ORIGINAL ARTICLE

Prognostic significance of radiographically detected arterial calcification in geriatric hip fracture patients: Abdominal aortic calcification as an independent predictor of mortality

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ABSTRACT

BACKGROUND: To investigate the prevalence and anatomical distribution of radiologically detected arterial calcification in the abdominal, iliac, and femoral arteries among patients aged ≥65 years undergoing surgical treatment for hip fracture, and to assess the impact of both the presence and localization of arterial calcification on patient survival.

METHODS: A retrospective analysis was performed on 270 patients who underwent surgical treatment for hip fractures between 2015 and 2024. The presence of arterial calcifications in the abdominal aorta, iliac arteries, and femoral arteries was assessed on plain radiographs, and their association with patient survival outcomes was investigated. In addition, demographic characteristics, fracture type, treatment modality, and intensive care unit admissions were systematically evaluated.

RESULTS: Arterial calcification was identified in 211 patients (78.1%). The mean survival time was significantly shorter in patients with arterial calcification (47.3 months, 95% CI: 40.7–53.8) compared with those without (76.9 months, 95% CI: 67.1–86.7) (Log-rank χ^2=17.23, p<0.001). Log-rank analysis further demonstrated statistically significant differences in survival between patients with and without calcification of the abdominal aorta (χ^2=21.39, p<0.001), iliac arteries (χ^2=18.21, p<0.001), and femoral arteries (χ^2=10.91, p=0.001). Cox regression analysis identified abdominal aortic calcification as an independent predictor of mortality in geriatric hip fracture patients (HR=3.43, 95% CI: 1.31–8.96, p=0.013), whereas iliac artery calcification (HR=1.53, p=0.284) and femoral artery calcification (HR=1.05, p=0.859) were not independently associated with survival after adjustment.

CONCLUSION: Iliac and femoral artery calcifications should not be regarded as independent predictors of mortality in geriatric patients with hip fractures. In contrast, abdominal aortic calcification has been identified as an independent prognostic determinant of mortality within this patient population.

Keywords: Abdominal aortic calcification; femoral artery calcification; hip fracture; mortality; iliac artery calcification.

INTRODUCTION

Hip fractures are traumatic injuries that cause a serious clinical and economic burden, particularly among people over the age of 65.[1] As the elderly population is growing worldwide, the incidence of osteoporotic hip fractures is also increasing. These fractures are associated with serious morbidity and mortality, as well as a reduced quality of life.[2-3] According to

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projections, there will be more than six million hip fracture cases worldwide each year by 2050.[4]

In recent years, the relationship between arterial calcification—particularly in the abdominal aorta as well as the iliac and femoral arteries—and bone health has attracted increasing attention.[5-9] The effects of arterial calcification on bone tissue are multifaceted and complex. Primarily, arterial stiffening and luminal narrowing may lead to reduced regional blood flow, thereby limiting the delivery of osteogenic cells and essential healing factors to the bone. These pathophysiological mechanisms can contribute to delayed bone repair and increase the risk of complications, particularly regarding fracture healing.[10] In addition, it has been shown that there is a bidirectional relationship between arterial calcification and osteoporosis, i.e., vascular calcification may coexist with low bone mineral density.[11] Furthermore, factors such as polypharmacy, malnutrition, and immobility, which are prevalent in older ages, may increase the extent of atherosclerotic changes.[12] Finally, the prognostic significance of arterial calcification on mortality may vary by vascular location, with calcification confined to the iliac or femoral arteries more likely representing localized disease and, therefore, having limited prognostic relevance. In contrast, abdominal aortic calcification, potentially reflecting advanced systemic atherosclerosis and its pronounced effects on central hemodynamics and end-organ perfusion, may have the greatest impact on survival.

In elderly patients undergoing surgery for hip fractures, arterial calcification not only complicates the surgical procedure by compromising bone quality but has also been associated with a higher incidence of postoperative complications—including increased bleeding, delayed wound healing, and elevated infection rates.[13]—and independently contributes to an increased mortality risk.[14] However, the number of studies addressing this subject in the literature is limited,[15-17] and the effects of arterial calcification on the mortality of geriatric patients undergoing hip fracture surgery have not been clearly established.

The objective of this study was to investigate the prevalence and anatomical distribution of radiologically detected arterial calcification in the abdominal aorta, iliac arteries, and femoral arteries among patients aged ≥65 years undergoing surgical treatment for hip fracture, and to assess the impact of both the presence and localization of arterial calcification on patient survival. It is hypothesized that the findings of this investigation will provide a basis for the future development of alternative therapeutic algorithms for hip fracture patients identified as high-risk or with limited survival prospects.

MATERIALS AND METHODS

Following approval from the local ethics committee (Non-Pharmaceuticals and Non-Medical Devices Research Ethics Committee, Protocol No: 09.2025.25-0316), the study was conducted in accordance with the principles of the Declaration of Helsinki and STROBE guidelines for observational studies. A retrospective review was conducted of patients aged 65 years and older who were admitted to the study hospital with proximal femur fractures (both femoral neck fractures and intertrochanteric fractures) between 2015 and 2024 and underwent surgical treatment. The inclusion criteria comprised patients who were:

- Aged 65 years and older,
- Admitted to the emergency department within eight hours of sustaining low-energy trauma,
- Diagnosed with proximal femur fractures (both femoral neck fractures and intertrochanteric fractures),
- Had available preoperative radiological imaging, including plain radiographs for the evaluation of arterial calcification, and complete postoperative follow-up data.

Exclusion criteria included patients with:

- Pathological fractures,
- High-energy trauma,
- Multiple fractures,
- Nonsurgical management,
- Subtrochanteric fractures,
- History of previous hip surgery and/or the need for revision surgery,
- Incomplete clinical or radiological records, incomplete follow-up data.

Following the application of these criteria, 270 patients were included in the analysis.

The surgical management of the hip fractures was determined by the specific type of fracture and its associated anatomical location (collum femoris or intertrochanteric). Intracapsular fractures were treated with partial hemiarthroplasty, while extracapsular fractures were managed with either proximal femoral intramedullary nailing or dynamic hip screw (DHS) fixation, as described in the literature.[18] All surgical procedures were carried out under standard sterile conditions by the same surgical team. The perioperative administration of antibiotic prophylaxis, in the form of two grams of intravenous cefazolin, occurred 30 minutes prior to induction and was continued for a duration of 24 hours postoperatively. Furthermore, low-molecular-weight heparin was initiated postoperatively for thromboembolism prophylaxis.

A comprehensive evaluation was conducted, encompassing demographic variables (age and gender), fracture classification (collum femoris or intertrochanteric), and the treatment modality employed (intramedullary nailing, hemiarthroplasty, or dynamic hip screw). The anesthetic technique (general, spinal, or combined), the interval between fracture occurrence and surgery, as well as postoperative intensive care unit (ICU) admission rates, were recorded.

The primary outcome measure of the study was overall sur-

vival, which was defined as the time interval from surgery to death. During the collection of survival data, current hospital records, personal health data obtained from healthcare facilities, records from the citizen and physician access portal (e-Nabız), and the Central Population Registry System (MERNIS) were reviewed to confirm patients' vital status. In cases where survival status was uncertain or to determine the date of death for deceased patients, first-degree relatives were contacted using telephone numbers recorded in the patients' files, and the date of death was verified.

A radiological assessment was conducted using preoperative plain radiographs, which were independently reviewed by two orthopedic surgeons (VBÖ and MG). In accordance with definitions described in the literature, vascular calcification was diagnosed when vascular structures on X-ray images of the abdomen and extremities demonstrated radiodensity similar to that of bone.[19] The presence and anatomical distribution of calcification were evaluated within the abdominal aorta, iliac arteries, and femoral arteries. In one instance of discordant interpretation of the precise localization of the calcification, a third senior orthopedic surgeon (BG) was consulted, and the final classification was determined by consensus. Patients were categorized according to the anatomical distribution of arterial calcification, and clinical outcomes were compared across the following groups: isolated abdominal aortic calcification, iliac artery calcification (with or without concomitant abdominal aorta involvement), and femoral artery calcification (with or without concomitant abdominal aortic and iliac artery calcification). The evaluation of iliac and femoral artery calcifications was performed using anteroposterior and lateral radiographs of the hip and pelvis, while the evaluation of abdominal aortic calcifications was performed using anteroposterior and lateral radiographs of the lumbar region. All evaluated radiographs were routine radiological examinations requested in geriatric patients who were admitted to our emergency department with hip fractures. However, in two cases, anteroposterior and lateral lumbar radiographs were not available in the hospital picture archive system. Consequently, a cohort of 268 patients was evaluated for abdominal aortic calcification. The necessary radiographs for the evaluation of iliac artery and femoral artery calcifications were available for all patients (n=270).

All statistical analyses were performed using IBM SPSS Statistics, version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive analyses were used to summarize baseline demographic and clinical characteristics, with continuous variables reported as means and standard deviations, and categorical variables presented as frequencies and percentages. Overall survival was estimated using the Kaplan–Meier method. Survival distributions were compared between patients with and without arterial calcification—evaluated separately for the abdominal aorta, iliac arteries, and femoral arteries—using the log-rank test. The primary objective of the statistical analysis was to assess differences in survival across these calcification groups. A P-value of less than 0.05 was considered statistically significant.

RESULTS

The study population comprised 270 patients aged 65 years and over who underwent surgical treatment for hip fractures (mean age: 80.6±10.3 years; male/female: 99/171). Intertrochanteric fractures were observed in 139 patients (51.5%), while collum femoris fractures were observed in 131 patients (48.5%). The treatment modalities implemented included proximal femoral nailing in 136 cases (50.4%), hemiarthro-

Table 1. Detailed demographic characteristics of the patients

	Total Number of Patients (%)
Age, years	80.56 ± 10.27
Gender	
Female	171 (63.3%)
Male	99 (36.7%)
Follow-up, months	24.87 ± 22.26
Fracture Type	
Intertrochanteric	139 (51.5%)
Collum femoris	131 (48.5%)
Fracture-to-surgery period, days	7.75 ± 6.49
Surgical Treatment	
Proximal Femoral Nailing	136 (50.4%)
Hemiarthroplasty	132 (48.9%)
Dynamic Hip Screw	2 (0.7%)
Anesthetic Technique	
General	161 (59.6%)
Spinal	82 (30.4%)
Combined	27 (10.0%)
Intensive Care Unit Stay	
Yes	192 (71.1%)
No	78 (28.9%)
Arterial Calcification (n=270)	
Yes	211 (78.1%)
No	59 (21.9%)
Abdominal Aortic Calcification (n=268)	
Yes	210 (78.4%)
No	58 (21.6%)
Iliac Artery Calcification (n=270)	
Yes	179 (66.3%)
No	91 (33.7%)
Femoral Artery Calcification (n=270)	
Yes	125 (46.3%)
No	145 (53.7%)
Patient Survival	
Yes	176 (65.2%)
No	94 (34.8%)

plasty in 132 cases (48.9%), and DHS fixation in two cases (0.7%). The most frequently preferred anesthetic technique was general anesthesia (59.6%), followed by spinal anesthesia (30.4%) and combined anesthesia (10.0%). A comprehensive list of demographic variables is provided in Table 1.

During the survival analysis, 94 patients (34.8%) died, whereas 176 patients (65.2%) remained alive. The mean overall survival time was 54.2 months (95% CI: 48.4–60.0), with a 12-month survival rate of 81.4%. Arterial calcification was detected in 211 patients (78.1%), while 59 patients (21.9%) exhibited no evidence of calcification. Patients with arterial calcification demonstrated a significantly shorter mean survival time (47.3 months, 95% CI: 40.7–53.8) compared with those without calcification (76.9 months, 95% CI: 67.1–86.7) (Log-rank χ^2=17.23, p<0.001) (Fig. 1A).

As mentioned before, unlike other cohorts (n=270), a cohort of 268 patients was evaluated for abdominal aortic calcification. The abdominal aortic calcification was observed in 210 out of 268 evaluable patients (78.4%). The mean survival period was 46.9 months (95% CI: 40.5–53.5) in patients with calcification versus 79.8 months (95% CI: 70.4–89.1) in those without. The application of log-rank analysis revealed a statistically significant disparity in survival outcomes between the groups (χ^2=21.39, p<0.001) (Fig. 1B).

Iliac artery calcification was observed in 179 patients (66.3%), while 91 (33.7%) patients exhibited no such calcification. Patients with iliac artery calcification exhibited a mean survival period of 46.1 months (95% CI: 39.0–53.1), compared with 69.4 months (95% CI: 60.3–78.5) in those without calcification. A significant difference in survival distributions was observed between the groups (Log-rank χ^2 = 18.21, p<0.001) (Fig. 1C).

Femoral artery calcification was detected in 125 patients (46.3%), whereas 145 patients (53.7%) exhibited no evidence of calcification. The mean survival time was 45.6 months (95% CI: 37.8–53.4) in patients with femoral artery calcification, compared with 63.0 months (95% CI: 54.8–71.3) in those without calcification. A significant difference in survival distributions was observed between the groups (Log-rank χ^2=10.91, p=0.001) (Fig. 1D).

The application of a Cox regression analysis identified abdominal aortic calcification as an independent predictor of mortality (HR=3.43, 95% CI: 1.31–8.96, p=0.013). Conversely, iliac artery calcification (HR=1.53, p=0.284) and femoral artery calcification (HR=1.05, p=0.859) were not found to be independently associated with survival after adjustment.

DISCUSSION

In the context of a globally aging population, hip fractures remain a major contributor to both morbidity and mortal-

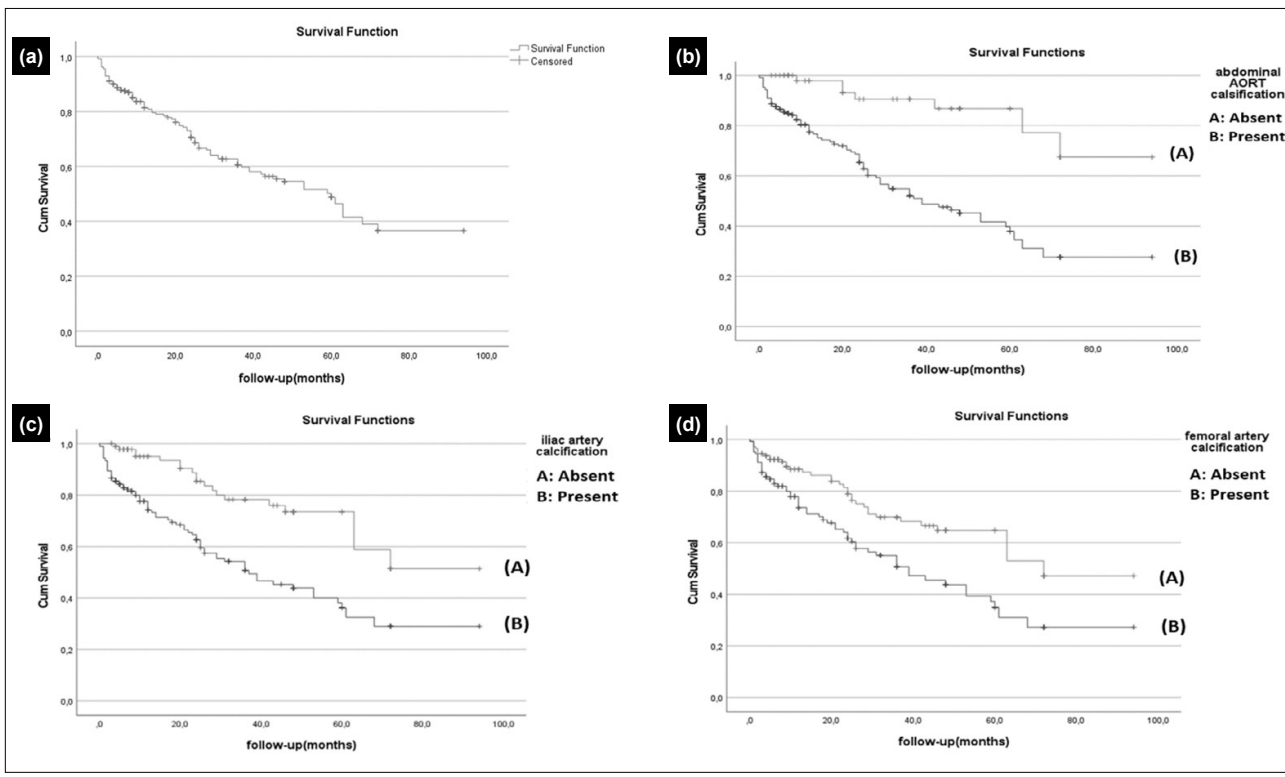


Figure 1. Cumulative Survival Curve Over the Follow-Up Period. **(a)** Overall survival of the study cohort following hip fracture surgery. **(b)** Comparison of survival between patients with and without abdominal aortic calcification. **(c)** Comparison of survival between patients with and without iliac artery calcification. **(d)** Comparison of survival between patients with and without femoral artery calcification.

ity.[20-22] Identifying prognostic factors influencing survival and delineating high-risk patient subgroups with reduced life expectancy may facilitate the development of alternative therapeutic strategies. The principal contribution of the present study to the existing body of literature is the demonstration of the association between the presence and anatomical localization of arterial calcification and mortality among patients aged 65 years and older with hip fractures. Although the impact of arterial calcification on mortality has been well established in the literature, studies examining its predictive value in specific patient populations, such as geriatric hip fracture patients, remain limited. Furthermore, existing research has largely focused on individual arterial territories. The principal strength and novel contribution of the present study lie in demonstrating the predictive effect of three distinct arterial calcifications—both individually and in combination—on mortality among patients aged 65 years and older with geriatric hip fractures.[15,16,23-28] The present study demonstrated that abdominal aortic calcification was an independent predictor of mortality (HR=3.43, 95% CI: 1.31–8.96, p=0.013). Conversely, while calcification in the iliac and femoral arteries was associated with diminished survival in unadjusted analyses (Log-rank χ^2=18.21, p<0.001, and Log-rank χ^2=10.91, p=0.001, respectively), these associations did not persist following multivariable adjustment (HR=1.53, p=0.284, and HR=1.05, p=0.859, respectively).

Extensive research has already demonstrated that abdominal aortic calcification is an independent and significant predictor of mortality.[23-25] A 2021 systematic review and meta-analysis of 52 studies on the subject concluded that abdominal aortic calcification is associated with an elevated risk of fatal cardiovascular events and all-cause mortality.[26] A study conducted in 2024 indicated that abdominal aortic calcification detected on lateral lumbar radiography was associated with all-cause mortality in older adults.[27] A prospective cohort study published in 2025 demonstrated the association of abdominal aortic calcification with all-cause mortality and emphasized its crucial role in identifying high-risk individuals.[28] On the other hand, the existing literature presents a conflicting set of opinions with regard to the impact of more distally located arterial calcifications on mortality. In 2021, Huynh et al. reported that iliac artery calcification is a significant predictor of mortality in patients suffering from chronic ischemia.[29] Furthermore, Birişik et al. reported in 2021 that femoral artery calcification was associated with increased mortality after geriatric hip fractures.[15] In contrast, the findings by Pazarci et al. in 2019 and Yolaçan and Güler in 2023 revealed that femoral artery calcification did not impact mortality in patients over 65 years of age with hip fractures.[16] Our data contribute to this knowledge by demonstrating that the prognostic effect is not uniform across vascular territories; rather, it is the presence of abdominal aortic calcification that exerts the most significant impact on survival. This may be explained by the central hemodynamic consequences of abdominal aortic involvement, which reflects advanced systemic atherosclerosis and has a greater influence on end-organ perfusion than more peripheral calcifications. By contrast, calcification localized to the iliac or femoral arteries may be more indicative of localized vascular changes without the same systemic prognostic weight.

The coexistence of several arterial calcifications and their similar clinical and prognostic effects is an expected finding. Indeed, in 2024, Meer et al. reported that femoral and crural calcifications correlate with coronary artery calcification and that arterial calcification presents as a systemic process occurring simultaneously in various arterial beds.[30] Our findings, however, are not consistent with these previously reported results. While all abdominal aortic, iliac, and femoral calcifications were found to be associated with shorter survival, regression analyses revealed that the only calcification localization with the characteristic of being an independent risk factor was the abdominal aorta. In fact, the distinction between independent and non-independent predictors holds significant clinical relevance. Although iliac and femoral calcifications were associated with reduced crude survival, they did not retain statistical significance after adjustment for confounding factors. This finding indicates that abdominal aortic calcification, which influences femoral and iliac artery calcifications, may affect mortality predictions and highlights the complexity of vascular health assessment in geriatric patients. Importantly, abdominal aortic calcification detected on routine radiographs can serve as a simple, accessible marker to identify high-risk patients without additional cost or advanced imaging. In circumstances where healthcare resources are limited, this prognostic indicator could facilitate the early identification of patients requiring closer monitoring during the perioperative period or rehabilitation pathways that are tailored to their individual needs.

From a rational standpoint, the identification of abdominal aortic calcification as a standalone risk factor for mortality has the potential to influence clinical decision-making. For instance, this marker could be incorporated into preoperative risk stratification algorithms alongside well-established predictors such as the American Society of Anesthesiologists (ASA) score, inflammatory markers, and frailty indices. In patients who have been identified as being particularly high-risk, clinicians may consider optimizing cardiovascular status in advance of surgery. They may also adjust surgical strategies or intensify postoperative surveillance and rehabilitation efforts. Furthermore, the acknowledgement of abdominal aortic calcification as a prognostic factor facilitates interdisciplinary collaboration, particularly between orthopedic surgeons, geriatricians, and cardiologists, in the management of these vulnerable patients.

The present study is facilitated by a relatively large, well-characterized cohort that has undergone standardized radiological assessments, in addition to comprehensive follow-up. However, it should be acknowledged that there are several limitations associated with this approach. Initially, the retro-

spective design introduces risks of selection and information bias. Secondly, although multivariable analyses were performed, this study specifically focused on the impact of visible calcification in the abdominal, iliac, and femoral arteries on mortality following geriatric hip fractures. This targeted focus was chosen because, while numerous studies have examined factors influencing hip fracture–related mortality, there remains a paucity of research addressing the prognostic role of arterial calcification in this context. Consequently, owing to the retrospective design and relatively limited sample size, several potential confounding factors associated with mortality—such as age, fracture type, comorbidity burden, Charlson Comorbidity Index, ASA score, preoperative frailty indices, nutritional status, pre-fracture nursing home residence, and comprehensive cardiovascular profiles—could not be fully accounted for. Thirdly, although the classification of calcification severity does not fully reflect the dynamic progression of vascular pathology, the absence of classification is a significant limitation. Finally, our findings derive from a single institution and may not be generalizable to other populations with differing demographics or healthcare systems.

In the future, the integration of vascular imaging with established orthopedic and geriatric risk scores has the potential to enhance the predictive accuracy for postoperative outcomes, preoperative risk stratification algorithms, and frailty indices. Interventional studies aimed at modifying vascular risk factors, improving perioperative optimization, and tailoring surgical strategies based on calcification status may further clarify the clinical utility of these findings.

CONCLUSION

A thorough understanding of the determinants of mortality in geriatric hip fracture patients is essential for accurate risk stratification, the formulation of evidence-based treatment algorithms, and the provision of appropriate counseling to patients and their caretakers. Although calcification of the iliac and femoral arteries has been associated with survival outcomes in this population, its effect appears to be contingent upon the presence of abdominal aortic calcification. Therefore, iliac and femoral artery calcification cannot be regarded as independent predictors of mortality. By contrast, abdominal aortic calcification has been identified as an independent prognostic factor for mortality in geriatric hip fracture patients aged 65 years and older. Future research should focus on prospective, multicenter studies to validate abdominal aortic calcification as a prognostic marker in hip fracture patients

Ethics Committee Approval: This study was approved by the Marmara University Faculty of Medicine, Non-Pharmaceuticals and Non-Medical Devices Research Ethics Committee (Date: 18.04.2025, Decision No: 09.2025.25-0316).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Geriatrik yaş kalça kırıklı hastalarıda radyografik olarak tespit edilen arteriyel kalsifikasyonun prognostik önemi: Mortalitenin bağımsız bir belirleyicisi olarak abdominal aort kalsifikasyonu

AMAÇ: Bu çalışmanın amacı, kalça kırığı nedeniyle cerrahi tedavi uygulanan ≥65 yaş hastalarda abdominal aort, iliak arterler ve femoral arterlerde radyolojik olarak saptanan arteriyel kalsifikasyonun prevalansı ve anatomik dağılımını araştırmak ve arteriyel kalsifikasyonun varlığı ile lokalizasyonunun hasta sağkalımı üzerindeki etkisini değerlendirmektir.
GEREÇ VE YÖNTEM: 2015-2024 yılları arasında kalça kırığı nedeniyle cerrahi tedavi uygulanan 270 hastanın retrospektif analizi gerçekleştirildi. Abdominal aort, iliak arterler ve femoral arterlerdeki arteriyel kalsifikasyonun varlığı düz radyografilerde incelendi ve hasta sağkalım sonuçları ile ilişkisi değerlendirildi. Ayrıca demografik özellikler, kırık tipi, tedavi yöntemi ve yoğun bakım ünitesine yatış gibi değişkenler sistematik olarak analiz edildi.
BULGULAR: Arteriyel kalsifikasyon 211 hastada (%78.1) saptandı. Ortalama sağkalım süresi, arteriyel kalsifikasyonu olan hastalarda (47.3 ay, %95 GA: 40.7–53.8), kalsifikasyonu olmayan hastalara kıyasla (76.9 ay, %95 GA: 67.1-86.7) anlamlı derecede daha kısaydı (Log-rank χ^2=17.23, p<0.001). Log-rank analizi ayrıca abdominal aort (χ^2=21.39, p<0.001), iliak arterler (χ^2=18.21, p<0.001) ve femoral arterlerdeki (χ^2=10.91, p=0.001) kalsifikasyon varlığı ile sağkalım arasında istatistiksel olarak anlamlı farklılıklar gösterdi. Cox regresyon analizinde abdominal aort kalsifikasyonu, geriatrik kalça kırıklı hastalarda mortalite için bağımsız bir prediktör olarak belirlendi (HR=3.43, %95 GA: 1.31–8.96, p=0.013). Buna karşılık iliak arter kalsifikasyonu (HR=1.53, p=0.284) ve femoral arter kalsifikasyonu (HR=1.05, p=0.859) ayarlama sonrası sağkalım ile bağımsız olarak ilişkili bulunmadı.
SONUÇ: Geriatrik kalça kırıklı hastalarda iliak ve femoral arter kalsifikasyonları mortalitenin bağımsız belirleyicileri olarak değerlendirilmemelidir. Buna karşın, abdominal aort kalsifikasyonu bu hasta grubunda mortalitenin bağımsız bir prognostik belirleyicisi olarak tanımlanmıştır.

Anahtar sözcükler: abdominal aort kalsifikasyonu; femoral arter kalsifikasyonu; iliak arter kalsifikasyonu; kalça kırığı; mortalite.

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