Investigation of the utility of lymph node fine needle aspiration cytology for the staging of malignant solid tumors in dogs

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Abstract

Background: Fine needle aspiration cytology (FNAC) of lymph nodes (LN) is routinely used for staging canine malignant solid tumors, but studies evaluating its efficacy are limited.

Objectives: The primary objectives of this study were to evaluate the sensitivity/specificity of FNAC and the significance of non-diagnostic FNAC when staging canine malignant solid tumors. A secondary objective was to determine the frequency of multiple nodal metastases.

Methods: Histopathological and FNAC assessments of LN (n = 259) draining malignant solid tumors were included. The sensitivity/specificity of FNAC was determined for 194 LN with diagnostic FNAC, using histopathology as the gold standard. The proportion of non-diagnostic FNAC and associated histopathological prevalence of metastasis were determined. Among the tumors with multiple LN assessed (88/189), the prevalence of multiple nodal metastases was determined.

Results: The sensitivity of FNAC was 67% for sarcomas, 100% for carcinomas, 63% for melanomas, 75% for mast cell tumors, and 100% for other round cell tumors. The specificity varied between 83% and 96%. Non-diagnostic FNAC was reported in 25% of LN sampled, most of which were non-enlarged and/or difficult to access, and 20% of which were metastatic on histopathology. When several LN were assessed, the prevalence of multiple nodal metastases was 24%.

Conclusions: Histopathologic LN evaluation cannot be robustly substituted with FNAC when staging selected canine solid tumors. When a diagnostic FNAC is elusive, as the prevalence of metastasis remains non-negligible in these cases, histopathological assessment is ideal. Finally, staging should not always be limited to the assessment of one single LN.
Introduction

Assessment of the loco-regional lymph nodes (LNs) is an integral part of the TNM clinical staging system for canine solid tumors, from the original version of the World Health Organization (WHO) staging scheme created in 1980, to the more recently published staging schemes. Loco-regional LN metastatic status has been correlated with prognosis in several tumor types, and represents a key element for the clinician to devise an appropriate, bespoke treatment plan for each individual tumor-bearing canine patient. Although histopathologic examination was the method originally recommended in the WHO staging system to assess regional LN status, assessment of the regional LNs in veterinary medicine is often performed using fine-needle aspiration cytology (FNAC). As it is a non-invasive, cost-effective, and rapid technique, FNAC is very appealing. In a large retrospective study, tumor staging was the second most common reason for sampling LNs, leading to the submission of 9.3% of LN FNAC. In a prospective study including 37 dogs diagnosed with a variety of tumors (16 carcinomas, 18 sarcomas, 7 mast cell tumors, 2 melanomas and 1 histiocytic sarcoma), the sensitivity and specificity of FNAC for assessing regional LNs were 100% and 96% respectively, with histopathology used as the gold standard. In another prospective study including 28 dogs with oral or maxillofacial neoplasms (8 squamous cell carcinomas, 5 fibrosarcomas, 5 melanomas and 10 other tumors), the accuracy of FNAC for LN staging was 90.5% when compared with histopathology. Similarly, in a recent large retrospective study, the sensitivity and specificity of FNAC in the detection of LN neoplasia were 66.6% and 91.5%, respectively. However, the latter study was primarily designed to determine the agreement between FNAC and histopathology for diagnosing nodal neoplasia, and was not specifically designed to assess the accuracy of FNAC in the setting of solid tumor staging.

In human oncology practice, LN extirpation followed by histopathologic examination is often performed to achieve an accurate clinical stage. An advantage of histopathologic
examination is the possibility of obtaining multiple tissue sections, and to allow the use of a comprehensive immunohistochemistry panel and/or other further assessments (e.g. PCR-based assessments), which might be necessary to improve the accuracy of staging.\textsuperscript{11} However, depending on the location and number of LNs removed, LN extirpation can be associated with complications and can have a negative impact on the quality of life of cancer patients.\textsuperscript{12, 13} The value of sentinel LN extirpation for the staging of several tumor types is currently under investigation. Many studies report an increase in the appropriateness of each LN extirpation using this approach, while decreasing the morbidity associated with routine, unguided and extensive LN dissection.\textsuperscript{12, 14} Some studies have investigated the possible utility of FNAC in the staging of human breast, head, and neck cancer, but the sensitivity of FNAC to detect metastasis was generally poor.\textsuperscript{15-17} However, other studies have suggested a role for ultrasound-guided FNAC of sentinel LNs, in the staging of other tumor types, in particular when used in a step-wise approach.\textsuperscript{18-21}

Only two relatively small prospective studies have assessed the accuracy of FNAC for LN staging in dogs, both finding good agreement with histopathology.\textsuperscript{8, 9} A more recent, large retrospective study found that FNAC was poorly sensitive in detecting LN neoplasia, however this study was not specifically designed to assess this technique in the setting of routine LN staging.\textsuperscript{10} We sought to enhance the evidence base in this area by designing a study to assess the reliability of FNAC for LN staging in dogs presented with a solid tumor. We also sought to elucidate the impact of non-diagnostic FNAC in the routine staging of canine solid tumors, as this limitation of FNAC had not been assessed before. Similarly, as previous studies assessed only one LN per tumor,\textsuperscript{8, 10} acknowledging that tumors can metastasize to several LNs, sometimes ”skipping” the anticipated local LN,\textsuperscript{22-24} our study included the assessment of several LNs and the impact of such wider LN sampling on staging results. The primary objectives of this study were two-fold: 1) to evaluate the reliability of
FNAC compared with histopathology in the staging of canine malignant solid tumors, and 2) to evaluate the clinical significance of non-diagnostic FNAC in the staging of canine malignant solid tumors. A secondary objective was to determine the impact of multiple LN assessment in the staging of canine malignant solid tumors.

**Materials and methods**

**Data collection**

Medical records of dogs presented to the University of Edinburgh Veterinary Teaching Hospital between February 2012 and February 2017 were reviewed to identify dogs with a histopathologic diagnosis of a malignant solid tumor with regional LN sampling. In all cases of histiocytic sarcomas and cutaneous lymphomas included in the study, no sign of distant involvement was noted at initial staging; which included thoracic radiographs, abdominal ultrasound, FNAC of liver and spleen, and bone marrow aspirate. Cases were included in this retrospective study if both FNAC and histopathology of LN(s) were available, and if the interval between FNAC and LN extirpation was <30 days. In some cases, several locoregional LNs were assessed by both methods in staging a single tumor. May-Grünwald-Giemsa-stained FNAC preparations were assessed by board-certified clinical pathologists, while histopathologic sections were routinely stained with H&E and assessed by board-certified anatomic pathologists.

Information collected from the medical records included dog signalment, tumor characteristics (histopathologic diagnosis, anatomic location and lateralization), LN characteristics (anatomic location, size, enlargement status (enlarged/not enlarged), use of ultrasound-guidance for FNAC, date of FNAC, date of extirpation). Tumor types were grouped into: sarcomas, carcinomas, melanomas, mast cell tumors, or other round cell tumors. Lymph node location was classified as: mandibular, prescapular, inguinal, popliteal,
sublumbar, or others. Determination of LN enlargement status was based on clinical examination and was classified as: none, mild, moderate, or marked. Although subjective, enlargement status was preferred to measured size for statistical analysis, as validated information defining the normal size of a normal LN for specific breeds and locations is still lacking, and as such categorization accurately reflects clinical practice. When the cellularity of the sample was too low to allow cytological LN assessment, FNAC was considered non-diagnostic. The LN metastatic status for both cytologic and histopathologic examinations was categorized as positive or negative. When metastasis was only suspected, a positive metastatic status was attributed to the LN. Cytologic and histopathologic criteria for the diagnosis of nodal mast cell tumor metastasis have previously been proposed. These criteria were not systematically used in the original reports, but were retrospectively applied whenever possible.

**Reliability of LN FNAC**

Only LNs with diagnostic FNAC were selected for this analysis. The sensitivity and specificity of FNAC in the detection of nodal metastasis was determined for all LNs and subsequently for each tumor group, using histopathologic examination as the gold standard. The possible influence of factors such as LN enlargement, time between FNAC and LN extirpation, and LN location, on the failure to obtain agreement between FNAC and histopathology was evaluated. Cases with false-negative and false-positive FNAC reports were reviewed in an attempt to find an explanation for the discrepancy with histopathology.

**Significance of non-diagnostic LN FNAC**

The proportion of non-diagnostic FNAC was determined overall and for each tumor group. The possible influence of several factors on the failure to obtain a diagnostic FNAC, such as LN enlargement status, ultrasound-guidance, and LN location, was evaluated. The
prevalence of histopathologic metastasis among the LNs with non-diagnostic FNAC was determined and compared to that among the LNs with diagnostic FNAC.

**Significance of multiple nodal metastases**

Tumors included in the study were reviewed and separated in two groups: tumors which had several LNs aspirated and removed for staging, and tumors which had a single LN assessed.

The proportion of each LN location, the prevalence of metastasis, and LN enlargement status were compared between the two groups. Among the tumors with multiple LNs assessed histopathologically, the prevalence of metastasis to several LNs was determined. The patterns of metastasis to several LNs was reviewed.

**Statistical analysis**

Differences in the prevalence of metastasis between the four subgroups of enlargement status (none, mild, moderate, marked) were assessed using Fisher’s exact test on pairwise comparisons and applying the Bonferroni correction. Differences in the prevalence of metastasis between the non-diagnostic and diagnostic FNAC subgroups, the tumors with multiple LNs and tumors with single LN assessed; the difference in overall agreement and agreement within each LN location; the difference in proportion of ultrasound guidance between the non-diagnostic and diagnostic FNAC subgroups; and the difference in proportion of specific LN locations sampled between the tumors with multiple LNs assessed and those with a single LN assessed were analyzed using the chi-square test of homogeneity and Fisher’s exact test where appropriate. Mann-Whitney U test was used to assess differences in LN enlargement status between the metastatic and non-metastatic LN subgroups; the non-diagnostic and diagnostic FNAC subgroups; the tumors with multiple LNs sampled and those with a single LN sampled; and the correlation of the interval between FNAC and LN extirpation and FNAC-histopathology agreement. The 95 % confidence intervals (CI) were
calculated using the exact binomial method. Statistical analyses were performed using commercially available statistics software (Minitab™ 17 Statistical Software; Minitab Inc., State College, Pennsylvania, PA, USA). A P-value of < 0.05 was considered statistically significant for all analyses.

Results

Three hundred and thirty-seven LNs investigated because of neoplasia were initially recruited to the study. Seventy-eight of these cases were excluded, 75 because FNAC had not been attempted prior to LN extirpation, and 3 because the time between FNAC and histopathology was > 30 days. The 259 remaining LNs included in this study were assessed for the staging of 189 tumors in 187 dogs. Primary tumors included a variety of different types, grouped as sarcomas (47 LNs assessed), carcinomas (46 LNs), melanomas (37 LNs), mast cell tumors (110 LNs), and other round cell tumors (19 LNs) (Table 1). One hundred and ninety-four of the FNACs were diagnostic in quality, while the remaining 65 FNACs were non-diagnostic.

The median time between FNAC and LN extirpation was 7 days (1 – 30 days). Ultrasound guidance was used in 16.5% (n=32) of the FNACs. The overall prevalence of metastasis, based on histopathologic examination, was 32.4 % (n=84). The anatomic site of the LNs were mandibular (n = 132), prescapular (n = 51), popliteal (n = 34), inguinal (n = 18), sublumbar (n = 17) and others (n = 7).

Lymph nodes were deemed not enlarged in 58.3% (n=151) of cases, mildly enlarged in 19.7% (n=51) of cases, moderately enlarged in 14.7% (n=38) of cases, and markedly enlarged in 7.3% (n=19) of cases. There was a significant difference in the prevalence of metastasis when the LNs were stratified by enlargement status \( P = 0.006 \) (Figure 1). Nodes with metastatic disease were significantly more likely to be deemed enlarged than non-
metastatic LNs in dogs bearing sarcomas \((P = 0.048)\), carcinomas \((P < 0.001)\), melanomas \((P = 0.035)\), and mast cell tumors \((P < 0.001)\), although statistics did not yield significant difference in dogs bearing other round cell tumors \((P = 0.351)\). All the markedly enlarged LNs were assessed for the staging of dogs bearing either apocrine gland anal sac adenocarcinomas or mast cell tumors. The normal nodal architecture was effaced and replaced by neoplastic cells in all the LNs deemed markedly enlarged, with the exception of only one non-metastatic LN which had moderately disorganized architecture but no neoplastic cells were observed.

**Reliability of LN FNAC**

Among the 194 LNs with diagnostic FNAC, 35 were from dogs bearing a sarcoma, 34 were from dogs bearing a carcinoma, 30 were from dogs bearing a malignant melanoma, 78 were from dogs bearing a mast cell tumor, and 17 were from dogs bearing another round cell tumor. Using histopathologic examination as the gold standard, the overall sensitivity of FNAC in the detection of LN metastasis was 81\% \((58/71; \text{CI 70–89\%})\), the overall specificity was 91\% \((112/123; \text{CI 84 – 95\%})\), and the overall agreement was 88\% \((170/194; \text{CI 82–92\%})\). The sensitivity and specificity of FNAC were also determined individually for the 5 previously defined tumor groups (Table 2). Grouping FNACs into those which agreed and those which disagreed with histopathology, there was no significant difference in the time between FNAC and LN extirpation \((P = 0.751)\), nor in LN enlargement status \((P = 0.587)\). When compared to the overall agreement between FNAC and histopathologic examination, there was no significant difference in agreement for each LN anatomic location.

Among the 13 false-negative FNAC results recorded, 2 were from dogs bearing a sarcoma, 3 from dogs bearing a malignant melanoma, and 8 from dogs bearing a mast cell tumor. In one of the sarcoma-bearing dog with a false negative FNAC, the LN was removed
15 days later and histopathologic examination revealed a completely effaced LN by neoplastic tumor cells. The dog was euthanized 3 weeks later due to progressive disease. In the second case, the LN was removed a couple of days after the FNAC, and a 400µm metastatic deposit was noted within the corticomedullary junction. The LN bed was treated with radiation therapy and the dog was still free of disease a year later. All 3 melanoma-bearing dogs with a false negative FNAC were euthanized within a few months of investigation with generalized metastatic disease. In all 3 of these cases, pigmented cells and some large non-pigmented cells were observed on FNAC and interpreted as melanophages or macrophages. In all 8 cases of false-negative FNACs from dogs bearing a mast cell tumor, only small numbers (<1%) of individualized, well-differentiated mast cells were noted on cytology. In most histopathologic examinations of these cases, marked increases in individualized mast cells or mast cell aggregates were noted, sometimes associated with atypical morphology, corresponding to the HN1 and HN2 classes of the histopathologic classification scheme for mast cell tumor LN metastasis previously proposed. In only one such LN did histopathologic examination reveal a focal effacement of the normal nodal architecture by mast cells (consistent with HN3 class).

Toluidine blue (TB) staining was performed in 3 LNs from dogs bearing a mast cell tumor, which confirmed pre-metastasis (HN1 class) in one case, early metastasis (HN2 class) in another, and refuted the diagnosis of possible metastasis based on prior H&E in the third case.

Among the 11 false-positive FNACs recorded, 4 were from dogs bearing a mast cell tumor, 2 from dogs bearing a malignant melanoma, 2 from dogs bearing a carcinoma, 2 from dogs bearing non-epitheliotropic cutaneous lymphoma, and 1 from a dog bearing a sarcoma ("high-low" maxillary fibrosarcoma). Interestingly, in the latter case, moderate number of mesenchymal cells with moderate anisocytosis and anisokaryosis were seen on FNAC and were interpreted as neoplastic; however, on histopathologic examination the mesenchymal cells observed, were interpreted as reactive cells related to the presence of multifocal fibrinoid
necrosis of arteriolar walls and associated fibroplasia. At the time of writing, 3 years after the initial diagnosis, this dog continues to be regularly rechecked and remains free of disease, after incomplete excision and definitive-intent radiation therapy of the primary site. In the 2 cases of non-epitheliotropic cutaneous lymphoma with a false-positive LN FNAC, uncertainty regarding the cytologic metastatic diagnosis was mentioned by the clinical pathologist, however metastasis was strongly favored. One case had definitive-intent radiation therapy delivered to a solitary lesion on right carpus based on a lack of dissemination on initial histopathology of the draining LN, but developed disseminated disease 4 months later. The other case had a solitary lesion on the lip which was completely excised, but the dog was lost to follow-up. In the 2 cases of carcinoma with a false-positive FNAC report, cohesive clusters of cells with an appearance compatible with the primary carcinoma (thyroid carcinoma and apocrine gland anal sac adenocarcinoma) were noted on cytology, but similar cells were not observed on histopathology despite requesting additional sections and cytokeratin immunohistochemistry. Both of these dogs were lost to follow-up. In the 2 cases of melanoma with a false-positive FNAC report, uncertainty regarding the cytologic metastatic diagnosis was mentioned by the clinical pathologist. Melanophages and fewer scattered melanocytes were described on both FNAC and histopathology, but in the latter were interpreted as a drainage reaction rather than metastasis as no cellular aggregates or atypia were present. Both of these dogs were lost to follow-up. In all 4 cases of mast cell tumor with a false-positive FNAC, uncertainty regarding the cytologic metastatic diagnosis was expressed by the clinical pathologist; increased number of individualized mast cells (up to 10 per high-power field), aggregates of 2-3 cells or loose groups of up to 8 cells, and moderate anisocytosis were noted on cytology. Unfortunately, the previously proposed cytologic criteria were not applied in the original FNAC reports and could not be retrospectively applied using the detail therein. Although the features noted on FNAC were also described on histopathology, they were
considered not to be consistent with metastasis. Unfortunately, the previously proposed
histopathologic criteria were not applied in the original reports and could not be retrospectively
applied using the detail therein,\textsuperscript{25} but no disruption or effacement of normal nodal architecture
was reported. Toluidine Blue staining was performed in one case, and was supportive of the
non-metastatic diagnosis made on routine histopathology. Two of these dogs were lost to
follow-up after 5 and 7 months, and the other two dogs were free of disease at the time of
writing, 1 and 2 years after diagnosis, following complete excision in one case, and incomplete
excision with adjuvant definitive-intent radiation therapy on the primary site in the second case.

**Significance of non-diagnostic LN FNAC**

Twenty-five percent of the FNACs were non-diagnostic. Among the 65 LNs with non-diagnostic quality FNAC, 12 were from dogs bearing a sarcoma, 12 a carcinoma, 7 a melanoma, 32 a mast cell tumor, and 2 another round cell tumor.

Lymph nodes with FNAC of non-diagnostic quality were significantly less likely to be
deemed enlarged than were LNs with FNAC of diagnostic quality ($P < 0.001$) (Figure 2).

Overall, most of the LNs with FNAC samples of non-diagnostic quality were not (n=50) to
mildly enlarged (n=13), with the exception of 2 moderately to markedly enlarged LNs which
were sampled using ultrasound guidance. Fine-needle aspiration cytology samples of non-
diagnostic quality were significantly more frequently sampled with ultrasound guidance than
were FNAC samples of diagnostic quality ($P = 0.002$) (Figure 3). When compared to the overall
proportion of FNAC samples of non-diagnostic quality (65/259), the only anatomic site which
had a significantly higher proportion of FNAC samples of non-diagnostic quality was the
inguinal LN ($P < 0.001$). However, the majority of the inguinal LNs sampled were guided by
ultrasound (16/18) and were deemed not enlarged (12/18). The prevalence of
histopathologically-proven metastasis was 20.0% among the LNs with non-diagnostic FNAC,
and 35.5% among the LNs with diagnostic FNAC, and this was significantly different ($P = 0.021$) (Figure 4).

**Significance of multiple nodal metastases**

Among the 189 dogs with a tumor included in the study, 88 cases had at least 2 LNs histopathologically assessed for staging as these LNs were thought to possibly drain the primary mass/be involved in the disease process. The tumors types with multiple LNs assessed included 14 sarcomas, 20 carcinomas, 18 melanomas, 29 mast cell tumors, and 7 other round cell tumors. Eighty of these dogs had 2 LNs extirpated, 7 had 3 LNs extirpated, and 1 oral malignant melanoma-bearing dog had 4 LNs extirpated. Lymph nodes removed included those in the mandibular (132, including 64 bilateral and 4 unilateral extirpations), prescapular (13, including 3 bilateral and 7 unilateral extirpations), popliteal (2, unilateral extirpations), inguinal (11, including 5 bilateral and 1 unilateral extirpations), sublumbar (15, including 7 bilateral and 1 unilateral extirpations) and other regions (14). Compared to cases with solitary LNs assessed, among the cases with multiple LNs assessed, there was a lower proportion of popliteal and prescapular LNs, but a higher proportion of mandibular LNs ($P < 0.001$). This is in part explained by the frequent bilateral extirpation of mandibular LNs in cases bearing tumors located on the head in the authors’ service. The overall prevalence of metastasis was 38.6% (34/88) among the cases with multiple LNs assessed, and 34.7% (35/101) among the cases with only one LN assessed, which was not significantly different ($P = 0.650$). There was no significant difference in the enlargement status of the LNs whether cases had single or multiple LNs assessed ($P = 0.762$). Among the cases with multiple LNs assessed, the prevalence of having ≥2 metastatic LNs was 23.9% (21/88) while 14.8% (13/88) of tumors with multiple LNs assessed had evidence of metastasis in only one LN. Therefore, of those tumors with metastasis which had multiple LNs sampled, 61.8% (21/34) of cases had metastasis to multiple LNs. Tumors types metastasizing to multiple LNs were
carcinomas (n=10), mast cell tumors (n=6), oral malignant melanomas (n=4), and one sarcoma (Table 3).

Discussion

Lymph node enlargement status was significantly associated with tumor metastasis in our study. This was true for all the tumor groups included in our study with the exception of other round cell tumors, possibly because of a type II error. Nevertheless, the prevalence of metastasis among non-enlarged LNs was also substantial (15%). This finding is consistent with one of the two previous studies conducted specifically on malignant melanomas, in which the prevalence of metastasis among non-enlarged LNs was also 15%, but the rate was 40% in the other study.11

The overall specificity of FNAC for the detection of tumor metastasis found in our study (91%) was similar to that found in a previous study (91.5%), however, the overall sensitivity was superior in our study (81%) compared to the same previous study (66.6%).11 This could be explained by differentiating features of this previous study in which cytologic and histopathologic examinations were not always performed on the same LN, the time interval between cytologic and histopathologic examinations was up to 80 days, and cases of multicentric lymphoma were included.10 Nonetheless, our results concur that although of high value and practicality, LN histopathologic examination cannot always be reliably substituted with FNAC.

The relatively low sensitivity of FNAC for detecting metastatic sarcomas in LNs (67%), also reported in a previous study,10 could be related, at least in part, to the poorly exfoliative nature of sarcomas limiting the representativeness of FNAC.28 The relatively poor sensitivity of FNAC for detecting metastatic malignant melanomas in LNs (63%), has also been anecdotally reported before.27,29 In one study assessing the efficacy of systemic
adjuvant therapies in dogs with excised oral malignant melanoma, 41 dogs had both cytologic
and histopathologic examinations of at least one LN, and the sensitivity and specificity of
FNAC were 78.1% and 64.1% , respectively. The specificity found in our study was
superior (91%), but these results highlight the difficulty in differentiating melanophages from
melanocytes, which is a challenge for both cytologic and histopathologic examinations. The
American Joint Committee on Cancer (AJCC) published guidelines for the use of
immunohistochemistry in the evaluation of melanoma-draining sentinel LNs in human
oncology practice, to facilitate the distinction between melanocytes and histiocytes. The
identification of even single-cell metastasis in a sentinel LN is now considered sufficient to
categorize patients as having dissemination. With the increasing use of sensitive
techniques for the detection of melanoma metastasis (immunohistochemistry, PCR), the
challenge to accurately differentiate malignant from benign melanocytes has become even
more important. Although these challenges have not been as clearly researched in canine
oncology practice, routine histopathologic examination alone is likely to be a suboptimal gold
standard for canine melanoma nodal metastasis assessment. This has been highlighted in a
recent study, in which the diagnosis of LN melanoma metastasis was changed in 46.9% of
dogs upon second opinion histopathology review. This might also explain in part why
several studies failed to find a prognostic value of LN metastasis in dogs, while LN
metastatic status is of important prognostic value in human melanoma. The robustness of
assessment of the diagnostic utility of FNAC for the detection of melanoma nodal metastasis
would be enhanced by an optimal gold standard, based on the results of a future comparison
of histopathology, immunohistochemistry, PCR, and combinations thereof, incorporating
follow-up.

Although one study found a perfect agreement between cytologic and histopathologic
examination for the detection of mast cell tumor nodal metastasis, the relatively low
sensitivity (75%) found in our study is more consistent with that reported in another study (68.7%). Cytologically it is often very difficult to differentiate reactive from well differentiated neoplastic mast cells within LN aspirates. Clinical pathologists often rely on the presence of the overall numbers of mast cells, their aggregation, and/or morphologic abnormalities to make such a distinction. It is therefore often difficult to determine the metastatic status of LNs draining canine mast cell tumors either cytologically or histopathologically. Criteria have previously been proposed to standardize the definition of mast cell tumor nodal metastasis for both techniques. These criteria were not systematically applied in our study, which makes it difficult to comment meaningfully on the sensitivity and specificity obtained by using the proposed criteria. A prospective study with the systematic application of these criteria for cytologic and histopathologic examination, together with follow up, would be necessary for a more reliable evaluation of FNAC accuracy. It should also be underlined that in all 4 false-positive FNACs assessing mast cell tumor LN metastases, the clinical pathologist expressed some uncertainty regarding the metastatic status; and for only 1/8 false-negative such FNACs, was the corresponding histopathologic classification HN3 (overt metastasis). Furthermore, TB staining invalidated the diagnosis of LN metastasis made initially on routine histopathology in 1 case, and the systematic use of TB staining might alter the determined sensitivity and specificity of FNAC in the detection of mast cell tumor nodal metastasis. Non-diagnostic FNAC was reported in 25% of our cases. This is comparable to the results of another study (27.2%) although only 9.3% of the LNs sampled were for tumor staging purposes in that study. In another study, only 5.7% of the cytologic samples were deemed non-diagnostic, but again the study did not exclusively include LNs FNAC sampled for tumor staging as in the current study. The results of our study suggest that FNAC might be technically limited for non-enlarged and/or deep LNs for which a diagnostic-quality
sample might not be easily obtainable. Size of the LN is a recognized limiting factor of FNAC in human medicine, and it is often observed that LN < 5 mm are difficult to sample.\textsuperscript{16} Histopathologic assessment of local LNs when FNAC is not possible because of a LN’s inaccessible location or small size has been recommended by some authors.\textsuperscript{22} Our results support this recommendation, as when diagnostic samples could not be obtained by FNAC in such LNs, the prevalence of metastasis remained substantial on histopathology (20%).

In previous studies, LN examination for tumor staging was limited to a single LN.\textsuperscript{5, 8, 10, 26, 37} In our study, 46.5\% of the tumors had several LNs assessed for staging. The prevalence of metastasis within several LNs was 23.9\%, suggesting that staging should not always be limited to the assessment of a single LN. This is in agreement with the results obtained with routine extirpation of bilateral mandibular and medial retropharyngeal lymphadenectomy for staging of head-based tumours,\textsuperscript{38} and with the use of sentinel LNs.\textsuperscript{22, 23, 39, 40} It remains for further research to investigate whether such cases have a worse prognosis when compared to those cases with a solitary LN metastasis. However, such results are very likely significant from a therapeutic aspect, if the response to an additionally metastatic LN were to be the use of a local therapy modality (i.e. surgical extirpation and/or irradiation) rather than systemic therapy modalities that might already be triggered by even a solitary metastatic LN. In our study, most of the tumors that were investigated for several metastatic LNs were located in the head and involved mandibular LNs, or were anal sac adenocarcinomas involving sublumbar LNs, which is consistent with other studies.\textsuperscript{6, 38} Notably, we report the occurrence of bilateral prescapular LN involvement in 3 tumors (2 mast cell tumors on the midline neck and 1 thyroid carcinoma), and bilateral inguinal LN involvement in 1 scrotal mast cell tumor. As systematic bilateral assessment of local LNs have been recommended for head-based tumors,\textsuperscript{38} bilateral nodal assessment for other locations could be of value, although this requires further investigation.
This study had several limitations, most of them being the consequence of its retrospective design. Cytologic and histopathologic examination was performed by different pathologists all of whom were board certified, although the sections were not systematically reviewed for the purposes of the study, therefore contributing to an inter-observer variation. In particular, previously proposed cytologic and histopathologic criteria for the diagnosis of mast cell tumor metastasis were not systematically applied.\textsuperscript{25,26} Cytological findings in some cases do not allow a certain diagnosis to be reached but they can point to a suspicion that needs to be confirmed through other methods. However, for the purpose of the study, metastatic status was dichotomized into “metastatic” and “non-metastatic”. Because dogs were assessed by different clinicians, the recording of LN enlargement status was subject to inter-observer variation. However, we believe that this effect was minimal as a significant difference in the prevalence of metastasis was noted for each tumor subgroup, and this approach reflects clinical practice. There was a variable interval between cytologic and histopathologic assessments, which could have affected their agreement, although this was intentionally limited. However, there was no significant difference in the interval between FNAC and histopathologic assessments between the LNs with agreement and those with disagreement.

**Conclusions**

In our study FNAC appeared to be a reliable tool to detect metastatic carcinomas and round cell tumors in LNs. Conversely, the sensitivity of FNAC in the detection of nodal metastasis was relatively low for sarcomas, melanomas and mast cell tumors. Although FNAC remains a non-invasive and affordable test typically obviating general anesthesia, when a negative result is obtained in these tumors, additional histopathologic assessment should be recommended for more robust staging information. Non-diagnostic FNAC reports are frequently encountered (25%) when staging tumor-draining LNs, particularly when the
LNs sampled are non-enlarged and/or have a deep location. Further histopathologic examination should be recommended in these cases, as the risk of metastasis in the non-diagnostic LN aspirates was 20% in our study. Finally, metastasis to multiple LNs seems to be relatively frequent, making investigation of multiple LNs valuable diagnostically and therapeutically.

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References


**Table 1. Primary tumor types with corresponding number of LNs.**

<table>
<thead>
<tr>
<th>Tumor type</th>
<th>Number of LNs</th>
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<tbody>
<tr>
<td><strong>Sarcomas</strong></td>
<td>47</td>
</tr>
<tr>
<td>Osteosarcoma</td>
<td>17</td>
</tr>
<tr>
<td>Soft Tissue Sarcoma</td>
<td>10</td>
</tr>
<tr>
<td>Sarcoma (not specified)</td>
<td>10</td>
</tr>
<tr>
<td>Fibrosarcoma</td>
<td>7</td>
</tr>
<tr>
<td>Hemangiosarcoma</td>
<td>2</td>
</tr>
<tr>
<td>Chondrosarcoma</td>
<td>1</td>
</tr>
<tr>
<td><strong>Carcinomas</strong></td>
<td>46</td>
</tr>
<tr>
<td>Apocrine gland anal sac adenocarcinoma</td>
<td>16</td>
</tr>
<tr>
<td>Oral squamous cell carcinoma</td>
<td>11</td>
</tr>
<tr>
<td>Thyroid carcinoma</td>
<td>8</td>
</tr>
<tr>
<td>Salivary gland adenocarcinoma</td>
<td>3</td>
</tr>
<tr>
<td>Gingival basosquamous cell carcinoma</td>
<td>2</td>
</tr>
<tr>
<td>Sebocytic sebaceous carcinoma</td>
<td>2</td>
</tr>
<tr>
<td>Mammary carcinoma</td>
<td>1</td>
</tr>
<tr>
<td>Pulmonary carcinoma</td>
<td>1</td>
</tr>
<tr>
<td>Cutaneous carcinoma (not specified)</td>
<td>1</td>
</tr>
<tr>
<td>Hepatocellular carcinoma</td>
<td>1</td>
</tr>
<tr>
<td><strong>Malignant melanomas</strong></td>
<td>37</td>
</tr>
<tr>
<td>Oral</td>
<td>32</td>
</tr>
<tr>
<td>Cutaneous</td>
<td>5</td>
</tr>
<tr>
<td>Type of Tumor</td>
<td>Cases</td>
</tr>
<tr>
<td>--------------</td>
<td>-------</td>
</tr>
<tr>
<td>Mast cell tumors</td>
<td>110</td>
</tr>
<tr>
<td>Cutaneous</td>
<td>77</td>
</tr>
<tr>
<td>Subcutaneous</td>
<td>20</td>
</tr>
<tr>
<td>Mucosal</td>
<td>9</td>
</tr>
<tr>
<td>Muco-cutaneous</td>
<td>4</td>
</tr>
<tr>
<td>Other round cell tumors</td>
<td>19</td>
</tr>
<tr>
<td>Oral plasma cell tumor</td>
<td>10</td>
</tr>
<tr>
<td>Histiocytic sarcoma</td>
<td>6</td>
</tr>
<tr>
<td>Non-epitheliotropic T-cell lymphoma</td>
<td>3</td>
</tr>
</tbody>
</table>
Table 2. Sensitivity, specificity, positive and negative predictive values (and 95% confidence intervals) of LN FNAC in the detection of tumor metastasis.

<table>
<thead>
<tr>
<th>Tumor types</th>
<th>Sensitivity (95% CI)</th>
<th>Specificity (95% CI)</th>
<th>PPV (95% CI)</th>
<th>NPV (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sarcomas</td>
<td>67% (24-94%)</td>
<td>96% (80-99%)</td>
<td>80% (30-99%)</td>
<td>93% (76-99%)</td>
</tr>
<tr>
<td>Carcinomas</td>
<td>100% (82-100%)</td>
<td>83% (51-97%)</td>
<td>92% (72-99%)</td>
<td>100% (66-100%)</td>
</tr>
<tr>
<td>Malignant melanomas</td>
<td>63% (26-89%)</td>
<td>91% (69-98%)</td>
<td>71% (30-95%)</td>
<td>87% (65-97%)</td>
</tr>
<tr>
<td>Mast cell tumors</td>
<td>75% (57-88%)</td>
<td>91% (77-97%)</td>
<td>86% (76-95%)</td>
<td>84% (70-92%)</td>
</tr>
<tr>
<td>Other round cell tumors</td>
<td>100% (20-100%)</td>
<td>87% (58-97%)</td>
<td>50 (10-91%)</td>
<td>100% (72-100%)</td>
</tr>
</tbody>
</table>

PPV, positive predictive value; NPV, negative predictive value; CI, confidence interval
Table 3. Data regarding the tumors with several metastatic LNs.

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Primary tumor</th>
<th>Location</th>
<th>Tumor type</th>
<th>Location</th>
<th>Lateralization</th>
<th>Enlargement</th>
<th>Metastasis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Apocrine gland anal sac adenocarcinoma</td>
<td>Anal sac</td>
<td>R</td>
<td>Medial iliac</td>
<td>R</td>
<td>3</td>
<td>Y</td>
</tr>
<tr>
<td>2</td>
<td>Apocrine gland anal sac adenocarcinoma</td>
<td>Anal sac</td>
<td>R</td>
<td>Medial iliac</td>
<td>R</td>
<td>3</td>
<td>Y</td>
</tr>
<tr>
<td>3</td>
<td>Apocrine gland anal sac adenocarcinoma</td>
<td>Anal sac</td>
<td>L</td>
<td>Medial iliac</td>
<td>L</td>
<td>3</td>
<td>Y</td>
</tr>
<tr>
<td>4</td>
<td>Apocrine gland anal sac adenocarcinoma</td>
<td>Anal sac</td>
<td>R</td>
<td>Medial iliac</td>
<td>R</td>
<td>3</td>
<td>Y</td>
</tr>
<tr>
<td>5</td>
<td>Apocrine gland anal sac adenocarcinoma</td>
<td>Anal sac</td>
<td>L</td>
<td>Medial iliac</td>
<td>L</td>
<td>3</td>
<td>Y</td>
</tr>
<tr>
<td>6</td>
<td>Apocrine gland anal sac adenocarcinoma</td>
<td>Anal sac</td>
<td>R</td>
<td>Medial iliac</td>
<td>R</td>
<td>3</td>
<td>Y</td>
</tr>
<tr>
<td>7</td>
<td>Thyroid carcinoma</td>
<td>Thyroid gland</td>
<td>R</td>
<td>Mandibular</td>
<td>R</td>
<td>2</td>
<td>Y</td>
</tr>
<tr>
<td>8</td>
<td>Thyroid carcinoma</td>
<td>Thyroid gland</td>
<td>L</td>
<td>Mandibular</td>
<td>R</td>
<td>2</td>
<td>Y</td>
</tr>
<tr>
<td>9</td>
<td>Squamous cell carcinoma</td>
<td>Tonsil</td>
<td>L</td>
<td>Mandibular</td>
<td>L</td>
<td>3</td>
<td>Y</td>
</tr>
<tr>
<td>10</td>
<td>Salivary gland adenocarcinoma</td>
<td>Parotid salivary gland</td>
<td>R</td>
<td>Parotid</td>
<td>R</td>
<td>0</td>
<td>Y</td>
</tr>
<tr>
<td>11</td>
<td>Malignant melanoma</td>
<td>Maxilla</td>
<td>L</td>
<td>Mandibular</td>
<td>L</td>
<td>2</td>
<td>Y</td>
</tr>
<tr>
<td>12</td>
<td>Malignant melanoma</td>
<td>Maxilla</td>
<td>R</td>
<td>Mandibular</td>
<td>R</td>
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<td>Y</td>
</tr>
<tr>
<td>13</td>
<td>Malignant melanoma</td>
<td>Maxilla</td>
<td>L</td>
<td>Mandibular</td>
<td>L</td>
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</tr>
<tr>
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<td>Malignant melanoma</td>
<td>Mandible</td>
<td>R</td>
<td>Mandibular</td>
<td>R</td>
<td>0</td>
<td>Y</td>
</tr>
<tr>
<td>15</td>
<td>Mast cell tumor (mucosal)</td>
<td>Upper lip</td>
<td>L</td>
<td>Mandibular</td>
<td>L</td>
<td>2</td>
<td>Y</td>
</tr>
<tr>
<td>16</td>
<td>Mast cell tumor (cutaneous)</td>
<td>Lower eyelid</td>
<td>L</td>
<td>Mandibular</td>
<td>L</td>
<td>3</td>
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</tr>
<tr>
<td>17</td>
<td>Mast cell tumor (cutaneous)</td>
<td>Scrotum</td>
<td>M</td>
<td>Inguinal</td>
<td>L</td>
<td>0</td>
<td>Y</td>
</tr>
<tr>
<td>18</td>
<td>Mast cell tumor (cutaneous)</td>
<td>Carpus</td>
<td>L</td>
<td>Prescapular</td>
<td>L</td>
<td>3</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>Lateralization</td>
<td>Enlargement</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>---</td>
<td>----------------</td>
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<td></td>
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</tr>
<tr>
<td>19</td>
<td>Mast cell tumor (cutaneous)</td>
<td>Axillary</td>
<td>L</td>
<td>3</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ventral neck</td>
<td>Prescapular</td>
<td>L</td>
<td>1</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Prescapular</td>
<td>Prescapular</td>
<td>R</td>
<td>0</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Mast cell tumor (cutaneous)</td>
<td>Chest</td>
<td>M</td>
<td>Prescapular</td>
<td>L</td>
<td>2</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prescapular</td>
<td>R</td>
<td>2</td>
<td>Y</td>
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</tr>
<tr>
<td>21</td>
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<td>Nasal cavity</td>
<td>R</td>
<td>Mandibular</td>
<td>R</td>
<td>2</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mandibular</td>
<td>L</td>
<td>2</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Lateralization was classified as left (L), right (R) or midline (M). Enlargement was classified as none (0), mild (1), moderate (2), or marked (3).
Figure captions

Figure 1. Prevalence of metastasis stratified by LN enlargement.

The error bars represent 95% confidence intervals.

Figure 2. Lymph node enlargement among non-diagnostic and diagnostic cytology samples.

The error bars represent 95% confidence intervals.

Figure 3. Proportion of FNAC performed via ultrasound-guidance among non-diagnostic and diagnostic FNAC samples.

The error bars represent 95% confidence intervals.

Figure 4. Prevalence of metastasis among the LNs with non-diagnostic and diagnostic FNAC samples.

The error bars represent 95% confidence intervals.