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Research Article

The effect of the Japanese Investigation Committee classification on hip joint survival after core decompression therapy in pre-collapsed avascular necrosis of the femoral head

Japon İnceleme Komitesi sınıflandırmasının, femur başı prekollaps avasküler nekrozunda kor dekompresyon tedavisi sonrası kalça eklemi sağkalımı üzerindeki etkisi

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Abstract

Aim: This study aimed to determine the failure rate of pre-collapse avascular necrosis (AVN) of the femoral head treated with core decompression (CD) and risk factors affecting the progression of the disease in patients by using an easily applicable staging system.

Material and Methods: A total of 174 hips from 134 patients diagnosed with precollapse AVN and treated with CD were retrospectively examined. Each hip was classified using the Japanese Investigation Committee (JIC) classification. The endpoint for joint survival following treatment was defined as the occurrence of total hip arthroplasty (THA). The risk analysis on joint survival of various independent variables (treatment type, age, gender, etiology) and the frequency of THA 2 and 5 years after treatment was calculated.

Results: The mean age of the patients was 44.0 ± 15.0 years, with the majority being male (71.8%). THA was performed in 28.7% of treated hips within two years and 40.2% within five years. The frequency of THA application within two years was 2% for type A, 8% for type B, 40% for type C1 and 50% for type C2. Age ($p=0.033$), type C1 ($p=0.028$) and type C2 ($p<0.01$). The rate of post-treatment THA in patients with AVN due to steroid use was found to be significantly higher than in other etiologies ($p<0.001$). The average survival time of type C1 hips despite treatment is 58.5 months, while the average survival time of type C2 hips is 42.8 months.

Conclusion: In patients with type C1 and C2, hip survival times are significantly shorter than those of type A and type B hips, regardless of previous treatment, and it is a risk factor for THA. Additionally, history of steroid use and age were found to be independent risk factors that shorten hip joint survival.

Keywords: avascular necrosis, core decompression, femoral head, classification, total hip arthroplasty

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Öz

Amaç: Bu çalışma, kor dekompresyon ile tedavi edilen prekollaps femur başı avasküler nekrozunun başarısızlık oranını ve hastalarda hastalığın ilerlemesini etkileyen risk faktörlerini kolay uygulanabilir bir evreleme sistemi kullanarak belirlemeyi amaçlamadı.

Gereç ve Yöntemler: Prekollaps avasküler nekroz tanısı almış ve kor dekompresyon ile tedavi edilmiş 134 hastanın 174 kalçası retrospektif olarak incelendi. Her kalça, Japon İnceleme Komitesi (JIC) sınıflandırması kullanılarak sınıflandırıldı. Tedavi sonrası eklem sağkalımının sonlanma noktası, total kalça artroplastisi yapılması olarak tanımlandı. Farklı bağımsız değişkenlerin (tedavi türü, yaş, cinsiyet, etiyoloji) eklem sağkalımına etkisi ve tedaviden sonraki 2 ve 5 yıl içinde THA sıklığı hesaplandı.

Bulgular: Hastaların ortalama yaşı 44.0 ± 15.0 yıl olup, çoğunluğu erkekti (%71,8). Tedavi edilen kalçaların %28,7'sine iki yıl içinde ve %40,2'sine beş yıl içinde THA yapıldı. İki yıl içinde THA uygulanma sıklığı tip A için %2, tip B için %8, tip C1 için %40 ve tip C2 için %50 idi. Yaş (p=0,033), tip C1 (p=0,028) ve tip C2 (p<0,01) anlamlı bulundu. Steroid kullanımına bağlı AVN'li hastalarda tedavi sonrası THA oranı diğer etiyolojilere göre anlamlı olarak daha yüksek bulundu (p<0,001). Tip C1 kalçaların tedaviye rağmen ortalama sağkalım süresi 58,5 ay iken, tip C2 kalçaların ortalama sağkalım süresi 42,8 aydı.

Sonuçlar: Tip C1 ve C2 olan hastalarda, kalça sağkalım süreleri, önceki tedaviden bağımsız olarak tip A ve tip B kalçalara göre anlamlı derecede daha kısadır ve bu, THA için bir risk faktörüdür. Ayrıca, steroid kullanım öyküsü ve yaş, kalça eklemi sağkalımını kısaltan bağımsız risk faktörleri olarak bulunmuştur.

Anahtar Kelimeler: avasküler nekroz, kor dekompresyon, femur başı, sınıflandırma, total kalça artroplastisi

Introduction

Femoral head avascular necrosis (AVN) is a multifactorial disease affecting young and middle-aged adults [1]. The most common risk factors are long-term intake of alcohol and corticosteroids [2, 3]. Although the mechanism of the development of the disease is not fully known, osteonecrosis in the subchondral bone and subsequent collapse of the joint surface cartilage occurs [4]. Spontaneous recovery is very rare in individuals with untreated AVN, so subchondral collapses that develop may cause early osteoarthritis, leading to the necessity for total hip arthroplasty (THA), including in young patients. Studies show that osteoarthritis due to AVN is responsible for 5 to 12% of all THA [5, 6]. For this reason, the most important prognostic indicator in patients with AVN is the collapse of the femoral head cartilage, and THA becomes inevitable in the subsequent period [7, 8].

Treatment of AVN is based on the stage of the disease. In the early stages of the disease, various joint-preserving procedures are applied to protect the joint and prevent collapse of the femoral head. Especially in young adults, early diagnosis and regenerative treatments are critical for hip joint survival. For this purpose, several interventions can be performed to postpone and reduce the possibility of hip replacement, including physical therapy, pharmacotherapy, bone flap transplantation with vascular pedicles, and core decompression (CD) of the femoral head [9-11]. CD is the most commonly used treatment for early AVN, and in recent years, bone marrow-derived mesenchymal stem cell concentrates (BMAC) have been added to this [3, 9, 12]. The ability of magnetic resonance imaging (MRI) to diagnose the disease with more than 90% sensitivity in the early stages has enabled us to apply more joint-preserving procedures in recent years [13, 14]. However, despite hip-preserving procedures applied in patients with early-stage AVN, femoral head collapse develops at rates ranging from 14 to 60.5%, depending on the volume, location, and depth of necrosis [15-17]. It has been reported that early collapse occurs in nearly one-third of pre-collapse cases with AVN, regardless of joint-preserving treatment methods, and many of these patients eventually require THA due to the development of secondary osteoarthritis [18].

This study aimed to determine the failure rate of pre-collapse AVN of the femoral head treated with CD and risk factors affecting the progression of the disease in patients by using an easily applicable staging system.

Material and Methods

This study was conducted in accordance with the ethical criteria of the 1964 Declaration of Helsinki and was approved by the institutional human research ethics committee (No: 2023-777). Between March 2013 and June 2018, 174 hips of 134 patients (92 men, 42 women) who were diagnosed with pre-collapsed AVN and treated with augmentation (BMAC) and non-augmentation CD (CD-BMAC and CD) methods were performed. The data were examined retrospectively. During treatment, bilateral hip involvement was present in 40 patients (29.8%). The median age

of the patients was 44 years (19-75 years), and the average follow-up period after treatment was 81 months (62-115 months).

The diagnosis of the patients was made based on history, physical examination, and radiological imaging, and the diagnosis of pre-collapse AVN was confirmed using two-way hip radiography, computed tomography (CT) of the affected hip, and MRI. Accordingly, diagnosed patients were grouped according to the JIC classification, a staging system based on the involvement of the weight-bearing surface of the femoral head [19]. There were 21 affected hip joints in the Type A group, 32 in the Type B group, 68 in the Type C1 group, and 53 in the Type C2. Forty-five patients had a history of corticosteroid use, and 14 patients had a history of excessive alcohol use. Additionally, six patients had a history of Systemic Lupus erythematosus, four patients had a history of hematological malignancy, and two patients had a history of sickle cell anemia. No etiological cause was detected in 63 patients, and they were classified in the idiopathic AVN group. While 78 of the diagnosed patients underwent only CD, 96 underwent CD-BMAC. The exclusion criteria included patients diagnosed with AVN and subchondral collapse, patients diagnosed with traumatic AVN, patients with AVN who underwent hip-preserving treatment options other than CD or CD-BMAC (osteotomy, bone graft, vascularized fibula, etc.), and patients under the age of 18.

In treated patients, the final hip survival time was defined as the time of THA. Accordingly, patients who underwent THA within two years after treatment were collected in Group 1, while patients who did not undergo THA were collected in Group 2. Patients in both groups were examined regarding JIC classification, etiology, treatment method, age, and gender, and risk analysis was performed. In addition, the hip survival of the patients in the second and fifth years was examined, and the average hip survival time was estimated depending on the variables.

Surgical technique

All patients underwent CD under general anesthesia. Under fluoroscopic guidance, three 2.5 mm endobutton guide wires were advanced into the affected hips from the greater trochanter along the long axis of the femoral neck to reach the subchondral necrotic area. After determining the most centrally placed guide wire, the decompression process was completed with a 4.5 mm endobutton thread. In patients who underwent augmentation with BMAC, 100 ml of bone marrow was taken percutaneously from the iliac crest for a single application, and intraoperative processing and concentration were performed. Approximately 4-5 ml of bone marrow concentrate was injected into the necrotic area with a special tip through the endobutton.

Statistical analysis

All data were analyzed with IBM SPSS Statistics for Windows 22.0 (IBM Corp., Armonk, NY, USA). Numerical data determined to be normally distributed based on the results of Kolmogorov-Smirnov tests are given as mean (standard deviation [SD]) values while non-normally distributed variables are given as median (25th-75th quartile) values. Categorical variables are given as numbers and percentages, and inter-group comparisons were conducted with Chi-square and Fisher exact tests. Binary Logistic regression analysis was performed to find variables associated with increased risk of THA during the two-year follow-up period. Kaplan-Meier analysis was used to determine the duration of THA in the second and fifth years of the patients. Significance was accepted at $P < 0.05$ (*) for all statistical analyses.

Results

The mean age of the patients was 44.0 ± 15.0 years, with the majority being male (71.8%). Demographic and clinical data of the patients included in the study are given in Table 1.

Of the 174 hips diagnosed with pre-collapsed AVN, CD was applied as a treatment method to 78 (44.8%), and CD-BMAC combination was applied to 96 (55.2%). The rate of progression to THA in treated hips within two years was 28.7% (50 hips), while the rate of progression within five years was calculated as 40.2% (70 hips). When the group that underwent THA (Group 1) and the group that did not (Group 2) were compared within two years, the male/female ratio was found to be similar in both groups (p=0,952). The proportion of patients with bilateral hip involvement was statistically similar in both groups (p=0,17). According to the JIC classification, the frequency of type A and type B hips was higher in the 2nd group, while the frequency of type C2 hips was significantly higher in the 1st group (p<0,001). When examined etiologically, the frequency of steroid intake was higher in group 1, while the frequency of idiopathic AVN was significantly lower (p<0.001). Alcohol intake history was similar between both groups (p>0,05). It was determined that the treatment applied in patients with AVN (CD or CD-BMAC) was statistically ineffective on hip survival (p = 0,618).

Age, stage C1 and C2 were found to be associated with the increased risk of THA in 2 years (p<0.05), while gender, bilateral involvement (and previous surgery method (0.715) were not associated with the risk of THA in 2 years. (p>0.05). Table 2 shows the results of the logistic regression analysis. The risk of THA in two years was higher in glucocorticoid and alcohol-induced AVN than in idiopathic AVN but was similar in other pairwise comparisons of etiological causes (p=0.02). Data are given in Table 2.

Table 1. Demographic and clinical features of the patients

	All patients (n=134, 174 hips)	Non-THA in 2 years (n=92, 124 hips)	THA in 2 years (n=42, 50 hips)
Age (median; IQR or mean ± SD)	44.0 (15.0)	44.0 (16.0)	47.0 (15.0)
Gender (n/%)			
Female	49 (28.2)	36 (29.0)	14 (28.0)
Male	125 (71.8)	88 (71.0)	36 (72.0)
Bilateral involvement (n/%)	40 (29.8)	32 (25.8)	8 (19.0)
JIC (n/%)			
A	21 (12.1)	20 (16.1)	1 (2.0)
B	32 (18.4)	28 (22.6)	4 (8.0)
C1	68 (39.1)	48 (38.7)	20 (40.0)
C2	53 (30.5)	28 (22.6)	25 (50.0)
Etiology (n/%)			
GC	59 (33.9)	24 (19.4)	24 (48.0)
Alcohol	19 (10.9)	8 (6.4)	8 (16.0)
İdiopathic	77 (44.3)	52 (41.8)	12 (24.0)
Hematological malignancy	5 (2.9)	3 (2.4)	1 (2.0)
SCA	2 (1.1)	1 (0.8)	1 (2.0)
SLE	12 (6.9)	4 (3.2)	4 (8.0)
Surgery method			
CD-B	96 (55.2)	67 (54.0)	29 (58.0)
CD	78 (44.8)	57 (46.0)	21 (42.0)
Time to THA (months)	-	16.0 (9.3)	-
Follow-up time (months)	72.0 (57.3)		

*THA: Total hip arthroplasty, IQR: Interquartile range, GC: Glucocorticoid, SCA: Sickle cell anemia, SLE: Systemic lupus erythematosus, CD-B: Core decompression bone graft, CD: Core decompression

Table 2. Binary logistic regression analysis of variables associated with increased risk of total hip arthroplasty in 2 years

Variables	OR	95% CI lower-upper	P-value
Age	1.036	1.002-1.070	0.036
Gender	0.857	0.384-1.915	0.707
JIC stage B	2.653	0.268-26.295	0.405
JIC stage C1	8.312	1.013-68.190	0.039
JIC stage C2	16.349	1.987-134.534	0.009
Bilateral involvement	0.632	0.251-1.588	0.328
Previous surgery method	1.070	0.512-2.233	0.858

CI, confidence intervals; JIC, Japanese Investigation Committee; OR, odds ratio

According to binary logistic regression analysis, age (p=0,033, OR:1.045), type C1 hip (p=0,029, OR:11,035), type C2 hip (p<0,01, OR:23.699), and history of steroid intake (p=0,019, OR: 14.876) were identified as risk factors associated with the probability of progression to THA within two years after treatment. Gender (p=0,663), bilateral hip joint involvement (p=0,196), and type of previous surgical method (p=0,715) were not found among the risk factors. When examined etiologically, it was found that the probability of THA application within two years was the lowest in patients with idiopathic AVN (p =0,046, OR: 0,220).

According to Kaplan-Meier analysis, the average time to THA of our treated patients with pre-collapse AVN was estimated as 59,310 months (SD: 2,366; 95% CI: 54,672-63,949 months), and in Type A hips, the average time to THA was 80,952 months (SD: 2,974; 95% CI: 75.123-86.782 months), while in type C2 hips this period was calculated as 42,868 months (SD: 4.141; 95% CI: 34.752-50.984 months) on average (Figure 1). When examined etiologically, the average time to THA after treatment in patients with a history of steroid intake is 49,746 months (SD: 4,240; 95% CI: 41,436-58,036 months), while this period is 67,532 months (SD: 3,028; 95% CI) in patients with idiopathic AVN. (61,598-73,467 months) (Figure 2).

Discussion

This study examined the effects of CD and the CD-BMAC combination on joint preservation in femoral head AVN treatment. THA was performed in 28.7% of patients within two years and 40.2% within five years. Age, type C1 and C2 hips in the JIC classification, and steroid use were identified as factors increasing the risk of THA. The treatment method (CD or CD-BMAC) was not statistically significant in influencing hip joint survival.

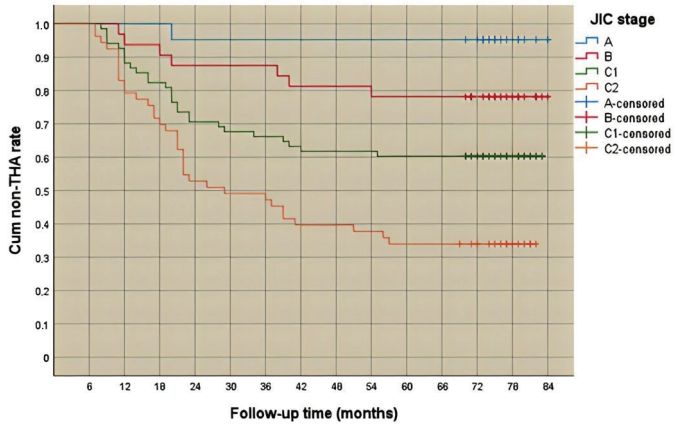

Figure 1. A: Kaplan-Meier graphic of time of not undergoing total hip arthroplasty according to Japanese Investigation Committee stage.

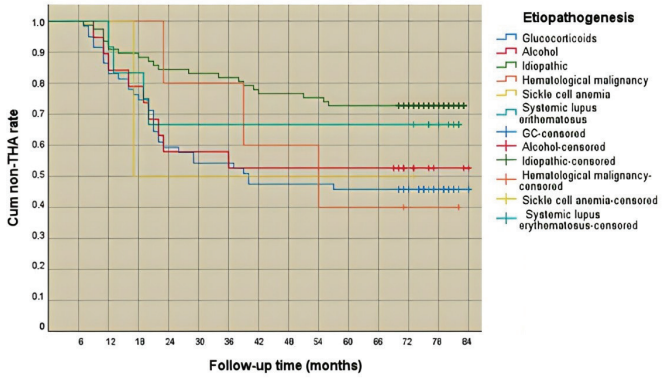

Figure 2. Kaplan-Meier graphic of time of not undergoing total hip arthroplasty according to etiopathogenesis.

Various classification systems have been widely used in making treatment decisions, choosing treatment methods, and estimating average hip survival in AVN. The effectiveness of each classification system in determining treatment and prognosis still needs clarification. However, the common view is that an ideal classification method should meet the following conditions. 1. It should be simple and easy to apply; 2. It should be reproducible and reliable among observers, 3. It should be able to predict the progression of AVN successfully; 4. It should be able to contribute to the choice of treatment. In our study, it has been shown that the JIC classification largely meets the above conditions and is successful in predicting hip survival and disease progression considering the JIC types. While the two-year hip joint survival rates of 21 JIC type A hips and 32 type B hips treated from our patients were 95.2% and 87.5%, respectively, in the five years, this rate was found to be 95.2% and 81.3%, respectively. However, two- and five-year survival rates decrease dramatically in type C1 and especially type C2 hips despite treatment. In our study, the two- and five-year survival rates of 68 type C1 hips were found to be 70.5% and 60.2%, respectively, while this rate was calculated to be 52.8% and 32%, respectively, for 53 type C2 hips. As a result, while hip joint survival continued greatly with treatment in JIC type A and type B hips, hip joint survival was at a different level despite treatment in type C1 and especially type C2 hips.

The widespread use of MRI in diagnosing and treating AVN has been a historical turning point. With the increased use of MRI, the rate of patients diagnosed in the pre-collapse stages and undergoing joint-preserving surgery has increased. For this reason, the importance of classification systems has increased, and researchers have focused on this issue again. Mont et al. conducted a literature review to define the methods used for AVN classification. They found that Ficat and Arlet, Association Research Circulation Osseous (ARCO), Steinberg, and modified Kerboul classifications were used in most studies [20-24]. The Ficat-Arlet and Steinberg staging systems, commonly utilized today, are insufficient in assessing progression, particularly in pre-collapse avascular necrosis (AVN), as they do not consider critical variables such as the size and location of necrosis, which play significant roles in the disease's progression [25, 26].

Additionally, users do not prefer the Steinberg staging system due to its complexity. The ARCO classification system was developed to create an international classification system [27]. However, since its most important shortcoming was that it did not include the location of necrosis, the explanations of the Japanese Investigation Committee were added in later revisions. With the latest updates, it has become a complex classification system containing six stages and different subgroups within these stages [28]. The reliability and reproducibility of the ARCO classification in its final form within and between users continues to be a matter of debate. In the Kerboul method, the necrosis volume was determined with some formulations by measuring the angle of the femoral surface where necrosis occurred using midcoronal and midsagittal magnetic resonance images [22-24]. However, since conversion tables and calculators are required to calculate the affected femoral head volume, it has yet to find widespread use among observers [29, 30].

The most important feature that distinguishes the JIC classification from other methods is that it evaluates the location and size of necrosis with a sensitive imaging method such as MRI [19]. In this system, it has been argued that as the lesions grow, they progress from medial to lateral and face more

acetabular load, resulting in early collapse and degenerative arthritis [31, 32]. In a study that investigated the connection between necrosis volume and disease progression using the 3D MRI method, Nishii et al. emphasized the importance of necrosis volume. However, they emphasized that even if the lesions are volumetrically small, collapse occurs much faster in laterally located lesions [33]. Sultan et al., in their study comparing the most preferred classification systems, emphasized that the JIC classification is more promising in following the disease prognosis and is simpler to use than others [32]. The results of Kuroda et al. supported this study. Their study found that the two-year collapse rate was 0% in type A and type B hips, while this rate was 36% in type C2 hips [34]. In our study, the disease had similar rates of hip joint survival.

One of the most important advantages of the JIC classification is its simple use. In this way, inter- and intra-observer reliability is high and can be easily repeated in different centers. In the study conducted by Nakamura et al., the interobserver reliability of the JIC classification was reported as 85% and the interobserver reliability as 82% [35]. In the study conducted by Takashima et al. in 2018, they compared Steinberg, Modified Kerboul, and JIC classifications in the same patient group [29]. Their study concluded that the reliability and reproducibility of the JIC classification were notably high, approaching perfection, making it more effective than the Steinberg and Kerboul classifications, particularly in predicting early-stage AVN progression. In our study, orthopedic surgeons who are experts in hip joints classified the affected hips without using any software or measurement programs.

Some remarkable findings were revealed in this study. Hip survival rates were worse in elderly patients and in patients with pre-collapse AVN due to steroid use, regardless of the treatment method. Our results were compatible with previous studies [36-39]. Another striking finding in our study is that the treatment (CD or CD-BMAC) did not affect hip joint survival. Many studies have investigated this issue before, but a definitive conclusion has yet to be reached. Although some studies claim that CD combined with BMAC treatment is more effective than CD treatment, others have not demonstrated one superiority over another [11, 17, 40, 41-43]. However, the common opinion is that CD and CD-BMAC treatments are clinically and radiologically effective in most early-stage AVN [29, 34, 40].

Our study has some limitations. First, the included patients had different etiological causes (steroids, alcohol, etc.). Depending on the etiology, the natural course of the disease may differ. Second, there is no intra-observer and inter-observer reliability study for the JIC classification. Third and the last, the time of THA application is taken as the final survival of the hip joint. Although our follow-up period seemed sufficient, patients may have been reluctant to have arthroplasty.

Conclusion

The JIC classification in pre-collapsed AVN is an effective method in choosing treatment and predicting the natural course of the disease. In type A and type B hips, CD or CD-BMAC gives good clinical and radiologic results and prolongs hip joint survival. However, especially in type C2 hips, the prognosis is poor, and hip survival times are short, regardless of treatment. Our study will make important contributions to other researchers developing treatment algorithms in the future. It will also guide patients and surgeons in predicting the natural course of the disease.

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Conflicts of Interest

The authors declare they have no conflicts of interest.

Ethics Approval

The study was approved by the Ankara Etlik City Hospital Clinical Research Ethics Committee (24/01/2024 - No: 2023-777).

Informed Consent

The need for informed consent was waived under the approval of the Local Ethics Committee due to the retrospective design.

Availability of Data and Material

The data that support the findings of this study are available on request from the corresponding author.

Authors' contribution

Concept – E.A., Design- E.A., Data collection and/or processing - E.A., I.K., A.T., H.E.T., and A.F., Analysis and/or interpretation - E.A., I.K., A.T., H.E.T., and A.F., Writing – E.A., Critical review- I.K., A.T., H.E.T., and A.F. All authors read and approved the final version of the manuscript.

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