk. Over time, IMPACT™ will acquire the quantitative data needed to help make the decisions objective.

Level 4A. Risk assessment for an outbreak scenario

Risk assessment for an outbreak usually involves group- or even population-level decisions. This paper presents two methods by which outbreak risk can be assessed. The first method, disease diagnosis, is derived from clinical signs or diagnostic test results (see Table V for examples). The categories of low, medium, and high risk are derived from data on morbidity and mortality rates from human medicine, experience with nonhuman primates in captivity, and limited disease experience in wild ape populations. Table V updates occur as new information becomes available. The second method, which is used for cases in which a definitive diagnosis cannot be made, incorporates a combination of clinical signs, postmortem examination results, and estimated transmission and mortality rates (Table VI). Data are analyzed by the IMPACT™ system and placed into risk categories and implementation strategies that are then confirmed by veterinarians. The risk categories were compiled from past experiences by a team of experienced field and captive primate veterinarians, as well as veterinary and human epidemiologists. Table VI is dynamic and will constantly be updated as IMPACT™ incorporates its own data into the decision tree.

To make risk categorization consistent and functional, parameters and clinical signs were defined and ranked by severity (Table I). The rate of transmission is defined as low (no or one new case in <3 days), medium (one new case every 2–3 days), and high (one or more new cases per day). Mortality rates are defined the same as transmission rates. If multiple observations are not

TABLE V. Risk Assessment for the MGVP Clinical Decision Tree by Disease Diagnosis

Disease	Morbidity in great apes	Mortality in great apes	Impact on humans
High risk			
Ebola	High	High	High
Other hemorrhagic fevers	High	High	High
Encephalomyocarditis	High	High	Medium
Rabies	Low	High	High
Polio	High	High	High
Shigella	High	High	Low
Mycobacterium tuberculosis	High	High	High
Mycobacterium bovis	High	High	High
Measles	High	High	Low
Strep pneumonia	High	High	Medium
Medium risk			
Entamoeba histolytica	Medium	Low	Medium
Rotavirus	Low	Low	Medium
Respiratory syncytial virus	High	Low	Medium
Monkeypox	High	Low	Medium
Low risk			
Parainfluenza	High	Low	Low
Coronavirus	Low	Low	Low
Salmonella	Low	Low	Low
Campylobacter	Low	Low	Low
Sarcoptes	Medium	Low	Low
Entamoeba coil	Medium	Low	Low
Microsporum	Medium	Low	Low
Mycoplasma pneumonia	High	Low	Low

available to calculate transmission and mortality rates, the field veterinarian must rely on past experience to estimate these rates.

Level 4B. Risk assessment for a non-outbreak scenario

The non-outbreak risk assessment usually involves decisions on the individual level rather than the population level. Clinical signs are characterized by the likelihood that they are infectious or noninfectious, as well as the likely route of introduction. If the signs are human-induced and life-threatening, and treatment is beneficial and practical, immediate intervention is warranted. If the situation is non-human-induced, whether infectious or noninfectious, then the following decision-making criteria are utilized:

- A. Low risk: Not likely life-threatening and will probably resolve without treatment.
- B. Medium risk: Potentially life-threatening and may need treatment.
- C. High risk: Likely life-threatening and needs treatment.

Since “natural” injuries and mildly abnormal clinical signs occur as part of a gorilla’s natural history, this non-outbreak intervention decision is still somewhat subjective and often relies on demographic information for decision-making. Once the risk assessment and categorization are completed, risk management protocols should be implemented (Fig. 1, level 5).

TABLE VI. Risk Assessment by Clinical Signs

Low risk category
1 dead with no clinical signs of infectious disease and no other animals with clinical signs of infectious disease
1 dead with no clinical signs of infectious disease and 1 or more individuals with mild or moderate clinical signs of infectious disease
No dead and mild or moderate clinical signs in ≤ 8 or $\frac{1}{2}$ of the group size
1 or more individual with infectious disease with an estimated low transmission rate and low mortality rate
Medium risk category
1 dead with clinical signs of infectious disease
No dead and combination of moderate and/or severe clinical signs in 2-4 animals
No dead and combination of moderate clinical signs in ≥ 8 individual in a group or $\frac{1}{2}$ of the group size
1 or more individuals with clinical signs of infectious disease with an estimated medium to low transmission of clinical rate but medium to high morality rate
1 or more individuals with clinical signs of infectious disease with an estimated medium to high transmission of clinical rate but medium to low morality rate
Combination of clinical signs never before observed regardless of severity
High risk category
1 dead with clinical signs of infectious disease
No dead and severe clinical signs in $>$ animal
No dead and a combination of moderate and severe clinical signs in > 4 animals
≥ 1 dead and severe clinical signs
≥ 1 dead with a combination of mild to moderate clinical signs in ≥ 8 individuals or $\frac{1}{2}$ the group size
≥ 1 gorilla with signs of an infectious disease and an estimated medium to high transmission rate and medium to high morality
An infant with severe clinical signs with a mother that has mild to moderate clinical signs
Suspected high zoonotic potential but unlikely to cause gorilla morality

Level 5: Risk Management

The goal of risk management is to reduce the implications or recurrence of an introduced hazard. Although risk-management plans must be tailored to the situation, the decision tree contains basic recommendations. Risk-management and implementation plans were developed for each risk category for both outbreak and non-outbreak situations (Fig. 1, level 5).

Risk-Management Actions in Non-Outbreak Situations

Low-Risk Category Actions:

1. Continue observations.
2. Collect noninvasive samples if deemed necessary.
3. Report the problem to the protected-area authorities (PAA), the host country wildlife veterinary authorities (HVA), and the MGVP project director (PD).

Medium-Risk Category Actions:

1. Review demographic information.
2. Consider immobilization and collection of invasive sample.
3. Provide treatment or any beneficial preventive action.

924 / Decision Tree Writing Group

4. Communicate this to the PAA, HVA, and PD.
5. Continue to monitor and report as for low risk.

High-Risk Category Actions:

1. Review demographic information.
2. Immobilize the subject for sample collection and treatment.
3. Make sure that international export permits are ready to ship samples if necessary.
4. Contact outside help if deemed desirable.
5. Formulate a written action plan.
6. Communicate this to the PAA, HVA, and PD.

Gorillas occasionally get their hands or feet accidentally caught in snares set to catch other animals. They are generally strong enough to break these snares free from their grounding, but are usually left with ropes or wires attached to their limbs. This is one example of a non-outbreak situation because it usually only involves one animal and there is no potential for the problem to be transmitted to other gorillas. The fact that snares are human-induced and often life-threatening calls for immediate intervention.

Risk Management Actions in Outbreak Situations

Low-Risk Category Actions:

1. Continue to observe and assess for progression to moderate or high risk.
2. Collect noninvasive samples.
3. Produce reports on MGVP response and observation to the PAA, HVA, and PD.

Medium-Risk Category Actions:

1. Intensify observations to watch for advancement to high risk.
2. Perform immobilizations if deemed necessary for diagnostic invasive sample collection.
3. Notify the PAA, HVA, PD, and other appropriate stakeholders and public health officials.
4. Prepare a formal report and written action plan regarding the problem and MGVP activities.

High-Risk Category Action:

1. Perform intervention(s) for diagnostics and treatment.
2. Assess new information and redefine plan if necessary.
3. Obtain additional help from regional or international resources/experts.
4. Put potentially necessary health resources on standby.
5. Obtain international export permits and distribute written protocols for immobilizations, treatments and drug dosages, vaccinations, and diagnostics to the invited health providers.
6. Communicate to all appropriate people (PAA, HVA, PD, stakeholders, and public health officials).
7. In the face of an expansive and extreme outbreak, the most extensive part of the contingency plan is implemented. When international veterinary

assistance is necessary, consultation other experts, such as epidemiologists and Geographical Information System (GIS) experts, and the Centers for Disease Control and Prevention and the World Health Organization should be utilized.

DISCUSSION

Table IV shows a scenario with a higher-than-normal prevalence of abnormal clinical signs, and Table VI shows a medium-risk outbreak situation in which the rate of transmission is high (≥ 1 new case/day) but the mortality rate is low (no mortality observed). One of the deficiencies of previous health data collection systems is that normally only data from unhealthy animals were recorded. One benefit of IMPACTTM is that it constantly incorporates new data, including those from normal, healthy individuals, and adjusts baseline prevalence rates accordingly. This allows assessments of risk to be based on the most up-to-date information available for the population of concern.

The design of this system has gone through multiple iterations. As its development progressed, many aspects were simplified and the definitions were made more clear and rigid to be of practical use. The last major modification was to tier the observation format into two data-collection forms: 1) a basic form to be completed by trackers, guides, and researchers, and 2) a complex form to be completed by health-care professionals. This alleviated the problem of trying to develop one form for all purposes and often failing to accomplish the intended goals.

Another difficult task was to develop standardized definitions for each clinical sign, and the criteria that would allow an observer to say they had seen enough of a parameter to call it normal. We realized that perfect definitions do not exist under field conditions, due to animal behavior and vegetation, and therefore we settled on definitions that are both practical and productive.

An example of how the development of this system has changed clinical approaches is the response to respiratory outbreaks, particularly those involving multiple infants. In one study [Nutter et al., 2005], respiratory disease was responsible for approximately 25% of the mortality in the corpses examined. Clinical respiratory outbreaks are common and usually pose the greatest risk to infants. In the past, even if an infant died with respiratory signs and other gorillas were showing similar signs, the dead infant would be left until the mother dropped it. This eliminated the possibility of performing a diagnostic postmortem examination. Now, if an infant dies with suspicious signs of infectious disease and/or other animals are showing signs of clinical illness, the mother is anesthetized, examined, sampled, and sometimes treated, while the dead infant is recovered for a thorough postmortem examination. Other animals are often treated as deemed appropriate based on the findings of the postmortem examination and diagnostic samples from the mother.

Although this system has helped standardize the decision to intervene, there are still times when human emotion will override the process, such as when a gorilla received treatment for a naturally occurring wound to the eyelid that caused an unsightly appearance. This situation should not have warranted an intervention and the wound should have been left to heal naturally. However, the authorities requested an intervention in order to avoid public criticism, and the procedure was successfully completed.

The clinical-response decision tree combines data-collection methods with a novel Internet-based risk analysis system (part of IMPACTTM function) to

direct implementation of action. With slight modifications, the system is also being used for a wild chimpanzee population, and could be modified for other wildlife populations as well.

In conclusion, this tool is helping to encourage quick, well informed, consistent, and rational decision-making. The observational data portion of IMPACT™ will become more powerful as the observation database builds with ongoing utilization of the system.

When coupled with a larger contingency plan that includes logistical support for field activities, public relations, and ecotourism activities, it can be a powerful tool for conserving this irreplaceable natural resource. It is our hope that the experience and knowledge gained by the MGVP and its partners in the development of this process will aid other great-ape conservationists in their endeavors. The clinical-response decision tree is the product of a multi-disciplinary group of veterinarians, epidemiologists, and public health professionals, with input and consensus from other stakeholders in mountain gorilla conservation.

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