Subcutaneous Emphysema in a European Hedgehog (*Erinaceus europaeus*) – a case study

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Abstract: There are many case studies in the literature of cats, dogs and horses with subcutaneous emphysema. There is little written information on the treatment of subcutaneous emphysema in hedgehogs. This case study will set out the medical, nutritional and environmental concerns and solutions when a European Hedgehog (*Erinaceus europaeus*) with subcutaneous emphysema was presented to ZSL Wildlife Health Services (WHS), London Zoo. There is a small population of European Hedgehogs in Regent's Park, London which includes the grounds of London Zoo. Royal Parks monitor this population and ZSL Wildlife Health Services at London Zoo provide medical treatment where needed.

Keywords:European Hedgehog; *Erinaceus europaeus*; subcutaneous emphysema; balloon syndrome

Introduction

Hedgehog population status in the UK

The first official Red List for British Mammals was published recently and has received authorisation on behalf of the International Union for the Conservation of Nature (IUCN) at a regional level. This list has classed the European Hedgehog as being vulnerable in the UK (Mathews & Harrower, 2020). A taxon is 'Vulnerable' when the best available evidence indicates that it meets specific criteria (A to E), and it is therefore considered to be facing a high risk of extinction in the wild (IUCN, 2012).

The hedgehogs of Regent's Park, London

The European hedgehogs (*Erinaceus europaeus*) in The Regent's Park (including London Zoo's grounds) are the only breeding population remaining in Central London. Studies carried out in 2014 and 2015 clearly showed that the population was small, vulnerable, and isolated. Every year since 2014 Royal Parks have undertaken a twice-yearly overnight survey of hedgehogs in Regent's Park (Gurnell et al., 2017). These surveys assess numbers, sex, general age, distribution, and health status. Some are fitted with tracking devices for the week that the survey takes place. All are individually identified by numbered tags that are glued on the spines. ZSL London Zoo Wildlife Health Services provide veterinary support; any hedgehogs that are deemed to be injured or medically compromised are taken to the zoo's WHS department for assessment and care.

Subcutaneous emphysema

Subcutaneous emphysema (SQE) is the presence of air under the skin. It has been more commonly known as balloon syndrome in hedgehogs as it is found under the dorsal skin and can expand the skin to its full stretch to look like a balloon. This balloon is unique to hedgehogs as they have a large skin surface area to allow them to curl up as a defense mechanism.

There can be different causes of this condition such as a clostridial bacterial infection which can cause gas gangrene or clostridial crepitant cellulitis (Bryant et al., 2002). It can also be caused by a full thickness wound that allows air into the subcutaneous space but not back out (sucking wound) usually with the movement of the thorax or body. A third

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cause can be by a traumatic event such as when the thorax is struck. This can lead to lung trauma, as well as rupture of the intercostal muscles if the trauma happens while the glottis is shut, allowing air to enter under the skin from the chest without any external wounds. Occasionally the cause may be a fractured rib, which can be seen on radiographs (Pizzi, 2019). Independent of whichever traumatic event occurs, a connection is often created between the lungs and the area under the skin. This can be a one-way valve and only when the pressures are equalised does the air stop entering with each breath i.e. when the skin is at its full stretch.

Clinical case report

A European Hedgehog (Erinaceus europaeus) was found within the zoo at the end of July 2019 on a Saturday morning, in daylight, by a keeper and brought to WHS department for assessment. The hedgehog was assessed by a veterinary nurse (VN) under consultation with the veterinary surgeon (VS).

Figure 1. Severe subcutaneous emphysema in a young male European hedgehog (*Erinaceus europaeus*).

Initial assessment

The hedgehog had copious subcutaneous emphysema (see Figure 1). He was sexed as male and looked to be a juvenile born the previous spring. The hedgehog was estimated to be approximately two months old. The hedgehog could walk on all four legs but had collapsed. The hedgehog was wet from heavy rain that had been falling for at least six hours prior. His vitals were: rectal temperature 32 °C, heart rate 250 BPM, respiratory rate 52 RPM (see expected parameters below). There were no visible wounds present at that time.

> Hedgehog Expected Physiological Parameters (British Hedgehog Preservation Society)
>
> Rectal Temperature is 35 °C ± 1 °C.
>
> Heart Rate – 200–280bpm (Rates as low as 2–48 bpm are reported during hibernation).
>
> Respiratory Rate – 25–50 rpm

The hedgehog had mild to moderate hypothermia, and the respiratory rate was just above high normal. He was 5% dehydrated determined by pinching skin on his foot and examination of his eyes. Squeaks and harsh lung sounds were heard on auscultation. The hedgehog was weighed and was 282 g.

Conscious radiographs (see Figure 2) positioned in right lateral and dorsoventral were taken which showed clear lungs and no obvious fractures or damage to the thorax. These were sent to the VS for assessment.

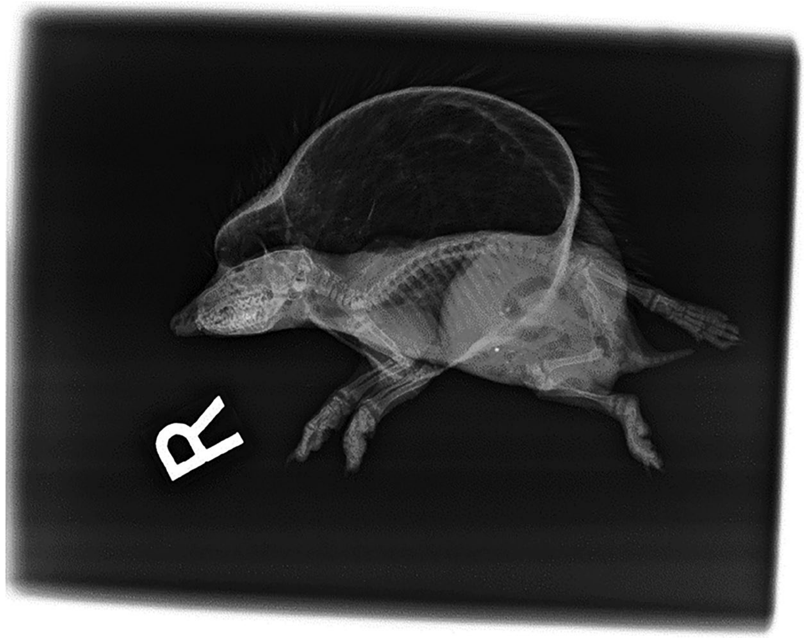

Figure 2. Right lateral conscious radiograph in a juvenile European hedgehog with severe subcutaneous emphysema.

Veterinary nursing care

The hedgehog was initially dried off and wrapped in a dry towel to reduce heat loss and by the end of the assessment his locomotion had improved.

An attempt was made to drain the emphysema with a 19 g 1” needle and the breathing became more laboured. The hedgehog seemed in pain when handling particularly over the thorax. Emphysema came back immediately. It was concluded that there must be a connection between the subcutaneous area and respiratory system.

It was decided not to give subcutaneous medications over the affected area in case they encountered the lung tissue. The VS prescribed meloxicam (Metacam, Boerhinger Ingelheim) at 0.1 mg/kg and a long acting amoxicillin (Amoxycare LA, Animalcare) at 15 mg/kg. These were injected intramuscularly into the hindleg. It was decided not to give subcutaneous fluids as they may have effectively drowned the hedgehog and because there was only 5% dehydration present. If the hedgehog did not eat or drink this would be reassessed. There were small number of fleas present and this was treated topically with selamectin and sarolaner (Stronghold Plus, Zoetis) at 0.4 ml/kg.

The hedgehog was put in an oxygen (O_2) cage and the oxygen concentrator was initially set at 10 L/min to fill the cage. The cage was in a room which housed no other animals, could be temperature controlled and was in a quiet part of the WHS department. This therefore provided the most ideal environment that was possible for a wild prey animal. The cage is approx. 339 L. It would therefore take 34 min to fill with oxygen-rich air at the oxygen concentrator's maximum flow rate of 10 L/min. The minute volume (MV) was calculated for the hedgehog. MV (L/min) = 0.01–0.02L/kg x rpm = 0.15–0.29 L/min. The flow rate should be doubled to ensure the oxygen was replenished and the CO_2 flushed out. In this case it was set at 2 L/min as the cage had such a large volume. An oxygen concentrator is beneficial in two ways; it provides oxygen at room temperature and if it is used over several days it is inexpensive and continuous.

The air conditioning in the room was set to 30 °C which is a high ambient temperature for a hedgehog whose ideal environmental temperature is between 19 °C and 21 °C (British Hedgehog Preservation Society). This was to try to increase his body temperature slowly without use of direct heat but by using passive rewarming that should help to increase body temperature in a mildly hypothermic hedgehog that is able to move by itself. Body temperature should be increased between 1.1 °C to 2.2 °C an hour (Quandt, 2018). Active warming should initially be directed toward warming the animal's core. Warm air such as from warm air blankets can be used to increase the body temperature. The use of direct heat including the use of heat pads can cause thermal injury to cold skin and can also cause 'rewarming shock'. Rewarming shock is when the direct heat causes the vessels of the extremities to dilate causing cold blood and the build-up of lactic acid to flow towards the core and cause a drop in core temperature and can also cause a drop in blood pressure (Quandt, 2018). Rapid rewarming can also cause these problems. Humidity in the O_2 cage needed to be considered. Humidity in London, UK is on average between 70% and 90% (Current results, 2020). A humidity of this percentage in a small cage can lead to condensation making breathing difficult and promote bacterial and fungal growth. Relative humidity between 40% and 55% is comfortable in an enclosed space and preferable in an oxygen cage (Sirois, 2017). There was a temperature and a humidity monitor in the cage, and this was checked regularly throughout the day to ensure that they remained within comfortable limits; this monitor could be observed without opening the cage door. Opening the cage door renders the O_2 therapy ineffective as it takes time to build up the O_2 levels to the required amount; opening the door therefore should be a restricted practice. ZSL Wildlife Health Services have an standard operating procedure (SOP) for oxygen therapy using the oxygen cage.

The hedgehog was offered a convalescence diet (Hills A/D) and water. The kcal requirements were worked out. KCal = 70 × (kg$^{0.75}$) = 70 × (0.28$^{0.75}$) = 27 kcal × 1.5 (growth factor) = 40 kcal = just under 1/4 tin A/D (170 kcal/156g can). The hedgehog was weighed daily to ensure there were adequate calories given. Although difficult to assess due to the balloon obscuring the pelvis, ribs, spine etc, body condition scoring (Varga et al., 2012) was carried out and it was 3/5. It was assumed the hedgehog had been eating prior and therefore did not need to have a stepped feeding programme. Radiographs showed some gas in the intestine but there was also some digesta seen. Wildlife Online (2020) states 'Hedgehog metabolism is adapted to the digestion of high protein invertebrate prey and unrestricted access to high-fat foods can result in hepatic steatosis (fatty liver disease)'. The A/D diet, which according to Hills literature is over 33% fat DW and 7.8% WW, would need to be changed to a more appropriate juvenile diet when he was stabilised. On Day six he was changed over to Royal Canin Kitten wet food. Although this still does not mimic the diet in the wild, it provides the nutrients in their ratio needed for a juvenile mammal. He was weighed daily in the morning to ensure that adequate calories were being provided.

The hedgehog slept for much of the first day, seemed comfortable and ate well but also did get up to walk around. Medications were continued throughout the weekend; the meloxicam was changed to an oral preparation at 0.1 mg/kg.

Surgical treatment and further nursing care

On Day three, the hedgehog had an anaesthetic procedure to assess any injuries and to deflate the balloon. The air can be removed by incising or aspirating through

Figure 3. Incision by a scalpel on the dorsum of a European hedgehog with severe subcutaneous emphysema.

Figure 4. A juvenile European hedgehog with subcutaneous emphysema before surgery.

the skin over the back (British Hedgehog Preservation Society, 2019). Anaesthesia was with isoflurane and oxygen via facemask. Two areas were surgically prepared and incisions through the skin (see Figure 3) with a sterile scalpel were made, one on each side of the dorsum. This caused the deflation of the balloon and we could see the real body size (see Figures 4 and 5). Two areas of exudating skin were found laterally along the body. These had not been present on initial assessment and were believed to have developed from grazing the skin when initially injured. They were swabbed for culture and then treated with a dilute chlorhexidine scrub and only one recurred throughout his stay. The cultures were negative for fungal growth but produced a light growth pure isolate Staphylococcus sp. (aurex-neg) which was believed to be commensal flora. The medications were repeated. He was returned to his O_2 cage where he was coughing intermittently. The deflation seemed to have made it more difficult to breath and caused an irritation. Without the pressure from the balloon and with the addition of openings made in the skin, these may have made the drawing in of air from the trachea alone difficult. The oxygen cage at this stage was beneficial.

Figure 5. A juvenile European hedgehog with subcutaneous emphysema after surgery.

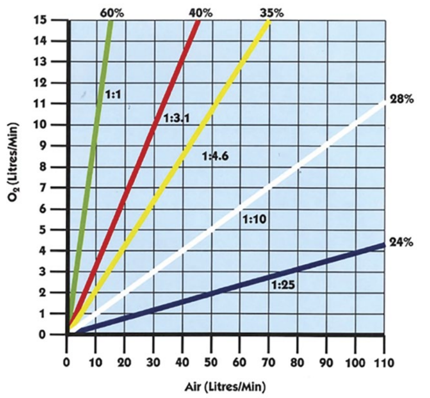

Figure 6. Venturi Chart (Pridie & Firth, 2011) to calculate the oxygen flow rate needed with each valve to obtain the correct minute volume.

On Day five the antibiotics were changed to cover a broader spectrum as the lungs and pleural spaces now were theoretically connected to the outside via the subcutaneous route. Amoxicillin clavulanate (Synulox, Zoetis) 12.5 mg/kg PO and marbofloxacin (Marbocyl, Vetoquinol) 3.6 mg/kg IM for seven days was prescribed. At this time, the hedgehog was also put on probiotics to prevent the negative effects of the antibiotics on his gut bacteria. A 1 mg/kg every 24 hr PO of bromhexine hydrochloride (Bisolvan, Boerhinger Ingelheim) was also added to aid the clearing of any bronchial secretions brought up by his coughing.

Oxygen therapy was continued, and a Venturi valve set was purchased to maintain an accurate percentage of oxygen rich air going into the cage. They work by drawing room air in through calibrated inlets and mixing with the oxygen from the concentrator or oxygen cylinder to produce specific percentage of oxygen rich air at a specific minute volume (see Figure 6). The hedgehog seemed to cope out of the oxygen cage so the oxygen percentage was started on the 35% oxygen valve and over the days was dropped down to 28% oxygen before being taken off oxygen altogether on day seven (air is 21% O_2 and the maximum O_2 with the venturi valves is 60%). Oxygen can be considered toxic if percentages are delivered greater than 60%. In human studies it was shown that 80% oxygen and above will wash out the nitrogen in the alveoli and can create a condition called absorption atelectasis (O'Brien, 2013). In another human paediatric study it was stated the patient is at risk for pulmonary oxygen toxicity if more than 50% oxygen is inhaled for longer than 48–72 hours (Sills, 2015). It may be assumed that the oxygen produced by the concentrator is 100% whereas most do not produce that concentration. The concentrator used in this case only produces 90% ± 3%. This would make some, but not a significant difference to the overall percentage delivered. At 90% oxygen from the concentrator as opposed to 100% there would be a calculated drop of 5% from 4.1 L/min O_2 to 3.9 L/min using the Venturi Chart.

It was decided to keep him in the WHS department for at least a further seven days to ensure the SQE did not refill and there were no complications. When the hedgehog was released the SQE had not returned in 15 days, supplemental oxygen had been ceased for 11 days and all medications ceased for seven days. The hedgehog was ID tagged with number tags glued to several of the spines by a member of the Royal Parks team and microchipped by the vet team so we would be able to identify him if he were ever captured again after release. The hedgehog was released to a nest box near to where the hedgehog was found. Some of the hedgehog's hay was transported with him to establish it as his nest box. It had rained recently and was due to rain lightly the day after release which would give him the best chance of finding food. The hedgehog was released at 9pm as it was getting dark.

A camera trap was placed which viewed the nest box and two days later the camera pictured him but not after that. Footage showed there was another, bigger hedgehog using the same area so our patient may have had to move to a new area. This is a normal occurrence for a juvenile hedgehog.

Discussion

Subcutaneous emphysema has many causes. As a result of the anatomy where there are continuous planes connecting soft tissues with the mediastinum and retroperitoneum, (Cudmore & Nath, 2012) it is often concomitant with a pneumomediastinum and/or a pneumothorax. In a study of 45 cats (Thomas & Syring, 2013) with pneumomediastinum, 30 had SQE. The causes of pneumomediastinum from the same study were, in order of prevalence, endotracheal intubation with intermittent positive pressure ventilation, trauma, tracheal foreign body and spontaneous pneumomediastinum (unknown cause). In dogs it has been caused by bite wounds and stick injuries. Diagnosis is by CT scan and/or radiography, although radiography is less reliable and will not show occult pneumomediastinum (Saber, 2020). Treatment of SQE depends on the cause; it can be resolved by medical, surgical or no treatment. It can often be a painful condition depending on severity with the separation of the tissues from the skin and therefore would need some pain relief particularly if there was trauma involved. If there was dyspnoea or tachypnoea present then oxygen therapy can be considered and if there is a wound, antibiotics would prevent infection. Some of the reasons for surgical intervention would be where medical treatment has proved unsuccessful and where there is an open wound present.

In this case there were no obvious full thickness skin wounds and therefore initially a medical approach was taken. There was quite a large degree of separation of the skin from the tissues and there was suspect painful trauma therefore pain relief was administered. Antibiotics were administered to cover potential infection caused by the trauma. Although no obvious initial dyspnoea was observed, there was the possibility of pneumothorax and/or a pneumomediastinum and therefore oxygen therapy was initiated. This proved beneficial when surgery was performed to reduce the SQE and subsequent dyspnoea occurred. Surgery was decided upon to relieve the large emphysema and to expedite the quick release back to the wild.

Conclusion

SQE is an unusual but not untreatable condition for veterinary practices and wildlife rehabilitation centers. The severity of the inciting cause and the length of time without treatment along with age and previous health status will dictate how well and how quickly hedgehogs will recover.

There is not much written about SQE in hedgehogs and as such information was gathered from various sources including our hedgehog and oxygen cage protocols which had drug doses, husbandry requirements and correct use of the oxygen cage.

The positive outcome for this hedgehog and the content of this article will hopefully encourage and assist in the future treatment and survival of hedgehogs with SQE in veterinary practice. European Hedgehogs in the UK are classed as a vulnerable population therefore appropriate veterinary care and rehabilitation may help to sustain this population.

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