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A Portable Fluid Administration System for Prolonged Intravenous Fluid Administration in Subadult and Adult White Rhinoceroses (*Ceratotherium simum*)

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ABSTRACT

While translocations of white rhinoceroses have become an important conservation tool, dehydration during long-distance transports has been identified as a welfare concern. Intravenous (iv) fluid administration might therefore be useful to mitigate dehydration; however, special requirements need to be met to make iv fluid administration suitable for large, wild rhinoceroses during transport. Requirements include a portable and robust system that is capable of delivering high flow rates, is easy to set up, and remains patent and operating for long periods of time while allowing the animals to freely stand or lay down in the transport crates. Due to the lack of suitable fluid administration systems, we developed a custom-made system consisting of 8 L drip bags, a three-part, 4.4-m–long, large bore and partially coiled administration set, and a robust, battery-operated infusion pump, which allowed us to successfully administer iv fluids at a maintenance rate of 1–2 mL/kg/h to eight rhinoceroses for 24 h during a mock transport. While iv fluid administration in transported rhinoceroses is time intensive and the large amount of drip bags required during lengthy transports might pose a limitation, the developed system may be useful for the long-distance transport of small groups of rhinoceroses. Furthermore, this system would be of value for injured or sick rhinoceroses, which require parenteral fluid therapy when commercially available infusion pumps cannot provide the large fluid volumes needed.

1 | Introduction

In light of the current poaching crisis, translocation of white rhinoceroses (*Ceratotherium simum*) over long distances has become a common conservation tool (Emslie, Amin, and Kock 2009). However, during translocations, rhinoceroses do not normally drink water, which makes dehydration a welfare concern (Pohlin et al. 2020). Intravenous (iv) fluid administration could be applied to mitigate dehydration, but a suitable fluid administration system for long-distance translocations of large animals like rhinoceroses needs to: (i) be portable and suited for rugged environmental conditions, including high levels of humidity, dust, vibration, and impact forces; (ii) be capable of delivering high flow rates (4.5 L/h for the administration of 2 mL/kg/h in a 2250 kg rhinoceros); (iii) be capable of remaining patent and operating, mostly unattended, for prolonged periods of time; (iv) allow for easy setup and connection when animals are loaded; and (v) allow the animals to stand and lie freely in transport crates.

Commercially available fluid administration systems were initially considered in the search for a system that fitted these

Research Highlights

We describe the development of a portable, robust iv fluid administration system for white rhinoceroses during a 24-h transport. It consists of 8 L drip-bags, a three-part, 4.4-m–long, large bore and partially coiled administration set, and a robust, battery-operated infusion pump.

criteria. One option commonly used in zoos (Ellie Milnes, pers. comm.) consists of a combination of gravity-based infusion and iv flow regulators inserted into the administration set, such as the Easydrop-Eurodrop IV Flow Regulators (GVS, Bologna, Italy). However, for gravity to be sufficient to administer large fluid volumes, drip bags need to be positioned high enough above the animal and crate, which is not possible during most rhinoceros translocations. Alternatively, the Droper Vet portable equine infusion pump (Droper, Olne, Belgium), a non-gravity, energy self–sufficient system based on mechanical compression allowing an infusion rate of up to 8.3 L/h is available; however, the system can only accommodate fluid bags of up to 1 L. We also considered commercially available infusion pumps commonly used in zoos (Ellie Milnes, pers. comm.) such as the Niki V4 Volumetric Infusion Pump (VetQuip, Sydney, Australia). However, with a battery life of only 16 h and a maximum fluid administration rate of 999 mL/h, it does not meet our requirements to administer large fluid volumes.

Ultimately, due to the lack of suitable fluid administration systems that meet the criteria above and the lack of commercially available large drip bags exceeding 3 L in South Africa, we developed a custom-made fluid administration system consisting of 8 L drip bags, a three-part, 4.4-m–long, large bore and partially coiled iv administration set, and a robust battery-operated high flow-rate infusion pump.

2 | Methodology

The portable fluid administration system, consisting of the infusion pump, 8 L fluid bags (filled with Ringer's lactate solution), and iv fluid administration and connection sets, were co-developed with and custom-made by Capricorn Biomedical (Johannesburg, South Africa).

The infusion pump (Figure 1A,B) consisted of a rugged 24.5 × 7.2 × 19.5 cm metal casing, a peristaltic pump unit with an on/off button, and a 24-V, 5-Ah lead-acid battery, which was pre-charged via a cable and integrated charging unit from a mains supply (230 V, 50 Hz). The pump head (Figure 1B) included a three-roller pump segment with rollers running on bearings, driven by a 24-V DC motor and gearbox with a speed control board. A potentiometer, with a locking mechanism to prevent accidental adjustments, was connected to this board to allow for variable control of the pump speed and hence fluid flow rates. A 6.5 × 3 cm LED screen displayed the pump speed as a percentage of maximum revolutions per minutes (RPM). The on/off button of the pump was protected by a hinged casing and spring-loaded locking mechanism, preventing inadvertent on/off switching.

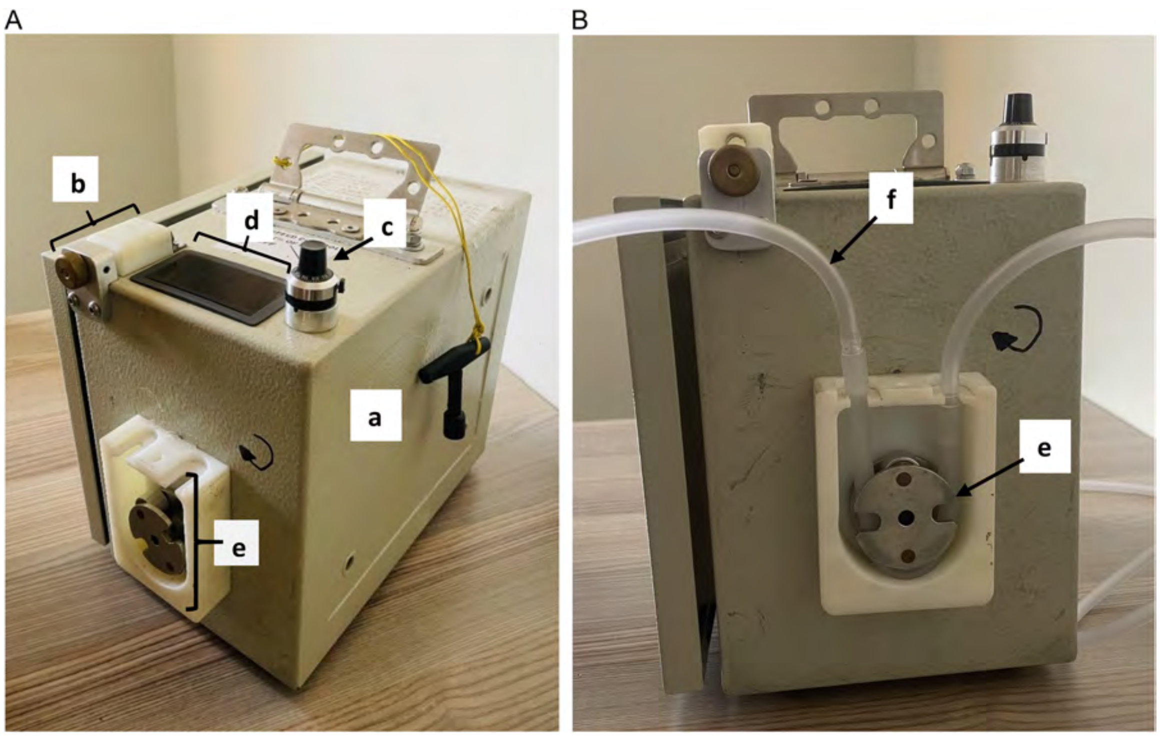

FIGURE 1 | Peristaltic infusion pump (A) with a rugged 24.5 × 17.2 × 19.5 cm metal casing (a), and an on/off button protected by a hinged casing and spring-loaded locking mechanism (b). The potentiometer (c), with a locking mechanism to prevent accidental adjustments, allowed for variable control of the pump speed/fluid flow rates. The 6.5 × 3 cm LED screen (d) displayed the pump speed as a percentage of maximum rounds per minutes (RPM). The pump head included a three-roller pump segment (e) with rollers running on bearings. The fluid administration line (f, blood-grade polyvinyl chloride [PVC] tubing) was inserted into the pump head roller system (B). [Color figure can be viewed at wileyonlinelibrary.com]

The fluid administration sets (Figure 2) were made from blood-grade polyvinyl chloride (PVC) tubing, with a lumen of 5 mm and a total length of 4.4 m. They consisted of three parts, connected by three-way stopcocks (South African Hospital Supplies, Cape Town, South Africa), which allowed for an easy setup when the animal was loaded into the crate and facilitated the exchange of parts of the administration set in case of damage or leakage. The first part (2.2 m) was connected to a drip bag and included a section of softer tubing (16.5 cm), which was inserted into the pump head roller system. The second part (0.6 m) was spring-coiled to reduce its hanging length (3 m total length when maximally stretched) to prevent the rhinoceros from stepping on or lying on the dripline, while still providing temporary stretching for movement and lying down. The third part (1.6 m) connected the rest of the administration system to the rhinoceros via a three-way stopcock connected to a winged 12-gauge catheter (L 80 mm, 430 mL/min, ⌀ 2.7 mm, Intraflon 2, Vygon, Ecouen, France), which was inserted into an auricular vein (*Vena auricularis*). The catheter was secured to the ear of the rhinoceros by simple interrupted sutures (Nylon size 0, Gabler Medical, Colchester, UK) (Figure 3). In addition, the dripline (Part 3) connecting to the catheter was half-looped and secured on the ear using simple interrupted nylon sutures (Figure 3). Part 3 of the dripline was further secured intermittently with loose simple interrupted sutures along the neck and nuchal hump, allowing it to glide freely with head movements while remaining on the dorsum, out of the way of the body and legs (Figure 4A). Part 3 was connected to Parts 1 and 2 of the administration set only once the rhinoceroses were loaded in the crates (Figure 4B).

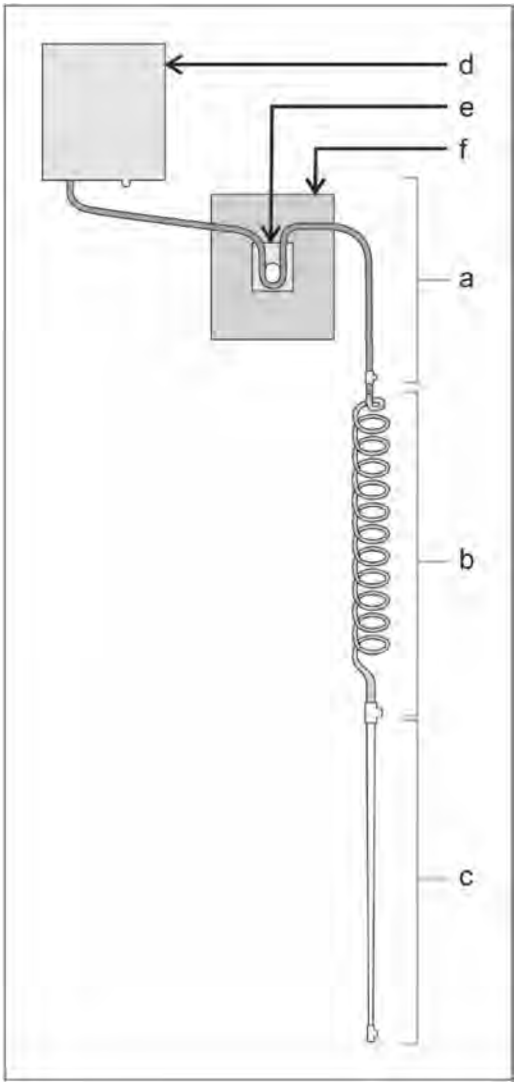

FIGURE 2 | Sketch of the fluid administration line consisting of three parts (a, b, and c) connected by three-way stopcocks: Part 1 (a, 2.2 m) connected into a drip bag (d) and was inserted into the pump head roller system (e) of the infusion pump (f). Part 2 (b, 0.6 m) was spring-coiled to reduce its hanging length (3 m total length when maximally stretched). Part 3 (c, 1.6 m) connected the rest of the administration system to the rhinoceros via a three-way stopcock to a winged 12-gauge catheter (not shown here).

The 8 L bags were made out of 0.4-mm–thick polypropylene sheets. The bottom of the bags contained two connection ports made out of thermoplastic elastomer (TPE). These ports allowed for the tight connection of the administration set (Part 1) and for connecting two drip bags together using a 0.5-m–long line-connector piece to extend the infusion duration without the need to change bags regularly, which is an advantage during long translocations.

A splint to stabilize the ear was made out of heavy-duty polyethylene (HDPE) piping (L 17–19 cm, ⌀ 6.5–7.5 cm, depending on rhinoceros size), wrapped in cotton wool padding, and covered in adhesive bandaging (BSN Medical, Pinetown, South Africa). The splint was placed on the inner surface of the pinna of the rhinoceros (Figure 5A) and was bandaged to the pinna using elastic bandaging (Sticky-Band VT 100 mm, Ascendis Animal Health, Johannesburg, South Africa), which also covered and stabilized the catheter and dripline. The splint ensured that the ear was kept straight so that the catheter would not kink, get damaged, or pull out (Figure 5B).

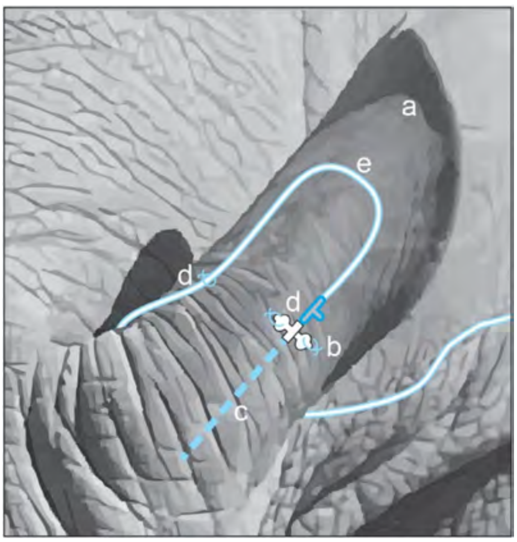

FIGURE 3 | Sketch of a rhinoceros ear (a) with the winged 12-gauge catheter (b) inserted into one auricular vein (c) and secured to the ear by simple interrupted nylon sutures (d) and the half-looped third part of the dripline (e), also secured on the ear using simple interrupted nylon sutures (d). [Color figure can be viewed at wileyonlinelibrary.com]

FIGURE 4 | (A and B) Part 3 of the dripline (a) was connected to the auricular catheter before loading the rhinoceros (A) and connected to part 2 (b) of the dripline once the rhinoceros was loaded into the crate (B). Part 3 of the dripline (a) was secured with simple interrupted nylon sutures on the ear and with intermittent loose simple interrupted sutures along the neck to the nuchal hump. [Color figure can be viewed at wileyonlinelibrary.com]

The infusion pump, drip bag/s, and foam for protection and positioning of the drip bag/s were placed in a 60-L cooler box (CampMaster safari cooler box 60 L) (Figure 6A) and secured on top of the crate (Figure 6B). The administration set was connected to the drip bag, inserted into the infusion pump (Figure 1B), and pulled through the fluid outlet hole of the cooler box to the outside (Part 1). From there, it was connected to the coiled line (Part 2), which went into the crate to the back of the rhinoceros and connected to the catheter line (Part 3).

At night, if temperatures dropped below 10°C, 0.3 L plastic bottles were filled with hot water and placed around the drip bags inside the cooler box to warm the iv fluids. Furthermore, the administration set outside of the cooler box, on top of the transport crate, was wrapped in bubble wrap to provide insulation.

This portable fluid administration system was developed and used in an approved research project aimed at studying the effects of fluid administration on stress and its pathophysiological consequences during long-distance translocations (University of Pretoria Animal Ethics #REC043-20).

3 | Results

We first trialed the iv fluid administration system during two translocations of seven white rhinoceroses (1 calf, 4 subadults, and 2 adults) over 13.5 h, which helped us to refine the administration system.

We then successfully administered iv fluids for 24 h, using the refined administration system, to a total of eight subadult ($n = 5$) and adult ($n = 3$) rhinoceroses that were placed in rhinoceros transport crates during a mock transport. For the first 4 h, fluid was administered at 2 mL/kg/h (2.5 L/h average) and then 1 mL/kg/h (1.25 L/h average) for the remaining 20 h. The pumps' batteries lasted for 24 h without recharging. The pumps' capacity to pump up to 4.5 L/h allowed fluids to be administered at 2 mL/kg/h in a 2250 kg rhinoceros, resulting in a flow rate of 75 mL/min in the fluid lines and catheter.

4 | Discussion

We successfully developed a simple, robust iv fluid administration system suitable for use in the field, which is capable of providing maintenance iv fluid rates in animals as large as adult white rhinoceroses.

We encountered several challenges with the infusion setup and refined various components over 2 years to fit the requirements of fluid administration during rhinoceros transport. Challenges included leakage of tubing and drip bags, which was solved by reinforcing all tubing connections and changing the material of

FIGURE 5 | (A and B) Ear splint placed on the inner surface of the pinna of the rhinoceros before bandaging (A) and the bandaged ear (B) to secure the ear splint and stabilize and protect the catheter and connecting dripline. The splint ensured that the ear of the rhinoceros was kept straight so that the catheter would not kink. [Color figure can be viewed at wileyonlinelibrary.com]

the drip bags from laminated low-density polyethylene/polyester sheeting to polypropylene sheets. The pump could not be set on a particular amount of fluid per hour, but only indicate the percentage of RPM at which the pump was running. Therefore, we had to first measure the fluid output at various speeds to calculate the pump settings for individual fluid needs.

Another commonly encountered issue in the testing phase was catheter kinking. The rhinoceroses leaned their heads against the side of the crates which pressed and bent their pinna, frequently leading to the catheter partially pulling out of the auricular vein and kinking. As a result, resistance and pressure built up in the administration lines, causing connection leaks. The problem was solved by using an "ear splint" to keep the pinna stable and straight, along with a rugged 12-gauge Intraflon 2 catheter, which was less prone to kinking. While the 12-gauge catheter would allow for a much higher flow rate than the actual rate required for the rhinoceroses (430 vs. 75 mL/min), the large lumen and sturdiness of the catheter ensured that even when the auricular vein and catheter were compressed, an adequate fluid flow rate could be maintained and the risk of lumen obstructions (e.g., blot clots) within the catheter was minimized. Elastic bandages around the ear and catheter further protected the catheter from moving, kinking, or getting damaged. The shorter Intraflon 2 catheter (9 cm) also proved favorable over a longer catheter (e.g., 20 cm over-the-wire catheters), as it resulted in less resistance, simplified catheter placement, and less risk of the catheter tip compressing at the base of the ear. Despite the measures mentioned above, occasional resistance to flow occurred, reducing the calculated fluid output, and required an adjustment of the pump speed to maintain the correct flow rate. Future pump models would benefit from a fluid output indicator and a remote alarm system giving alerts when resistance increases or air bubbles occur.

Overall, this system met the criteria for successful iv fluid administration in white rhinoceroses during transport, as it was compact and robust, capable of delivering high fluid volumes for 24 h, and it worked reliably whether the animals were standing or lying freely in the crates. However, the process of iv fluid administration in rhinoceroses is time intensive. In addition, during long-distance transports, the high number of drip bags required may be a limiting factor due to restricted

FIGURE 6 | (A and B) Infusion pump (a) along with one drip bag (b) and pieces of foam (c) for protection and positioning of the drip bags in the 60-L cooler box (A) and the cooler box strapped down on top of the rhinoceros crate (B). [Color figure can be viewed at wileyonlinelibrary.com]

storage space on vehicles. Therefore, this system will mostly be useful for long-distance transport of small groups of rhinoceroses. It may also be useful for injured or sick rhinoceroses requiring parenteral fluid therapy, and in other large wildlife species when commercially available infusion pumps cannot provide large fluid volumes required.

With growing evidence of the negative impacts of climate change on wildlife populations, it is likely that conservation translocations of large species will be increasingly needed (Seddon 2010; McLachlan, Hellmann, and Schwartz 2007) and that translocations may take place in hot weather, making successful fluid administration during transport an increasing necessity to ensure welfare.

Acknowledgments

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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