Blood Reference Values: Welfare Markers in *Erinaceus europaeus*

Subjects: Biodiversity Conservation

Contributor: Sofia Rosa, Ana Cristina Silvestre-Ferreira, Felisbina Luisa Queiroga

Understanding the blood reference values in healthy western European hedgehogs (*Erinaceus europaeus*) is crucial, particularly given their expanding range into human habitats where they face contaminants and potential disease agents. As bioindicators of environmental pollution and carriers of zoonotic agents, hedgehogs play a vital role in One Health studies. Their health status serves as an indicator of the well-being of wildlife populations but also directly impacts broader wildlife conservation efforts and human health.

Keywords: Erinaceus europaeus ; western-European hedgehog ; blood reference values ; disease ; health

1. The Western-European Hedgehog (*Erinaceus europaeus*): Well-Being in Danger

The western-European hedgehog, *Erinaceus europaeus*, is a mammal species found in Europe, characterized by its adaptability to various environments and nocturnal insectivorous habits. It exhibits primitive characteristics in morphology and behaviour, such as solitary habits and reliance on acute senses for survival [1]. Hedgehogs prefer landscapes with shrubs and hedges, although they inhabit diverse habitats and exhibit dietary adaptability to anthropogenic pressures [2].

These animals hibernate during colder months, reproducing after hibernation with a polygamous mating system [1]. While they are considered of "least concern" according to the IUCN, their population faces threats from natural mortality during hibernation, predation from badgers and others, the occurrence of road traffic accidents and human-induced factors like habitat alteration and pollution [3].

Moreover, hedgehogs face additional challenges due to their role as hosts for a wide variety of parasites and pathogens, which exacerbate their existing complexities and contribute to heightened mortality rates and reduced reproductive success. These include ectoparasites such as fleas (*Siphonaptera)*, commonly found on the front legs, neck, head, chest, and belly, as well as mites and ticks (Acari), which typically infest various parts of the body including furred sections, around the eyes, ears, and the anal region. In addition, hedgehogs harbour endoparasites like nematodes such as *Crenosoma striatum*, the predominant lung parasite, as well as trematodes, cestodes (although less common), and acanthocephalans. They also serve as hosts for bacteria, viruses, fungi, and protozoa. Furthermore, some of these parasites are zoonotic, meaning they can be transmitted to humans, highlighting the importance of understanding and managing hedgehog health in both wildlife and public health contexts [1][4][5][6].

Additionally, the Western european hedgehog's intricate ecological habits and multifaceted interactions with various animals and humans make it a pivotal sentinel in a comprehensive One Health approach, providing invaluable insights into the ecology of emerging viruses. Their presence as bioindicators aids in discerning environmental contamination, while also highlighting their role as potential carriers of tickborne zoonotic agents, posing threats upon both direct and indirect physical contact. Moreover, systematic reviews have identified *E. europaeus* as carriers of zoonotic pathogens, with urban areas posing a higher risk of interaction between hedgehogs and humans or companion animals, thus underscoring the importance of balanced coexistence and responsible interactions. This urban interaction may have both positive aspects, such as aiding in pest control, and negative consequences, including the potential transmission of diseases and the risk of injuries to hedgehogs and companion animals. In essence, the ecological role of hedgehogs extends beyond their charming appearance, making them crucial indicators and potential carriers of infectious agents in our shared environment [7][8].

2. Blood Reference Values

Defining reference intervals (RI) for hematological and serum biochemistry is crucial in assessing the health of wild animal populations [9]. However, research on *E. europaeus* remains limited, with only three studies dedicated to determining hematological parameter reference intervals and two studies exploring biochemical analysis [10][11][12]. These investigations have focused on healthy animals residing in recovery centers, allowing for ample sample collection. Nevertheless, it's imperative to acknowledge that findings from these studies may not fully represent observations in their natural habitats.

Tables 1 and 2 present a detailed summary of published RI values for crucial blood parameters, contributing to a deeper comprehension of the hematological and serum biochemical profiles observed in healthy western-European hedgehogs [10][11][12].

In a study conducted in England and published in 2002 by Lewis et al. [10], 50 hedgehogs were examined. This study is the first to provide values for hemograms of healthy E. europaeus in captivity but lacks information on biochemical and protein electrophoresis parameters (**Table 1**).

Rossi and colleagues [12] conducted a study published in 2014, investigating 50 hedgehogs from three rehabilitation centers in Northern Italy. This study explores the impact of overwintering on hedgehog hematologic (**Table 1**) and biochemical variables, describing, for the first time, a set of routine serum biochemical parameters for this species (**Table 2**).

Another study, carried out in northern Portugal [11] by Rosa and colleagues and published in 2023, analyzed data from 37 healthy hedgehogs kept in captivity in a rehabilitation centre in Northern Portugal. This study encompasses a broader scope, including hematology, biochemistry, and protein electrophoresis reference intervals, thus offering unique data not covered in previous studies (parameters such as RDW, MPV, and PCT for hematology; AST, total bilirubin, sodium, potassium, and chloride for biochemistry, and the electrophoretic profile) (see **Tables 1** and **2**).

Table 1. RI for hematological parameters in the species *Erinaceus europaeus* obtained from published studies [10][11][12].

Parameters	RI	LRL 90% CI	URL 90% CI
	6.2–10.0 [a]		
RBC (M/μL)	4.1–10.2 [b]	3.5–4.8 [b]	9.5–10.9 [b]
	6.0–10.4 × 10^6 [c]	5.4–6.5 × 10^6 [c]	9.8–10.9 [c]
	25–46 [a]		
%HCT	19.4–41.1 [b]	16.7–21.9 [b]	38.6–43.6 [b]
	25–41 [c]	0.23–0.27 [c]	0.39–0.42 [c]
	96–166 [a]		
HGB (g/L)	6.6–13.8 [b]	5.7–7.5 [b]	13.0–14.6 [b]
	8.37–14.93 [c]	7.61–9.23 [c]	141.8–156.3 [c]

	6.2–10.0 [a]		
MCV (fL)	34.3–55.8 [b]	33.7–35.2 [b]	50.5–59.7 [b]
	0.0345–0.0453 [c]	0.0335–0.0358 [c]	44.0–46.6 [c]
	13.7–17.5 [a]		
MCH (pg)	12.0–19.1 [b]	11.8–12.3 [b]	17.4–20.9 [b]
	12.7–15.8 [c]	12.4–13.1 [c]	15.4–16.1 [c]
	34.8–42.2 [a]		
MCHC (g/dL)	30.9–36.4 [c]	30.2–31.6 [c]	35.8–37.0 [c]
	31.29–40.0 [c]	30.20–32.38 [c]	385.8–412.0 [c]
%RDW	22.5–35.6 [b]	21.0–24.1 [b]	34.0–37.1 [b]
%RETIC	* [b]	* [b]	* [b]
	0.2–5.0 [c]	0.0–0.3 [c]	3.8–6.3 [c]
RETIC (K/μL)	11.5–705.7 [b]	2.6–29.0 [b]	549.2–892.2 [b]
	10.7–423.8 [c]	3.2–23.4 [c]	318.4–539.6 [c]
%nRBCs	0.1–6.5 [c]	0.0–0.3 [c]	4.4–8.6 [c]
nRBCs (10^6/L)	0.01–0.63 [c]	0.00–0.03 [c]	0.40–1.11 [c]
	1.7–11.4 × 10^9 [a]		
WBC (K/μL)	2.5–15.7 [b]	1.0–4.0 [b]	14.2–17.3 [b]
	2.2–13.9 × 10^9 [c]	1.1–3.5 × 10^9 [c]	12.3–15.7 × 10^9 [c]
%NEU	23.8–81.6 [b]	16.1–30.6 [b]	74.4–88.6 [b]
	16.2–53.1 [c]	11.6–20.6 [c]	47.6–58.0 [c]
%LYM	14.6–59.9 [b]	9.6–20.0 [b]	54.5–65.1 [b]
	31.2–69.6 [c]	26.7–36.4 [c]	65.0–75.0 [c]

%MONO	3.5–24.4 [b]	3.1–4.2 [b]	14.3–44.9 [b]
	0.1–7.5 [c]	0.0–7.6 [c]	5.9–9.1 [c]
%EOS	2.4–26.9 [b]	2.0–3.0 [b]	14.7–75.2 [b]
	0.0–12.0 [c]	0.0–0.0 [c]	8.5–16.3 [c]
%BASO	* [b]	* [b]	* [b]
	0.4–8.7 [c]	0.2–0.9 [c]	7.2–10.6 [c]
NEU (K/μL)	0.42–6.38 [a]		
	0.8–10 [b]	0.2–1.5 [b]	8.2–11.5 [b]
	0.9–5.9 × 10^9 [c]	0.8–1.2 × 10^9 [c]	4.8–7.2 [c]
LYM (K/μL)	0.85–7.77 [a]		
	0.4–6.3 [b]	0.0–0.9 [b]	5.5–6.8 [b]
	0.6–7.2 × 10^9 [c]	0.0–1.4 × 10^9 [c]	6.2–8.2 [c]
MONO (K/μL)	0.00–0.48 [a]		
	0.2–1.4 [b]	0.2–0.3 [b]	1.1–1.6 [b]
	0.0–0.6 × 10^9 [c]	0.0–0.0 × 10^9 [c]	0.5–0.7 [c]
EOS (K/μL)	0.00–1.35 [a]		
	* [b]	* [b]	* [b]
	0.0–2.2 × 10^9 [c]	0.0–0.9 × 10^9 [c]	1.6–3.0 [c]
BASO (K/μL)	0.00–0.28 [a]		
	* [b]	* [b]	* [b]
	0.0–0.7 × 10^9 [c]	0.0–0.1 × 10^9 [c]	0.6–0.8 [c]
PLT (K/μL)	29–338 [a]		
	31.3–567.1 [b]	3.2–71.5 [b]	472.2–660.3 [b]
	48.9–169.4 × 10^9 [c]	12.4–86.1 × 10^9 [c]	403.1–523.7 [c]

MPV (fL)	13.2–17.9 [b]	12.7–13.9 [b]	17.4–18.4 [b]
%PCT	0.1–0.8 [b]	0.0–0.2 [b]	0.7–0.9 [b]

a—study of Lewis et al., 2002 [10]; b—study of Rosa et al., 2023 [11]; c—study of Rossi et al., 2014 [12]; RI, Reference Interval; LRL, Lower Reference Limit; URL, Upper Reference Limit; CI, Confidence Interval. * Non-Computable. RBC, Red Blood Cells; HCT, Hematocrit; HGB, Hemoglobin; MCV, Mean Cell Volume; MCH, Mean Corpuscular Hemoglobin; MCHC, Mean Corpuscular Hemoglobin Concentration; RDW, Red Blood Cell Distribution Width; %RETIC, Reticulocyte percent; RETIC, Reticulocyte count; nRBCs, Nucleated Red Blood Cells count; %nRBCs, Nucleated Red Blood Cells percent; WBC, White Blood Cell; %NEU, Neutrophil percent; %LYM, Lymphocyte percent; %MONO, Monocyte percent; %EOS, Eosinophil percent; %BASO, Basophil percent; NEU, Neutrophil count; LYM, Lymphocyte count; MONO, Monocyte count; EOS, Eosinophil count; BASO, Basophil count; PLT, Platelet count; MPV, Mean Platelet Volume; PCT, Plateletcrit.

Table 2. RI for biochemical parameters in the species *Erinaceus europaeus*, obtained from published studies [10][11][12].

Parameters	RI	LRL 90% CI	URL 90% CI
GLUCOSE (mg/dL)	57.0–160.0 [a]	43.0–72.2[a]	144.0–175.3[a]
	77.4–135.0 [b]	126.0–84.6[b]	126.0–140.4[b]
TOTAL PROTEINS (g/dL)	3.4–8.3 [a]	2.8–3.9 [a]	7.6–8.9 [a]
	4.44–8.83 [b]	3.93–5.29 [b]	8.15–9.59 [b]
ALBUMIN (g/dL)	2.1–4.5 [a]	1.8–2.4 [a]	4.2–4.8 [a]
	2.73–4.17 [b]	2.51–2.94 [b]	8.15–9.59 [b]
ALT (U/L)	* [a]	* [a]	* [a]
	43.3–194.3 [b]	39.4–49.5 [b]	153.9–247.0 [b]
ALP (U/L)	19.2–217.8 [a]	17.8–22.7 [a]	166.3–281.4 [a]
	68.3–255.7 [b]	60.6–82.2 [b]	215.8–292.6 [b]
CREATININE (mg/dL)	0.1–0.9 [a]	0.1–0.1 [a]	0.7–1.0 [a]
	0.23–1.98 [b]	0.19–0.29 [b]	1.33–3.01 [b]
UREA (mg/dL)	* [a]	* [a]	*[a]
	142.2–372.6 [b]	113.4–180 [b]	18.8–22.7[b]
PHOSPHORUS (mg/dL)	2.7–12.7 [a]	1.6–3.9 [a]	11.4–14.0 [a]
	27.0–63.0 [b]	25.2–28.8[b]	54.0–73.8 [b]

CALCIUM (mg/dL)	5.6–11.5 [a] 23.4–57.6 [b]	1.4–7.4 [a] 14.4–30.6 [b]	11.0–11.7 [a] 52.2–59.4[b]
CHOLESTEROL (mg/dL)	* [a] 36.0–95.4 [b]	* [a] 28.8–43.2 [b]	* [a] 86.4–102.6 [b]
TRIGLYCERIDES (mg/dL)	22.9–88.5 [a] 2.16–13.5 [b]	10.6–35.7 [a] 1.62–3.06 [b]	75.1–100.9 [a] 11.16–16.38 [b]
GAMMA-GT (U/L)	1.8–151.8 [a] 5.2–47.5 [b]	* [a] 4.1–6.9 [b]	* [a] 38.0–64.2 [b]
GLOBULINS (g/dL)	0.4–4.7 [a] 1.71–4.83 [b]	0.1–0.9 [a] 1.33–2.17 [b]	3.6–5.9 [a] 4.32–5.37 [b]
AST (U/L)	10.8–38.7 [a]	9.6–13.4 [a]	27.0–53.0 [a]
BILIRUBIN (mg/dL)	* [a]	* [a]	* [a]
SODIUM (mmol/L)	129.8–153.1 [a]	124.1–135.1 [a]	150.3–155.6 [a]
POTASSIUM (mmol/L)	2.5–5.4 [a]	2.0–2.9 [a]	4.9–5.9 [a]
CHLORIDE (mmol/L)	100.3–120.1 [a]	97.2–103.6 [a]	117.0–123.2 [a]
Protein electrophoresis [a]			
Albumin (g/dL)	1.7–3.5	1.4–2.1	3.1–3.8
α1-Globulin (g/dL)	0.3–0.9	0.2–0.4	0.8–1.1
α2-Globulin (g/dL)	0.2–0.9	0.1–0.4	0.8–1.0
β-Globulin (g/dL)	0.6–3.4	0.5–0.8	1.8–8.9
γ-Globulin (g/dL)	0.0–0.1	0.0–0.0	0.4–2.5

a—study of Rosa et al., 2023 [11]; b—study of Rossi et al., 2014 [12]; RI, Reference Interval; LRL, Lower Reference Limit; URL, Upper Reference Limit; CI, Confidence Interval. * Non-computable. ALT, Alanine Aminotransferase; ALP, Alkaline Phosphatase; AST, Aspartate Aminotransferase.

An important consideration is that the currently available data are exclusively derived from hedgehogs housed in captivity. This emphasizes the need for caution when applying these findings to wild populations. Stressors experienced in captivity and during handling must be considered, as they could influence results and subsequently affect reference intervals [13]. Additionally, slight variations observed among studies conducted in different European countries underscore the necessity for more extensive research. These subtle differences highlight the importance of tailoring reference interval determinations to suit the specific conservation and rehabilitation practices in diverse regions. Integrating these insights enables to achieve a more comprehensive understanding of E. europaeus, thereby making significant contributions to species conservation [14]. Moreover, disparities in methodologies and laboratory practices may introduce variations that could potentially impact results [15].

3. Conclusions

Blood reference values play a critical role in identifying health issues among *Erinaceus europaeus*, aiding in species conservation efforts by providing valuable insights into the overall health and well-being of hedgehog populations. Additionally, these reference values facilitate early disease detection, allowing for prompt intervention and management strategies to mitigate potential threats to hedgehog populations and their ecosystems. Further research is essential to understand seasonal variations and age-related changes in hematological and biochemical values. Integration of genomic and proteomic data, along with investigating environmental stressors, can provide a comprehensive understanding of hedgehog health. Considering factors like location and sex during blood draws is crucial, especially before administering treatments in rescue centers. Establishing blood reference values for wild hedgehogs is challenging but necessary for enhancing understanding of their physiology and ecological resilience. Combining different types of data is important for understanding threats to both hedgehogs and humans, in line with the One Health approach.

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