CASE STUDIES

Characterization of bone marrow aspirate reports in dogs and cats: A retrospective study

Caracterización de informes de aspirado de médula ósea en perros y gatos: un estudio retrospectivo

Caracterização de laudos de aspirados de medula óssea em cães e gatos: estudo retrospectivo

Ingrid J Roldán-Carvajal[1*]; David Alzate-Velásquez[2]; Julián D Muñoz-Duque[3]; Andrés F Mesa-Oquendo[4]; Jorge E Salazar-Flórez[5]; Patricia E Jaramillo-Arbeláez[1]

[1] *Grupo de Investigación HEMO, Escuela de Microbiología, Universidad de Antioquia. Medellín, Colombia.*
[2] *Clínica Veterinaria Caninos y Felinos. Medellín, Colombia.*
[3] *Grupo de Investigación en Patobiología QUIRÓN, Facultad de Ciencias Agrarias, Universidad de Antioquia. Medellín, Colombia.*
[4] *Universidad CES, Medellín, Colombia.*
[5] *Fundación Universitaria San Martín, Sede Sabaneta, Colombia*.

Received: August 16, 2024. Accepted: November 8, 2024

***Corresponding author:** Calle 67 No. 53-108, Bloque 5, Medellín, Colombia. Email: ingrid.roldan@udea.edu.co

eISSN: 2256-2958 **Rev Colomb Cienc Pecu**
https://doi.org/10.17533/udea.rccp.v38n2a9

To cite this article:

Roldán-Carvajal IJ, Alzate-Velásquez D, Muñoz-Duque JD, Mesa-Oquendo AF, Salazar-Flórez JE, Jaramillo-Arbeláez PE. Characterization of bone marrow aspirate reports in dogs and cats: A retrospective study. Rev Colomb Cienc Pecu. Year, Vol, number, and pages pending. DOI: https://doi.org/10.17533/udea.rccp.v38n2a9

Abstract

Background: Bone Marrow Aspirate (BMA) allows the study, staging, and monitoring of multiple conditions with bone marrow involvement. The BMA report is a crucial component of the post-analytical stage and significantly influences the veterinarian's understanding and decision-making process. **Objective:** To describe the zoographic, clinical, and quality characteristics of BMA reports, as well as the frequency of diagnoses and associated factors in dogs and cats treated at veterinary centers in Colombia from 2012 to 2023. **Methods:** This was a cross-sectional descriptive study. Data on zoographic and clinical variables were extracted from BMA reports and consultations; the frequency of diagnoses and associated factors were determined. Adherence to reporting quality was evaluated using established guidelines for BMA in dogs, cats, and humans. **Results:** A total of 135 BMA reports were reviewed from eight veterinary institutions: 116 for dogs and 19 for cats, with a mean age of 5.22 ± 3 years; 53% were males. The most common indication for BMA was anemia, alone or with other abnormalities. The least adhered-to reporting elements were puncture site (91.9%), relevant clinical data (85.2%), and morphological evaluation by cell line (52.6%). Additionally, 27.4% of the reports were excluded due to poor sample quality. The most frequent diagnosis in dogs was hypoplasia (36.1%), while in cats, it was neoplasia (40.0%). Erythroid hyperplasia and neoplasms were more prevalent in males, whereas granulocytic hypoplasia was more common in females. **Conclusions:** BMA as a diagnostic tool in dogs and cats in Colombia is rare. A significant proportion of samples did not meet quality criteria, and there was low adherence to reporting guidelines.

Keywords: *bone marrow; bone marrow aspirate; cat diseases; dog diseases; hematology; hyperplasia; neoplasms; pets.*

Resumen

Antecedentes: El aspirado de médula ósea permite el estudio, estadificación y seguimiento de múltiples entidades con compromiso medular; el informe es un componente esencial de la etapa

posanalítica y los ítems establecidos por cada institución influyen significativamente en la comprensión y toma de decisiones por parte del médico tratante**. Objetivo:** Describir características zoográficas, clínicas y de calidad, así como la frecuencia de diagnósticos y sus factores asociados en informes de aspirado de médula ósea de caninos y felinos atendidos en centros veterinarios de Colombia durante el período 2012-2023. **Métodos:** Estudio descriptivo transversal. A partir de los informes de aspirado de médula ósea e interconsultas, se extrajeron variables zoográficas, clínicas y se determinó la frecuencia de diagnósticos y factores asociados a estos. Se evaluó la adherencia al reporte de variables de calidad contrastando con directrices para el reporte de aspirados de médula ósea en caninos, felinos y humanos. **Resultados:** A partir de 8 instituciones veterinarias, se obtuvieron 135 informes de aspirado de médula ósea, 116 caninos y 19 felinos, con una edad promedio de 5.22 ± 3 años, el 53% fueron machos; la indicación más frecuente fue anemia persistente sola o acompañada de otra alteración. Los ítems con menor adherencia en el reporte de resultados fueron sitio de punción (91.9%), datos clínicos relevantes (85.2%) y valoración morfológica por línea (52.6%). El 27.4% de los informes fue excluido por causas asociadas a la calidad de la muestra. El diagnóstico más común en caninos fue hipoplasia (36.1%) y en felinos neoplasia (40.0%); la hiperplasia eritroide y las neoplasias fueron más comunes en machos, en tanto que la hipoplasia granulocítica fue más frecuente en hembras. **Conclusiones:** El estudio de médula ósea como herramienta diagnostica en caninos y felinos atendidos en Colombia es poco frecuente. Se encontró un porcentaje significativo de muestras que no cumplían con criterios de calidad y baja adherencia a las guías para el reporte de resultados.

Palabras clave: *aspirados de médula ósea; enfermedades de los gatos; enfermedades de los perros; hematología; hiperplasia; mascotas; médula ósea; neoplasias.*

Resumo

Antecedentes: A aspiração da medula óssea permite o estudo, estadiamento e monitorização de múltiplas entidades com envolvimento medular; O laudo é componente essencial da etapa posanalítica e os itens estabelecidos por cada instituição influenciam significativamente o entendimento e a tomada de decisão do médico assistente. **Objetivo:** Descrever as características zoográficas, clínicas e de qualidade, bem como a frequência dos diagnósticos e seus fatores associados nos relatos de aspirados de medula óssea de cães e gatos atendidos em centros veterinários na Colômbia durante o período 2012-2023. **Métodos:** Estudo descritivo transversal. Dos laudos de aspirados de medula óssea e das interconsultas, foram extraídas

variáveis zoográficas e clínicas e determinadas a frequência dos diagnósticos e os fatores associados a eles. A adesão às variáveis de qualidade do relato foi avaliada por meio de diretrizes contrastantes para o relato de aspirados de medula óssea em cães, gatos e humanos. **Resultados:** De 8 instituições veterinárias foram obtidos 135 laudos de aspirados de medula óssea, 116 cães e 19 gatos, com idade média de 5,22 ± 3 anos, 53% eram do sexo masculino; A indicação mais frequente foi anemia persistente isolada ou acompanhada de outra alteração. Os itens com menor adesão na notificação dos resultados foram locais da punção (91,9%), dados clínicos relevantes (85,2%) e avaliação morfológica por linha (52,6%). 27,4% dos laudos foram excluídos por motivos associados à qualidade da amostra. O diagnóstico mais comum em cães foi hipoplasia (36,1%) e em gatos neoplasia (40,0%); A hiperplasia e a neoplasia eritróide foram mais comuns nos homens, enquanto a hipoplasia granulocítica foi mais comum nas mulheres. **Conclusões:** O estudo da medula óssea como ferramenta diagnóstica em cães e gatos tratados na Colômbia é raro. Foi encontrada uma percentagem significativa de amostras que não atendiam aos critérios de qualidade e baixa adesão às diretrizes para reporte de resultados.

Palavras-chave: *animais de estimação; aspirados de medula óssea; doenças do cão, doenças do gato; hematologia; hiperplasia; medula óssea; neoplasias.*

Introduction

Bone Marrow Aspirate (BMA) is an essential tool for studying, staging, and monitoring various conditions involving the bone marrow (Javinsky, 2012; Stacy and Harvey, 2017). This technique offers accurate diagnoses and is relatively safe, with minimal risks and few complications (Woods *et al.*, 2021). The effective use of BMA in routine veterinary practice requires proper sample collection, precise smear interpretation, and comprehensive reporting that provides clear diagnostic information (Messick, 2023).

The BMA report is a crucial component of the post-analytical stage and significantly influences the veterinarian's understanding and decision-making process (Hawkins, 2012; Sciacovelli *et al.,* 2016*).* A thorough report must include all elements for sample traceability, patient identification, correlation with complete blood count, and clinical signs or prior studies. It should also compare findings with reference values and, where appropriate, suggest further tests such as immunophenotyping, cytochemistry, cytogenetics, and molecular biology. These

comprehensive reports help veterinarians make differential diagnoses and better understand the findings (Stacy and Harvey, 2017).

Advancements in human and veterinary hematology have prompted the development of guidelines aimed at standardizing processes from test requests to result reporting (Riley *et al.*, 2021; Ritt, 2022). In veterinary medicine, these guidelines frequently draw from human models, leveraging physiological similarities across species like dogs, cats, and humans (Comazzi *et al.*, 2017; Rütgen *et al.*, 2022).

In Colombia, there is a limited availability of publications on this topic, which has led to the oversight of important aspects regarding the use of BMA in the dog and cat populations, which numbered over eleven million in 2022 (Ministerio de Salud y Protección Social, 2022).

The aim of the present study was to describe the zoographic, clinical, and quality characteristics of BMA reports, as well as the frequency of diagnoses and associated factors in dogs and cats treated in veterinary centers in Colombia from 2012 to 2023.

Materials and methods

Ethical considerations

This study was approved by the Animal Experimentation Ethics Committee of the University of Antioquia (Act 146 of 2022).

Study design

A descriptive cross-sectional study was conducted using convenience sampling of veterinary medical centers and laboratories from various municipalities in Colombia. The study focused on collecting BMA reports for dogs and cats from January 2012 to October 2023.

Description of Reports

The zoographic, clinical, and quality characteristics of the BMA reports were described using univariate statistical analysis. Qualitative variables were assessed through relative and absolute frequencies, while measures of central tendency and dispersion were applied to quantitative variables.

Four age groups were defined based on the American Animal Hospital Association guidelines. For cats: kitten (0-1-year-old), young adult (1-6-year-old), mature adult (7-10-year-old), and senior (>10-year-old). For dogs: puppy (0-1-year-old), adult (1-6-year-old), senior (7-11-year-old), and geriatric (>12-year-old) (Creevy *et al*., 2019). Dog breeds were grouped into small, medium, and large categories, as described by Posada *et al*. (2014).

Quality characteristics of reports

The quality characteristics of the reports were defined by compiling guidelines from the International Council for Standardization in Hematology (Lee *et al*., 2008), the Royal College of Pathologists of Australasia (2014), and veterinary literature encompassing criteria for evaluating and reporting BMA in dogs and cats (Abella-Bourgès *et al*., 2005; Cowell and Valenciano, 2023; Grindem *et al*., 2002; Mylonakis and Hatzis, 2014; Raskin and Messick, 2012; Stacy and Harvey, 2017).

To ensure adherence to these criteria in the institution's issued report, it was determined that the data must be included within the report itself, regardless of any additional information provided in clinical history by the clinician requesting the bone marrow study. The variables were categorized into two groups: basic and analytical.

Basic variables include essential information that should be present in the report regardless of the bone marrow material. These include patient identification, details of the requesting veterinarian detail, a summary of the patient's clinical history, specifics about the bone marrow puncture, any observed presence of bone marrow particles or spicules, and a concluding summary.

Analytical variables include aspects directly associated with the analysis of the obtained bone marrow material. These variables include assessments of cellularity, differential counts, morphological evaluations, and cellular indices.

Frequency of diagnoses

Reports were excluded if they lacked essential data for interpretation or if the sample quality was compromised due to factors such as the absence of particles, hemodilution, mechanical damage, or poor preservation. In this context, a diagnosis was construed as a judgment or outcome derived from the comprehensive analysis of the sample's analysis, as documented in

each report by the professional responsible for the interpretation. This encompassed consideration of both neoplastic and non-neoplastic conditions, as well as instances where no abnormalities were detected, for estimating both relative and absolute frequencies.

Factors associated with diagnoses

Fisher's exact test was applied to compare the zoographic and clinical characteristics versus diagnoses in BMA of the study population, using a significance level of $p < 0.05$. The analyses were conducted using Jamovi® software version 2.3.

Results

A total of 139 veterinary centers across nineteen nationwide departments (25 municipalities) were contacted. Of these, 32% (45/139) offered BMA collection, reading, or both. However, half of these outsourced the service. Out of the remaining 22 institutions, eight agreed to participate. Most of these were pathology laboratories that received samples from 46 veterinary centers in capital municipalities of seven departments (Table 1).

Table 1. Distribution of BMA reports from dogs and cats by department in Colombia (2012 and 2023).

Department	Number of reports (%)
Antioquia	76 (56.3%)
Cundinamarca	1 (0.7%)
Valle del Cauca	16 (11.8%)
Atlántico	7 (5.1%)
Tolima	3 (2.2%)
Casanare	1 (0.7%)
Meta	13 (9.6%)
Missing	18 (13.3%)
Total	**135 (100%)**

A total of 135 BMA reports were obtained; 73.3% of these were reported between 2018 and 2023. There were 116 dogs and 19 cats, with an average age of 5.2 ± 3-year-old (dogs 5.5 ± 3.2, median 6; cats: 3.1 ± 3.0, median 2), of which 53.3% were male.

192 **Table 2.** Hematological and clinical abnormalities reported in dogs and cats' consultations.

Abnormalities (n = 83)	n	%
Hematological (n = 75)		
Pancytopenia	13	17.3
Anemia and thrombocytopenia	13	17.3
Thrombocytopenia	11	14.7
Anemia	8	10.7
Anemia and leukocytosis	7	9.3
Anemia, thrombocytopenia, and leukocytosis	5	6.7
Leukopenia	5	6.7
Leukocytosis	5	6.7
Thrombocytopenia and leukopenia	4	5.3
Anemia and thrombocytosis	2	2.7
Anemia, thrombocytosis, and leukopenia	1	1.3
Thrombocytopenia and leukocytosis	1	1.3
History of infectious agents (n = 17)		
Dogs	*14*	
Ehrlichia spp.	3	17.6
Anaplasma spp.	3	17.6
Ehrlichia spp. and *Anaplasma spp.*	2	11.8
Babesia spp.	1	5.9
Hepatozoon spp.	1	5.9
Mycoplasma spp.	1	5.9
Missing	3	17.6
Cats	*3*	
Mycoplasma spp.	2	11.8
Bartonella spp.	1	5.9
Signs* (n = 41)		
Fever	11	26.8
Constitutional syndrome	21	51.2
Lymphadenopathy	5	12.2
Organomegaly	12	29.2

* One patient may be classified into multiple categories concurrently.

193 Among the patients with consultations (n = 83/135; 61.4%), 75/83 (90%) presented
194 hematological alteration, 17/83 (20%) had a history of hemotropic agent infections and 41/83

(49%) reported clinical signs (Table 2). To a lesser extent, musculoskeletal abnormalities, respiratory signs, ascites, and petechiae were reported; blast cells were reported in three blood smears, and one cat was assessed positive for feline leukemia virus.

The aspirate samples were mostly taken from live patients 130/135 (96.3%), and the sample collection site was reported in only 36/135 (26.6%) cases. The sites included the sternum (n=1), femur (n=4), humerus (n=27), ilium (n=2), and tibia (n=2).

A total of 39 dog breeds were identified. The breeds with three or more individuals included Beagle, Golden Retriever, French Poodle, Labrador, German Shepherd, Shih Tzu, Springer Spaniel, Yorkshire Terrier, Schnauzer, Pinscher, Pitbull, and mixed breeds. In cats, nine breeds were identified: Bombay, British Shorthair, Domestic Shorthair, European Shorthair, Balinese, Russian Blue, Exotic, and Persian. However, 8/19 (42%) were mixed breeds. The distribution of dog breeds by size was small 22/116 (19%), medium 69/116 (59%), and large 24/116 (21%). Additionally, adults of both species were the most common age group (Table 3).

Table 3. Frequency of patients by species and age group (2012 and 2023).

Group		**n**	**%**
Dogs (n = 116)			
Puppy	(0 – 1-year-old)	8	6.9
Adult	(1 – 6-year-old)	59	50.8
Senior	(7 – 11-year-old)	38	32.7
Geriatric	(>12-year-old)	4	3.4
Missing		7	6.0
Cats (n = 19)			
Kitten/puppy	(0 – 1-year-old)	4	21.0
Young adult	(1 – 6-year-old)	12	63.1
Mature adult	(7 – 10-year-old)	2	10.5
Senior	(>10-year-old)	1	5.2

Quality characteristics of reports

The variables detailed in Tables 4 and 5 were analyzed to evaluate the quality of the reports. Among the fundamental elements comprising the header of a BMA report, two reports lacked data regarding the requesting physician or institution. However, all reports adequately identified the institution providing the service, including internal coding, specified sample type, and provided dates of receipt or result issuance, as well as the owner's name and the patient's

species. Notably, some reports omitted to record the name, age, sex, and breed of certain patients (Table 4).

Additionally, only 11/135 (8.1%) of the reports specified the puncture site for the aspirate. Relevant clinical data were missing in 115/135 (85.2%) of cases. Furthermore, the presence or absence of particles was not reported in 36/135 (26.7%) of cases, and 7/135 (5.2%) of reports lacked a conclusion (Table 4).

Table 4. Quality characteristics of dogs and cats BMA reports: basic variables.

Variable	Reported n = 135	
	Yes n (%)	**No n (%)**
Patient's name	133 (98.5)	2 (1.4)
Age	126 (93.3)	9 (6.7)
Sex	133 (98.5)	2 (1.5)
Breed	134 (99.3)	1 (0.7)
Requester information	133 (98.5)	2 (1.5)
Puncture site	11 (8.1)	124 (91.9)
Relevant clinical data	20 (14.8)	115 (85.2)
Presence of marrow particles	99 (73.3)	36 (26.7)
Conclusion or interpretation	128 (94.8)	7 (5.2)

Regarding the analytical variables, many reports were missing data on cellularity, differential count, morphological evaluation, and indices (Table 5). Out of the 104 reports where the differential count was reported, only 90 presented it in relative values. Furthermore, out of the 85 reports where the total number of counted cells was reported, 18 had counts performed on fewer than 300 cells.

Table 5. Quality characteristics of dogs and cats BMA reports: analytical variables.

Variables of report	Reported (n = 135)		
	Yes n (%)	**No n (%)**	**Not applicable n (%)**
Cellularity	97 (71.9)	25 (18.5)	13 (9.6)
Differential count	104 (77.0)	18 (13.3)	13 (9.6)
Number of cells evaluated	85 (63.0)	37 (27.4)	13 (9.6)
Morphological assessment by cell line	50 (37.0)	71 (52.6)	14 (10.4)
Indices	95 (70.4)	17 (12.6)	23 (17.0)
Myeloid/erythroid	95 (100)	0 (0)	
Maturation	73 (76.8)	22 (23.2)	

Diagnosis Frequency

Out of the total BMA reports, 37/135 (27.4%) (4 from cats and 33 from dogs) were excluded due to sample quality issues. The diagnosis frequency was established for both species from the remaining 98/135 reports (72.6%). Neoplastic, hyperplastic, and hypoplastic groups were subclassified according to the affected cell line (Table 6). The male-to-female ratio was maintained, with 54/98 (55.1%) being males.

The most common diagnoses in dogs were erythroid, granulocytic, or combined hypoplasia, while neoplasia was more prevalent in cats. Infectious agents were identified as the sole alteration in five reports (Table 6). However, they were found in 16 BMA: *Anaplasma spp*. in three, *Ehrlichia spp*. in seven, *Babesia spp*. in two, *Hepatozoon spp*. in one, *Leishmania spp*. in one, and co-infection by *Anaplasma spp.* and *Ehrlichia spp.* in two cases. In three cases, the species of hemotropic reported in the BMA matched the initial consultation report. Likewise, in eight cases of hematopoietic tissue infections, patients presented with associated marrow alterations, including decreased cellularity, myelodysplasia, medullary aplasia, and hypoplasia, while three of these cases also exhibited hyperplasia and reactive bone marrow.

246 **Table 6.** Diagnosis frequency in dogs and cats BMA reports

Diagnostic	Dogs n=83		Cats n=15		Total n=98	
	n	**%**	**n**	**%**	**n**	**%**
Hypoplasia	*30*	*36.1*	*1*	*6.7*	*31*	*31.6*
Erythroid	7	23.3	0	0.0	7	22.6
Granulocytic	11	36.7	0	0.0	11	35.5
Erythroid and granulocytic	12	40.0	1	100.0	13	41.9
Neoplasia	*14*	*16.8*	*6*	*40.0*	*20*	*20.4*
Lymphoproliferative						
Acute	3	21.4	1	16.7	4	20.0
Chronic	3	21.4	1	16.7	4	20.0
Myeloproliferative						
Acute	1	7.1	2	33.3	3	15.0
Chronic	2	14.3	1	16.7	3	15.0
Myelodysplasia						
Granulocytic	4	28.6	1	16.7	5	25.0
Erythroid	1	7.1	0	0.0	1	5.0
Hyperplasia	*13*	*15.7*	*4*	*26.4*	*17*	*17.3*
Erythroid	3	23.1	3	75.0	6	35.3
Granulocytic	8	61.5	0	0.0	8	47.1
Granulocytic and erythroid	2	15.4	1	25.0	3	17.6
Reactive Bone Marrow	8	9.6	2	13.3	10	10.2
Medullary Aplasia	7	8.4	2	13.3	9	9.2
Normal Bone Marrow	6	7.2	0	0.0	6	6.1
Infectious agents	5	6.0	0	0.0	5	5.1

247 Chronic lymphoproliferative disorders included one case of plasma cell neoplasia in a dog,
248 while chronic myeloproliferative disorders reported chronic eosinophilic leukemia in a cat.
249 Myelodysplastic neoplasms detailed maturation changes in the nucleus and cytoplasm
250 exceeding 10%. Prussian blue staining for ring sideroblastic identification was not reported.

Among the five patients with lymphadenopathy, one was diagnosed with chronic myeloproliferative leukemia and two with acute lymphocytic leukemia.

Factors associated with diagnoses

Granulocytic hypoplasia was more common in females (9/44; 20.5%) than males (2/54; 3.7%; p = 0.011). However, neoplasms were more common in males (16/54; 29.6%) than in females (4/44; 9.1%; p = 0.013), and erythroid hyperplasia was only present in males (6/54; 11.1%; p = 0.031; Table 7). Hypoplasia occurred more frequently in dogs (30/83; 36.1%) than in cats (1/15; 6.7%; p = 0.032). However, erythroid hyperplasia was more common in cats (3/15; 20.0%) than in dogs (3/83; 3.6%; p = 0.044). Granulocytic hyperplasia was more frequent in individuals of small breeds (4/13; 30.8%; p = 0.013). There was no breed predominance in cats for any diagnosis, as was the case when evaluating the disaggregated dog breeds. Four of the patients who presented with medullary aplasia had pancytopenia (4/9; 44.4%; p = 0.002). Other individuals with pancytopenia were diagnosed with hypoplasia, myelodysplasia, and *Ehrlichia spp.* infection.

Table 7. Factors associated with bone marrow diagnoses in dogs and cats from Colombia (2012-2023).

Factors	**Diagnostic**				**p-value**
	Yes		**No**		
	n	**%**	**n**	**%**	
			Medullary Aplasia		
Pancytopenia					
Yes	4	44.4	5	55.6	0.002
No	3	5.7	50	94.3	
			Granulocytic Hypoplasia		
Sex					
Female	9	20.5	35	79.5	0.011
Male	2	3.7	52	96.3	
			Hypoplasia		
Species					
Dogs	30	36.1	53	63.9	0.032
Cats	1	6.7	14	93.3	
			Hyperplasia erythroid		
Species					
Dogs	3	3.6	80	96.4	0.044
Cats	3	20.0	12	80.0	

Sex					
Female	0	0	44	100	0.031
Male	6	11.1	48	88.9	
			Hyperplasia granulocytic		
Breed					
Small	4	30.8	9	69.2	
Medium	2	3.8	51	96.2	0.013
Large	2	12.5	14	87.5	
			Neoplasia		
Sex					
Female	4	9.1	40	90.9	0.013
Male	16	29.6	38	70.4	

Discussion

The total number of BMA reports obtained during the study period from the eight institutions contrasts significantly with the findings described by Weiss (2006a, 2006b) and Turinelli *et al*. (2015, 2018). Weiss (2006a) compiled 203 samples from cats and 717 from dogs in a single American institution over eight years. Turinelli *et al*. (2015) gathered 295 dogs' samples over two years and 152 cats samples over three years in a European laboratory. These comparisons suggest that using BMA is less common in Colombia than in other countries. Similarly, these publications found that bone marrow evaluation is more frequent in dogs than in cats, consistent with the findings of this study, where the ratio of dogs to cats was 8:1. In Colombia, this disparity could be related to dogs being more common pets than cats (Ministerio de Salud y Protección Social, 2022). Additionally, considering that hematological alterations in cats are commonly associated with highly prevalent viral infections, it is possible that BMA is not routinely performed as a differential diagnostic technique (Molina, 2020; Ortega *et al*., 2020; Santisteban *et al*., 2021).

Persistent anemia, alone or accompanied by other abnormalities, was the most common indication for requesting the aspiration, followed by thrombocytopenia. These findings coincide with the study by Turinelli *et al*. (2015), where 37.6% of patients had persistent anemia. This hematological abnormality is a common finding in veterinary practice, with common causes including solid tumor cancer, hematopoietic cancer, inflammatory disease, immune-mediated disease, and renal damage (Chervier *et al.*, 2012; Grzelak and Fry, 2022).

Therefore, in cases of non-regenerative, persistent anemia of unknown cause, performing BMA for differential diagnosis is crucial (Raskin and Messick, 2012).

Some of the data recorded in the result reports lacked information such as sex, age, consultation history, description of particles, cellularity, morphological evaluation by cell line, and differential count. These omissions hinder the correct interpretation of a BMA. Experts in human hematopathology have demonstrated the advantages of implementing synoptic reports, which gather basic and analytical elements while avoiding unstructured narrative reports (Sever *et al*., 2016). This approach facilitates the analysis of the results against established diagnostic criteria, considering that the final report directly impacts the decision-making of the treating physician (Mylonakis and Hatzis, 2014; Stacy and Harvey, 2017).

As previously described, sample quality is a well-known limiting factor in the analytical process of BMA (Trejo-Ayala *et al.*, 2015). This study excluded 27.4% of samples due to quality issues. This finding aligns with Turinelli *et al.*, (2015, 2018), where the percentage of non-diagnostic samples in dogs and cats was 30.5% and 26.5%, respectively. However, these findings differ from those reported by Weiss (2006a, 2006b), where the percentage of non-diagnostic samples was 2.5% in cats and 1.6% in dogs. Hemodilution has been described as the primary cause of rejection of aspirates, and deficiencies associated with this error are improved with laboratory staff assistance in particle fishing or selection and extension (Riley *et al*., 2021). However, expertise in the sampling process lies exclusively with the clinician, as demonstrated by Siddon *et al.* (2021).

The most frequent diagnosis in dogs was hypoplasia (36.1%), a rate closely aligned with Girardi *et al*. in Brazil, with 26.2% in 65 dogs, considering that these were patients with pancytopenia. This differs from the findings of this research compared to those reported by Weiss (4.3%) and Turinelli *et al.* (7.8%) (Turinelli *et al.*, 2015; Weiss, 2006b). This group of abnormalities has been linked to medication use, chemical substances, radiation, infections, immune disorders, and neoplasms in both humans and animals (Grimes and Fry, 2015; Javinsky, 2012; Moore *et al.*, 2023). In this study, a detailed investigation into the causes of these abnormalities in patients was constrained by the lack of additional clinical history information.

Moreover, hyperplasia ranked next, with a frequency of 15.7% in dogs, a value close to that previously reported by other authors in patients treated in the United States (20.2%) and

European countries (25.1%) (Turinelli *et al.*, 2015; Weiss, 2006b). Non-neoplastic hyperplasia must be correlated with clinical findings and diagnostic aids to determine the causes, as they may be transient processes resulting from the medullary response to hemolytic anemias, chronic inflammatory processes, or other factors (Haines *et al*., 2022; Orazi *et al.* 2006).

Despite the small sample size, neoplasms were the most common diagnoses in cats. No specific cell line predominated, resulting in similar proportions of lymphoproliferative, myeloproliferative, and myelodysplastic disorders. For instance, Gilroy *et al.* (2011) documented a case of chronic eosinophilic leukemia in a male cat exhibiting persistent eosinophilia, mirroring findings in our study. Similarly, Campbell *et al.* (2013) reported 18 cases of chronic lymphocytic leukemia in cats over 10 years, while Patel *et al.* (2005) identified 16 cases of multiple myeloma in cats over eight years. Both studies applied diagnostic criteria to both peripheral blood and bone marrow, revealing a considerable number of cases compared to our study's findings over a longer period. This discrepancy underscores a potential underdiagnosis of marrow conditions in dogs and cats.

Additionally, vector-borne diseases have been associated with various hematological abnormalities, often manifesting as reductions in one or more cell lines (Bonilla-Aldana *et al.*, 2022; Tommasi *et al.*, 2014). This observation aligns with our study's results, where eight patients with myelodysplasia, aplastic anemia, and hypoplasia showed evidence of *Ehrlichia spp.*, *Babesia spp.*, and *Anaplasma spp.* in BMA, which were not previously detected in peripheral blood samples.

A higher frequency of males was observed in the neoplasm group, which differs from the findings of Turinelli *et al.* (2015, 2018), who reported similar sex ratios for malignancy. Other studies in dogs have described a greater predisposition in males to various neoplasms; however, specific records regarding sex predisposition to hematopoietic neoplasms were not found (Pinello *et al*., 2022). In a study conducted on 3400 dogs, it was found that males are diagnosed with cancer at an earlier age than females (Rafalko *et al*., 2023); however, in the present study, no association between age and diagnosis was found, despite the majority of patients being in the adult stage at the time of aspiration.

Nine cases were identified concerning the association between females and granulocytic hypoplasia. It has been described that the bone marrow of dogs is highly susceptible to suppression induced by endogenous or exogenous estrogens (Sontas *et al.*, 2009; Weiss, 2022).

However, complementary information was not available to identify treatments or underlying conditions that may have favored the development of the disorder.

No publications discussing sexual predisposition in dogs or cats were found for erythroid hyperplasia; for this study, all cases were males. This has been associated with peripheral causes of cell destruction and myelodysplastic neoplasms (Haines *et al*., 2022; Newman *et al*., 2022; Weiss *et al*., 2001).

In addition, alterations were reported in the megakaryocytic line, nor were there descriptions of the use of BMAs in patient follow-up, lymphoma staging, or the application of molecular biology techniques, cytogenetics, microbiological cultures, and immunophenotyping in any of the reports as complementary studies for the final diagnosis. However, these techniques are applied in veterinary medicine to define lineage and clonality and establish prognoses (Evans, 2023; Rout *et al.*, 2019). It should be noted that the availability of these tests is limited in Colombia.

To our knowledge, this is the first publication on the characterization of BMA reports in dogs and cats in the country. Thus, it is likely the first report on the frequency of diagnoses in BMAs for both species. The study of BMA as a diagnostic tool in dogs and cats treated at participating veterinary centers in Colombia is limited. The most reported diagnosis in dogs is hypoplasia, while neoplasms were more frequent in cats, considering the number of individuals.

This study shows the need to adhere to the guidelines for the BMA report with the purpose of improving diagnostic accuracy, shortening times, and avoiding reprocessing. Likewise, it is necessary to improve the technique for obtaining and extending the sample, avoiding particle-free and hemodiluted samples.

The use of BMA allowed us to diagnose and rule out central hematologic alterations in dogs and cats with multiple clinical and laboratory findings. Moreover, this tool allows making differential diagnoses in cases in which the BMA result is normal, concluding the peripheral origin.

Declarations

Funding

The project did not receive any funding for its execution.

Conflict of interest:

The authors declare no conflicts of interest.

Author contributions:

Roldán-Carvajal: Project design, institution search, manuscript writing. Alzate-Velásquez: Project design, institution search, manuscript editing. Muñoz-Duque: Project design, institution search, manuscript editing. Mesa-Oquendo: Institution search, manuscript editing. Salazar-Flórez: Statistical analysis, manuscript editing. Jaramillo-Arbeláez: Project design, manuscript writing.

Use of artificial intelligence (AI):

No AI or AI-assisted technologies were used during the preparation of this work.

References

Abella-Bourgès N, Trumel C, Chabanne L, Diquélou A. Myélogramme et biopsie de moelle osseuse. EMC - Vétérinaire 2005; 2(2): 74-95. https://doi.org/10.1016/j.emcvet.2005.05.001

Bonilla-Aldana DK, Gutiérrez-Grajales EJ, Osorio-Navia D, Chacón-Peña M, Trejos-Mendoza AE, Pérez-Vargas S, Valencia-Mejía L, Marín-Arboleda LF, Martínez-Hidalgo JP, Reina-Mora MA, González-Colonia LV, Cardona-Ospina JA, Jiménez-Posada EV, Diaz-Guio DA, Salazar JC, Sierra M, Muñoz-Lara F, Zambrano LI, Ramírez-Vallejo E, Rodríguez-Morales AJ. Haematological Alterations Associated with Selected Vector-Borne Infections and Exposure in Dogs from Pereira, Risaralda, Colombia. Animals 2022; 12(24): 3460-3475. https://doi.org/10.3390/ani12243460

Campbell MW, Hess PR, Williams LE. Chronic lymphocytic leukaemia in the cat: 18 cases (2000-2010). Vet Comp Oncol 2013; 11(4): 256-264. https://doi.org/10.1111/j.1476-5829.2011.00315.x

Chervier C, Cadoré JL, Rodriguez-Piñeiro MI, Deputte BL, Chabanne L. Causes of anaemia other than acute blood loss and their clinical significance in dogs. J Small Anim Pract 2012; 53(4): 223-227. https://doi.org/10.1111/j.1748-5827.2011.01191.x

Comazzi S, Avery PR, Garden OA, Riondato F, Rütgen B, Vernau W. European canine lymphoma network consensus recommendations for reporting flow cytometry in canine hematopoietic neoplasms. Cytometry Part B 2017; 92(5): 411-419. https://doi.org/10.1002/cyto.b.21382

Cowell RL, Valenciano AC, *Diagnóstico citológico y hematológico del perro y el gato*. España. Elsevier 2023;5th ed.

Creevy KE, Grady J, Little SE, Moore GE, Strickler BG, Thompson S, Webb JA. 2019 AAHA Canine Life Stage Guidelines. J Am Anim Hosp Assoc 2019; 55(6): 267-290. https://doi.org/10.5326/jaaha-ms-6999

Evans SJM. Flow Cytometry in Veterinary Practice. Vet Clin North Am Small Anim Pract 2023; 53(1): 89-100. https://doi.org/10.1016/j.cvsm.2022.07.008

Gilroy C, Forzán M, Drew A, Vernau W. Eosinophilia in a cat with acute leukemia. Can Vet J 2011; 52(9): 1004-1008. PMCID: PMC3157058

Girardi AF, Campos AN, Pescador CA, Almeida AD, Mendonça AJ, Nakazato L, Oliveira AC, Sousa VR. Quantitative analysis of bone marrow in pancytopenic dogs. Semina-ciencias Agrarias 2017; 38: 3639-3646. https://doi.org/10.5433/1679-0359.2017v38n6p3639

Grimes CN, Fry MM. Nonregenerative Anemia: Mechanisms of Decreased or Ineffective Erythropoiesis. Veterinary Pathology 2015; 52(2): 298-311. https://doi.org/10.1177/0300985814529315

Grindem CB, Neel JA, Juopperi TA. Cytology of bone marrow. Vet Clin North Am Small Anim Pract 2002; 32(6): 1313-1374. https://doi.org/10.1016/s0195-5616(02)00052-9

Grzelak AK, Fry MM. Anemia of Inflammatory, Neoplastic, Renal, and Endocrine Diseases. In: Brooks MB, Harr KE, Seelig DM, Wardrop KJ, Weiss DJ, editors. Schalm's Veterinary Hematology 7th ed. Nueva Jersey: Wiley-Blackwell. 2022; p. 313-317. https://doi.org/https://doi.org/10.1002/9781119500537.ch39

444 Haines JM, Mackin A, Day MJ. Immune-Mediated Anemia in the Dog. In: Brooks MB, Harr
445 KE, Seelig DM, Wardrop KJ, Weiss DJ, editors. Schalm's Veterinary Hematology 7th ed.
446 Nueva Jersey: Wiley-Blackwell 2022; p. 278-291.
447 https://doi.org/10.1002/9781119500537.ch35
448
449 Hawkins R. Managing the pre- and post-analytical phases of the total testing process. Ann Lab
450 Med 2012; 32(1): 5-16. https://doi.org/10.3343/alm.2012.32.1.5
451
452 Javinsky E. Hematology and Immune-Related Disorders. In: Little SE, editor. The Cat: Clinical
453 Medicine and Management 2nd ed. Georgia: Elsevier Saunders 2012; p. 643-703.
454 https://doi.org/10.1016/B978-1-4377-0660-4.00025-9
455
456 Lee SH, Erber WN, Porwit A, Tomonaga, M, Peterson LC. ICSH guidelines for the
457 standardization of bone marrow specimens and reports. Int J Lab Hematol 2008; 30(5): 349-
458 364. https://doi.org/10.1111/j.1751-553X.2008.01100.x
459
460 Messick JB. A Primer for the Evaluation of Bone Marrow. Vet Clin North Am Small Anim
461 Pract 2023; 53(1): 241-263. https://doi.org/10.1016/j.cvsm.2022.08.002
462
463 Ministerio de Salud y Protección Social. Cobertura Vacunación antirrábica de perros y gatos
464 por departamento y municipio. Colombia: biblioteca digital. 2022.
465 https://www.minsalud.gov.co/BibliotecaDigital/vacunacion-antirrabica-perros-gatos2022
466
467 Molina V. Prevalence of the Feline Leukemia Virus (FeLV) in Southern Valle de Aburrá,
468 Colombia. Rev Med Vet 2020; 40: 9-16. https://doi.org/10.19052/mv.vol1.iss40.2
469
470 Moore C, Krishnan K. Bone Marrow Failure. StatPearls [Internet] 2023.
471 https://www.ncbi.nlm.nih.gov/books/NBK459249/
472
473 Mylonakis M, Hatzis A. Practical bone marrow cytology in the dog and cat. J Hellenic Vet
474 Med Soc 2014; 65(3): 181-196. https://doi.org/10.12681/jhvms.15534
475

476 Newman A, Stokol T. Immune-Mediated Anemia in the Cat. In: Brooks MB, Harr KE, Seelig
477 DM, Wardrop KJ, Weiss DJ, editors. Schalm's Veterinary Hematology 7th ed. Nueva Jersey:
478 Wiley-Blackwell 2022; p. 292-299. https://doi.org/10.1002/9781119500537.ch36
479
480 Orazi A, O'Malley DP, Arber DA. The hyperplasias. In Orazi A, Arber DA, O'Malley DP,
481 editors. Illustrated Pathology of the Bone Marrow 1st ed. Cambridge: Cambridge University
482 Press 2006; p. 31-38. https://doi.org/10.1017/CBO9780511543531
483
484 Ortega C, Valencia AC, Duque-Valencia J, Ruiz-Saenz J. Prevalence and Genomic Diversity
485 of Feline Leukemia Virus in Privately Owned and Shelter Cats in Aburrá Valley, Colombia.
486 Viruses 2020; 12(4); 464-477. https://doi.org/10.3390/v12040464
487
488 Patel RT, Caceres A, French AF, McManus PM. Multiple myeloma in 16 cats: a retrospective
489 study. Vet Clin Pathol 2005; 34(4): 341-352. https://doi.org/https://doi.org/10.1111/j.1939-
490 165X.2005.tb00059.x
491
492 Pinello K, Pires I, Castro AF, Carvalho PT, Santos A, de Matos A, Queiroga F, Canadas-Sousa
493 A, Dias-Pereira P, Catarino J, Faísca P, Branco S, Lopes C, Marcos F, Peleteiro MC, Pissarra
494 H, Ruivo P, Magalhães R, Severo M, Niza-Ribeiro J. Cross Species Analysis and Comparison
495 of Tumors in Dogs and Cats, by Age, Sex, Topography and Main Morphologies. Data from
496 Vet-OncoNet. Vet. Sci 2022; 9(4): 167-185. https://doi.org/10.3390/vetsci9040167
497
498 Posada O S, Gomez OL, Rosero NR. Application of the logistic model to describe the growth
499 curve in dogs of different breeds. Rev MVZ Córdoba 2014; 19: 4015-4022.
500 https://doi.org/10.21897/rmvz.121
501
502 Rafalko JM, Kruglyak KM, McCleary-Wheeler AL, Goyal V, Phelps-Dunn A, Wong LK,
503 Warren CD, Brandstetter G, Rosentel MC, DiMarzio L, McLennan LM, O'Kell AL, Cohen
504 TA, Grosu DS, Chibuk J, Tsui DWY, Chorny I, Flory A. Age at cancer diagnosis by breed,
505 weight, sex, and cancer type in a cohort of more than 3,000 dogs: Determining the optimal age
506 to initiate cancer screening in canine patients. PLoS One 2023; 18(2): e0280795.
507 https://doi.org/10.1371/journal.pone.0280795
508

Raskin RE, Messick JB. Bone marrow cytologic and histologic biopsies: indications, technique, and evaluation. Vet Clin North Am Small Anim Pract 2012; 42(1): 23-42. https://doi.org/10.1016/j.cvsm.2011.10.001

Riley RS, Gandhi P, Harley SE, Garcia P, Dalton JB, Chesney A. A Synoptic Reporting System to Monitor Bone Marrow Aspirate and Biopsy Quality. J Pathol Inform 2021; 12: 23-29. https://doi.org/10.4103/jpi.jpi_53_20

Ritt MG. Epidemiology of Hematopoietic Neoplasia. In: Brooks MB, Harr KE, Seelig DM, Wardrop KJ, Weiss DJ, editors. Schalm's Veterinary Hematology 7th ed. Nueva Jersey: Wiley-Blackwell; 2022. p. 457-462. https://doi.org/10.1002/9781119500537.ch58

Rout ED, Burnett RC, Yoshimoto JA, Avery PR, Avery AC. Assessment of immunoglobulin heavy chain, immunoglobulin light chain, and T-cell receptor clonality testing in the diagnosis of feline lymphoid neoplasia. Vet Clin Pathol 2019; 48(S1): 45-58. https://doi.org/https://doi.org/10.1111/vcp.12767

Rütgen BC, Bouschor J. Classification and General Features of Lymphoma and Leukemia. In: Brooks MB, Harr KE, Seelig DM, Wardrop KJ, Weiss DJ, editors. Schalm's Veterinary Hematology 7th ed. Nueva Jersey: Wiley-Blackwell; 2022;p. 528-537. https://doi.org/10.1002/9781119500537.ch65

Santisteban RR, Muñoz-Rodríguez LC, Díaz Nieto J, Pachón-Londoño V, Curiel-Peña J. Seroprevalencia del virus de inmunodeficiencia felina (VIF) y el virus de la leucemia felina (ViLeF) en gatos del centro de Risaralda, Colombia. Rev Inv Vet Perú 2021; 32(3): e18901. https://doi.org/10.15381/rivep.v32i3.18901

Sciacovelli L, Aita A, Padoan A, Pelloso M, Antonelli G, Piva E, Chiozza ML, Plebani M. Performance criteria and quality indicators for the post-analytical phase. Clin Chem Lab Med 2016; 54(7): 1169-1176. https://doi.org/10.1515/cclm-2015-0897

Sever C, Abbott CL, de Baca ME, Khoury JD, Perkins SL, Reichard KK, Taylor A, Terebelo HR, Colasacco C, Rumble RB, Thomas NE. Bone Marrow Synoptic Reporting for Hematologic Neoplasms: Guideline From the College of American Pathologists Pathology and

Laboratory Quality Center. Arch Pathol Lab Med 2016; 140(9): 932-949. https://doi.org/10.5858/arpa.2015-0450-SA

Siddon AJ, Kroft SH. The Lab as a Driver of Quality in the Preanalytical Realm: The Case of Technologist-Assisted Bone Marrow Biopsies. Am J Clin Pathol 2021; 157(4): 480-481. https://doi.org/10.1093/ajcp/aqab180

Sontas HB, Dokuzeylu B, Turna O, Ekici H. Estrogen-induced myelotoxicity in dogs: A review. Can Vet J 2009; 50(10): 1054-1058. PMCID: PMC2748286

Stacy NI, Harvey JW. Bone marrow aspirate evaluation. Vet Clin North Am Small Anim Pract 2017; 47(1): 31-52. https://doi.org/10.1016/j.cvsm.2016.07.003

Tommasi ASD, Baneth G, Breitschwerdt EB, Stanneck D, Dantas-Torres F, Otranto D, Caprariis D. Anaplasma platys in Bone Marrow Megakaryocytes of Young Dogs. J Clin Microbiol 2014; 52(6): 2231-2234. https://doi.org/doi:10.1128/jcm.00395-14

Turinelli V, Gavazza A, Stock G, Fournel-Fleury C. Canine bone marrow cytological examination, classification, and reference values: A retrospective study of 295 cases. Res Vet Sci 2015; 103: 224-230. https://doi.org/10.1016/j.rvsc.2015.10.008

Turinelli V, Gavazza A. Retrospective study of 152 feline cytological bone marrow examinations: preliminary classification and ranges. J Feline Med Surg 2018; 20(12): 1158-1168. https://doi.org/10.1177/1098612x18757602

The Royal College of Pathologists of Australasia. Bone marrow specimen (aspirate and trephine biopsy) structured reporting protocol. 1st ed. RCPA. 2014. ISBN: 978-1-74187-964-3

Trejo-Ayala RA, Luna-Pérez M, Gutiérrez-Romero M, Collazo-Jaloma J, Cedillo-Pérez MC, Ramos-Peñafiel CO. Bone marrow aspiration and biopsy. Technique and considerations. Rev Med Hosp Gen Méx 2015; 78(4): 196-201. https://doi.org/10.1016/j.hgmx.2015.06.006

Weiss DJ, Aird B. Cytologic Evaluation of Primary and Secondary Myelodysplastic Syndromes in the Dog. Vet Clin Pathol 2001; 30(2): 67-75. https://doi.org/https://doi.org/10.1111/j.1939-165X.2001.tb00261.x

Weiss DJ. A retrospective study of the incidence and classification of bone marrow disorder in cats (1996–2004). Comp Clin Path 2006a; 14: 179-185. http://dx.doi.org/10.1007/s00580-005-0575-1

Weiss DJ. A retrospective study of the incidence and the classification of bone marrow disorders in the dog at a veterinary teaching hospital (1996–2004). J Vet Intern 2006b; 20(4): 955-961. https://doi.org/10.1111/j.1939-1676.2006.tb01811.x

Weiss DJ. Blood and Bone Marrow Toxicity Induced by Drugs, Heavy Metals, Chemicals, and Toxic Plants. In: Brooks MB, Harr KE, Seelig DM, Wardrop KJ, Weiss DJ, editors. Schalm's Veterinary Hematology 7th ed. Nueva Jersey: Wiley-Blackwell 2022; p. 122-132. https://doi.org/10.1002/9781119500537.ch15

Woods GA, Simpson M, Boag A, Paris J, Piccinelli C, Breheny C. Complications associated with bone marrow sampling in dogs and cats. J Small Anim Pract 2021; 62(3): 209-215. https://doi.org/10.1111/jsap.13274