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Microvascular Perfusion Assessment During Core Decompression For Avascular Necrosis Of The Femoral Head: A Novel Intraoperative Monitoring Approach – A Case Report

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ABSTRACT

Background: Avascular necrosis (AVN) of the femoral head results from impaired bone microcirculation and can progress to collapse if untreated. Core decompression is the standard joint-preserving option in early stages, but assessment of its effect relies on delayed postoperative imaging. Real-time intraoperative perfusion evaluation is rarely used, though it may demonstrate immediate vascular improvement. Indocyanine green (ICG) near-infrared fluorescence provides dynamic perfusion imaging, but its role in AVN surgery remains scarcely documented.

Case Presentation: We report a 32-year-old male presenting with eight months of right groin pain aggravated by weight-bearing. MRI confirmed Ficat–Arlet stage II AVN of the right femoral head. The patient underwent fluoroscopy-guided core decompression. Intraoperative microvascular perfusion assessment was performed using ICG near-infrared fluorescence imaging. Baseline imaging demonstrated delayed and diminished fluorescence of the femoral head. Following core decompression and curettage, repeat ICG injection revealed significant improvement in fluorescence intensity and reduced time-to-peak signal, indicating enhanced microvascular perfusion. The procedure was completed without complications. Postoperatively, the patient followed a partial weight-bearing protocol and demonstrated progressive symptomatic improvement. At one-year follow-up, the patient remained pain-free with preserved femoral head architecture and no radiological evidence of collapse. The case reports the feasibility and clinical utility of intraoperative microvascular perfusion assessment during core decompression for AVN. Real-time perfusion imaging provides functional confirmation of revascularization, potentially enhancing surgical decision making and prognostication.

KEYWORDS: Avascular necrosis, femoral head, core decompression, microvascular perfusion, indocyanine green, near-infrared fluorescence

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INTRODUCTION

Avascular necrosis (AVN) of the femoral head is a progressive and potentially debilitating condition characterized by compromised microcirculation to the femoral head, leading to ischemia, osteocyte death, subchondral collapse, and eventual secondary osteoarthritis. It commonly affects young and middle-aged adults, significantly impairing mobility, productivity, and overall quality of life (1). Although several etiological factors have been identified including chronic corticosteroid use, excessive alcohol consumption, trauma, hemoglobinopathies, metabolic disorders, and idiopathic causes the final common pathway remains vascular insufficiency and impaired bone remodelling. Early recognition and timely intervention are essential to prevent irreversible structural collapse and the need for total hip arthroplasty, especially in younger patients (2).

Core decompression has long been the most widely accepted joint-preserving surgical procedure for early-stage AVN, particularly Ficat–Arlet stages I and II, where structural integrity of the femoral head remains preserved. The technique seeks to reduce intraosseous pressure, enhance venous outflow, alleviate mechanical stress, and stimulate angiogenesis and reparative bone turnover (3). Various modifications such as multiple drilling, use of vascularized or non-vascularized bone grafts, autologous bone marrow concentrate, stem cell augmentation, and porous implants have been developed to improve outcomes. However, despite these advancements, assessment of the physiological impact of core decompression remains largely indirect and delayed (4). Clinical improvement and radiological changes often take months to manifest, and imaging modalities such as MRI, though highly sensitive for diagnosis, cannot provide real-time information on intraoperative perfusion dynamics (5).

Microvascular perfusion is central to understanding both the pathogenesis and treatment response in AVN. Yet, intraoperative assessment of femoral head blood flow is seldom performed due to limitations in available techniques (6). Traditional methods such as intraosseous pressure measurement or laser Doppler flowmetry offer only point measurements, require specialized equipment, and are technically demanding. In contrast, indocyanine green (ICG) near-infrared (NIR) fluorescence imaging has emerged as a simple, safe, and reproducible method to assess soft-tissue and bone perfusion in real time (7). ICG is a fluorescent dye that binds to plasma proteins and emits light when excited by near-infrared wavelengths, allowing visualization of vascular

flow and tissue perfusion. Its role is well established in plastic and reconstructive surgery, gastrointestinal anastomosis, neurosurgery, and peripheral vascular assessment. However, its application within orthopedic surgery particularly in AVN remains limited and sparsely reported (8).

Assessing intraoperative perfusion during core decompression could offer several advantages. It may provide immediate confirmation of improved vascularity, help quantify physiological response, and guide intraoperative decision-making, such as the need for additional drilling or biologic augmentation (9). Furthermore, perfusion patterns may have prognostic significance in predicting postoperative outcomes and risk of femoral head collapse. Real-time imaging could also enhance standardization of surgical technique and contribute to research aiming to stratify patients based on perfusion response (10).

This case report presents a patient with early-stage femoral head AVN in whom intraoperative microvascular perfusion was evaluated using ICG NIR fluorescence imaging during core decompression. The report highlights the feasibility, safety, and potential utility of this technique in providing functional insights beyond conventional structural assessment. By demonstrating immediate perfusion improvement following decompression, this case emphasizes the potential of perfusion imaging as a valuable adjunct in the surgical management of AVN.

CASE PRESENTATION

Patient Information: A 32-year-old male presented to the orthopaedic outpatient clinic with an eight-month history of right hip pain. The pain was insidious in onset, localized to the groin, and progressively worsened over the past three months. It intensified with weight-bearing activities, prolonged standing, and stair climbing, while partially relieved by rest and NSAIDs. There was no history of trauma, long-term corticosteroid usage, major systemic illness, hemoglobinopathies, or previous hip surgery. The patient reported occasional social alcohol consumption but had no other significant risk factors. His medical, family, and psychosocial histories were otherwise unremarkable.

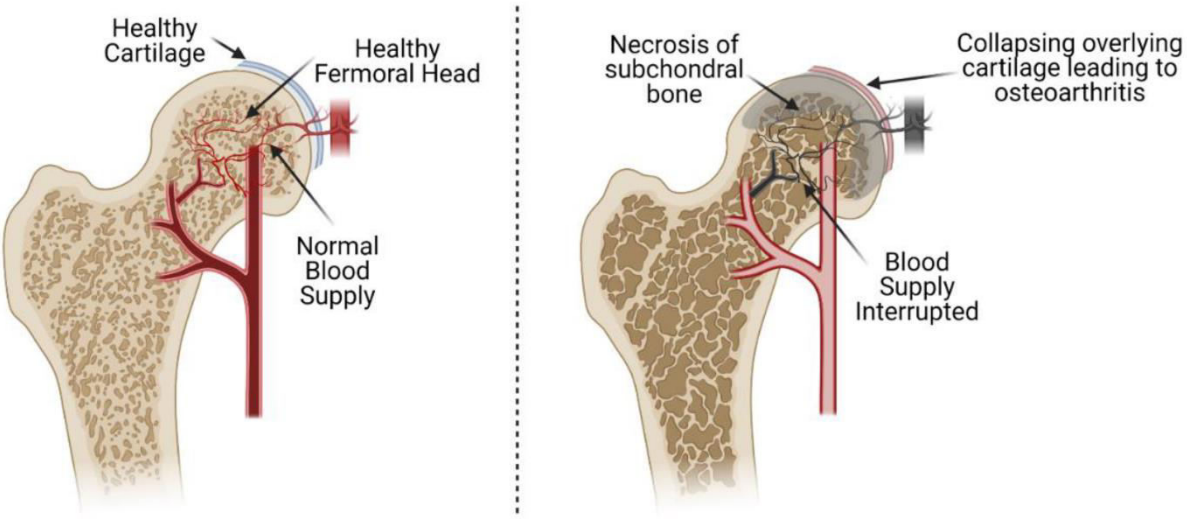

Fig 1: Comparison of Normal Femoral Head Vascularity and Avascular Necrosis Pathology.

Clinical Findings: On examination, the patient had an antalgic gait and mild tenderness over the anterior hip region. Range of motion assessment revealed painful limitation of flexion beyond 100° and internal rotation, while extension and abduction were relatively preserved. There were no deformity, limb length discrepancy, or signs of muscle atrophy. Neurovascular examination of the affected limb was normal. Systemic examination findings were within normal limits.

Diagnostic Assessment: Pelvic radiographs (anteroposterior and frog-leg lateral views) demonstrated subtle sclerosis and early cystic changes in the anterosuperior quadrant of the right femoral head, without subchondral collapse. MRI revealed a serpiginous hypointense line on T1-weighted images with hyperintense signal on T2/STIR sequences, consistent with Ficat–Arlet stage II AVN. The contralateral hip appeared normal. Baseline laboratory tests including complete blood count, ESR, CRP, renal and liver panels were unremarkable. After multidisciplinary discussion, core decompression was planned as a joint-preserving procedure.

Fig 2: Intraoperative fluoroscopic image demonstrating guidewire placement into the necrotic zone of the femoral head during core decompression

Therapeutic Intervention: Under spinal anaesthesia, the patient was positioned supine on a radiolucent table. Using a lateral approach to the proximal femur and C-arm guidance, a guidewire was advanced into the necrotic area of the femoral head. A 10-mm cannulated reamer was used to create a core tract up to the subchondral plate. Necrotic cancellous bone was curetted gently. For intraoperative perfusion assessment, indocyanine green (ICG) at 0.25 mg/kg was administered intravenously. A near-infrared camera system recorded baseline perfusion before drilling. Repeat imaging after decompression revealed significantly increased fluorescence intensity and shorter time-to-peak enhancement, suggesting improved microvascular perfusion. The tract was then packed with cancellous autograft from the ipsilateral iliac crest, and the wound was closed in layers. No intraoperative complications occurred.

Follow-Up and Outcomes: The patient was kept on partial weight-bearing with crutches for six weeks and then gradually progressed to full weight-bearing. At the six-week review, pain had markedly decreased. By three months, the patient had resumed daily activities with minimal discomfort. At one-year follow-up, he remained pain-free with a Harris Hip Score improvement from 58 preoperatively to 88 postoperatively. Follow-up radiographs showed preservation of the femoral head contour without evidence of collapse or degenerative changes.

DISCUSSION

Avascular necrosis (AVN) of the femoral head continues to pose a significant management challenge, particularly in young adults where preservation of the native hip joint is a priority. The pathophysiology involves disruption of the microvascular network supplying the femoral head, resulting in ischemia, cellular death, and eventual structural collapse. Early intervention before subchondral collapse is crucial, and core decompression remains the preferred joint-preserving procedure in Ficat–Arlet stages I and II (1). Despite widespread use, one of the inherent limitations of core decompression is the absence of an intraoperative method to objectively confirm improvement in femoral head perfusion. Traditionally, success has been inferred from symptom relief and delayed radiological changes, both of which may take months to manifest (11).

The application of indocyanine green (ICG) near-infrared (NIR) fluorescence imaging in this case provides a unique real-time functional assessment of microvascular perfusion during core decompression. ICG imaging is well-established in many surgical fields for evaluating tissue viability, flap perfusion, anastomotic integrity, and vascular flow. Its use in orthopaedic surgery, specifically AVN, is limited but highly promising (12). The technique offers a dynamic visualization of perfusion patterns and enables intraoperative comparison before and after decompression. In our patient, the marked increase in fluorescence intensity and improved time-to-peak enhancement post-decompression indicated immediate physiological benefit and verified that the intervention achieved its objective of enhancing blood flow (13).

Several advantages arise from incorporating perfusion assessment during AVN surgery. First, it provides objective confirmation of improved microcirculation, allowing surgeons to validate the adequacy of decompression. Second, it may help stratify patient prognosis, as individuals demonstrating strong perfusion recovery may have lower risk of progression to collapse. Third, it may guide intraoperative decisions, especially in complex or borderline cases. For instance, inadequate perfusion improvement could prompt additional drilling, modification of technique, or the use of biologic augmentation such as bone marrow aspirate concentrate or stem-cell–enhanced grafting. Finally, perfusion mapping enables collection of quantifiable, reproducible data that could improve standardization of surgical protocols (14).

Previous studies using alternative methods such as laser Doppler flowmetry or intraosseous pressure monitoring have shown promise but remain limited due to technical difficulty, invasiveness, or inability to map perfusion across a broader area. In contrast, ICG NIR imaging offers a wider field of view, rapid acquisition, ease of repeatability, and minimal additional operative time. Its safety profile is well established, with low risk of allergic reactions when used in standard doses (15).

The sustained clinical improvement and preservation of femoral head architecture in our patient support the likelihood that improved perfusion correlates with favourable long-term outcomes. However, this observation must be interpreted cautiously. A single case cannot establish a definitive causal relationship, and long-term success in AVN depends on several factors including aetiology, lesion size, patient compliance, and biological response. Nevertheless, the physiological plausibility and immediate intraoperative findings strengthen the argument for further exploration of perfusion imaging as an adjunctive tool (16).

Several limitations merit consideration. First, NIR fluorescence provides a relative, rather than absolute, measure of perfusion and can be influenced by hemodynamic factors. Standardized imaging protocols are therefore essential. Second, the penetration depth of NIR signal through bone is limited; the fluorescence observed represents indirect regional perfusion rather than direct visualization of intraosseous flow. Third, equipment availability and cost may restrict use in resource-limited settings. Despite these limitations, the technique remains feasible, safe, and informative (17).

Overall, this case underscores the potential value of intraoperative microvascular perfusion assessment in AVN surgery. As technology advances and evidence accumulates, perfusion imaging may become an integral part of joint-preserving strategies, improve surgical precision and help predict outcomes in this complex condition.

CONCLUSION

This case demonstrates the successful use of intraoperative microvascular perfusion assessment using indocyanine green near-infrared fluorescence imaging during core decompression for early-stage femoral head AVN. The technique provided real-time visualization of perfusion improvement following decompression, offering functional confirmation of enhanced microvascular flow an insight not achievable with conventional imaging. The patient experienced sustained symptomatic relief and preservation of femoral head structure at one-year follow-up, supporting the potential relationship between improved perfusion and favourable outcomes. Although further studies with larger cohorts are required, this report highlights the feasibility, safety, and clinical utility of incorporating perfusion imaging into AVN surgery. Real-time vascular assessment may serve as a valuable adjunct for guiding intraoperative decisions, predicting prognosis, and refining joint-preserving treatment strategies for AVN.

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