ORIGINAL RESEARCH

Findings at presentation in primary CNS diffuse large B-cell lymphoma of the brain: A comparison of immunocompetent and immunodeficient patients

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Abstract

Background/Objectives: Primary central nervous system lymphoma (PCNSL) is a rare tumour with poor prognosis. Due to the increased number of patients with PCNSL over the past two decades our purpose are to describe magnetic resonance imaging (MRI) and Computed Tomography (CT) findings in (PCNSL) of the brain, and to study the differences between immunocompetent and immunodeficient patients with PCNSL.

Methods: A retrospective, descriptive study was performed with 59 patients diagnosed of PCNSL in two hospitals from 1997 to 2010. Immunocompetent (n=38) and immunodeficient (n=21) patients were compared and differences between both groups were analyzed. Patients were evaluated according to sex, age, median time from clinical symptoms presentation to pathologic diagnosis, clinical symptoms, location, number of lesions, size, MRI and CT characteristics. Significance was defined as $p < 0.05$.

Results: MRI findings: 50% of lesions in immunocompetent and 52.4% in immunodeficient group were heterogeneous, 89.5% of lesions in immunocompetent and 85,7% in immunodeficient were hypo-isointense on T1WI; 63.2% of lesions in immunocompetent and 76.2% in immunodeficient group were hyperintense on T2WI. CT images: 48.39% of lesions in immunocompetent and 20% in immunodeficient group were hyperdense. Statistically significant differences between immunocompetent and immunodeficient patients were found when evaluating the age ($p < 0.000$) and median time from clinical symptoms presentation to pathologic diagnosis ($p < 0.008$).

Conclusions: MRI and CT are able to define imaging characteristics of PCNSL, promoting a quick diagnosis. There are no significant differences between immunocompetent and immunodeficient patients for MR and CT features.

Key words

Lymphoma, Brain, Immunocompromised host, Neuroimaging, Magnetic Resonance Imaging, Computed Tomography

1 Introduction

Primary central nervous system lymphoma (PCNSL), a rare form of extranodal non-Hodgkin's lymphoma, occurs in the brain, leptomeninges, spinal cord or eyes, in the absence of systemic lymphoma at the time of diagnosis. PCNSLs are

diffuse large B-cell lymphomas in the majority of cases [1], constituting approximately 3%-5% of all malignant tumors of the central nervous system (CNS), 1% of non-Hodgkin's lymphomas in immunocompetent patients and up to 17%–42% of all acquired immunodeficiency syndrome (AIDS)-related lymphomas [2]. The incidence of PCNSL in Western countries is five per one million person-years [3]. After a continual increase over the past two decades, epidemiologic data suggest a recent stabilization or decrease in the incidence of PCNSL [1], particularly among young patients suffering from AIDS, probably associated with the development of new active antiviral drugs. In contrast, the incidence of PCNSL remains high among older adults who are mostly immunocompetent [4], in patients with inherited immunodeficiencies and in those with an acquired immunodeficiency, such as transplantation and oncology patients [2].

The pathogenesis of PCNSL is obscure. The peak incidence is in the sixth decade [5] and primarily affects men [6-8]. The clinical presentation is variable. Early diagnosis of PCNSL is crucial for proper management in both immunocompetent and immunocompromised individuals. A visible tumor on imaging is essential for suspicion of CNS lymphoma, which can then lead to early histologic diagnosis. Contrast-enhanced cranial magnetic resonance imaging (MRI) is the imaging modality of choice in evaluating a patient with suspected PCNSL. If MRI is not possible or is contraindicated, a contrast-enhanced cranial computed tomography (CT) scan is recommended.

PCNSL has a poor prognosis in immunocompetent as well as in immunocompromised patients, although in recent years, highly active antiretroviral therapy and the increasing use of chemoradiotherapy have significantly increased survival of human immunodeficiency virus (HIV)-positive patients. The optimal treatment for PCNSL in both immunocompetent and immunodeficient patients has not been determined. The most common approach has been to use agents such as methotrexate and cytarabine. However, owing to the high frequency of Epstein-Barr virus infection in HIV patients, antiviral therapy-based regimens have been applied. Prior to these advances in therapy, the median survival without treatment was only 1.8–3.3 months from the time of diagnosis [4]. In comparison, patients treated more recently have a longer median survival (30 months) [5]. Although the prognosis remains poor for the majority of patients, approximately 20%–30% of cases are cured [3].

Owing to the rarity of PCNSL, the disease has been challenging to study. The purpose of this study is to describe clinical, MRI and CT findings in primary CNS diffuse large B-cell lymphoma of the brain, and to study the differences between immunocompetent and immunodeficient patients with PCNSL. Our patient pool consisted of all patients diagnosed over the last 13 years in two neurological, neurosurgery and oncology reference hospitals in northwestern our country. We sought to identify the distinctive imaging features at presentation of PCNSL that may allow for quick and accurate differential diagnosis, particularly as the therapeutic management of these two groups vary.

2 Patients and methods

The archives of two University Hospitals (from January 1, 1997, to December 31, 2010), with a reference population of approximately 835 000 patients, were retrospectively examined for clinical and demographic data, including MRI and CT examinations, on patients with histologically proven diffuse large B-cell PCNSL of the brain. Only patients with MRI examinations were included. Fifty-nine patients fulfilled the inclusion criteria (38 immunocompetent and 21 immunodeficient).

All our patients were evaluated according to the following: gender; age; median time from presentation of clinical symptoms to pathologic diagnosis; clinical symptoms at presentation; lesion location: right, central or left hemisphere, frontal lobe, parietal lobe, temporal lobe, occipital lobe, cerebellum or deep structures (including intraventricular, corpus callosum, basal ganglia and brainstem); number of lesions: 1, 2, 3, 4 or $\geqslant$ 5; MRI features (we studied the lesion that was susceptible for biopsy in the case of multifocal lesions): general MRI pattern (homogeneous or heterogeneous), necrotic appearance (necrosis was defined as an area within a contrast-enhancing lesion that lacked enhancement, but produced a hyperintense signal on T2-weighted images (WI)), hemorrhage (hemorrhage was defined as an area that appeared

hyperintense on both T1WI and T2WI), size (measured on contrast-enhanced T1WI), boundaries (poorly defined or precise), signal intensity (relative to gray matter) on T1WI and T2WI, enhancement characteristics (predominantly homogeneous/heterogeneous and presence of ringlike enhancement), diffusion-weighted image (DWI) and MR spectroscopy features, edema (was rated as extensive if it exceeded the contrast-enhancing lesion in size, as moderate if it was > 25% – 100% lesion size and as mild if it was ≤ 25% lesion size), mass effect (absence, mild when there was no significant impact and marked if it had important consequences such as displacement of midline structures, secondary hydrocephalus or cerebral herniation), dural and osseous involvement; CT features: general pattern (homogeneous or heterogeneous), attenuation of lesions (relative to gray matter) and enhancement characteristics (predominantly homogeneous/heterogeneous and presence of ringlike enhancement). Immunocompetent and immunodeficient patients were compared and differences between these groups were analyzed.

MRI imaging was performed at 1.5 T field strength. All our patients were imaged with T2WI, T1WI and contrast-enhanced T1WI (obtained after intravenous administration of 0.1 mmol/kg gadodiamide or gadoteric acid). Owing to the multicenter nature of the study, sequences varied slightly in repetition time (TR) and echo time (TE). Additionally, axial contrast-enhanced images were obtained for 36 patients (after injecting a volume of 100 ml at a rate of 2 ml/s). The more recent studies included DWI (twelve patients) with maps of the apparent diffusion coefficient (ADC) (nine patients) and single-voxel MR spectroscopy (four patients) in which the major metabolites N-acetylaspartate (NAA), creatine (Cr), choline (Cho), myo-inositol (mI), lactate (Lac), as well as lipids/macromolecules (Lip/MM), were evaluated.

CT imaging was performed using scanners with 2 (1997-2002), 16 (2002-2006) and 64 detectors (2006-2011). CT scans were performed on 46 patients with 5-mm-thick axial plain scan images.

One neuroradiologist and two general radiologists evaluated the imaging studies independently. We performed a descriptive analysis of all variables recorded for immunocompetent and immunodeficient patients. The chi-square test was used to evaluate differences between qualitative variables. The association between quantitative and qualitative variables was assessed using Student's t-test or ANOVA (Mann-Whitney or Kruskal-Wallis for non-parametric comparisons). Statistical analyses were performed using a software package, SPSS17 for Windows. Significance was defined as $p < 0.05$.

The Regional Committee for Medical Research Ethics approved this retrospective study and waived informed consent.

3 Results

The 59 patients were classified into two groups: immunocompetent (n=38, 64.4%) and immunodeficient (n = 21, 35.6%).

3.1 Immunocompetent patients

The immunocompetent group was composed of 38 patients (21 men [55.3%] and 17 women [44.7%]) with a mean age of 63.21 ± 13.58 years (range 15–84 years). The median time from presentation of clinical symptoms to pathologic diagnosis was 52.34 ± 47.18 d (range 6–196 d).

The most frequent clinical signs at the time of presentation were ataxia in 15 patients (39.5%), aphasia in 13 patients (22%), headache and hemiparesis/hemiplegia in 10 patients (26.3%) and disorientation in 9 patients (23.7%). Less frequent were constitutional syndrome (5 patients/13.2%), epileptic seizures, decreased awareness (4 patients/10.5%) and behavioral problems (3 patients/7.9%).

The majority of patients had supratentorial lesions (94.7%, n = 36), and the posterior fossa was involved in 34.2% (n = 13). In the immunocompetent group, the lesions were located mainly in deep structures (68.4%, n = 26), the frontal lobe (28.9%, n = 11) and the parietal lobe (26.3%, n = 10) (see Table 1). Lesions were located in the right hemisphere in 55.2% (n = 21), in the left hemisphere in 68.4% (n = 26), and there was central involvement in 52.6% (n = 20) of patients.

In immunocompetent patients with PCNSL, lesions were solitary in 42.1% (n = 16). The number of lesions varied, and the mean number of lesions was 2.03 ± 1.42 (range 1–5). The mean size of all lesions at the time of diagnosis was 2.97 ± 1.14cm (range 1cm-5.6cm).

Table 1. Lesion location in immunocompetent and immunodeficient patients
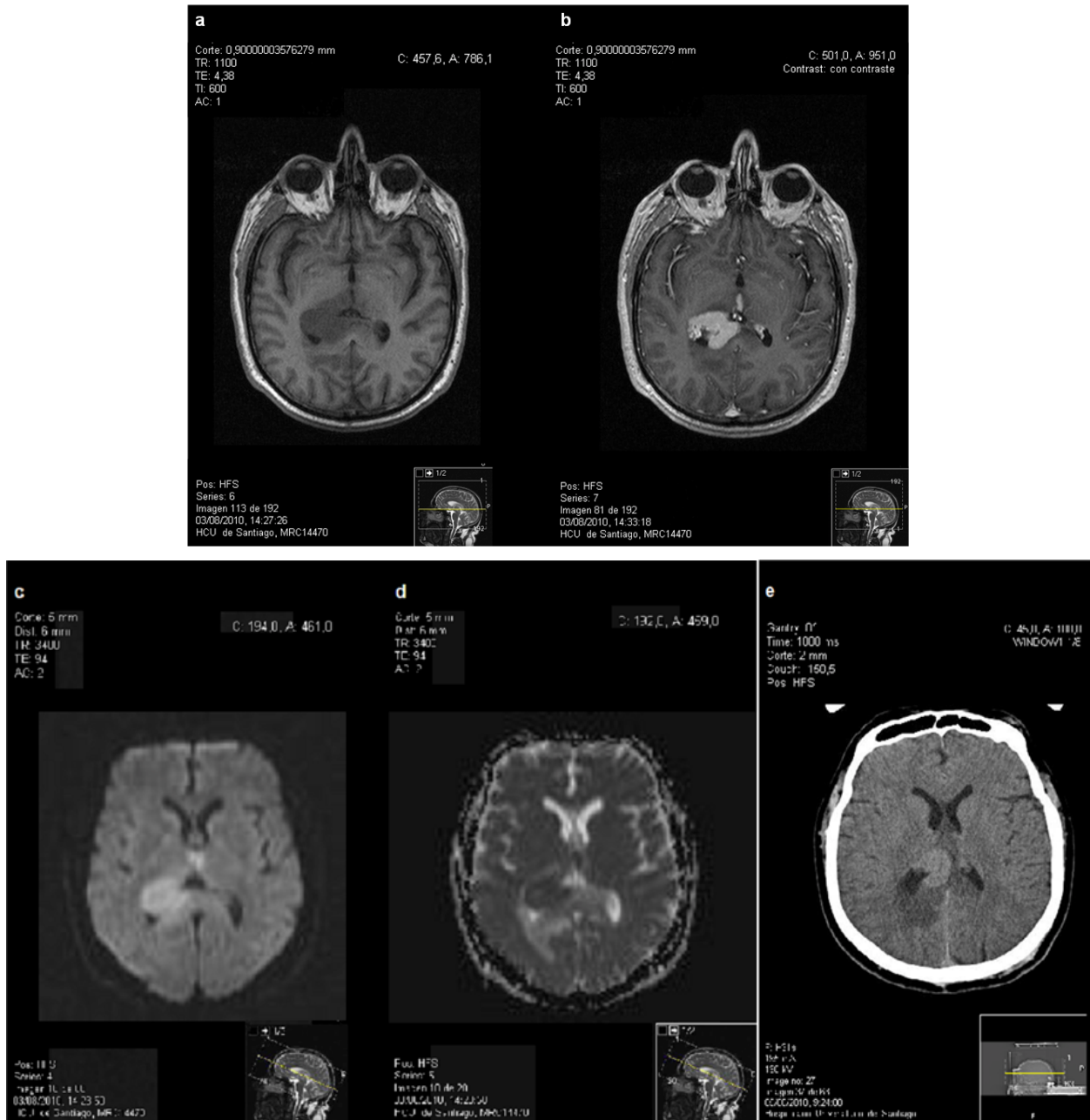
Location	Immunocompetent patients (%)	Immunodeficient patients (%)
Frontal lobe	11 (28,9)	10 (47,6)
Parietal lobe	10 (26,3)	10 (47,6)
Temporal lobe	6 (15,8)	3 (14,3)
Occipital lobe	4 (10,5)	2 (9,5)
Basal ganglia	19 (50)	8 (38,1)
Corpus Callosum	11 (28,9)	5 (23,8)
Intraventricular	3 (7,9)	3 (14,3)
Cerebellum	8 (21,1)	3 (14,3)
Brain Stem	7 (18,4)	4 (19)
Right	21 (55,2)	9 (42,9)
Central	20 (52,6)	8 (38,1)
Left	26 (68,4)	17 (81)

MRI findings (see Figure 1a-d) showed that the lesions were heterogeneous in half of the immunocompetent patients (n = 19). Necrosis was seen in 13.2% (n = 5) and hemorrhagic degeneration was present in 18.4% (n = 7). In half of the lesions (n = 19), the boundaries were poorly defined. On T1WI sequences, most lesions appeared to be hypo or isointense 89.50% (n = 34) (see Figure 2a). The signal intensity of the lesions on T2-WI was frequently hyperintense 63.2% (n = 24) (see Figure 2b). Following injection of the contrast agent, all lesions showed enhancement. Contrast enhancement was strong in 84.2% (n = 32) and mild in 15.8% (n = 6) of patients. Enhancement was homogeneous in 52.6% (n = 20), heterogeneous in 34.2% (n = 13) and ring-like in 13.2% (n = 5) of patients (see Table 2). Perilesional edema was present in 92.1% (n = 35), extensive edema was seen in 23.7% (n = 9), moderate edema in 39.5% (n = 15) and mild edema in 28.9% (n = 11) of patients. A mass effect was seen in 81.6% (n = 31), a marked mass effect in 23.7% (n = 9) and a mild mass effect in 57.9% (n = 22) of patients. Dural involvement was found in 10.5% (n = 4) of patients. No patient showed bone involvement. Of the nine patients with DWI sequences, 6 patients (66.6%) had restricted diffusion with a low ADC, whereas the remaining 3 patients (33.3%) had lesions that did not restrict (with high ADC in 1 patient [we do not have ADC maps for the 2 other patients]). Single-voxel MR spectroscopy (4 patients) showed high lactate/lipid and Cho peaks, and a diminished NAA peak in 100% of patients. The mI peak was high in 50% (n = 2) of patients and reduced in the other 50% (n = 2).

Table 2. MRI enhancement characteristics in immunocompetent and immunodeficient patients.

		Immunocompetent patients (%)	Immunodeficient patients (%)
Pattern	Homogeneous	20 (52.6)	7 (33.3)
	Heterogeneous	13 (34.2)	7 (33.3)
	Ring-like	5 (13.2)	6 (28.6)
	No enhancement	0 (0)	1 (4.8)
Grade	Mild	6 (15.8)	3 (14.3)
	Strong	32 (84.2)	17 (81)

Thirty-one patients (71.4%) underwent CT imaging. Among these patients, 29% (n = 9) of lesions appeared hypodense compared with the gray matter, 22.58% (n = 7) were isodense and 48.39% (n = 15) appeared hyperdense (see Figure 1e). Enhanced CT scans were available for 24 of the 31 patients. All 24 of these subjects showed lesion enhancement, with a marked enhancement in 79.2% (n = 19) and a mild enhancement in 20.8% (n = 5). Homogeneous enhancement was found in 54.2% (n = 13), heterogeneous enhancement was seen in 33.3% (n = 8) and ring enhancement was observed in 12.5% (n = 3) of these 24 immunocompetent patients.
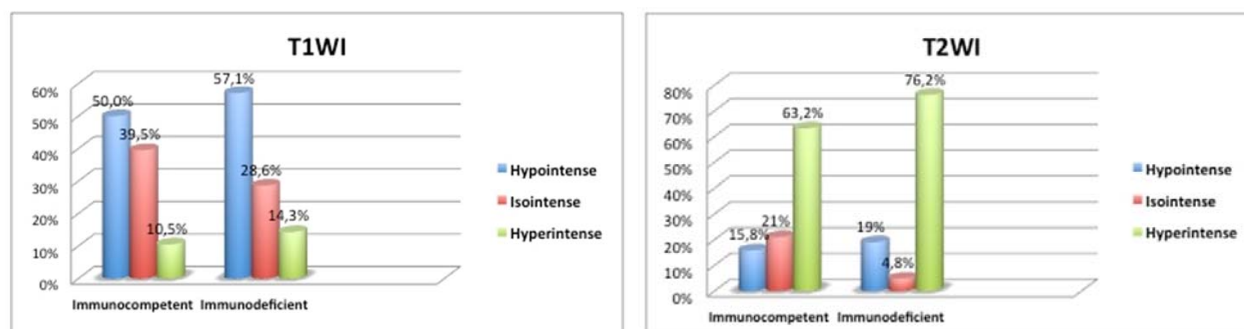
Figure 1. Images of common features of PCLNS in immunocompetent patients. A 64-year-old patient with multifocal PCLNS with peri/intraventricular and corpus callosum involvement. Note the hypointense lesion on a T1-WI (a) with strong and homogeneous enhancement on post-contrast axial T1WI (b), and a hyperdense lesion on plain CT image (e). DWI reveals restricted diffusion within the tumor with high signal intensity on DWI (c) and a corresponding low signal intensity on the ADC map (d).

3.2 Immunodeficient patients

Twenty-one patients (13 men and 8 women) were immunodeficient. Eleven were individuals with HIV infection. The remaining 10 had other etiologies; immunosuppressive therapy post-transplantation (4 patients), oncology patients with other primary tumor (4 patients), or immunosuppressive therapy for other reasons (1 patient with rheumatoid arthritis, 1 patient with hepatitis B virus infection). The mean age was 45.75 ± 17.71 years (range 7–78). The median time from presentation of clinical symptoms to pathologic diagnosis was 29.29 ± 14.39 d (range 8–60d). The most frequent clinical

signs at the time of presentation in immunodeficient patients were hemiparesis/hemiplegia in 7 patients (33.3%), headache in 6 patients (28.6%) and ataxia in 4 patients (19.0%). Less frequent were aphasia and epileptic seizures in 3 patients (14.3%).

Figure 2. T1WI and T2WI characteristics. Bar graphs show the features of the lesions on T1WI (a) and T2WI (b) in immunocompetent and immunodeficient patients.

Eighteen patients (85.7%) had supratentorial lesions, with the posterior fossa involved in 7 patients (33.3%). The lesions involved principally the frontal lobe (47.6%, n = 10), parietal lobe (47.6%, n = 10) and deep structures (47.6%, n = 10) (see Table 1). Lesions were located predominantly in the left hemisphere (81%, n = 17). A single lesion was found in 61.9% (n = 13) of patients. The mean number of lesions was 1.90 ± 1.45 (range 1–5). The mean size of all lesions at the time of diagnosis was 3.18 ± 1.29 cm (range 1.6–5cm).

MRI findings (see Figure 3a-c) revealed that the lesions were heterogeneous in 52.4% (n = 11) of patients. Necrosis was seen in 23.8% (n = 5) and hemorrhagic degeneration in 23.8% (n = 5). The lesions had clear borders in 57.1% (n = 12) of patients. Most of the lesions appeared to be hypo-isointense (85.7%, n = 18) on T1WI and hyperintense 76.2% (n = 16) on T2WI sequences (see Figure 2a, b). Only one lesion did not show enhancement. Contrast enhancement was strong in 81% (n = 17) and mild in 14.3% (n = 3) of patients. Enhancement was homogeneous in 33.3% (n = 7), heterogeneous in 33.3% (n = 7) and ring-like in 28.6% (n = 6) (see Table 2). Extensive edema was seen in 47.6% (n = 10), moderate edema in 23.8% (n = 5), mild edema in 23.8% (n = 5) and no edema in one patient (4.76%). A mass effect was seen in 81% (n = 17). Of these, a marked mass effect was seen in 28.6% (n = 6), and 52.4% (n = 11) had a mild mass effect. Dural involvement was found in 14.3% (n = 3) of immunodeficient patients. No patient showed bone involvement. DWI sequences were available for 3 patients. Among these, one patient (33.3%) had a restricting lesion with a low ADC, and the remaining 2 patients (66.6%) had lesions that did not restrict (1 patient had a high ADC, while ADC data were not available for the remaining patient). MR spectroscopy was not performed on the immunodeficient patients.
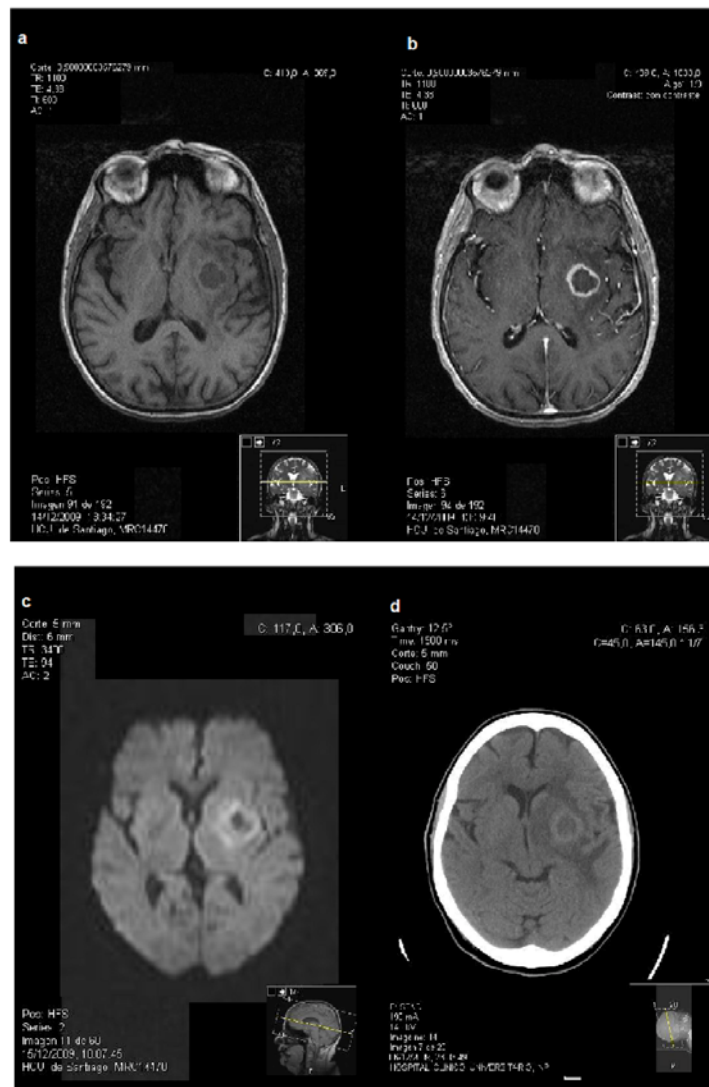
Fifteen patients (81.58%) underwent CT scans (see Figure 3d). Among these, 60% (n = 9) of lesions appeared hypodense, 20% (n = 3) were isodense and 20% (n = 3) appeared hyperdense. Enhanced CT scans were available for 12 patients, and all but one of these patients showed lesion enhancement. Marked enhancement was seen in 90.90% (n = 10) and mild enhancement in 9.09% (n = 1). Homogeneous enhancement was found in 63.63% (n = 7), heterogeneous enhancement in 9.09% (n = 1) and ring enhancement in 27.27% (n = 3).

3.3 Statistical analysis

Patients in the immunodeficient group were significantly younger than patients in the immunocompetent group ($p < 0.000$), and immunocompetent patients had a significantly longer interval between clinical presentation and pathologic diagnosis ($p < 0.008$).

There were no significant differences between immunocompetent and immunodeficient groups for the following: gender ($p = 0.621$), clinical sym*p*toms, supratentorial ($p = 0.337$) or posterior fossa location ($p = 0.946$), location in a lobe or deep

structures ($p = 0.117$), hemisphere location, monofocal lesions ($p = 0.764$), number of lesions ($p = 0.734$), uniform ($p = 0.861$), necrotic ($p = 0.077$) or hemorrhagic ($p = 0.807$) degeneration, size ($p = 0.548$), boundary features ($p = 0.599$), signal intensity on T1WI ($p = 0.712$) or T2WI ($p = 0.190$), behavior on DWI ($p = 0.454$), enhancement features on MRI (presence: $p = 0.356$; degree: $p = 0.937$ and morphology: $p = 0.242$), edema (presence: $p = 1.000$; degree: $p = 0.294$), mass effect (presence: $p = 0.953$; degree: $p = 0.654$), dural involvement ($p = 0.691$), density on CT ($p = 0.157$), or enhancement features on CT (presence: $p = 0.333$; degree: $p = 0.251$ and morphology: $p = 0.189$). There was a significant association between MRI and CT enhancement characteristics ($p < 0.000$).

Figure 3. Images of common features of PCLNS in immunodeficient patients. A 73-year-old patient with lymphoma in the left basal ganglia, including axial T1WI (a), postcontrast axial T1WI (b), DWI (c) and plain CT image (d). Note a hypointense (a) and hypoattenuated (d) lesion with ring enhancement (b). No restricted diffusion in the central lesion is revealed (c). Pathology confirmed a PCNSL necrotic lesion.

4 Discussion

We found a significant difference with regard to age. Patients from the immunodeficient group were significantly younger (by almost two decades). This was also observed by others [8]. The pathology is likely to develop earlier and faster when

the immune system is compromised. The appearance of PCNSL is more common in males, as reported in other studies [2, 6-8]. We found this bias to be especially marked in the immunodeficient group.

In our present study, the time between the onset of symptoms and diagnosis was less than half of that reported in some other studies [6, 7, 9, 10]. The interval was almost twice as long in immunocompetent patients when we compared the two groups. This might reflect rapid medical intervention in immunosuppressed patients, which illustrates the importance of a good, integrated and coordinated multidisciplinary health system (emergency medicine, neurology, neurosurgery, radiology, pathology, etc.).

The clinical presentation was very diverse, but similar in both groups. The most frequent symptoms at presentation were headache, hemiparesis/hemiplegia and ataxia. These symptoms were similar to those described by others [7]. Seizures were less commonly observed than with other types of brain tumors, probably because PCNSL involves predominantly subcortical white matter and deep locations rather than epileptogenic gray matter [1].

Generally, lymphomas preferentially involve deep parenchyma, especially the basal ganglia [2, 6]. In fact, in our study, more than half of the lesions were located in deep structures. Most of the lesions were supratentorial, which agrees with the existing literature [4, 9, 12, 13], and predominantly affecting the frontal and parietal lobes (especially in immunodeficient patients). The posterior fossa has been reported to be a rare site for tumors in the literature [9, 12]. However, in our study, we found lesions in the posterior fossa in up to a third of the patients. Perhaps this discrepancy results from difficulty in adequately visualizing the posterior fossa in CT scans in some of the previous studies we reviewed. In our present study, all the patients were also examined with MRI.

Lesions were generally located in the left hemisphere, perhaps because this hemisphere is usually more active. We found no studies that thoroughly describe the location as either right, left or central. The mean number of lesions was approximately 2 per patient, which is similar to the numbers cited in a previous study [13]. The literature indicates that more than half of patients have only a single lesion [1, 9, 14, 15], as was the case in our study, although a high rate of multiple lesions was found in immunodeficient patients in previous studies [4, 9, 16-18]. In striking contrast, our group of immunocompromised patients had an even greater chance of having a single lesion than the immunocompetent patients, a finding that could help us in differentiating PCNLS from toxoplasmosis in immunodeficient patients (particularly for HIV-positive patients), which is usually multifocal [19]. The size of lesions in both groups was similar. The average lesion size in our present study was greater than that found in a previous study [20]. This could be explained by the fact that, for cases with multifocal lesions, we measured the lesion that was most amenable to biopsy, which in some cases corresponded to the largest lesion.

4.1 MRI features

The two groups did not differ substantially in terms of homogeneity. Hemorrhagic and necrotic-cystic degeneration were uncommon in untreated lesions in previous studies [2, 6, 9, 20]. However, in our present study, we had numerous cases with these types of degeneration, being seen in almost half of the immunodeficient patients, although the lesions were not greater in size, as might be suspected. Given that these findings are not the most characteristic, we must include in the differential diagnosis (especially in immunocompetent patients) glioblastoma or metastases that often bleed or are necrotic.

There is controversy as to the definition of the borders. Some authors describe the majority of lesions as having well-defined borders [12], while others report poorly-defined borders in immunocompetent patients [21]. In our study, we did not observe clear differences in boundary characteristics between the two groups.

As with other studies [2, 6, 9, 12, 22], on T1WI, we found that the lesions were mostly hypointense or isointense, without evidence of striking differences between the two groups. With respect to T2WI, most lesions were hyperintense, in

contrast to the results cited by some authors [23], in which the lesions were mostly iso-hypointense, but in agreement with multiple other studies [9, 12, 22, 24]. Our result may have been influenced by the high percentage of necrosis in our study.

Following contrast agent injection, we observed an intense enhancement in the vast majority of patients in our study (indicating disruption of the blood-brain barrier, which is a reflection of the aggressiveness of this type of tumor). This was also found in other studies, where only 10% of untreated lesions were unenhanced [2] (1% in immunocompetent patients [9, 25]). This percentage increases for post-transplant immunodeficient patients [26]. Progressive multifocal leukoence-phalopathy should be included in differential diagnosis, mainly in immunodeficient patients, when there is white matter T2 hyperintensity without enhancement [19].

With regard to the pattern of enhancement, in our study, as in previous studies [6, 8, 27, 28], we observed a predominance of homogeneous enhancement in the immunocompetent group. A clear predilection existed in the immunodeficient patients for heterogeneous enhancement (accounting for heterogeneous enhancement and ring enhancement together). This finding is consistent with that of numerous other reports [1, 8, 12, 16, 29].

Diffusion within the tumor is considered a surrogate marker of tumor cellularity, and water diffusion is often restricted in PLCNSLs because they are highly cellular tumors [11]. In our study, we did not observe a clear tendency in DWI, although in immunocompetent patients, twice as many lesions were restricted than in immunodeficient patients (perhaps due to the high percentage of necrosis). This is similar to some other studies showing high rates of restricted diffusion in immunocompetent patients [30]. We must consider, especially in immunodeficient patients, that in lesions with peripheral enhancement and central necrosis, abscesses should be included in the differential diagnosis, as they have a typical restricted pattern in DWI [19].

Although in some studies, mass effect and edema were recorded as infrequent findings [9, 17], in more recent publications, edema was frequently observed, and was generally mild [29] or moderate [24]. That it is rare to find serious edema is due to the infiltrative nature of the tumor [6], which also engenders a slight mass effect. According to recent studies, more than half of patients in both groups have lesions with a mass effect, and an even greater percentage have perilesional edema, which is especially marked in immunodeficient patients.

Only a small percentage of our patients showed dural involvement. This finding is consistent with the literature [2, 9, 12]. Nevertheless, we must take into consideration the fact that there is a clear disagreement between radiological results and those obtained with lumbar puncture [9] (which is considered the most reliable indicator of leptomeningeal involve-ment [31]). Only a small percentage of lumbar puncture-diagnosed meningeal involvement is confirmed radiologically [32]. Therefore, the exclusion of leptomeningeal seeding from the PCNSL is not possible with imaging methods alone. CSF analysis by lumbar puncture remains indispensable [20].

4.2 CT features
We observed differences in the density of the lesions (although not statistically significant). Half of the immunocompetent patients' lesions were hyperdense, in line with the literature [9, 24]. In contrast, in the majority of the immunodeficient patients, the lesions were hypodense. The absence of enhancement is very rare [9]; in our studies only one patient did not show enhancement of the lesion. The vast majority of lesions tend to enhance homogeneously and intensely, although heterogeneous enhancement is more frequent in immunodeficient patients.

This study is limited by the drawbacks inherent to retrospective observational studies of case histories. In addition to potential information and selection bias, the sample size was small (rare disease), and there were typical problems arising in the collection of data from medical records. However, we do not believe that the results were significantly affected by the use of different CT scanners, because attenuation values (relative to gray matter) and enhancement characteristics did not significantly vary.

5 Conclusion

PCNSL is associated with a large spectrum of radiological findings, and its presentation can be similar to that of inflammatory diseases, infectious diseases or other brain tumors [19]. Increasingly, the role of MRI is not limited to demonstrating the anatomical details of the lesion. Currently, newer advanced imaging techniques, such as DWI, perfusion MRI, perfusion CT, MR spectroscopy, positron emission tomography (PET) and single photon emission computed (SPECT) metabolic imaging, may potentially aid in the differentiation of CNS lymphoma from other brain lesions [33].

There were no significant differences between immunocompetent and immunodeficient groups in MR or CT features. However, the most common radiological findings in immunocompetent patients with PCNSL of the brain at the time of presentation was multifocal disease, hypo-isointensity on T1-WI, hyperintensity on T2-WI, and hyperdense lesions on CT, with strong and homogeneous enhancement with both MR and CT. In contrast, in immunodeficient patients, the most common radiological findings were solitary lesion, hypo-isointensity on T1- WI, hyperintensity on T2- WI and hypodense lesions on CT, with strong and heterogeneous enhancement with both MR and CT imaging.

Acknowledgments

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