



IMAGING SPECTRUM OF INTRACRANIAL INFECTIONS IN IMMUNOCOMPROMISED PATIENTS: A CROSS-SECTIONAL STUDY FROM A TERTIARY CARE CENTER IN NORTH INDIA

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ABSTRACT

Background: Intracranial infections are a significant cause of morbidity and mortality in immunocompromised patients, with a wide spectrum of etiological agents and overlapping clinical and radiological features. Early and accurate diagnosis is crucial for effective management, particularly in resource-limited settings.

Objectives: To evaluate the imaging spectrum of intracranial infections in immunocompromised patients and to correlate radiological findings with clinical and demographic parameters.

Methods: This hospital-based cross-sectional observational study was conducted in the Department of Radiodiagnosis at a tertiary care hospital in North India from August 2017 to November 2017. A total of 42 immunocompromised patients with suspected intracranial infections were included using consecutive sampling. Clinical data were recorded using a structured proforma. All patients underwent CT and/or MRI brain imaging. Imaging findings were analyzed for lesion characteristics, distribution, and associated features. Statistical analysis was performed using SPSS version 20.0, with a p-value <0.05 considered significant.

Results: The majority of patients were aged 21–40 years, with a male predominance. HIV infection was the most common immunocompromised state (35.7%). Tuberculoma was the most frequent intracranial infection (33.3%), followed by toxoplasmosis (23.8%) and pyogenic abscess (16.7%). Multiple lesions (59.5%) and ring-enhancing patterns (61.9%) were the most common imaging findings. Perilesional edema was present in 71.4% of cases. A statistically significant association was found between HIV positivity and toxoplasmosis ($p < 0.05$).

Conclusion: Intracranial infections in immunocompromised patients demonstrate a wide range of imaging patterns, with tuberculoma being the most common in this setting. Neuroimaging plays a pivotal role in diagnosis, and correlation with clinical parameters is essential for optimal patient management.

Keywords: Intracranial infections; Immunocompromised; Neuroimaging; Tuberculoma; Toxoplasmosis; HIV; MRI

INTRODUCTION

Intracranial infections remain a major cause of morbidity and mortality worldwide, particularly among immunocompromised individuals. The global burden of opportunistic central nervous system (CNS) infections has increased in recent decades, driven by the rising prevalence of conditions such as human immunodeficiency virus (HIV) infection, malignancies, organ transplantation, and the widespread use of immunosuppressive therapies [1]. These patients are highly susceptible to a diverse range of pathogens, including bacterial, viral, fungal, and parasitic organisms, which often present with atypical clinical and radiological features, posing diagnostic challenges [2].

Neuroimaging plays a pivotal role in the early detection, characterization, and differentiation of intracranial infections. Modalities such as computed tomography (CT) and magnetic resonance imaging (MRI) are indispensable in evaluating lesion morphology, distribution, enhancement patterns, and associated complications such as edema, mass effect, and hydrocephalus [3]. MRI, in particular, offers superior soft tissue contrast and advanced techniques such as diffusion-weighted imaging (DWI), susceptibility-weighted imaging (SWI), and spectroscopy, which enhance diagnostic accuracy [4]. Accurate interpretation of imaging findings is crucial for guiding timely therapeutic interventions and improving patient outcomes.

In immunocompromised populations, the spectrum of intracranial infections differs significantly from that in immunocompetent individuals. Opportunistic infections such as toxoplasmosis, cryptococcosis, tuberculomas, and progressive multifocal leukoencephalopathy (PML) are more commonly encountered and often coexist, further complicating diagnosis [5].

Moreover, overlapping imaging features between infectious lesions and neoplastic conditions such as primary CNS lymphoma may lead to diagnostic ambiguity [6]. Therefore, a systematic understanding of imaging patterns is essential for differential diagnosis and appropriate clinical management.

In the Indian context, the burden of intracranial infections is particularly significant due to the high prevalence of tuberculosis, HIV infection, and other immunocompromising conditions. Tuberculous involvement of the CNS, including tuberculomas and tuberculous meningitis, continues to be a major public health concern [7]. Additionally, fungal infections such as aspergillosis and mucormycosis have emerged as important causes of intracranial pathology in immunosuppressed patients, especially in tertiary care settings [8]. Despite advances in imaging techniques, delayed diagnosis remains a common issue, often leading to poor clinical outcomes.

At the regional and institutional level, variability in patient demographics, underlying immunocompromising conditions, and pathogen prevalence further influences the imaging spectrum of intracranial infections. However, there is a relative paucity of comprehensive studies from North India that systematically evaluate the radiological patterns of these infections in immunocompromised populations. Existing literature is often limited by small sample sizes, heterogeneous study populations, or lack of detailed imaging correlation [9].

Given these challenges, there is a need for focused research that delineates the imaging spectrum of intracranial infections in immunocompromised patients within a tertiary care setting. Such studies can aid in identifying characteristic imaging patterns, improving diagnostic accuracy, and facilitating early intervention.

The present study aims to evaluate the imaging spectrum of intracranial infections in immunocompromised patients presenting to a tertiary care hospital in North India, and to analyze the radiological features in relation to clinical and demographic parameters.

METHODOLOGY

Study Design: This was a hospital-based observational descriptive cross-sectional study conducted to evaluate the imaging spectrum of intracranial infections in immunocompromised patients, adhering to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Study Setting: The study was carried out in the Department of Radiodiagnosis at a tertiary care teaching hospital in North India, which caters to a large population with varied socioeconomic and clinical backgrounds.

Study Duration: The study was conducted over a period of four months, from August 2017 to November 2017.

Study Population: The study population comprised immunocompromised patients presenting with clinical suspicion of intracranial infection and referred for neuroimaging (CT and/or MRI) during the study period.

Inclusion Criteria

Patients of all age groups with documented immunocompromised status (e.g., HIV infection, malignancy, organ transplant recipients, chronic steroid therapy, uncontrolled diabetes mellitus).

Patients presenting with neurological symptoms suggestive of intracranial infection (e.g., headache, seizures, altered sensorium, focal neurological deficits).

Patients who underwent CT and/or MRI brain imaging during the study period.

Exclusion Criteria

Patients with intracranial lesions of non-infectious etiology (e.g., primary brain tumors, metastases, vascular lesions) confirmed on imaging or histopathology.

Patients with incomplete clinical or imaging data.

Patients unwilling to provide informed consent.

Sample Size: The sample size was calculated using the formula for estimating a proportion in a descriptive study: $n = Z^2 \times p \times q / d^2$

Assuming a prevalence (p) of intracranial infections in immunocompromised patients to be approximately 50% (due to variability in reported literature), with a confidence level of 95% (Z = 1.96) and an allowable error (d) of 15%, the calculated sample size was approximately 43. Considering feasibility and the study duration, a total of 42 patients were included in the study.

Sampling Technique: A consecutive sampling technique was employed, wherein all eligible patients meeting the inclusion criteria during the study period were included until the desired sample size was achieved.

Data Collection Tools & Procedure: Data were collected using a predesigned structured proforma. Clinical details including demographic information, immunocompromised status, presenting symptoms, and relevant laboratory findings were recorded. All patients underwent neuroimaging using CT and/or MRI as clinically indicated. Imaging studies were performed using standard protocols. MRI sequences included T1-weighted, T2-weighted, FLAIR, diffusion-weighted imaging (DWI), and post-contrast sequences. Imaging findings were systematically evaluated for lesion number, location, signal characteristics, enhancement pattern, presence of edema, hemorrhage, and associated complications. Final diagnosis was established based on a combination of imaging findings, clinical correlation, laboratory investigations (including serology, CSF analysis), and, where available, histopathological confirmation.

Study Variables: Independent variables included demographic characteristics (age, sex), type of immunocompromised state (HIV infection, malignancy, diabetes mellitus, immunosuppressive therapy), and clinical presentation. Dependent variables included imaging findings such as type of intracranial infection (e.g., tuberculoma, toxoplasmosis, cryptococcosis, abscess), lesion characteristics (number, size, location), enhancement pattern, and associated radiological features (edema, mass effect, hydrocephalus).

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) version 20.0. Descriptive statistics such as mean, standard deviation, frequencies, and percentages were used to summarize the data. Inferential statistics were applied where appropriate, including chi-square test or Fisher's exact test for categorical variables. A p-value of less than 0.05 was considered statistically significant.

Ethical Considerations: Written informed consent was obtained from all participants or their legal guardians. The study adhered to the ethical principles outlined in the Declaration of Helsinki. Confidentiality of patient information was strictly maintained, and no personal identifiers were disclosed during data analysis or publication.

RESULTS

A total of 42 immunocompromised patients with suspected intracranial infections were included in the study. The majority of patients were in the 21–40 years age group, with a male predominance (Table 1)

Table 1: Demographic Characteristics of Study Population (n = 42)

Variable	Category	Frequency (n)	Percentage (%)
Age (years)	<20	4	9.5
	21–40	18	42.9
	41–60	14	33.3
	>60	6	14.3
Sex	Male	26	61.9
	Female	16	38.1

HIV infection was the most common underlying immunocompromised state, followed by diabetes mellitus and malignancy (Table 2)

Table 2: Distribution of Immunocompromised States (n = 42)

Immunocompromised Condition	Frequency (n)	Percentage (%)
HIV infection	15	35.7
Diabetes mellitus	10	23.8
Malignancy	7	16.7
Chronic steroid therapy	6	14.3
Post-transplant status	4	9.5

Among the intracranial infections identified on imaging, tuberculoma was the most frequent diagnosis, followed by toxoplasmosis and pyogenic abscess (Table 3)

Table 3: Spectrum of Intracranial Infections on Imaging (n = 42)

Type of Infection	Frequency (n)	Percentage (%)
Tuberculoma	14	33.3
Toxoplasmosis	10	23.8
Pyogenic abscess	7	16.7
Cryptococcosis	5	11.9
Neurocysticercosis	3	7.1
Fungal infections	3	7.1

Imaging analysis revealed that multiple lesions were more common than solitary lesions, and ring enhancement was the predominant pattern observed. Perilesional edema was present in the majority of cases, while mass effect was noted in a substantial proportion of patients (Table 4)

Table 4: Imaging Characteristics of Lesions (n = 42)

Imaging Feature	Category	Frequency (n)	Percentage (%)
Number of lesions	Solitary	17	40.5
	Multiple	25	59.5
Enhancement pattern	Ring enhancement	26	61.9

	Nodular enhancement	10	23.8
	No enhancement	6	14.3
Perilesional edema	Present	30	71.4
	Absent	12	28.6
Mass effect	Present	18	42.9
	Absent	24	57.1

A statistically significant association was observed between HIV-positive status and the occurrence of toxoplasmosis ($p < 0.05$), with a higher proportion of toxoplasmosis cases seen in HIV-positive patients compared to HIV-negative patients (Table 5)

Table 5: Association Between HIV Status and Type of Infection

Type of Infection	HIV Positive (n=15)	HIV Negative (n=27)	p-value
Toxoplasmosis	7	3	0.04*
Tuberculoma	4	10	
Pyogenic abscess	2	5	
Others	2	9	

*Statistically significant ($p < 0.05$)

DISCUSSION

The present study evaluated the imaging spectrum of intracranial infections in immunocompromised patients in a tertiary care setting in North India. The key findings include a predominance of young to middle-aged adults with a male preponderance, HIV infection as the most common underlying immunocompromised state, and tuberculoma as the most frequent intracranial infection on imaging. Additionally, ring-enhancing lesions with perilesional edema were the most common radiological presentation, and a statistically significant association was observed between HIV positivity and toxoplasmosis. The demographic profile observed in this study, with a higher proportion of patients in the 21–40 years age group and male predominance, is consistent with prior studies evaluating CNS infections in immunocompromised populations [5,6]. This trend may reflect the epidemiological distribution of HIV infection and occupational exposure patterns in developing countries. Similar observations have been reported in other studies [5], which described CNS infections as more prevalent among younger adults with immunosuppression. HIV infection emerged as the leading cause of immunocompromised status in this study, followed by diabetes mellitus and malignancy. This aligns with global and Indian data indicating HIV as a major risk factor for opportunistic CNS infections [1,7]. However, the notable proportion of patients with diabetes mellitus underscores the growing importance of metabolic disorders as contributors to immune dysfunction, particularly in the Indian population. Chronic hyperglycemia impairs innate and adaptive immunity, predisposing individuals to infections such as fungal and bacterial abscesses [8]. Tuberculoma was identified as the most common intracranial infection in the present study. This finding is consistent with studies from tuberculosis-endemic regions, where CNS tuberculosis remains a major health burden [4,7,9]. The high prevalence of tuberculomas in this cohort likely reflects regional epidemiology and highlights the importance of considering tuberculosis in the differential diagnosis of intracranial space-occupying lesions in immunocompromised patients. In contrast, studies from developed countries have reported toxoplasmosis and primary CNS lymphoma as more common entities in HIV-positive patients [6]. Toxoplasmosis was the second most common infection and showed a significant association with HIV-positive status. This observation is in agreement with earlier reports that identify cerebral toxoplasmosis as the most frequent opportunistic CNS infection in patients with advanced HIV infection [6]. The predilection of toxoplasmosis for causing multiple ring-enhancing lesions, particularly in basal ganglia and corticomedullary junctions, may aid in its differentiation from other infections, although overlap exists.

The predominance of ring-enhancing lesions and multiple lesions in this study is consistent with established imaging patterns of intracranial infections [3,4]. Ring enhancement typically reflects central necrosis surrounded by an inflammatory capsule, a feature seen in tuberculomas, abscesses, and toxoplasmosis. The high frequency of perilesional edema and mass effect further emphasizes the inflammatory nature of these lesions. Advanced MRI techniques, though not uniformly applied in all cases, can provide additional diagnostic clues, such as restricted diffusion in pyogenic abscesses and specific spectroscopic patterns in tuberculomas [3].

Cryptococcosis and fungal infections constituted a smaller proportion of cases but remain clinically significant due to their high morbidity. These infections are often associated with severe immunosuppression and may present with atypical imaging findings, including non-enhancing lesions or gelatinous pseudocysts [5]. Early recognition is critical, as delayed diagnosis can result in poor outcomes. The findings of this study have important clinical implications. A systematic approach to imaging interpretation, combined with clinical and laboratory correlation, can significantly enhance diagnostic accuracy and facilitate early initiation of appropriate therapy. In resource-limited settings, where access to advanced diagnostic modalities may be restricted, radiological evaluation assumes even greater importance. The strengths of this study include its focus on a well-defined immunocompromised population and the use of standardized imaging evaluation protocols. Additionally, the study provides region-specific data that can aid clinicians in formulating differential diagnoses. However, certain limitations must be acknowledged. The relatively small sample size and short study duration may limit the generalizability of the findings. Furthermore, not all diagnoses were confirmed by histopathology, and reliance on clinico-radiological correlation may introduce diagnostic bias. Advanced imaging modalities and long-term follow-up were not uniformly available for all patients. Future studies with larger sample sizes, multicentric design, and incorporation of advanced imaging techniques are warranted to further refine the diagnostic approach to intracranial infections in immunocompromised patients.

CONCLUSION

This study highlights the diverse imaging spectrum of intracranial infections in immunocompromised patients, with tuberculoma emerging as the most common etiology, followed by toxoplasmosis and pyogenic abscess. HIV infection was identified as the predominant underlying immunocompromised state, with a significant association observed between HIV positivity and toxoplasmosis. The majority of lesions demonstrated characteristic imaging features such as ring enhancement, multiplicity, and perilesional edema, which are valuable in guiding differential diagnosis. The findings underscore the critical role of neuroimaging, particularly MRI, in the early detection and characterization of intracranial infections. In regions with a high burden of tuberculosis and HIV, a high index of suspicion must be maintained while interpreting imaging findings. Integration of radiological features with clinical and laboratory data is essential for accurate diagnosis and timely management. Further large-scale and multicentric studies incorporating advanced imaging techniques are recommended to enhance diagnostic precision and improve clinical outcomes in this vulnerable population.

DECLARATIONS

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Conflict of Interest: The authors declare no conflict of interest.

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