International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Mri Brain in Alcohol-related Neurological Disorders: a Pictorial Essay with Emphasis on Diffusion-weighted Imaging and Arterial Spin Labeling

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Abstract

Background and Objectives: Alcohol Use Disorder (AUD) and acute alcohol intoxication are associated with a wide spectrum of neurological complications resulting in structural and functional alterations within the brain. Magnetic Resonance Imaging (MRI) plays a pivotal role in the diagnosis and characterization of these abnormalities. This pictorial essay aims to illustrate the diverse neuroimaging manifestations of alcohol-related brain injury and highlight the role of Arterial Spin Labeling (ASL) and Diffusion-Weighted Imaging (DWI) in evaluating cerebral perfusion and diffusion changes.

Methods: A retrospective review of MRI brain examinations of 50 patients with a history of chronic alcohol use or acute alcohol intoxication was performed. Conventional MRI sequences along with DWI and ASL perfusion imaging were assessed for alcohol-related neurological complications including chronic alcohol-related brain atrophy, Wernicke encephalopathy, Marchiafava-Bignami disease, hepatic encephalopathy, osmotic demyelination syndrome, cerebral venous sinus thrombosis, hypoxic encephalopathy, and post-ictal changes.

Results: Among the 50 patients, chronic alcohol-related brain injury was identified in 34 (68%), with cerebral cortical atrophy (62%) and white matter volume loss (56%) representing the most common findings. Cerebellar atrophy was present in 36% of patients. Acute alcohol-related encephalopathies were observed in 16 (32%) patients. Wernicke encephalopathy was the most frequently encountered acute complication (14%), followed by hepatic encephalopathy (10%), osmotic demyelination syndrome (8%), and Marchiafava-Bignami disease (6%). ASL imaging demonstrated altered cerebral perfusion patterns and DWI revealed restricted diffusion in acute encephalopathies corresponding to cytotoxic edema.

Conclusion: MRI effectively demonstrates the broad spectrum of alcohol-related brain abnormalities, ranging from chronic neurodegenerative changes to acute potentially reversible encephalopathies. DWI and ASL perfusion imaging provide valuable complementary information and may enhance the assessment of alcohol-induced neurological disorders.

1. INTRODUCTION

Alcohol Use Disorder (AUD) represents one of the most prevalent and consequential public health challenges worldwide. According to the World Health Organization (WHO), harmful alcohol use accounts for approximately 3 million deaths annually, with the neurological burden forming a substantial proportion of this toll. The spectrum of alcohol-related neurological injury is broad, encompassing both acute, potentially life-threatening encephalopathies and insidious chronic neurodegenerative changes that accumulate over years of excessive consumption.

The central nervous system (CNS) is exquisitely vulnerable to the toxic effects of ethanol and its metabolites. Alcohol exerts direct neurotoxic effects through oxidative stress, mitochondrial dysfunction, glutamate excitotoxicity, and thiamine depletion. Chronically elevated alcohol intake leads to widespread cortical atrophy, preferential cerebellar degeneration, and progressive white matter volume loss. Superimposed acute complications, including Wernicke encephalopathy (WE), hepatic encephalopathy (HE), Marchiafava-Bignami disease (MBD), osmotic demyelination syndrome (ODS), and hypoxic-ischemic injury further compound the structural and functional damage.

Magnetic Resonance Imaging (MRI) has become the cornerstone neuroimaging modality for detecting, characterizing, and monitoring alcohol-related brain injury. Its superior soft-tissue contrast, multiplanar capability, and the availability of advanced functional sequences make it uniquely suited for comprehensive assessment. Conventional sequences including T1-weighted, T2-weighted, and FLAIR imaging provide structural details, while Diffusion-Weighted Imaging (DWI) with apparent diffusion coefficient (ADC) mapping enables detection of cytotoxic edema, acute ischemia, and restricted diffusion hallmarks of acute encephalopathies. Arterial Spin Labeling (ASL), a non-invasive perfusion technique, provides quantitative cerebral blood flow (CBF) measurements without the need for exogenous contrast agents, offering unique insights into hemodynamic alterations in alcohol-related conditions.

Despite the clinical importance of these conditions, the neuroimaging literature dedicated to systematic characterization of the full MRI spectrum of alcohol-related brain injury, with particular emphasis on DWI and ADC findings alongside ASL perfusion, remains limited. A pictorial and analytical approach incorporating both structural and functional MRI parameters may substantially improve diagnostic accuracy and clinical decision-making.

This study was therefore designed to systematically review and illustrate the MRI findings in a cohort of patients with confirmed alcohol-related neurological disorders, to analyze DWI and ADC characteristics across the etiological spectrum, and to evaluate the complementary role of ASL perfusion imaging. The findings are discussed in the context of current evidence to provide a clinically applicable neuroimaging framework for practitioners encountering patients with AUD-related neurological complications.

2. OBJECTIVES

2.1 Primary Objectives

- To systematically review and categorize MRI brain findings in patients with a history of chronic alcohol use disorder or acute alcohol intoxication.
- To characterize the DWI and ADC map findings across the spectrum of alcohol-related neurological complications.
- To evaluate the role of ASL perfusion imaging in assessing cerebral blood flow abnormalities associated with alcohol-related brain injury.

2.2 Secondary Objectives

- To analyze the demographic distribution (age and sex) of patients presenting with alcohol-related neurological complications.
- To determine the frequency and relative proportions of different etiological categories of alcohol-related brain injury within the study cohort.
- To correlate neuroimaging findings with clinical presentations and highlight imaging patterns that facilitate early diagnosis.
- To outline the clinical implications of advanced MRI techniques (DWI, ASL) in distinguishing reversible from irreversible brain injury and in guiding therapeutic management.

3. MATERIALS AND METHODS

3.1 Study Design

This was a retrospective, observational, cross-sectional study employing a pictorial essay format with quantitative analysis of neuroimaging findings. The study involved a systematic review of archived MRI brain examinations performed on patients with documented alcohol use disorder or acute alcohol-related neurological presentations. The retrospective design was chosen to enable comprehensive collection of varied and representative cases across the full spectrum of alcohol-related brain injury without prospective interference with clinical management.

3.2 Study Area

The study was conducted at a tertiary care university hospital equipped with a dedicated neuroradiology unit. The institution serves as a major referral center for neurological and psychiatric disorders, including alcohol use disorder, for a large geographic catchment area. All MRI examinations were performed on a 3.0 Tesla MRI system (GE Discovery MR750 or equivalent) using standard neuroimaging protocols including conventional sequences and advanced functional sequences (DWI, ASL).

3.3 Study Period

The study encompassed a period of two years, from January 2022 to December 2023. All MRI brain examinations performed during this period on patients meeting the inclusion criteria were reviewed. This duration was considered sufficient to accumulate an adequate sample of diverse alcohol-related neurological cases spanning both chronic and acute presentations.

3.4 Study Population

The study population comprised patients referred to the radiology department for MRI brain examination who had a confirmed or strongly suspected history of chronic alcohol use disorder or acute alcohol intoxication. Patients were identified through electronic medical records, radiology information systems, and cross-referencing with the department of neurology, psychiatry, and emergency medicine. A total of 50 patients meeting the inclusion criteria were included in the final analysis.

3.5 Sampling Method

A consecutive sampling method was employed. All patients who met the pre-defined inclusion criteria and underwent MRI brain examination during the study period were sequentially enrolled until the target sample size was achieved. No randomization was applied; the consecutive approach ensured inclusion of all available cases without selection bias related to clinical severity or imaging characteristics, thereby maintaining representativeness of the full etiological spectrum.

3.6 Inclusion Criteria

Patients were included if they satisfied all of the following criteria:

- Age 18 years or above at the time of MRI examination.
- Documented history of chronic alcohol use disorder (as per DSM-5 criteria) or confirmed acute alcohol intoxication based on clinical assessment, laboratory findings, and/or history.
- Availability of complete MRI brain examination including at minimum: T1-weighted, T2-weighted, FLAIR, and DWI sequences.
- MRI performed for evaluation of neurological symptoms attributable to or potentially related to alcohol use (altered sensorium, seizures, focal neurological deficits, cognitive impairment, gait disturbance, or visual changes).
- Adequate image quality for diagnostic interpretation.

3.7 Exclusion Criteria

Patients were excluded if any of the following criteria were met:

- Incomplete MRI examination or non-diagnostic image quality due to motion artifact or technical failure.
- Neurological symptoms primarily attributable to a known non-alcohol-related etiology (e.g., primary brain tumor, multiple sclerosis, metabolic disorder unrelated to alcohol use).
- Pregnancy at the time of MRI examination.
- Contraindication to MRI (ferromagnetic implants, pacemaker, cochlear implant, severe claustrophobia).
- Refusal of informed consent (for patients enrolled prospectively during the review period).
- Age below 18 years.

3.8 Ethical Considerations

The study was conducted in strict accordance with the ethical principles outlined in the Declaration of Helsinki (2013 revision) and Good Clinical Practice guidelines. Prior to commencement, ethical clearance was obtained from the Institutional Ethics Committee (IEC) of the affiliated hospital and medical university. As the study was primarily retrospective in design, a waiver of individual patient consent was granted by the IEC, contingent upon strict maintenance of patient anonymity and data confidentiality.

All patient data were anonymized prior to analysis; personal identifiers were replaced with unique study codes. Electronic data were stored on encrypted, password-protected servers accessible only to the principal investigators. No additional invasive procedures were performed solely for research purposes, and clinical management was not influenced by study participation. Results were reported in aggregate form to prevent individual identification.

3.9 Study Tools and Data Collection Procedures

3.9.1 MRI Protocol

All MRI brain examinations were performed on a 3.0 Tesla MRI scanner. The standard neuroimaging protocol included the following sequences:

- Axial T1-weighted MPRAGE (TR/TE: 2400/2.27 ms, TI: 900 ms, voxel size: 1x1x1 mm isotropic)
- Axial and coronal T2-weighted TSE (TR/TE: 5000/93 ms, slice thickness: 5 mm)
- Axial FLAIR (TR/TE/TI: 9000/125/2500 ms, slice thickness: 5 mm)
- Axial DWI with echo-planar imaging (b-values: 0 and 1000 s/mm2; ADC maps automatically generated)
- Axial Gradient Echo T2* (SWI) for hemorrhagic detection

- ASL perfusion (pseudo-continuous ASL; post-labeling delay: 2000 ms; CBF maps generated)
- Post-contrast T1 MPRAGE with gadolinium-based contrast agent (in selected cases)

3.9.2 Image Analysis

All MRI examinations were independently reviewed by two fellowship-trained neuroradiologists with a minimum of 5 years post-fellowship experience, blinded to detailed clinical information. Disagreements were resolved by consensus or by referral to a senior neuroradiologist. Findings were systematically recorded using a structured data collection form encompassing the following parameters:

- Demographic information: age, sex, duration of alcohol use, clinical presentation.
- Structural MRI findings: presence and degree of cortical atrophy (global, frontal, parietal, temporal), cerebellar atrophy, white matter volume loss, callosal abnormalities.
- DWI findings: presence, location, and pattern of restricted diffusion (focal, multifocal, confluent); quantitative ADC values measured by placing regions of interest (ROI) in abnormal areas.
- ASL findings: presence and pattern of hyperperfusion or hypoperfusion; regional CBF quantification.
- Specific diagnostic entities: characteristic imaging patterns of WE, HE, MBD, ODS, CVST, hypoxic encephalopathy, post-ictal changes.

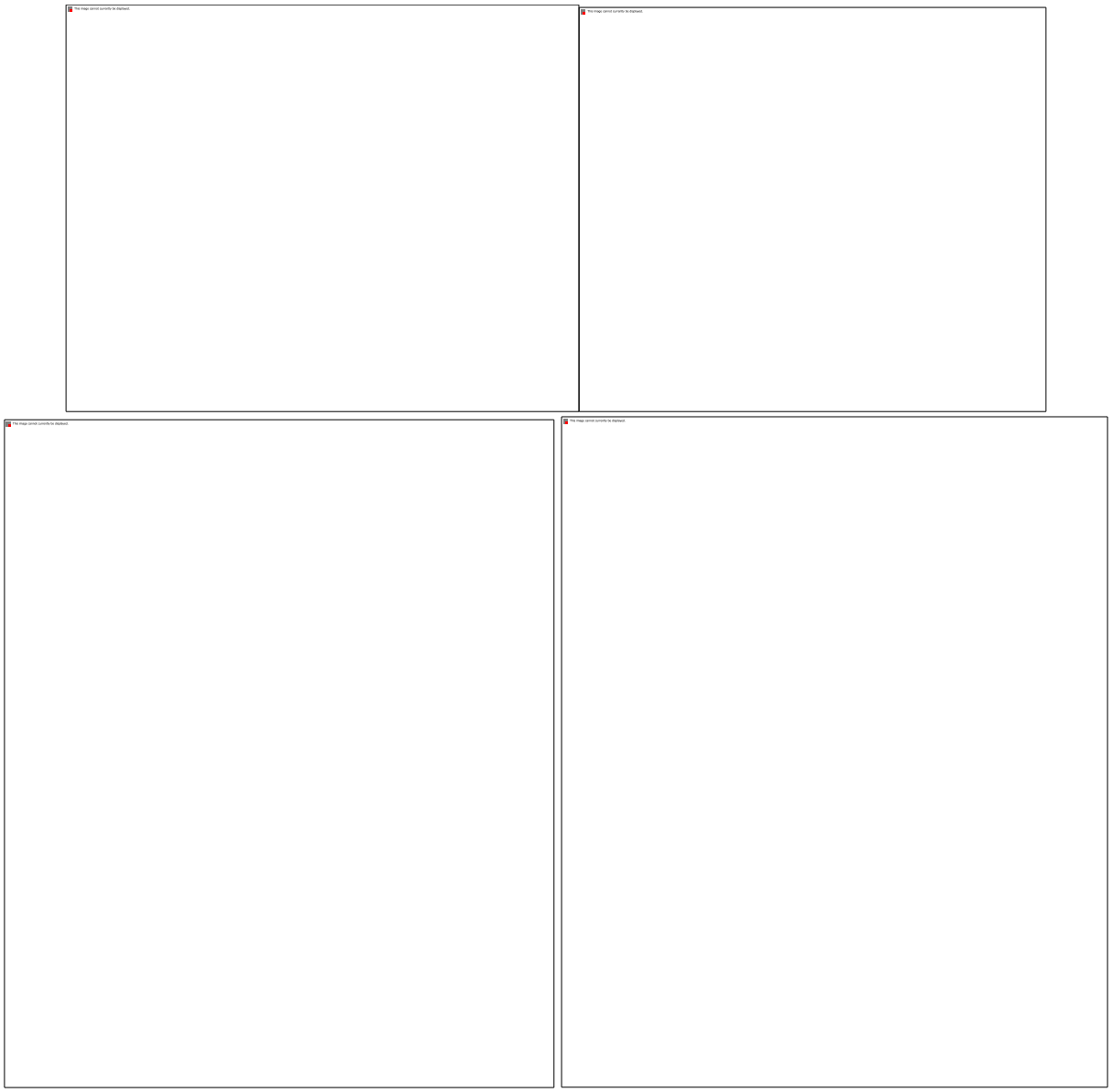

Fig 1. A patient with wernickes encephalopathy showing diffusion restriction and low value on ADC in subcortical whiter matter of right parietal, temporal and occipital lobe, with hypo/isointense on T1 with low CBV on ASL perfusion.

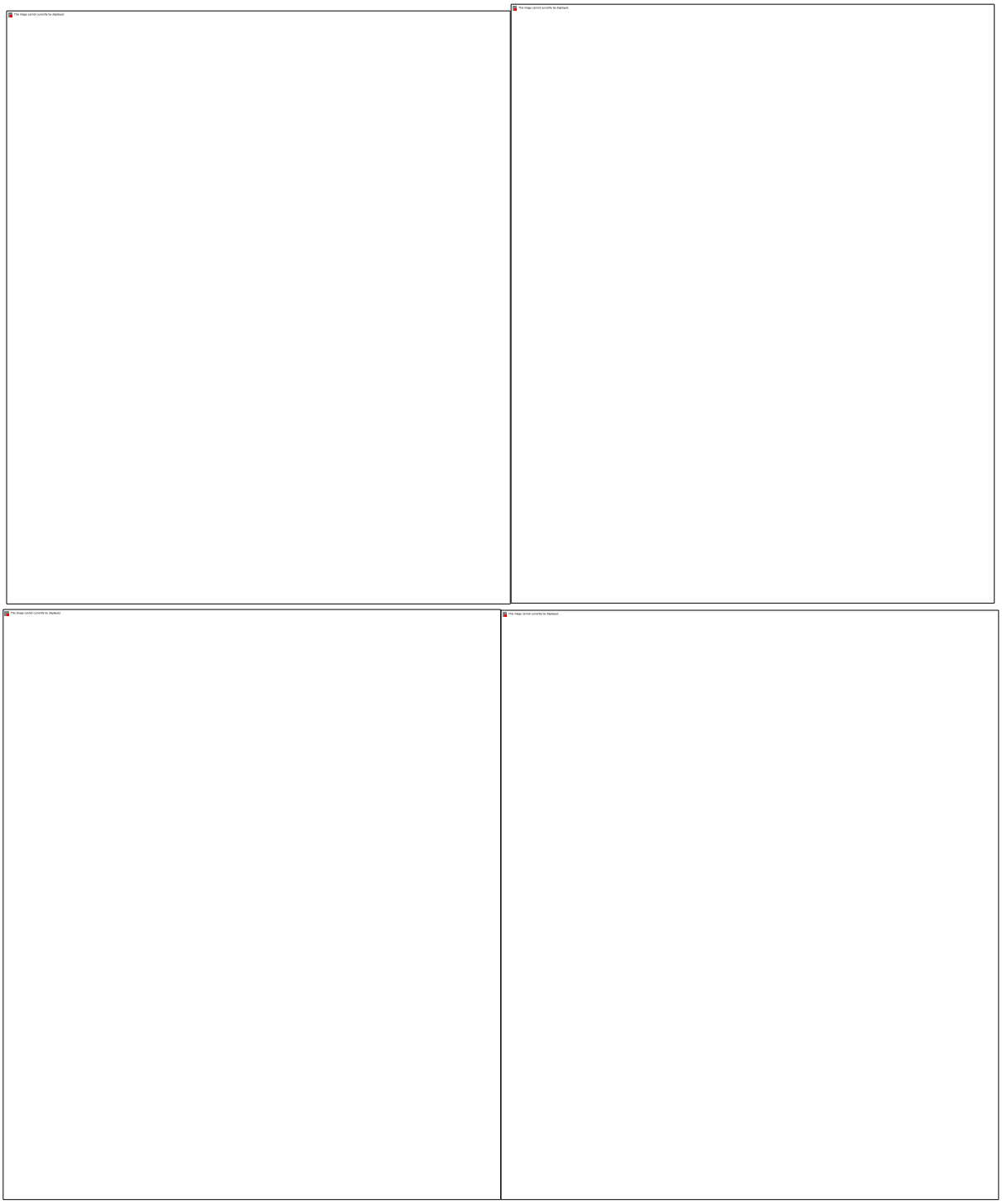

Fig 2. Altered signal intensity areas noted involving central pons sparing the corticospinal tracts giving trident sign, which appears hypointense on T1WI, hyperintense on T2/FLAIR, showing diffusion restriction on DWI and low CBV on ASL perfusion.

3.10 Statistical Analysis

Data were collected, coded, and entered into SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize the study variables. Continuous variables (age, ADC values, CBF measurements) were expressed as mean ± standard deviation (SD) or median with interquartile range (IQR) depending on the normality of distribution (assessed by Shapiro-Wilk test). Categorical variables (sex, etiological categories, DWI findings, ASL findings) were expressed as frequencies and percentages.

Chi-square test or Fisher's exact test was used to assess associations between categorical variables where appropriate. Independent samples t-test or Mann-Whitney U test was used for comparison of continuous variables between groups. A p-value of less than 0.05 was considered statistically significant. All tables and statistical summaries are presented in the results section.