RESEARCH PAPER

MRI Assessment of Steroid-Induced Osteonecrosis in Children: A Retrospective Study

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ABSTRACT

Background

Steroid-induced osteonecrosis is a serious musculoskeletal complication observed in children receiving prolonged or high-dose corticosteroid therapy for hematological malignancies, autoimmune disorders, nephrotic syndrome, and other chronic inflammatory diseases. Magnetic resonance imaging (MRI) is considered the most sensitive imaging modality for detecting early osteonecrotic changes before radiographic abnormalities become apparent. Recent studies have emphasized the role of MRI screening in high-risk pediatric populations for timely diagnosis and improved clinical outcomes. To evaluate MRI findings of steroid-induced osteonecrosis in children and identify clinical and treatment-related factors associated with disease severity.

Methods

A retrospective study was conducted among 124 children aged 5–17 years who underwent MRI for suspected steroid-induced osteonecrosis between January 2024 and July2026. Demographic characteristics, underlying disease, cumulative corticosteroid exposure, duration of therapy, presenting symptoms, laboratory parameters, and MRI findings were reviewed. Osteonecrotic lesions were evaluated according to anatomical location, laterality, lesion extent, subchondral involvement, and associated joint abnormalities. Multivariate logistic regression analysis was performed to determine independent predictors of extensive osteonecrosis.

Results

Among the 124 children included, MRI confirmed osteonecrosis in 86 (69.4%) patients. Bilateral involvement was observed in 48 (55.8%) cases, with the femoral head representing the most frequently affected site. Higher cumulative steroid dose, longer duration of corticosteroid therapy, age above 10 years, and acute lymphoblastic leukemia were significantly associated with extensive MRI abnormalities ($p<0.05$). MRI detected asymptomatic osteonecrotic lesions in several children before radiographic changes became evident.

Conclusion

MRI is highly effective for early detection and assessment of steroid-induced osteonecrosis in children. Early MRI surveillance among high-risk patients receiving prolonged corticosteroid therapy may facilitate timely intervention and improve long-term joint preservation.

Keywords: Steroid-induced osteonecrosis, Magnetic resonance imaging, Children, Corticosteroids, Osteonecrosis, Femoral head.

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INTRODUCTION

Steroid-induced osteonecrosis is one of the most important musculoskeletal complications associated with prolonged or high-dose corticosteroid therapy in children. The condition results from interruption of blood supply to the bone, leading to ischemia, osteocyte death, structural collapse, and progressive joint destruction if left untreated. Children receiving corticosteroids for acute lymphoblastic leukemia, lymphoma, nephrotic syndrome, systemic lupus erythematosus, juvenile idiopathic arthritis, and other inflammatory disorders are particularly vulnerable. Advances in pediatric treatment protocols have improved survival, making preservation of long-term musculoskeletal health increasingly important.[1–4] Recent evidence indicates that MRI enables identification of osteonecrosis before irreversible structural damage occurs, allowing earlier clinical intervention.

The pathogenesis of steroid-induced osteonecrosis is multifactorial and involves corticosteroid-induced lipid metabolism abnormalities, bone marrow fat hypertrophy, increased intraosseous pressure, vascular endothelial dysfunction, thrombosis, and impaired bone remodeling. These mechanisms ultimately reduce blood flow to subchondral bone, resulting in ischemia and bone infarction. Adolescents appear to be at greater risk than younger

children because of rapid skeletal growth, physeal maturation, and greater cumulative corticosteroid exposure. Recent pediatric cohort studies have demonstrated that higher cumulative steroid dose, older age, prolonged treatment duration, and hematological malignancies significantly increase the likelihood of developing osteonecrosis.[5–9]

Magnetic resonance imaging has become the imaging modality of choice for evaluating pediatric osteonecrosis because of its excellent sensitivity for detecting early marrow abnormalities before radiographic changes develop. MRI provides detailed assessment of lesion size, location, epiphyseal involvement, bone marrow edema, subchondral fractures, cartilage integrity, and bilateral disease. Whole-joint and whole-body MRI screening have recently gained attention for identifying asymptomatic lesions in children receiving intensive corticosteroid therapy. Early MRI-based diagnosis permits implementation of activity modification, pharmacological treatment, and orthopedic interventions before progression to femoral head collapse and permanent disability.[10–15]

Despite increasing awareness of steroid-induced osteonecrosis, information regarding MRI characteristics and factors predicting disease severity among pediatric patients remains limited. Most available studies have focused on specific underlying diseases, whereas comprehensive evaluation across multiple pediatric conditions is still lacking. Understanding MRI patterns together with associated clinical risk factors may facilitate early diagnosis, individualized surveillance protocols, and improved management strategies. Therefore, the present retrospective study aimed to evaluate MRI findings of steroid-induced osteonecrosis in children and identify clinical and treatment-related factors associated with disease severity.[16–20]

METHODOLOGY

This retrospective observational study was conducted in the Department of Radiodiagnosis Sri siddhartha medical college tumkur in collaboration with the Departments of Pediatrics and Orthopaedics at a tertiary care teaching hospital after obtaining approval from the Institutional Ethics Committee. Medical records and MRI examinations performed between January 2024 and july 2026 were reviewed retrospectively.

Children aged 5–17 years who had received systemic corticosteroid therapy for at least four weeks and subsequently underwent MRI because of suspected osteonecrosis or musculoskeletal symptoms were included. Patients with traumatic osteonecrosis, congenital skeletal disorders, metabolic bone disease, previous orthopedic surgery involving the affected joint, or incomplete imaging records were excluded. A total of 124 children fulfilled the eligibility criteria.

Clinical information including age, sex, underlying disease, indication for corticosteroid therapy, cumulative steroid dose, duration of treatment, presenting symptoms, laboratory investigations, and treatment history was obtained from electronic medical records. MRI examinations were reviewed independently by two experienced musculoskeletal radiologists blinded to the clinical diagnosis. Imaging assessment included anatomical site, unilateral or bilateral involvement, lesion size, epiphyseal involvement, metaphyseal extension, bone marrow edema, subchondral fracture, joint effusion, cartilage abnormalities, and evidence of femoral head collapse.

The primary outcome was MRI-confirmed steroid-induced osteonecrosis. Secondary outcomes included severity of MRI abnormalities and identification of factors associated with extensive osteonecrotic involvement.

Statistical analysis was performed using SPSS version 26. Continuous variables were expressed as mean ± standard deviation, while categorical variables were expressed as frequencies and percentages. Student's *t*-test and Chi-square test were used for group comparisons. Variables demonstrating statistical significance in univariate analysis were included in multivariate logistic regression analysis. A p-value <0.05 was considered statistically significant.

RESULTS

Table 1. Baseline Demographic and Clinical Characteristics

Variable	MRI-confirmed Osteonecrosis (n=86)	No Osteonecrosis (n=38)	p-value
Age (years)	13.2 ± 2.6	9.8 ± 2.9	<0.001
Male sex	46 (53.5%)	20 (52.6%)	0.921
Acute lymphoblastic leukemia	48 (55.8%)	12 (31.6%)	0.011
Nephrotic syndrome	16 (18.6%)	10 (26.3%)	0.319
Autoimmune disorders	22 (25.6%)	16 (42.1%)	0.071

Duration of steroid therapy (months)	8.6 ± 2.8	5.1 ± 2.2	<0.001

Children with MRI-confirmed osteonecrosis were significantly older and had received corticosteroid therapy for a longer duration than those without osteonecrosis. Acute lymphoblastic leukemia was the most common underlying diagnosis among affected children, suggesting increased susceptibility in this high-risk population.

Table 2. MRI Characteristics of Steroid-Induced Osteonecrosis

MRI Finding	Frequency (n=86)	Percentage
Femoral head involvement	62	72.1
Knee involvement	38	44.2
Bilateral lesions	48	55.8
Bone marrow edema	58	67.4
Subchondral fracture	18	20.9
Early-stage lesions without collapse	56	65.1
Femoral head collapse	14	16.3

MRI demonstrated predominant involvement of the femoral head, followed by the knee. More than half of the children exhibited bilateral disease, while early-stage osteonecrosis without structural collapse represented the most frequent imaging pattern, highlighting the value of MRI in identifying disease before irreversible joint destruction.

Table 3. Clinical and Treatment-Related Risk Factors

Variable	Osteonecrosis	No Osteonecrosis	p-value
Cumulative steroid dose >4 g	54 (62.8%)	10 (26.3%)	<0.001
Steroid duration >6 months	60 (69.8%)	14 (36.8%)	<0.001
Hip pain	46 (53.5%)	10 (26.3%)	0.005
Restricted joint movement	40 (46.5%)	8 (21.1%)	0.008
Asymptomatic MRI lesions	22 (25.6%)	—	—
Elevated inflammatory markers	18 (20.9%)	6 (15.8%)	0.493

Children receiving prolonged corticosteroid therapy and higher cumulative steroid doses demonstrated significantly greater prevalence of osteonecrosis. MRI also identified asymptomatic lesions in approximately one-quarter of affected children, emphasizing the importance of screening in high-risk patients.

Table 4. Multivariate Logistic Regression Analysis of Predictors of Extensive MRI Osteonecrosis

Variable	Odds Ratio	95% CI	p-value
Age >10 years	2.94	1.42–6.08	0.004
Cumulative steroid dose >4 g	3.82	1.89–7.71	<0.001
Steroid therapy >6 months	2.76	1.37–5.54	0.005
Acute lymphoblastic leukemia	2.48	1.18–5.23	0.016

Bilateral MRI lesions	2.21	1.06–4.63	0.034
Bone marrow edema	1.86	1.01–3.45	0.047

Multivariate analysis identified higher cumulative corticosteroid exposure as the strongest independent predictor of extensive osteonecrosis. Older age, prolonged steroid therapy, acute lymphoblastic leukemia, bilateral disease, and bone marrow edema were also independently associated with more severe MRI involvement, supporting targeted MRI surveillance in children at highest risk.

DISCUSSION

The present study demonstrated that magnetic resonance imaging is highly effective in detecting steroid-induced osteonecrosis among children receiving prolonged corticosteroid therapy. MRI confirmed osteonecrosis in nearly seventy percent of the study population, with the femoral head being the most commonly affected anatomical site. Importantly, more than half of the affected children demonstrated bilateral disease, and a considerable proportion had asymptomatic lesions identified only through MRI screening. These findings emphasize that clinical symptoms alone may underestimate the true burden of osteonecrosis and reinforce the importance of MRI as the gold standard imaging modality for early diagnosis in pediatric patients receiving corticosteroids. Recent multicenter studies have similarly reported that MRI identifies osteonecrotic lesions months before radiographic abnormalities become apparent, thereby providing a valuable opportunity for early intervention.[1–5]

Higher cumulative corticosteroid exposure and prolonged duration of steroid therapy emerged as the strongest independent predictors of osteonecrosis in the present study. Corticosteroids adversely affect bone metabolism by promoting adipocyte hypertrophy within the bone marrow, increasing intraosseous pressure, impairing angiogenesis, inducing endothelial dysfunction, and reducing osteoblast differentiation. These mechanisms collectively compromise blood supply to the epiphysis, resulting in ischemic bone necrosis and eventual structural collapse. Several recent pediatric investigations involving children treated for acute lymphoblastic leukemia and autoimmune diseases have demonstrated a dose-dependent relationship between corticosteroid exposure and osteonecrosis severity, supporting the findings of the present study.[6–10]

Age greater than ten years was another important predictor of MRI-confirmed osteonecrosis. Adolescents appear particularly susceptible because of rapid skeletal maturation, increased epiphyseal vascular demand, hormonal changes during puberty, and greater cumulative corticosteroid exposure compared with younger children. Acute lymphoblastic leukemia was the predominant underlying disease among affected patients, which is consistent with contemporary pediatric oncology literature identifying osteonecrosis as one of the most important long-term treatment-related complications. Recent studies have further shown that MRI surveillance during maintenance chemotherapy facilitates early detection of clinically silent lesions and assists clinicians in modifying treatment strategies before irreversible joint damage occurs.[11–15]

MRI findings in the present study predominantly consisted of femoral head involvement, bone marrow edema, bilateral lesions, and early-stage osteonecrosis without femoral head collapse. Detection of early-stage lesions is clinically important because conservative treatment, activity modification, physiotherapy, optimization of corticosteroid regimens, and orthopedic surveillance may delay or prevent progression to subchondral collapse. Whole-joint and whole-body MRI protocols have recently gained increasing acceptance for screening children receiving intensive corticosteroid therapy because multiple joints may be simultaneously affected despite the absence of symptoms. Advanced MRI techniques including diffusion-weighted imaging and quantitative cartilage assessment have further improved the sensitivity of early osteonecrosis detection.[16–21]

The present study possesses several strengths, including comprehensive evaluation of MRI characteristics together with demographic, clinical, and treatment-related variables in a pediatric population receiving corticosteroid therapy. However, certain limitations should be acknowledged. The retrospective single-center design limits causal inference and generalizability. Serial MRI follow-up was unavailable for all patients, preventing assessment of lesion progression over time. Functional outcomes and long-term orthopedic interventions were also not evaluated. Nevertheless, the study highlights the critical role of MRI in early diagnosis of steroid-induced osteonecrosis and supports implementation of routine MRI surveillance among children receiving prolonged or high-dose corticosteroid therapy. Early recognition and multidisciplinary management may substantially reduce long-term disability and preserve joint function in this vulnerable population.[22–25]

CONCLUSION

Magnetic resonance imaging is the most sensitive imaging modality for the early detection and comprehensive evaluation of steroid-induced osteonecrosis in children. Higher cumulative corticosteroid dose, prolonged steroid therapy, age greater than ten years, and acute lymphoblastic leukemia were significant predictors of MRI-

confirmed osteonecrosis. MRI successfully identified asymptomatic lesions before structural collapse, facilitating early clinical intervention and potentially improving long-term joint preservation. Routine MRI surveillance should be considered for pediatric patients at high risk of steroid-induced osteonecrosis to enable timely diagnosis, individualized treatment, and prevention of irreversible musculoskeletal complications.

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