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An earthquake reality: Fasciotomy wounds and treatments

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ABSTRACT

Earthquake-induced crush syndrome and subsequent acute kidney injury are important issues that affect morbidity and mortality. Fasciotomies prolong the length of stay in intensive care unit in patients with compartment syndrome due to the complications it causes. Infections and delayed wound healing are two common complications among these. Therefore, early closure of fasciotomy wounds is recommended. Although different treatments can be applied for treatment of wounds, data on this subject in pediatric patients are insufficient. We report the case of a 15-year-old girl who developed acute renal failure due to crush syndrome after being trapped in the wreckage for 9 hours and undergoing fasciotomy procedures for four locations, in the left extremity, two in the thigh and two in the cruris. Hemodialysis, antihypertensive, and antibiotic treatment were administered during the intensive care follow-up due to acute kidney injury, hypertension, and sepsis. With negative pressure therapy, silver alginate wound dressing, and hyperbaric oxygen therapy, all wounds epithelialized within two months. However, rehabilitation for drop foot syndrome caused by nerve cuts in the left extremity continues.

Keywords: Earthquake, fasciotomy wounds, negative pressure therapy (VAC), hyperbaric oxygen therapy

In compartment syndrome, fasciotomy is the only known treatment option, it can usually save the extremities [1]. In surgical fasciotomy, the release of the skin and muscle fascia results in a sudden decrease in compartment pressure and a significant increase in the volume of the affected muscle compartment [2]. However, reperfusion injury caused by fasciotomy and complications from the procedure has both local and systemic consequences [3]. Although it is recommended for the fasciotomy wounds to be closed as soon as possible to reduce the risk of complications, doing so may result in increased muscle pressure and re-compartment syndrome [4]. Prolonged hospitalization, wound infection, the need for advanced surgery for skin grafting, osteomyelitis, pain, nerve injury, permanent muscle weakness, chronic venous insufficiency, and cosmetic issues are all important issues for fasciotomy patients [5]. Wound management aims to debride necrotic tissues and minimize damage by preventing moisture loss. For this

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purpose, there are different treatment options for wound healing. These include skin grafts, negative pressure therapy (Vacuum Assisted Closure-VAC), dermal apposition techniques (Gradual Suture Approximation), and hyperbaric oxygen therapy (HBOT). It is unclear which technique is best for treating wounds, especially in children [6]. Here, a 15-year-old girl was trapped under the wreckage after the earthquake and had two fasciotomies in the cruris and thigh due to compartment syndrome in the left lower extremity, who also had crush syndrome, is presented.

CASE PRESENTATION

After 9 hours under the wreckage, a 15-year-old girl developed compartment syndrome in her left lower extremity. It was discovered that she had four fasciotomies on her left thigh and cruris, and four sessions of hemodialysis (HD) treatment following acute kidney damage (AKI) due to compartment syndrome. At the family's request, the case was referred and admitted to the Bursa City Hospital Pediatric Intensive Care Clinic (PICU) eight days later. The patient's physical examination revealed a moderately poor general condition, GCS 15, and a suture secondary to trauma in the frontal region, she was followed up in the room air at admission. There were fasciotomies on both medial and lateral sides of the left cruris and thigh, distal pulses were palpable and no fractures were detected in the extremities. The patient had no problems in left hip and knee movements, her left foot flexion and dorsiflexion were limited and she had a drop foot. She had intense fragrant discharge in more than one of the thigh fasciotomies. Fasciotomies in the thigh area had a cavitary appearance. The laboratory values in the follow-up are shown in Table 1. Cranial CT and MRI scans were reported as normal. On admission, the patient had a urine output of <0.3 ml/kg/hour. For forced diuresis, 3000 ml/m^2 IV fluids and 2 mg/kg/day furosemide were started. Piperacillin-Tazobactam and Teicoplanin were started ampirically according to the glomerular filtration rate (GFR) after cultures were taken from the wound sites. Intermittent HD was restarted in the case whose urine output was not sufficient despite IV fluid and furosemide, and blood pressure systolic-diastolic >95p. On the 17th day, HD was performed due to fluid overload symptoms, blood pressures above 99p, and consciousness change. Repeated cranial diffusion MRI and CT scan findings were evaluated as normal. Antihypertensive treatment with amlodipine, enalapril and propranolol was started for the case with high blood pressure values. Since the blood pressure was sometimes above 99p during this period, IV esmolol treatment was also applied for 2 days in addition to this

Table 1. Case laboratory findings

	Day 1	Day 3	Day 7	Day 14	Day 21	Day 30	Day 40	Day 60
Hb (g/dL)	9.4	8.1	8.2	7.2	7	8.6	9.4	11.3
Hct (%)	26.9	23.6	24	20.4	20.2	26.8	27.9	33.4
WBC (10^3/mm^3)	20.3	28.7	19.3	13.4	14.3	17.3	9.2	7.4
Plt (10^3 /mm^3)	142	134	143	163	163	315	319	329
Urea (mg/dL)	91.4	106.1	138.7	175.9	107.2	20.1	22.3	19.3
Creatinin (mg/dL)	3.48	4.05	3.65	4.02	1.5	0.44	0.38	0.42
CK (IU/L)	9526	2664	441	217	60	57	61	60
Na (mEq/L)	128	128	130	131	152	144	136	136
K (mEq/L)	3.6	3.5	5.1	5.3	2.6	4.8	4.5	4.2
Ca (mg/dl)	8.6	8.7	7.5	9.3	12.3	8.6	9.8	9.8
Albumin (g/L)	26.6	21.8	25.4	20.5	30.3	30.4	39	38.9
CRP (mg/L)	46.1	15.3	90.5	28	25.5	47.1	25.1	4.2
Procalcitonin	5.83	2.86	67.8	2.38	0.57	0.85	0.47	0.19

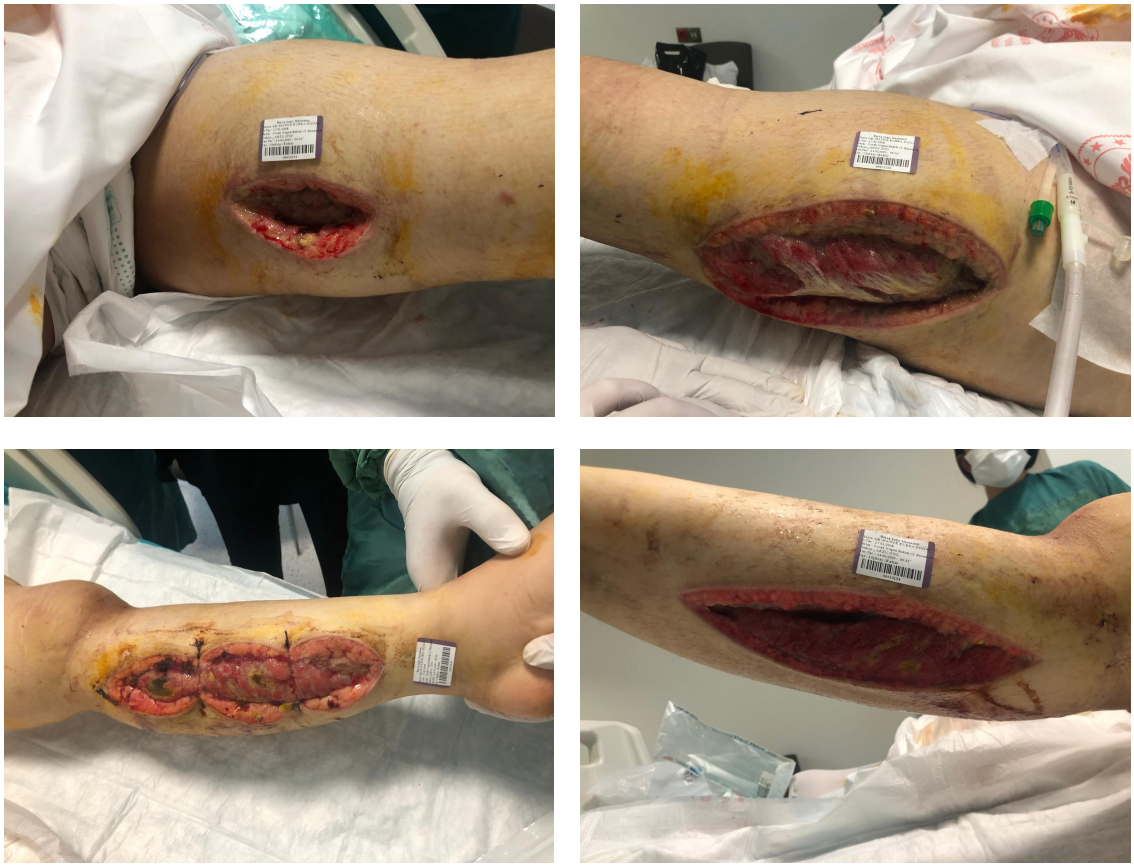

Fig 1. Fasciotomy wounds at admission.

treatment. HD was performed 8 times in the first 17 days of the patient's stay in the intensive care unit and 23 days in the ward. The patient was followed up for 37 days in the intensive care unit and 23 days in the ward. In the following days, urination increased, the findings of compartment syndrome completely regressed, and she did not need HD again. After the 30th day of her hospitalization, her antihypertensive treatments were gradually reduced and she was discharged with amlodipine 0.3 mg/kg.

All four fasciotomy wounds were followed closely from the first day of admission (Fig. 1). Infections due to fasciotomy wounds are shown in Table 2. The antibiotic treatment was changed to meropenem and colistin based on GFR due to the reproduction of Acinetobacter Baumannii in the initial wound cultures. Since the growth of colistin-sensitive Acinetobacter Baumannii continued in repetitive wound cultures, it was continued for 30 days. Vancomycin was added to the treatment on the 20th day of hospitalization due to Staphylococcus Hominis growth in the blood culture, and when there was no growth in the blood cultures, it was discontinued on the 14th day of treatment. Physiotherapy was applied for pain-related limitation of motion and subsequent muscle weakness. The patient who was experiencing mood disorders from the beginning did not comply with physiotherapy and avoided mobilization, prophylactic low molecular weight heparin was administered during her stay. The child was evaluated by a psychiatric physician and mirtazepine treatment was started.

In addition to antibiotic treatments for fasciotomy wounds, VAC therapy, silver alginate wound dressing and HBOT were applied along with general wound care from hospitalization. The patient had sutures on the 3rd thigh wound at the earthquake center on admission due to the "Gradual Suture Approximation" procedure (Fig. 1). During this period, the wound looked infected and the sutures were removed, considering that this procedure was conducted early. A total of 8 sessions of VAC therapy were applied to the medial and lateral thigh fasciotomies, changing every three

Table 2. Case wound culture results

	Wound 1	Wound 2	Wound 3	Wound 4
Day 1	*A. Baumannii* (Colistin sensitive)	*A. Baumannii* (Colistin sensitive)	*A. Baumannii* (Colistin sensitive)	*A. Baumannii* (Colistin sensitive)
Day 14	*A. Baumannii* (Colistin sensitive)	*A. Baumannii* (Colistin sensitive)	*A. Baumannii* (Colistin sensitive)	*A. Baumannii* (Colistin sensitive)
Day 21	No Reproduction	No Reproduction	*A. Baumannii* (Colistin sensitive)	*A. Baumannii* (Colistin sensitive)
Day 25	Epitelized	Epitelized	*A. Baumannii* (Colistin sensitive)	*A. Baumannii* (Colistin sensitive)
Day 30			No Reproduction	No Reproduction
Day 46			No Reproduction	No Reproduction
Day 60			Epitelized	

days due to their cavitary appearance. The VAC instillation system, which provided periodic irrigation with the hypochlorous acid solution (Crystalin®: pH7.1, active chloride content 200 ppm), was used in the last three VAC applications due to the reproduction in the wound culture. No cavities were observed in the two distal fasciotomies, so daily dressing with silver alginate wound dressing was applied. HBOT treatment, which was planned to be done daily, could only be applied for a total of 12 sessions due to the patient's lack of compliance.

Bleeding in the form of leakage was common, es-

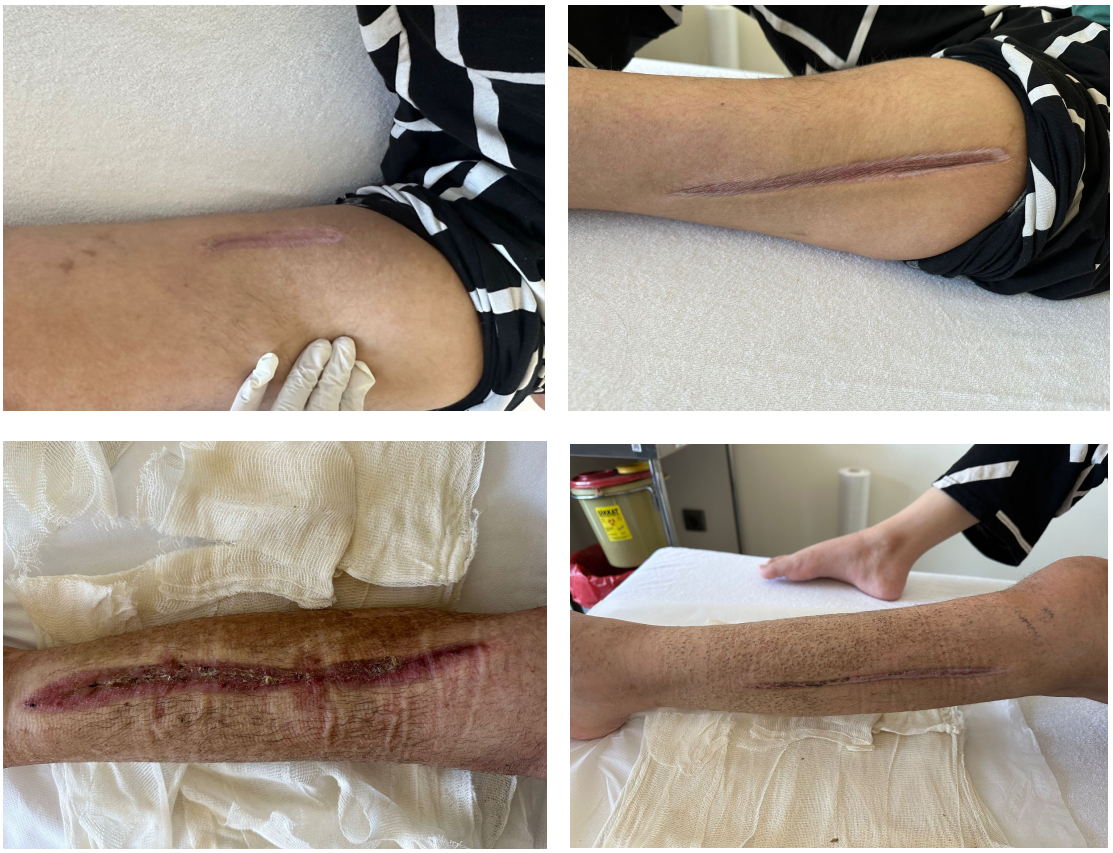

Fig 2. Fasciotmy wounds 3 months after admission.

pecially during VAC treatment. Erythrocyte transfusion was performed 4 times in the first 15 days. Hemodialysis treatment, frequent blood draw for examination purposes and bleeding due to VAC treatment were considered causes of anemia. With these treatments, there was no bacterial growth in the first and second fasciotomy wounds on the thigh on the 21st day and the wounds were epithelized on the 28th day. No bacterial growth was found in the third and fourth wounds of the cruris on the 30th day, these wounds epithelized on the 60th day after discharge. It took the longest time for the number 3 wound, located medial to the cruris, to be fully epithelialized. The images of the patient's fasciotomy wounds in the 3rd month are shown in Fig. 2. The patient, whose physiotherapy compliance is still not good, has lost muscle mass in both legs as well as drop foot syndrome in the left leg where a fasciotomy was performed. EMG was planned for evaluation of nerve damage but the patient did not consent to EMG. Kidney functions and blood pressures returned to normal, and outpatient controls in child psychiatry and pediatric nephrology are performed.

DISCUSSION

According to official figures, 50,783 people died and 122 thousand people were injured in the earthquakes of 7.8 and 7.5 Mw, which occurred 9 hours apart, the epicenter of which was in Kahramanmaraş Pazarcık and Ekinözü districts on February 6, 2023. Compartment syndrome and subsequent AKI are common problems associated with mortality in cases dug out of the wreckage during earthquakes [7]. However, wound infection and sepsis are other serious problems in patients who develop compartment syndrome and therefore undergo fasciotomy [8]. The damage caused by these wounds lengthens the hospital stay, even if infection problems are well managed. The healing process is hampered by psychological trauma caused by the disaster, particularly in pediatric patients. During our patient's hospitalization, serious complications such as compartment syndrome, AKI, the need for dialysis as a result of this, stage 2 hypertension, psychological problems that required treatment, wound infection, and sepsis developed. All these complications are closely related. Data on the care and treatment of fasciotomy wounds following compartment syndrome are inadequate in the literature, particularly in pediatric patients. Therefore, in particular, fasciotomy wounds, related infections and their treatment are primarily discussed here.

Compartment Syndrome is a medical emergency characterized by decreased blood flow and oxygen delivery to muscle and nerve tissue as well as increased intramuscular pressure. Increased compartment pressure can result in muscle necrosis, nerve damage, and limb loss. In order to reduce intramuscular pressure, a fasciotomy is performed to surgically release the fascia surrounding the compartment. It is critical to close the fasciotomy wounds as soon as possible to minimize infection, functional loss, and cosmetic risks.

Data on compartment syndrome and fasciotomy in major earthquakes are limited, and unfortunately, the majority of them are from Türkiye. One of the biggest data sources we have is the data obtained from 639 patients in 15 hospitals due to crush syndrome in the 1999 Marmara earthquake by Erek *et al*. In this article, it was reported that fasciotomies were opened in 323 (50.5%) of the patients and that these fasciotomy wounds were associated with sepsis and mortality [7]. However, information about the treatment and prognosis of the wounds is not given here. Reproduction in the fasciotomy wounds and sepsis were the factors that most affected the patient's morbidity in our case. Aerobic and opportunistic anaerobic bacteria have been reported to be the most commonly isolated microorganisms in the wound area of crush syndrome patients [9]. The importance of early closure of fasciotomy wounds was mentioned again in the study evaluating the infections in crush syndrome after the Marmara earthquake, and especially the risk of bleeding and infection was emphasized. In this study, 51 growths in 41 fasciotomy wounds from 30 patients were evaluated, and the three most common bacteria in wound cultures were found to be Acinetobacter spp (23 reproduction), Pseudomonas aeruginosa (11 reproduction), and Methicillin Resistance Staphylococcus aureus (9 reproduction) [8]. Acinetobacter Baumannii growth was observed in recurrent cultures taken from four wound sites in our patient, and colistin and meropenem treatment was administered in accordance with the antibiogram.

After the Marmara earthquake, 16 patients who underwent fasciotomy were sent to a plastic surgery

center 400 km away from the earthquake center, and the treatment results of these patients were reported by Duman *et al*. [10]. Accordingly, in 4 patients (25%) had their extremity amputated after fasciotomy, 4 patients (25%) required rehabilitation after treatment, and 8 patients (50%) were reported to have fully recovered. Again, it was stated in this study that only one patient had two fasciotomy wounds that required rehabilitation after treatment, but no information was provided about the wound treatment. No case has been reported in the literature with 4 fasciotomy wounds on the same extremity after an earthquake. Although there were 4 fasciotomy wounds in the same extremity, all wounds healed and closed, and no amputation was required in our case, however, unfortunately, drop foot syndrome developed due to nerve damage in this extremity, and the patient's rehabilitation continues.

A partial-thickness skin graft is a popular option for the early closure of fasciotomy wounds. However, the wound area should be suitable for this and there should be no infection. The use of grafts is limited by problems such as sensory loss during follow-up, the risk of graft non-adherence, and, in some cases, poor cosmetic appearance [6]. This treatment option was excluded for our patient due to early wound infections and a large wound area. Another accepted treatment option for fasciotomy wounds is Gradual Suture Approximation. Staples are placed along the wound edges, and the suture is passed crosswise through these staples and tied lightly. Every 48 hours, it is tightened at the bedside. It is a simple, safe and cheap method. Staple displacement, ischemia, and tissue necrosis are among the rare complications. The presence of infection in the wound area, however, limits this treatment option [6]. Our patient also had stitches in accordance with the "Gradual Suture Approximation" procedure carried out at the earthquake center. Considering that these sutures would not be effective on the infected wound, they were removed. Since the wound closure was good in later periods, this procedure was not needed.

In our case, VAC therapy and a silver alginate wound dressing technique were used to treat four large fasciotomy wounds on the left extremity. VAC therapy is a treatment that involves sterile closure of the wound area and continuously or intermittently applying negative pressure to the wound. It promotes wound healing by increasing local blood flow, decreasing local edema, promoting granulation tissue development, fighting infection by reducing bacterial colonization, providing a moist wound environment, and accelerating epithelialization. Antiedema efficacy of VAC therapy gains importance in tissue healing in wounds with prominent edema, such as fasciotomy wounds [6, 11]. The use of VAC in the treatment of fasciotomy wounds in pediatric patients has been shown to be safe and effective. In their 2009 article, Gabriel *et al*. reported that the closure time of fasciotomy wounds with the use of VAC therapy in pediatric patients was 5 to 10 days and no complications were encountered. [12]. However, there are also negative opinions about VAC treatment. In a recent study, Kakagia *et al*. [4] discovered a higher need for skin grafts, a higher cost, and a more extended treatment duration in the treatment of VAC when compared to the Stepped Stitching Approach technique.

In general, VAC therapy is well tolerated in pediatric patients. The most common side effects are pain, bleeding and skin irritation, but they are usually rare. It is critical to monitor bleeding in fasciotomy wounds after VAC application [11, 13]. Our patient's resistance to treatment was caused by the presence of pain. Furthermore, there was oozing bleeding in wound 3 at first, but no such complication was observed in the other wounds. We believe that VAC treatment was the most effective treatment for our patient's wounds. Grafts were not required in our patients, although they were mentioned in the literature, particularly after VAC treatment. Considering our patient's wounds, wound healing times were deemed reasonable.

Silver alginate wound dressings are preferred in the treatment of fasciotomy wounds with abundant exudate due to their natural absorbent and antimicrobial properties [14]. In our patient, silver alginate absorbent wound dressing was preferred for distal fasciotomy wounds with a more limited cavitary structure. It was regarded as an adjunctive treatment to the primary treatment: VAC treatment.

HBOT is a treatment based on breathing 100% oxygen in a pressurized cabin. It is intended to benefit from the antiedema and antihypoxic effects of increased tissue partial oxygen pressure with HBOT in crush wounds. The literature on the use of HBOT in pediatric fasciotomy wounds is limited, but available

data suggest that these patients may benefit from HBOT. In a 1998 article, it was reported that the results obtained with HBOT in 13 children with crush injury were at a desirable level when evaluated on the parameters of mortality, soft tissue loss and amputation rate [15]. In a case series of 3 cases in which HBOT and VAC treatment were applied together and supported with a gradual suturing approach, it was reported that the wounds closed in 3-18 days [16]. The 12 sessions of HBOT treatment used on our patient significantly aided the other two treatments. However, in one case that emerged from the wreckage, taking the patient with a mask to a closed area was deemed the most significant disadvantage of this treatment in pediatric patients. We had to discontinue this treatment on some days when she received HBOT due to the patient's resistance. With VAC, silver alginate wound dressings, and HBOT, the wounds on the thigh healed in one month and the wounds on the cruris closed in two months in our patient.

CONCLUSION

As a result, Türkiye is located within the earthquake zone; unfortunately, new earthquakes are expected. In these earthquakes, fasciotomy wounds will also be encountered along with many problems. One of the primary goals should be to perform surgical fasciotomies only when necessary. Although this intervention is often life-saving, it sometimes causes serious complications. All treatment options for these wounds should be considered, and appropriate treatment should be planned. Silver alginate wound dressings and HBOT, both VAC therapy and supportive treatments, appear to be good options for pediatric patients. However, we need more data on this subject especially for the children.

Informed Consent

Written informed consent was obtained from the patient's family for the publication of this case report.

Authors' Contribution

Study Conception: HE, AO; Study Design: HE, AO; Supervision: HE, AO; Funding: N/A; Materials: AO, GY, BM; Data Collection and/or Processing: GK, ÜY, BA; Statistical Analysis and/or Data Interpretation: GY, AO, ŞB; Literature Review: BA, BM, GY; Manuscript Preparation: HE, AO, GY and Critical Review: GY, ŞB.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

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