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Optimizing Blood Management in Total Knee Arthroplasty: An Analytical Study on the Impact of Preoperative and Intraoperative Factors

Total Diz Artroplastisinde Kan Yönetiminin Optimize Edilmesi: Ameliyat Öncesi ve Ameliyat Sırasındaki Faktörlerin Etkisine İlişkin Analitik Bir Çalışma

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ABSTRACT

Aim: In surgeries like arthroplasty that involve joint resection, preoperative evaluations of the patient's comorbidities and medications are conducted to reduce blood loss. This study aimed to address factors that can influence the need for blood transfusion due to significant blood loss, in conjunction with preventative measures applied before and after surgery.

Materials and Methods: Patients who underwent knee arthroplasty from 2017 to 2022, and for whom necessary follow-up parameters were available, were included in the study. Patients with incomplete data, bleeding diathesis, or preoperative albumin, platelet, prothrombin time, and international normalized ratio levels outside the normal range were excluded.

Results: The study included a total of 479 patients. A positive and very weak significant correlation was found between body mass index and intraoperative blood loss. Patients with diabetes showed significantly higher intraoperative blood loss, drainage volume, total blood loss, and the difference in preoperative and postoperative hemoglobin compared to those without diabetes. There were no statistically significant differences in intraoperative blood loss, drainage volume, or total blood loss between patients with and without cardiovascular disease. Patients not receiving tranexamic acid (TXA) had higher intraoperative blood loss compared to those receiving intravenous (IV) TXA and lower compared to those receiving local TXA. The IV group had lower intraoperative blood loss compared to the local group.

Conclusion: In conclusion, patient-related factors and pre- and post-operative measures are crucial in managing blood loss in knee arthroplasty. The goal should be to eliminate the need for transfusions and thus prevent possible complications associated with blood transfusions.

Keywords: Total knee arthroplasty, blood transfusion, blood loss, comorbidities

ÖZ

Amaç: Eklem rezeksiyonu içeren artroplasti gibi ameliyatlarda, kan kaybını azaltmak için hastanın eşlik eden hastalıkları ve ilaçları hakkında ameliyat öncesi değerlendirmeler yapılır. Bu çalışma, ameliyattan önce ve sonra uygulanan önleyici tedbirlerle birlikte, önemli kan kaybı nedeniyle kan transfüzyonu ihtiyacını etkileyebilecek faktörleri ele almayı amaçlamaktadır.

Gereç ve Yöntem: 2017-2022 yılları arasında diz artroplastisi geçiren ve gerekli takip parametreleri mevcut olan hastalar çalışmaya dahil edildi. Eksik verileri olan, kanama diatezi olan veya ameliyat öncesi albümin, trombosit, protrombin zamanı ve uluslararası normalize oranı seviyeleri normal aralığın dışında olan hastalar hariç tutuldu.

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Bulgular: Çalışmaya toplam 479 hasta dahil edildi. Vücut kitle indeksi ile ameliyat sırasındaki kan kaybı arasında pozitif ve çok zayıf anlamlı bir korelasyon bulundu. Diyabetli hastalarda, diyabeti olmayanlara kıyasla anlamlı derecede daha yüksek ameliyat sırasındaki kan kaybı, drenaj hacmi, toplam kan kaybı ve ameliyat öncesi ve sonrası hemoglobin farkı görüldü. Kardiyovasküler hastalığı olan ve olmayan hastalar arasında intraoperatif kan kaybı, drenaj hacmi veya toplam kan kaybında istatistiksel olarak anlamlı bir fark görülmedi. Traneksamik asit (TXA) almayan hastalarda intravenöz (IV) TXA alanlara kıyasla daha yüksek, lokal TXA alanlara kıyasla daha düşük intraoperatif kan kaybı görüldü. IV grupta lokal gruba kıyasla daha düşük intraoperatif kan kaybı görüldü.

Sonuç: Sonuç olarak, diz artroplastisinde kan kaybını yönetmede hasta ile ilgili faktörler ve ameliyat öncesi ve sonrası önlemler çok önemlidir. Amaç, kan transfüzyonu ihtiyacını ortadan kaldırmak ve böylece kan transfüzyonuyla ilişkili olası komplikasyonları önlemek olmalıdır.

Anahtar Kelimeler: Total diz protezi, kan transfüzyonu, kan kaybı, eşlik eden hastalıklar

INTRODUCTION

Total knee arthroplasty (TKA) is commonly performed for advanced-stage knee osteoarthritis. Following TKA, patients may encounter postoperative complications including superficial or deep infections at the surgical site, hematoma formation, deep vein thrombosis, or significant bleeding that necessitates transfusion[1]. In surgeries like arthroplasty that involve joint resection, preoperative evaluations of the patient's comorbidities and medications are conducted to reduce blood loss. Various methods can also be applied intraoperatively to minimize blood loss. These methods often include the use of tourniquets, and local or intravenous (IV) administration of tranexamic acid (TXA)[2,3]. In knee replacement surgeries, bleeding generally occurs postoperatively. The amount of blood loss can be assessed intraoperatively as well as postoperatively by measuring the amount drained[4]. Hemoglobin (HGB) levels are monitored, and the need for transfusion is determined based on the drop in HGB levels. There are certain risks associated with transfusions after significant blood loss. According to a study by Politis et al.[5] in 2022 using data from the International Haemovigilance Network Database, 25% of reported adverse reactions (ARs) were severe, resulting in 368 deaths. Among the 284 cases of transfusion-transmitted infections, 187 were bacterial in nature, 84 were viral, and 13 stemmed from parasites or fungi, resulting in nine fatalities. ARs related to the respiratory system, including transfusion-associated circulatory overload, transfusion-related acute lung injury, and transfusion-associated dyspnea, accounted for 8.3% of all ARs, 20.1% of severe incidents, and 52.2% of mortality cases[5]. Other studies have also reported transmission of infectious diseases such as Hepatitis C virus or human immunodeficiency virus and acute reactions related to transfusions[6,7]. This study aimed to address factors that can influence the need for blood transfusion due to significant blood loss, in conjunction with preventative measures applied before and after surgery.

MATERIALS AND METHODS

The study received ethics approval from the Ethics Committee of the University of Health Sciences Türkiye, Ümraniye Training and Research Hospital (decision no: B.10.TKH.4.34.H.GP.0.01/332, date: 17.10.2024). Patients who underwent knee arthroplasty from 2017 to 2022, had a preoperative HGB level above 10, and for whom necessary follow-up parameters were available, were included in the study. In our clinic, in accordance with the recommendation of the hematology department, a preoperative HGB level of ≥10 g/dL is required prior to major surgeries such as TKA, in order to minimize complications associated with blood transfusion.

Patients with incomplete data, bleeding diathesis, or preoperative albumin, platelet, prothrombin time, and international normalized ratio levels outside the normal range were excluded. Demographic variables including age and sex, along with the presence of comorbidities such as hypertension, diabetes, and cardiovascular disease were assessed. Additionally, factors such as the use and duration of a tourniquet, administration of TXA (both locally and IV), intraoperative blood loss, volume of postoperative drainage, necessity for transfusion, and values of preoperative and postoperative HGB and hematocrit (HCT) were examined. Intraoperative blood loss was estimated by combining suction volume and weighed swabs, adjusted for irrigation fluid.

All data were obtained from the hospital's Health Information System. Acetylsalicylic acid (ASA) medication was discontinued 5 days prior to surgery for patients using it. HGB levels were routinely checked on the first and second postoperative days. All patients were monitored for at least two days postoperatively until wound and HGB levels normalized. In our clinic, if the postoperative HGB level is ≤8 g/dL or if the patient exhibits clinical signs of anemia, blood transfusion is planned in accordance with the transfusion protocols recommended by the hematology department. This HGB threshold is also supported by the literature[8,9]. Patients requiring more than one unit of red blood cells (RBCs) also received one unit of fresh frozen plasma. Routine deep vein thrombosis prophylaxis was applied to all patients postoperatively and continued until discharge. Clexane 0.4 mL subcutaneous was routinely administered as prophylaxis, along with ankle exercise for mechanical prophylaxis starting from the first day. A mobilization and quadriceps exercise program was implemented on the second postoperative day. Patients who developed wound discharge in the form of serous fat necrosis from clexane were switched to 100 mg ASA. Drains were removed routinely when the output fell below 50 cc. Drain output was recorded before each emptying and was always maintained under negative pressure.

Statistical Analysis

Statistical analysis were conducted using the Number Cruncher Statistical System 2007 software (Kaysville, Utah, USA). Descriptive statistics including mean, standard deviation, median, frequency, ratio, minimum, and maximum were employed to analyze the study data. The distribution of data was evaluated using the Shapiro-Wilk test. The Kruskal-Wallis test was employed to compare variables across three or more independent groups, such as IV, local, or no use of TXA. For comparisons between two independent groups, such as the presence or absence of comorbidities, the Mann-Whitney U test was utilized. The Spearman's correlation analysis was conducted to assess relationships between continuous variables, including HGB levels and blood loss. Multiple linear regression analysis was performed to identify the factors influencing the difference between preoperative and postoperative HGB values. Additionally, ROC curve analysis was used to determine cut-off values for quantitative variables, such as HGB levels associated with an increased risk of transfusion.

Significance levels were set at $p<0.01$ and $p<0.05$.

RESULTS

The study included a total of 479 patients. Mean age was 66.5±7.6, with preoperative HGB levels averaging 11.46±1.14 and postoperative levels at 9.59±1.35. Hypertension was present in 45.9% of the patients, diabetes in 39.7%, and cardiovascular diseases in 42%. Mean body mass index (BMI) was found to be 38.1±8.5. All mean values are shown in Table 1. A positive and very weak significant correlation was found between BMI and intraoperative blood loss ($r=0.118$, $p<0.05$). However, no statistically significant correlation was found between BMI and postoperative HGB, postoperative HCT, operation duration, drainage amount, total blood loss, and the difference in HGB levels before and after surgery ($p>0.05$).

Tourniquet duration was negatively and weakly correlated with intraoperative blood loss ($r=-0.268$, $p<0.01$), amount from drainage ($r=-0.122$, $p<0.01$), and total blood loss ($r=-0.205$, $p<0.01$). There was a positive and weak significant relationship between tourniquet duration and the difference in preoperative and postoperative HCT ($r=0.247$, $p<0.01$) and HGB ($r=0.170$, $p<0.01$).

A very high and positive significant correlation was observed between intraoperative blood loss and total blood loss ($r=0.927$, $p<0.01$), while there was a positive and very weak significant correlation with the difference in preoperative and postoperative HGB ($r=0.164$, $p<0.01$).

Similarly, while there was a very high and positive significant correlation between the amount from drainage and total blood loss ($r=0.931$, $p<0.01$), there was a positive and very weak significant correlation with the difference in preoperative and postoperative HGB ($r=0.147$, $p<0.01$).

No statistically significant association was observed between the duration of the operation and variables such as intraoperative blood loss, drainage volume, total blood loss, and the differences in preoperative and postoperative HCT and HGB levels ($p>0.05$).

The presence of hypertension was not associated with statistically significant differences in intraoperative blood loss, the difference between preoperative and postoperative HGB and HCT levels, or total blood loss ($p>0.05$). However, patients with hypertension exhibited a significantly lower drainage volume compared to those without hypertension ($p=0.001$, $p<0.05$).

Patients with diabetes showed significantly higher intraoperative blood loss, drainage volume, total blood loss, and the difference in preoperative and postoperative HGB compared to those without diabetes ($p=0.001$, $p<0.05$).

No statistically significant differences were observed in intraoperative blood loss, drainage volume, or total blood loss between patients with and without cardiovascular disease ($p>0.05$). However, the difference between preoperative and postoperative HGB and HCT levels was significantly greater

Table 1. Average values

Parameter	Mean ± SD	Minimum-maximum (median)
Age	66.53±7.69	18-87 (67)
Body mass index	38.1±2.85	30-46 (38)
Preop HGB	11.46±1.14	9-15 (11.1)
Postop HGB	9.59±1.35	6.4-13.4 (9.7)
Preop HCT	35.11±5.16	19.2-44 (35.5)
Postop HCT	28.98±4	0-38.5 (29)
Tourniquet time	43.43±43.7	0-120 (60)
Operation time	107.34±30.41	30-180 (105)
Intraoperative blood loss	367.12±177.53	150-800 (400)
Blood from drain	241.65±148.54	50-600 (200)
Total blood loss	608.77±297.51	200-1300 (600)
Preop-postop HCT difference	6.44±3.94	-3.2-24 (6.4)
Preop-postop HGB difference	1.87±1.08	-2-9 (1.8)

HGB: Hemoglobin, HCT: Hematocrit, SD: Standard deviation in patients with cardiovascular disease compared to those without (p=0.001, p<0.05).

In our study, TXA was administered IV to 276 patients, topically to 73 patients, and 130 patients did not receive TXA (Table 2).

Regarding the use of TXA, there were significant differences in intraoperative blood loss (p=0.001, p<0.05). Patients not receiving TXA had higher intraoperative blood loss compared to those receiving IV TXA (p=0.001, p<0.05) and lower compared to those receiving local TXA (p=0.001, p<0.05). The IV group had lower intraoperative blood loss compared to the local group (p=0.001, p<0.05). The IV group also had lower drainage volumes compared to the local group (p=0.001, p<0.05). Total blood loss was higher in the non-TXA group compared to the IV group (p=0.001, p<0.05) and lower compared to the local group (p=0.001, p<0.05). Total blood loss was also lower in the IV group compared to the local group (p=0.001, p<0.05).

The multiple linear regression analysis conducted to assess the impact of independent variables on the difference between preoperative and postoperative HGB levels yielded statistically significant results (F: 40.790, p<0.001). There was a positive and moderate significant relationship between independent variables and the preoperative-postoperative HGB difference (R: 0.640, p<0.001). The independent variables in the model explained 41% of the total variance of the preoperative-postoperative HGB difference (p<0.01).

Upon examining the regression coefficients, it was observed that diabetes (β: 0.088; p<0.001) and local TXA application (β: 0.132; p<0.001) had a positive effect on the preoperative-postoperative HGB difference, while transfusion (β: -0.138; p<0.001) had a negative and significant impact. Consequently, it was seen that patients with diabetes and those who received local TXA had a higher preoperative-postoperative HGB difference compared to those who did not.

The ROC analysis identified a reliable cutoff point for the preoperative-postoperative HGB difference at 1.6, with a sensitivity of 93.5% and specificity of 55.9% (Table 3; Figure 1). "A HGB difference >1.6 g/dL predicted transfusion need with 93.5% sensitivity".

DISCUSSION

The characteristics of patients, such as preoperative comorbidities, BMI, or preoperative HGB and HCT levels, influence total blood loss and the need for transfusion. It has been shown in prospective, retrospective, and clinical trial studies that the preoperative HGB value is an indicator of postoperative transfusion needs[10-12]. There is no consensus on the threshold values for HGB and HCT. The importance of a patient's age, weight, and comorbidities varies across studies. In our study, we analyzed in detail the relationship between preoperative factors and perioperative practices aimed at reducing blood loss with blood loss indicators.

Table 2. Distribution of patients' comorbidities and TXA usage

		n	%
Hypertension status	Yes	220	45.9
	No	259	54.1
Diabetes status	Yes	190	39.7
	No	289	60.3
Cardiovascular comorbidity	Yes	201	42.0
	No	278	58.0
Tranexamic acid usage	No	130	27.1
	IV	276	57.6
	Local	73	15.2
Transfusion status	Yes	123	25.7
	No	356	74.3

TXA: Tranexamic acid

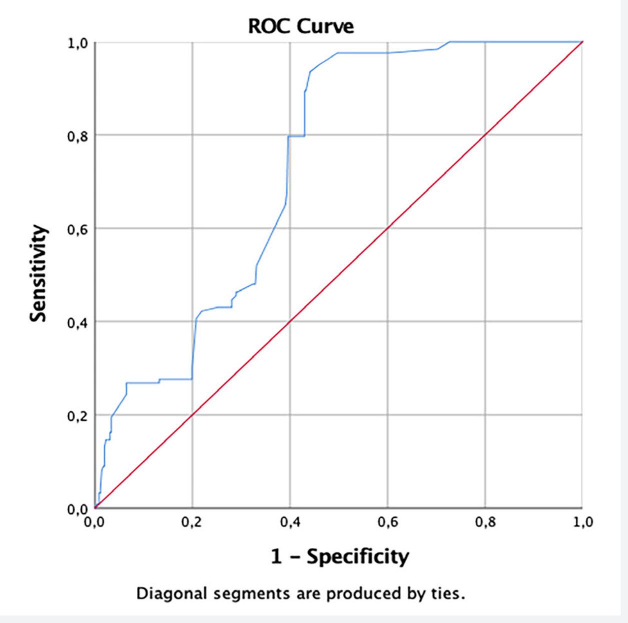

Figure 1. Preop-postop HGB difference: ROC analysis
HGB: Hemoglobin

Table 3. ROC analysis result: cut-off and AUC value

Parameter	Sensitivity (%)	Specificity (%)	Cut-off point	Area under curve
Preop-postop HGB difference	93.5%	55.9%	1.6	0.732

HGB: Hemoglobin, AUC: Area under the curve

In our study, no statistically significant associations were observed between BMI and various postoperative outcomes, including HGB levels, HCT levels, operation duration, blood loss from drainage, total blood loss, and the difference between preoperative and postoperative HGB levels ($p>0.05$). We demonstrated that patients with a higher BMI have higher intraoperative blood loss ($r= 0.118$, $p<0.05$) but this did not affect the total blood loss ($p>0.05$). Frisch et al.[13] in their study mentioned that patients with high BMI lose a smaller percentage of their total blood volume due to their increased blood losses and thus have lower transfusion rates. Bashaireh et al.[14] also showed that high BMI is not a risk factor for postoperative blood transfusion. Additionally, low body weight is associated with a smaller RBC volume, making it more difficult for lighter patients to compensate for blood loss[15]. In our study, consistent with the findings in the literature, the requirement for transfusion was not influenced by high BMI in patients. This observation is attributed to the higher blood volume in patients with elevated BMI, which allows them to tolerate greater intraoperative blood loss without necessitating transfusions.

Working under a tourniquet has, as expected, shown positive effects in reducing perioperative blood loss, as well as decreasing the amount from drainage and total blood loss. Studies, like those by Alcelik et al.[16], have shown that using a tourniquet reduces both intraoperative and total blood loss . Another study with a small patient group by Tan et al.[17] compared groups with and without a tourniquet and found no significant differences were observed in drainage volume, total blood loss, postoperative HGB levels, or the requirements for blood transfusion between the two groups.

Our study found that increases in intraoperative blood loss and the amount from drainage led to increases in both total blood loss and the difference between preoperative and postoperative HGB levels. However, the duration of the operation did not create a statistically significant difference in perioperative and postoperative parameters related to blood loss.

While no significant differences were noted in blood loss measures among hypertensive patients, they did exhibit significantly lower drainage volumes ($p=0.001$). This could suggest a physiological adaptation in hypertensive individuals that minimizes visible bleeding, potentially due to vascular changes such as increased arterial stiffness. Alternatively, it may reflect more conservative surgical drainage practices in patients with hypertension, due to concerns over their altered hemodynamic responses. These findings highlight the need for tailored surgical management strategies for hypertensive patients and warrant further investigation to better understand the interplay between hypertension and surgical outcomes.

Berenholtz et al.[18] identified chronic complications of diabetes as an independent risk factor for blood transfusions in their study. Similarly, Slover et al.[19] study with a large patient series demonstrated that accompanying comorbidities increase the need for blood transfusions. A systematic review by Barr et al.[20] also indicated that diabetes and cardiovascular diseases were among the comorbidities that increased the need for transfusions. While specific comorbidities may vary, they are generally associated with a decreased capacity to tolerate anemia While no significant differences were noted in blood loss measures among hypertensive patients, they did exhibit significantly lower drainage volumes ($p=0.001$). This could suggest a physiological adaptation in hypertensive individuals that minimizes visible bleeding, potentially due to vascular changes such as increased arterial stiffness. Alternatively, it may reflect more conservative surgical drainage practices in patients with hypertension, due to concerns over their altered hemodynamic responses. These findings highlight the need for tailored surgical management strategies for hypertensive patients and warrant further investigation to better understand the interplay between hypertension and surgical outcomes.

While total blood loss did not differ significantly between patients with and without cardiovascular disease, those with cardiovascular conditions experienced a more pronounced drop in HGB and HCT levels. This discrepancy may be attributed to several factors. First, patients with cardiovascular disease often have compromised cardiac output and tissue perfusion, which can exacerbate the physiological impact of any blood loss, making them more susceptible to hemodynamic fluctuations. Additionally, these patients might have pre-existing anemia or be on medications like anticoagulants that could amplify the impact of blood loss on HGB and HCT levels despite similar volumes of blood loss. This observation underscores the need for cautious perioperative management and possibly more aggressive postoperative monitoring and intervention in patients with underlying cardiovascular disease.

Notably, in patients with diabetes, statistically significant results were noted, including increased intraoperative blood loss, drainage volume, total blood loss, and a heightened difference in HGB levels from preoperative to postoperative measurements.

Some surgeons prefer to use TXA IV or topically during TKA, while others do not use it at all. The use of TXA in controlling perioperative and postoperative bleeding has been shown to be safe and effective[21]. TXA can be administered using various methods including IV, topical, and oral applications[22]. Furthermore, studies have shown that it reduces postoperative HGB drop and the need for transfusions[23]. Fillingham et al.[24] have demonstrated that TXA is superior to placebo in reducing blood loss and the risk of transfusion. Recent studies advocate for the routine use of IV TXA in arthroplasty surgeries due to its effectiveness in reducing bleeding. Our study observed that patients who did not receive TXA had higher intraoperative blood loss compared to the IV group, but lower than those who received topical applications. The volume of blood drained was lower in the IV group compared to the topical group. Additionally, total blood loss was greater in the topical group than in the IV group, yet lower in patients who did not receive TXA compared to those who underwent topical applications. The observed discrepancy, where higher blood loss is associated with local TXA, may reflect inconsistencies in application or insufficient dosages compared to IV administration.

Drainage use is also quite common to reduce the need for transfusions and the incidence of bleeding[25]. The American Academy of Orthopedic Surgeons (AAOS) recommends the use of drains in arthroplasty, stating that there is no difference in complications or outcomes between patients with or without drains[26]. However, some studies have indicated that there may be certain drawbacks associated with a decrease in HGB levels. Our study found a highly significant positive relationship between the amount of drainage and total blood loss ($r= 0.931$, $p<0.01$). Yet, the implication of this relationship in clinical practice is unclear, aligning with the AAOS's ambivalence towards the utility of drains in reducing transfusion needs. There is also a very weak but statistically significant positive relationship between the preoperative and postoperative HGB difference ($r=0.147$, $p<0.01$). Madan et al[23]. noted that the amount drained varied from 0-700 mL; there was no statistical significance between the amount drained and either HGB drop or the need for blood transfusion (p-value=0.401). However, they observed a significant increase in HGB reduction and the requirement for blood transfusions associated with drainage. Watanabe et al.[27] findings further revealed that the average decrease in HGB was more pronounced in the drainage group one day post-surgery. Conversely, other research has presented contrary evidence, indicating that there were no statistically significant differences in HGB levels or the frequency of blood transfusions during the initial six weeks post-operation[28]. This highlights the complexity of the effects of drainage on postoperative outcomes and emphasizes the need for further research to clarify its efficacy and application in arthroplasty.

Study Limitations

We acknowledge certain limitations in our study. The relatively small number of patients and the retrospective nature of data collection are among these limitations. We believe that prospective randomized controlled trials with larger patient populations would be useful in identifying factors that affect blood loss and the need for transfusions. Additional limitations of this study include its single-center design, potential variability in surgical techniques among different surgeons, and the absence of detailed data regarding the dosage and timing of TXA administration.

CONCLUSION

In conclusion, patient-related factors and pre- and post-operative measures are crucial in managing blood loss in knee arthroplasty. The goal should be to eliminate the need for transfusions and thus prevent possible complications associated with blood transfusions. To achieve this, strategies involving multiple measures should be developed and implemented. Additionally, patients with chronic preoperative anemia should have their anemia managed before planning surgical treatment.

Ethics

Ethics Committee Approval: The study received ethics approval from the Ethics Committee of the University of Health Sciences Türkiye, Ümraniye Training and Research Hospital (decision no: B.10.TKH.4.34.H.GP.0.01/332, date: 17.10.2024).

Informed Consent: It has been shown in prospective, retrospective, and clinical trial studies that the preoperative HGB value is an indicator of postoperative transfusion needs.

Footnotes

Authorship Contributions

Surgical and Medical Practices: M.T., S.K.Ç., Concept: M.T., S.K.Ç., Design: M.T., S.K.Ç., Data Collection or Processing: M.T.A., M.M.O., Analysis or Interpretation: M.T.A., Literature Search: M.M.O., Writing: M.T., S.K.Ç.

Conflict of Interest: No conflict of interest was declared by the authors.

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