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Article

Euthanasia Complications in Non-Domestic Species

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Abstract: There are very few studies describing euthanasia complications in non-domestic species. The goal of this study was to survey veterinarians to determine what complications may commonly occur during the euthanasia of non-domestic species. An online survey was sent to seven professional organization listservs containing veterinarians most likely to practice on non-domestic species. Forty-one cases of euthanasia complications were reported. The most common taxa reported were mammals, (23/41, 56%), followed by avian (8/41, 20%), reptile (7/41, 17%), and fish (3/41, 7%). Most animals were reported to have been anesthetized prior to euthanasia (28/41, 68%). The most common method of euthanasia was pentobarbital (27/41, 66%). The reported euthanasia complications included "took an excessive amount of euthanasia solution" (12/41, 29%), "heart would not stop" (9/41, 22%), "animal awoke at a later time" (4/41, 10%), "a secondary method of euthanasia was required" (4/41, 10%), and "other" (12/41, 29%). This study reports complications that can occur during the euthanasia of non-domestic species. The concept of dysthanasia, a euthanasia with an undesirable outcome, has not been previously discussed in the context of zoo, wildlife, aquarium, and exotic pet practice. Strategies to reduce dysthanasia from both animal and human perspectives are explored, including alternative euthanasia techniques, principal-based euthanasia, and mental health implications.

Keywords: euthanasia; euthanasia complication; zoo euthanasia; wildlife euthanasia; non-domestic

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1. Introduction

Euthanasia is a vital component of veterinary practice. In order to provide a rapid, painless, and distress-free death, guidelines have been established by the American Veterinary Medical Association which include acceptable methods of euthanasia in a variety of species [1]. This manuscript includes sections on laboratory animals, avians, fish, aquatic invertebrates, and zoologic and free-ranging non-domestic animals [2]. Additionally, a set of guidelines was published by the American Association of Zoological Veterinarians on euthanasia methods in non-domestic animals [1]. Recommendations for non-domestic species have been continuously updated as the field advances its understanding of the efficacy of various euthanasia methods, such as immersion with tricaine methanesulfonate (MS-222) at high doses was previously considered to be an adequate method of euthanasia in fish [3]. However, a recent study has shown that immersion with tricaine methanesulfonate (MS-222) is not always efficacious, and a secondary method such as pithing is now recommended [3]. Although additional research is continually being conducted to determine the most appropriate methods for euthanizing non-domestic species, there is still a paucity of information as to what methods work, what does not work, and where improvements can be made to provide the best care for these patients [4,5].

There are many physiologic and logistical factors that make euthanizing non-domestic species more complex than domestic species. Some anatomic and physiologic challenges include patient size, such as patients that are too small or too large to easily obtain IV access, tolerance of prolonged hypoxemia (such as fish and reptiles), altered drug metabolism (such as ectothermic animals, those that exhibit the dive reflex, or those that undergo hibernation or brumation), cardiovascular variations from "standard" mammalian anatomy,

and differing responses to drugs across taxa and species [4–7]. Euthanizing non-domestic species can also come with a variety of logistical challenges, including euthanizing in a non-clinical environment such as in the animal's exhibit, in an aquarium setting, or in the wild. Human safety concerns can play a role in euthanasia methodology when working with a variety of potentially dangerous species. Medication choice and dosing may be limited based on cost, regulatory status, and impact on the surrounding ecosystem [5,8–10]. Monitoring equipment may not be available or may not function appropriately in some non-domestic species due to size or physiology. Additionally, determining death may be less straightforward than it is in domestic species because the cessation of a heartbeat may not always be consistent with brain death, and in some species heartbeat or respiration can resume after long periods of inactivity [3–5,7]. All these factors may predispose to euthanasia-related complications.

A newly described term, dysthanasia, has been coined as the antithesis of euthanasia and encompasses a variety of undesirable outcomes [11]. These include pain or distress of the animal, improper euthanasia technique, and distress or anguish of the observers [11]. This framework and proposed strategies for avoiding dysthanasia were developed with domestic animals and client-based interactions in mind, but are nonetheless applicable to non-domestic species. Understanding common euthanasia complications can help to reduce the occurrence of dysthanasia and to help practitioners provide a good death for their patients as well as promote the well-being of clients, animal keepers, and other observers during euthanasia.

The goal of this study was to survey veterinarians to determine what complications may commonly occur during the euthanasia of non-domestic species and how to learn from them and prevent them. We hypothesized that complications would be reported in all major vertebrate taxa and that a variety of standardly practiced euthanasia techniques could result in complications when utilized in non-domestic species.

2. Materials and Methods

Survey: A 57-item online survey was developed and sent to veterinary professional organizations that were deemed most likely to include practitioners that work with non-domestic species. The organizations included were: the American Association of Zoo Veterinarians (AAZV), the Association of Avian Veterinarians (AAV), the Association of Reptile and Amphibian Veterinarians (ARAV), the Association of Exotic Mammal Veterinarians (AEMV), the Wildlife Disease Association (WDA), the American Association of Wildlife Veterinarians (AAWV), and the American College of Emergency and Critical Care (ACVECC). The survey was approved by the North Carolina State University Institutional Review Board (NCSU IRB Protocol #23988, approved 6/18/21). The survey was distributed by email or by online newsletter with a link to an online survey platform (REDCap; Vanderbilt University). An introductory letter was included, explaining the purpose of the survey. The survey was anonymous, and participation was voluntary. The survey asked the participant whether they had ever experienced a euthanasia complication involving a non-domestic species. If they responded yes, respondents would be prompted to answer questions about the complication, including the type of ownership of the animal being euthanized (i.e., client-owned, zoo, aquarium, or wildlife), whether the animal was anesthetized prior to euthanasia and by what method, which method of euthanasia was used, the dose of medication used if known, the method of confirming death, the complication that occurred, the taxa and species of the animal involved, and whether any legal ramifications occurred as a result of the complication.

Questions were primarily multiple-choice, with the option of answering "other," at which point the respondent would be prompted to write in a response. Open-ended options were available for additional comments. The survey consisted of branching logic so that questions appeared based on answers to previous responses. After completing this portion of the survey, respondents were given the option to describe another euthanasia complication case, at which point they restarted the survey with the same questions. When

all complications were recorded, demographic information (age, sex, and career stage) was collected. Respondents could skip any question they did not want to answer or did not apply to them.

Data analysis: Descriptive statistics (mean, median, and range) were calculated for demographic information using Alcula online software (http://www.alcula.com, accessed on 14 November 2021). Midpoint coding was used for the age range for ease of analysis and to maintain the privacy of the respondents.

3. Results

Complications: Forty-five practitioners responded to the survey. Of those, sixteen responded "yes" to the question of whether they had experienced a euthanasia complication or not, but included no further information. Therefore, twenty-nine surveys were considered suitable for analysis. Ten respondents included more than one complication (eight included two complications, and two included three complications), resulting in forty-one described cases of euthanasia complications. The classes of the animals in the reported cases included mammal (23/41, 56%), avian (8/41, 20%), reptile (7/41, 17%), and fish (3/41, 7%). No amphibians or invertebrates were reported in this survey. A full list of reported species is included in Table 1. Most species were only reported once. However, four species were reported more than once (red-eared slider (*Trachemys scripta elegans*) $n = 2$; black bear (*Ursus* spp.) $n = 2$, ferret (*Mustela putorius furo*) $n = 3$; and bald eagle (*Haliaeetus leucocephalus*) $n = 2$). The ownership status of the animals included client-owned (13/41, 32%), wildlife (12/41 29%), zoo (13/41, 32%), aquarium (2/41, 5%), and research (1/41, 2%).

Table 1. A survey was conducted on euthanasia complications in non-domestic species. This table lists all of the species that were reported with their scientific name, if available.

Species with Reported Euthanasia Complications	
Baboon (unspecified)	Chipmunk (*Tamias striatus*)
Red-eared slider (*Trachemys scripta elegans*) *	Pygmy slow loris (*Nycticebus pygmaeus*)
Bearded dragon (*Pogoan vitticeps*)	Guinea pig (*Cavia porcellus*)
Northern right whale (*Eubalaena glacialis)*	Tortoise (unspecified)
Giraffe (unspecified)	Rabbit (*Oryctolagus cuniculus*)
Bald eagle (*Haliaeetus leucocephalus*) *	Mouse (*Mus musculus*)
Black bear (*Ursus* spp.) *	Chicken (*Gallus gallus domesticus*)
Horse (*Equus caballus*)	Elk (*Cervus canadensis*)
Snapping turtle (*Chelydra serpentina*)	Western scrub jay (*Aphelocoma californica*)
Hoof stock (unspecified)	Humpback whale (*Megaptera novaeangliae*)
Sea lion (unspecified)	Eel (unspecified)
Military macaw (*Ara militaris*)	Jack (*Caranx hippos*)
Osprey (*Pandion haliaetus*)	Mexican beaded lizard (*Heloderma horridum*)
Fallow deer (*Dama dama*)	Turkey vulture (*Cathartes aura*)
Mexican lance head rattlesnake (*Crotalus polystictus*)	Cow (*Bos taurus*)
Banded butterflyfish (*Chaetodon striatus*)	Duck (unspecified)
Rock hyrax (*Procavia capensis*)	Not listed
Ferret (Mustela putorius furo) †	

* = reported twice, † = reported 3 times.

When asked whether the animals were anesthetized prior to euthanasia, 28/41 (68%) responded yes, 8/41 (20%) responded no, and 5/41 (12%) gave no response. The reported methods of euthanasia included pentobarbital (27/41, 66%), potassium chloride (3/41, 7%), captive bolt (1/41, 2%), tricaine mesylate (3/41, 7%), gunshot (2/41, 5%), and other (5/41, 12%). The "other" methods listed included exsanguination, freezer, carbon dioxide, cervical dislocation, and isoflurane overdose. The reported dosing of euthanasia drugs was variable but always fell within the recommendations of the AVMA guidelines [2]. The reported methods of confirming death included stethoscope (24/41, 59%), Doppler (4/41, 10%), electrocardiogram (2/41, 5%), cardiac ultrasound (2/41, 5%), no method of confirmation (3/41, 7%), or other (6/41,

15%). The "other" methods that were used varied, but were all primarily observation-based, such as an absence of voluntary movement or absence of respiration.

The reported euthanasia complications included "took an excessive amount of euthanasia solution" (12/41, 29%), "heart would not stop" (9/41, 22%), "animal awoke at a later time" (4/41, 10%), "a secondary method of euthanasia was required" (4/41, 10%), and "other" (12/41, 29%). Table 2 summarizes the euthanasia complications and lists the "other" complications that were reported. When asked whether there were any legal ramifications associated with the euthanasia, 40/41 (98%) reported that there were none. One respondent reported backlash from local law enforcement and the owner of the animal, but no legal recourse.

Table 2. A survey was conducted on euthanasia complications in non-domestic species. This table lists all reported complications, along with the number of times they were reported.

Euthanasia Complications	Number of Times Reported
Heart would not stop	9
Animal awoke at a later time	4
Took an excessive amount of euthanasia solution	12
A secondary method of euthanasia was required	4
Other:	
Multiple gunshots required	2
Adverse public response	1
Prolonged tremoring and agonal breathing	4
Regurgitation and aspiration	1
Difficulty injecting euthanasia solution into peripheral vein	3
Heart re-starting with stimulation	1

Demographics: Of the 29 respondents considered for analysis, 19 (66%) were female, 5 (17%) were male, and 5 (17%) chose not to answer. The midpoint mean age of respondents was 43.5 years (SD 12.9 years). Age range categories reported were 20–30 (5/29, 17%), 31–40 (5/29, 17%), 41–50 (5/29, 17%), 51–60 (4/29, 14%), 60 or older (5/29, 17%), and no response (5/29, 17%). The reported career stage included early career (9/29, 31%), mid-career (10/29, 34%), late career (6/29, 21%), and no response (4/29, 14%).

4. Discussion

This study reports complications that can occur during the euthanasia of non-domestic species. Complications were most commonly reported in mammals (23/41, 56%). This was a surprising finding, as the authors hypothesized that euthanasia complications would most commonly occur in species that were most physiologically divergent from those seen in a typical small animal practice. Although this survey does not necessarily represent the overall prevalence of euthanasia complications, it is worth noting that the rate of complications in mammals may be higher than we anticipate. It is possible that this reporting is biased by the fact that mammals are euthanized more frequently than other taxa. However, depending on the type of practice this may not always be the case, and it is worth noting that non-domestic animals with similar physiology to dogs and cats may have a higher rate of complication than we realize. Information regarding how commonly each practitioner euthanizes a given taxon was not collected and therefore cannot be used to determine the overall prevalence of mammalian euthanasia complications. The most common method of euthanasia in mammals was pentobarbital (14/23) and the most common complication was listed as "other," indicating a variety of complications which were summarized in Table 2. Although the variety of complications and species reported within the mammalian class makes it difficult to report overall trends, many of the complications described in mammals were related to the appearance of the euthanasia which may have been distressing for the humans witnessing the euthanasia rather than the animal itself.

In six out of eight reported cases in birds, pentobarbital was the method of euthanasia. In the seventh and eighth cases, isoflurane overdose and cervical dislocation were used,

respectively. The most commonly reported complication was "heart would not stop" (5/8), followed by "took an excessive amount of euthanasia solution" (2/8), and "other" (1/8) which was described as "agonal breathing and tremoring." Although avian species tend to metabolize drugs rapidly, these results indicate that standard mammalian doses of pentobarbital may at times be insufficient as a sole euthanasia agent.

Six out of the seven reported reptile cases were euthanized using pentobarbital. The remaining case was euthanized by freezing and awoke at a later time. This was noted as not being a euthanasia performed by a veterinarian but rather being brought to a veterinarian after the attempted euthanasia took place. Freezing is not a euthanasia method approved by the AVMA [2]. The other reported complications included "a secondary method of euthanasia was required" (3/7), "took an excessive amount of euthanasia solution" (1/7), and "other" (1/7) which was described as "heart stopped but muscle fasciculations and large muscle contractions continued for >30 min." A recent study evaluating euthanasia methods in leopard geckos (*Euublepharis macularius*) found that intracardiac pentobarbital resulted in rapid, smooth death following injectable anesthesia with alfaxolone [12]. However, other methods of euthanasia including intracoelomic pentobarbital and intracardiac lidocaine overdose resulted in either prolonged time to cardiac arrest or recovery at a later time, respectively [12]. This is consistent with the finding that although pentobarbital is an acceptable method of euthanasia in reptiles, route and dose may be crucial to inducing a rapid death, potentially due in part to reptiles' tolerance of prolonged hypoxemia as well as the fact that cessation of a heartbeat does not necessarily indicate cerebral death [12]. When possible, intracardiac pentobarbital following anesthesia may reduce the occurrence of complications in reptiles.

In all three fish cases, MS-222 was the listed method of euthanasia. Complications reported included "took an excessive amount of euthanasia solution" and "heart restarted at a later time." This finding is consistent with other reports that have found MS-222 to be insufficient as a sole euthanasia agent [3]. These reports support the need for a secondary method of euthanasia such as intracardiac pentobarbital, potassium chloride, or pithing to ensure a successful death in fish.

Across taxa, pentobarbital was the most common method of euthanasia (27/41, 66%).

Although not every case reported a dose, the doses that were reported were within or above the recommendations provided by the AVMA [2]. This indicates that traditional doses of pentobarbital may not always be sufficient in non-domestic species. Various factors including route, anesthetic plane, and cardiovascular status of the animal may impact the success of drug delivery and effectiveness and were outside the scope of this survey. However, when euthanizing non-domestic species, it may be prudent to utilize a secondary method of euthanasia such as intravenous potassium chloride in order to avoid prolonged or complicated euthanasia. The most common method of confirming death was a stethoscope (24/41). Although not always feasible, utilizing multiple methods of confirmation of death (Doppler, ECG, cardiac ultrasound, and end-tidal carbon dioxide) may reduce the risk of euthanasia complications, particularly in animals that may be difficult to auscultate due to size or conformation.

Routes of euthanasia solution administration that were not reported in any cases included intrarenal and intrahepatic injections. A recent survey of small animal practitioners indicates that there is a growing trend of intra-organ injection of euthanasia solutions [13]. While clinicians still reported IV injection as their preferred method overall, intrahepatic injections were ranked second in dogs and intrarenal injections were ranked second in cats [13,14]. A recent retrospective of intrarenal injection for euthanasia in cats also indicated that this method resulted in rapid and smooth death, comparable to IV injection [14]. Although these methods will not be feasible in all patients, they should be considered as an alternate route of euthanasia in non-domestic species. Several respondents of this survey mentioned difficult IV access and/or cardiovascular collapse as challenges that may have led to the euthanasia complication that they encountered. Intrarenal and intrahepatic injections may be especially useful in smaller patients when IV access is challenging or in

patients in which intracardiac administration is either not feasible or not desirable due to the perception of others observing the procedure.

Participants in this survey were fairly equally distributed amongst age ranges and career stages, with a midpoint mean age of respondents of 43.5 years (SD 12.9 years). There was no overt association between euthanasia complication rate and the age or career stage of the practitioner. The majority of respondents were female (19/29), with a lower proportion of males (5/29) or unlisted (5/29). This was interpreted as a reflection of the higher proportion of females in the veterinary profession, rather than the association between gender and euthanasia complication rate.

One finding of note was the number of reported complications that were reported from technically appropriate instances of euthanasia. These cases met the criteria of a "good death" from an animal suffering standpoint but were potentially distressing for the veterinarian or others present for the euthanasia. Ten out of forty-one reported cases were considered to meet this criterion and reported complications included agonal breathing, muscle tremors, convulsions, and other similar responses that were unlikely to have resulted in any conscious suffering on the part of the animal. Although these described complications fall within what may be expected during the active dying process, the emotional toll they can take on observers can be significant nonetheless. This type of euthanasia complication falls within the scope of the term dysthanasia, which is used to describe a euthanasia with an undesirable outcome, including an adverse effect on any human observers [11].

There is very little literature describing this form of dysthanasia in general, and a particular paucity when it comes to non-domestic species. One study discusses the experiences and coping strategies of individuals that euthanize wildlife [10]. This study also found that most participants reported that social and emotional support arising from the stress of euthanasia was not generally available [13]. Strategies identified by this study for reducing moral stress included improving communication around the justification for euthanasia as well as institutional training and support for individuals practicing euthanasia [10]. These findings are supported by recent work on dysthanasia, which advocates a principle-based approach to euthanasia rather than an outcome-based approach [11]. This framework includes communication around expectations and goals for euthanasia, with emphasis on an understanding that even when appropriate methods are applied, undesirable outcomes may occur. It also emphasizes that a complication is not equivalent to failure. This type of framework can be adapted for each specific situation but can be useful in minimizing the stress of the person euthanizing as well as those present for the euthanasia. This may be especially useful for the field of zoo and aquarium medicine, in which keepers and aquarists are commonly present for euthanasia and often have a long-standing, collegial relationship with the euthanizing veterinarian. Additionally, zoos and aquariums face increased public visibility and scrutiny around euthanasia decisions. Therefore, increasing communications around these topics both within institutions as well as in relation to the public may play an important role in decreasing the moral stress of those involved with the euthanasia. While these strategies may not reduce the rate of complications during euthanasia, they can be successfully utilized to decrease the component of dysthanasia related to human distress.

Although many of the reported complications were not expanded upon past the multiple-choice selections offered, it is worth noting that some complications are inherently more severe than others. Complications such as "took an excessive amount of euthanasia solution" (12/41, 29%) are worth describing in that it is important to know that some species may require higher doses of pentobarbital than previously reported. However, the implications of this type of complication in a euthanasia scenario are likely to be minimal. On the other hand, complications such as "awoke at a later time," which was reported four times in this survey (9.7%) have a much higher potential for severe repercussions. Although the sample size is too small to make robust conclusions, these four complications warrant further discussion. Two of the four cases were euthanized using methods that are

not currently recommended by the AVMA (a fish in MS-222 immersion and a reptile placed in a freezer) [1]. These are therefore unlikely to be of clinical significance. The remaining two cases were both black bears (*Ursus* spp.) that had been anesthetized and euthanized using pentobarbital, with death confirmed via observation of apnea and a lack of audible heartbeat using a stethoscope. Both bears resumed ventilation and audible heartbeat at a later time, though never became fully conscious. Although this information is anecdotal and represents only two cases, this type of scenario could have a significant impact in terms of legal, emotional, and human safety ramifications. Further investigation is warranted to determine whether certain species have a higher risk of euthanasia complications and what additional measures should be taken to prevent potentially dangerous scenarios such as these.

One limitation of this study is the relatively small sample size for the multiple variables reported, resulting in a lack of formal statistical analysis. One possible cause of the low response rate could be fear of reporting due to the stigma around euthanasia complications. Additionally, multiple disclaimers were required by the IRB reviewing the survey due to the sensitive nature of the material, which may have discouraged responders. No claims about the prevalence of euthanasia complications in this species can be made from this report. Rather, it describes complications that may occur in these species and the implications of those complications. This study was also based on voluntary self-reporting from clinicians and therefore may not be a wholly accurate description of the most common euthanasia complications that occur in non-domestic species. However, reporting these initial findings may be crucial in deconstructing the stigma around euthanasia complications and encouraging participation in future studies. Additional work may explore euthanasia complications within specific taxa or species more deeply, as well as how often clinicians perceive these complications to occur.

5. Conclusions

This study reports euthanasia complications that may commonly occur in non-domestic species. Complications were most frequently reported in mammals, and the type of complication reported varied between classes of animals. The concept of dysthanasia, a euthanasia with an undesirable outcome, has not been previously discussed in the context of zoo, wildlife, aquarium, and exotic pet practice and warrants further attention. Strategies to reduce dysthanasia from both the animal and human perspective include alternative euthanasia techniques, multiple methods of confirming death, principle-based euthanasia, and communication between those witnessing the euthanasia.

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Data Availability Statement: Due to the sensitive nature of the content and a desire to maintain anonymity of respondents the dataset will not be made publicly available.

Conflicts of Interest: The authors declare no conflict of interest.

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