Distal Lower Extremity Revascularization for Limb Salvage After Close Shotgun Injuries

Yakın Mesafeden Av Tüfeği ile Yaralanmalarda Ekstremite Koruyucu Distal Alt Ekstremite Revaskülarizasyonu

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ABSTRACT Objective: Most of the time, amputation is unavoidable depending on the severity of the destruction in extremity injured by close range shotgun trauma. We hereby present our surgical results regarding a case series of patients in whom we performed limb salvage surgery for close-range, below-knee shotgun injuries. **Material and Methods:** This cross-sectional study was made between May 2012 and October 2013. Data regarding the patient demographics, operative parameters, and the post-operative course were prospectively collected by recording on a printed chart (9 patients). **Results:** All patients had fragmented tibial fractures, and 6 patients had also fibula fractures. The posterior tibial artery was the most commonly injured artery (8 patients). Five patients had double arterial and 4 patients had triple arterial damage. Four patients received primary revascularization to the extremity, 3 received autologous graft interposition with great saphenous vein, and 2 received distal bypasses with the popliteal artery being used as the inflow source. The non-viable soft tissue was removed. External fixation was performed for bone fractures. Injured nerves were primarily repaired. The median hospital stay was 11 days (8-15 days). Four patients achieved improvement in limb functions whereas the remaining 5 patients had permanent neurologic impairment during follow-up. **Conclusion:** Gunshot wounds causes lower extremity vascular injury associated with high risk of amputation if accompanied by severe bone fracture and soft tissue damage. Rapid diagnosis and early surgical intervention are essential to decrease the rate of amputation, and achieve a functional recovery. Reconstructive surgery may be successfully performed for patients who are under risk for probable amputation.

Key Words: Shotgun; limb salvage; amputation

ÖZET Amaç: Dokudaki tahribatın ciddiyetine bağlı olarak, yakın mesafeden av tüfeğiyle yaralanan ekstremitede amputasyon çoğunlukla kaçınılmazdır. Bu çalışmada yakın mesafeden maruz kalınan diz altı av tüfeği yaralanmalarında ekstremitenin kurtarılması amacıyla ameliyat edilen hastaların cerrahi sonuçlarının tartışılması amaçlanmıştır. **Gereç ve Yöntemler:** Çalışma Mayıs 2012 ile Ekim 2013 tarihleri arasında gerçekleştirilmiştir. Hastalara (9 hasta) ait demografik veriler, operatif parametreler ve postoperatif döneme ait sonuçlar prospektif olarak kayıt altına alınmıştır. **Bulgular:** Tüm hastalarda parçalı tibia kırığı mevcutken, 6 hastada ek olarak fibula kırığı bulunmaktaydı. Posterior tibial arter en çok (8 hastada) yaralanan damardı. Beş hastada diz altı iki arterde, ve 4 hastada ise üç arterde de yaralanma mevcuttu. Dört hastaya primer tamir uygulanırken, 3'üne otolog safen ven ile greft interpozisyonu, 2 hastaya da popliteal arterden kan getirmek üzere distal baypas uygulandı. Viabilitesini yitiren dokular rezeke edildi. Kemik kırıklarına sıklıkla eksternal fiksasyon uygulandı. Sinir yaralanmaları primer tamir edildi. Medyan hastane kalış süresi 11 gündü (8-15 gün). Dört hastada ekstremite fonksiyonlarında düzelme gözlenirken, kalan 5 hastada takipte kalıcı nörolojik etkilenme olduğu saptandı. **Sonuç:** Ciddi kemik kırığı ve yumuşak doku hasarı mevcudiyetinde, av tüfeği yaralanmaları alt ekstremitede yüksek amputasyon riskini beraberinde getirmektedir. Hızlı tanı ve erken rekonstruktif cerrahi amputasyon oranını azaltmada ve fonksiyonel düzelmeyi sağlamada önem arz etmektedir. Amputasyona gitmesi muhtemel vakalarda rekonstruktif cerrahi başarılı sonuçlar sağlayabilmektedir.

Anahtar Kelimeler: Av tüfeği; ekstremite sağaltımı; amputasyon

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The gunshot injuries of the lower extremity comprise an important part of the emergency vascular surgery. War injuries in recent history have led to major advances in vascular reconstruction techniques. Alhough the amputation rates were as high as 73% with ligation being the preferred technique for arterial injuries in the past, today this rate decreased to as low as 1% through the developments in early transport, diagnosis and the complex treatment techniques evolved.[1,2] Using effective and rapid treatment methods, it is possible to prevent complications in these risky patients such as amputation, loss of motor function, infection, and especially death from reperfusion injury and multiorgan failure.

The injury that the patient faced with when a military and civilian firearm injury occurred is closely related with the ballistic range of the bullet used, the range of shot, and the location of injury. Unlike many other types of guns, the shotguns fired in a close-range cause a higher extent of tissue destruction because they mostly result in contamination, fragmented open fractures, and tissue loss. Amputation is unavoidable in most of the time depending on the severity of the destruction in extremity.

Here, we present our surgical results regarding a case series of patients in whom we performed limb salvage surgery for close-range, below-knee shotgun injuries, presented as Gustillo-Anderson type IIIc fractures.

MATERIAL AND METHODS

The study was approved by the institutional ethics committee. The informed consents were obtained from each patient on admission to hospital. This cross-sectional study included 9 patients who underwent surgery between May 2012 and October 2013. Data regarding the patient demographics, operative parameters and the data from the postoperative course were prospectively collected by recording them on a printed chart.

Eligible patients were those who presented with Gustillo-Anderson type IIIc below-knee fracture (open segmental fractures with extensive soft tissue damage or a traumatic amputation, typical for gunshot injuries requiring vascular repair) that occurred after a shotgun fired at close range, and those who considered to have repairable/reconstructable damages.[3] The patients with an irreparable damage were not included (i.e. those presented with their bones being almost completely fragmented or soft tissues extensively burned/damaged). The patients who had concomitant damage to another part of their body including head, chest or abdomen, and those who required urgent management for life-threatening conditions were also excluded. Nine out of 13 patients with Gustillo-Anderson Type III fractures presented to our hospital between the dates given above were considered eligible for the present study.

The initial assessment was made with participation of the orthopedist, the vascular surgeon, the plastic surgeon and the anesthesiologist. The vascular surgeon immediately took control of the bleeding in the emergency room when necessary. The plain and lateral X-rays were taken to decide reconstruction method (Figure 1). Vascular diagnosis was made by intravenous contrast enhanced computed tomography (CT). Upon agreement by all participating disciplinarians that the patients would benefit from vascular repair and a concomi-

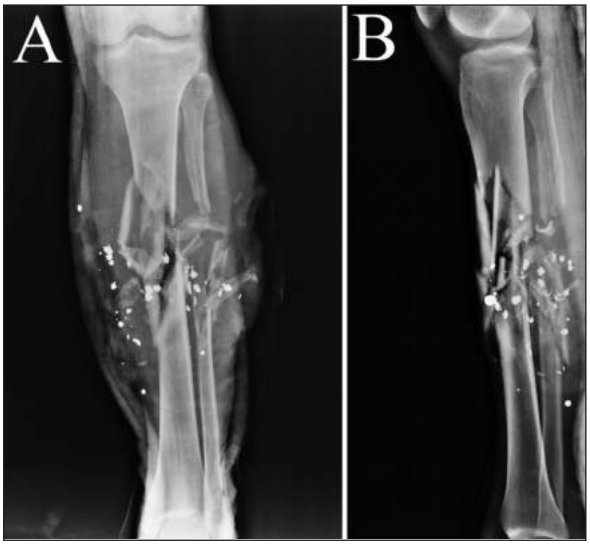

FIGURE 1: Close-range shot-gun injury of a 36-year-old man. Radiogram shows fragmented tibia and fibula fractures.

tant bone and soft tissue reconstruction, The patient was taken to the operating room on emergency conditions.

In the operating room, the patient was initially administered nasal oxygen. The vital signs were monitored, and a large venous line was introduced. Fluid infusion was started. Total intravenous general anesthesia was induced with propofol, rocuronium, and fentanyl, and the anesthesia was maintained in a standardized fashion.

SURGICAL TECHNIQUE

All patients received tetanus vaccine and dual antibiotics before the operation. A manometer was applied above the knee to control bleeding within the operative field. Following surgical antisepsis and draping, initial surgical exploration was performed by the orthopedists to prevent any damage to the reconstructed vessels by sharp-edged fractures, and achieve the final length of the extremity before deciding the method of revascularization. The lesion was harshly irrigated with saline, and the broken bone fragments were removed. The pellets and foreign objects were cautiously removed. Because the injuries were close to the knee in all patients, intramedullary fixation and plaque implantation were not performed. All patients received external fixation. After bone stabilization, the tourniquet was deflated, and the vascular surgeons began exploration for vascular trauma. After the preparation of the arterial inflow and outflow sites, 100 IU/kg of intravenous heparin was given.

Then, the distal arterial flow was provided by performing a distal autogenous graft bypass, graft interposition or end-to-end anastomosis of the native vessels. Three out of the four patients we performed primary repair had been shot at anteromedial surface of the shant, and one at the posteromedial shant. The surgical exploration was carried out by directly entering the wound; we did not need to undertake proximal control in these patients. Upon ensuring an adequate amount of backbleeding, we could, in these four patients, re-approximate the cut ends of at least two of three calf arteries after the bone was stabilized. Although the K-wires which were transfixed to the tibial corpus somewhat affected the surgical comfort during vascular repair, the operation uneventfully proceeded with a standardized end-to-end anastomosis. The patients in whom an autologous saphenous graft was performed received the similar procedures, as described.[4] The amount of backbleeding was confirmed, and the injured vessel was explored in both directions. The thrombosed or dissected parts were cut, and the edges were trimmed before beginning anastomosis. The anastomosis was performed end-to-end for interposition, and end-to-side for distal bypass (Figure 2).

Every effort was made to preserve all arterial and venous structures that were found during exploration. For the purpose of preserving the venous circulation and preventing venous thrombosis, we preferred, as much as possible, to harvest the contralateral great saphenous vein. Finally, the plastic surgeons took part in the operation. The necrotic and severely contaminated tissue fragments were removed, then injured peripheral nerves, tendons and muscles were repaired. All patients received fasciotomies to relieve pressure. The wound was left open when the skin edges could not be approximated for primary closure, or the wound was considered as a contaminated wound.

POSTOPERATIVE CARE

After operation, all patients were transferred into the tertiary intensive care unit, and placed on mechanical ventilation. In order to prevent struggling and uncontrolled motion during recovery from anesthesia, extubation was not performed in the operating room. In addition to intravenous fluid administration, analgesics and antibiotics, the patients also received subcutaneous low molecular weight heparin, acetylsalicylic acid, and pentoxifylline infusion. A duplex scan was performed in all patients to evaluate the arterial and venous patencies.

The patients were reassessed 1 week, 1, 3, 6 and 12 months after the operation (Figure 3). The mean follow-up period was 16 months. All patients were referred to physical rehabilitation clinic after they had full wound recovery.

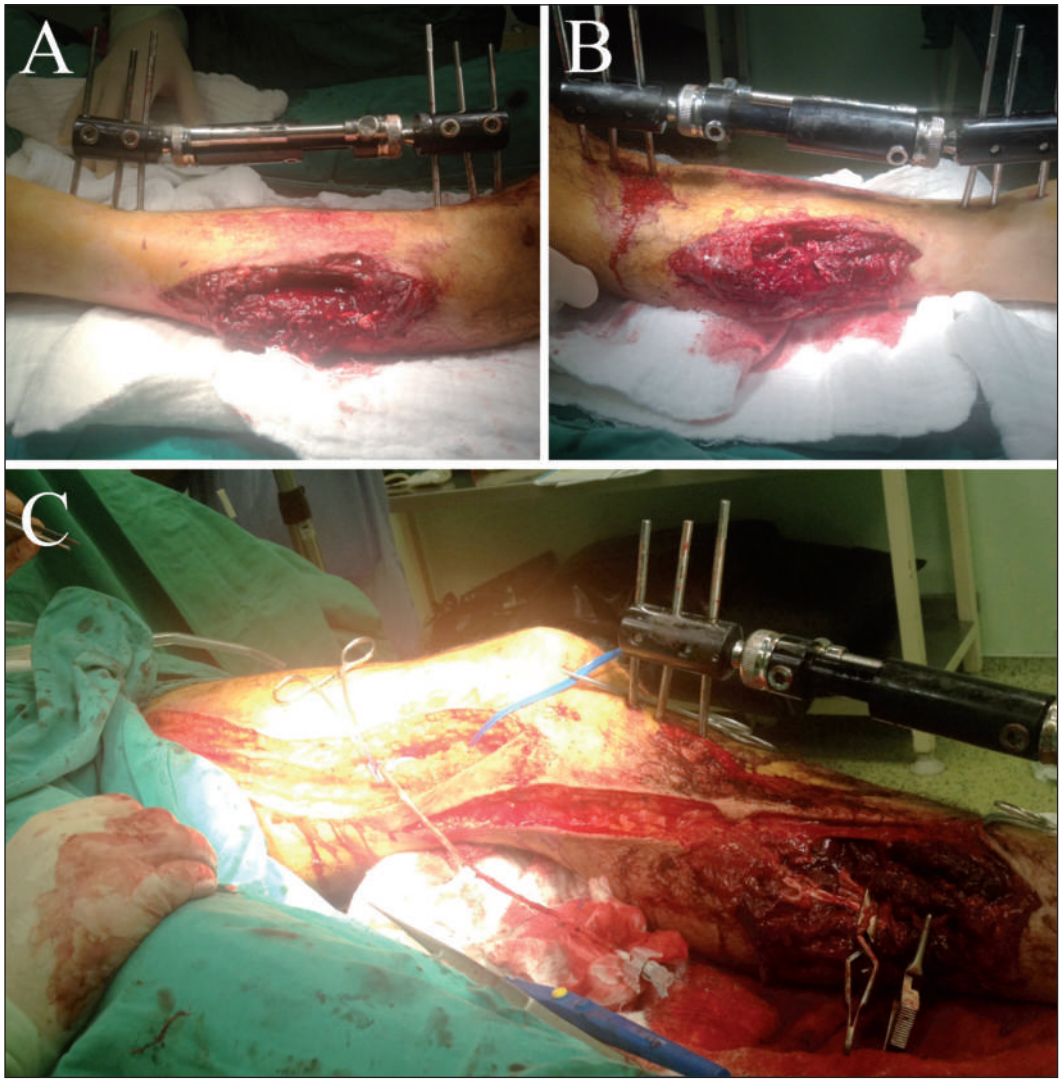

FIGURE 2: Intraoperative view of the patient presented in Figure 1. All infragenual arteries and the popliteal vein were injured. **A)** Lateral view of the tissue defect after external fixation of tibia. **B)** Medial view of the tissue defect. **C)** Ipsilateral saphenous vein graft (SVG) was tranpositioned between popliteal artery and posterior tibial artery. SVG was also used to repair popliteal vein injury. We preferred contralateral SVG to preserve venous circulation, but the patient had a contralateral SVG striping history.

STATISTICAL ANALYSIS

Normally distributed continuous variables were expressed as mean ± standard deviation. Categorical variables were defined as frequencies and percentages (%). Descriptive statistical analyses were performed with SPSS 13.0 software (SPSS Chicago, Illinois).

RESULTS

The patients' demographics are given in Table 1. The median time from trauma to admittance was 2 hours (range: 30 minutes to 6 hours). All patients had close range gunshot injuries confined to only one extremity. Eight patients had been hit by multiple small pellets whereas one patient had been hit by an expanding bullet consisting of multiple large bullets (informally known as dumdum bullet). The symptoms and findings on admission are given in Table 2.

All patients entered to the operating room within the first hour of their admission. None of them had primary or secondary amputation. Any reoperation was not performed for vascular complications, but one patient underwent a second re-

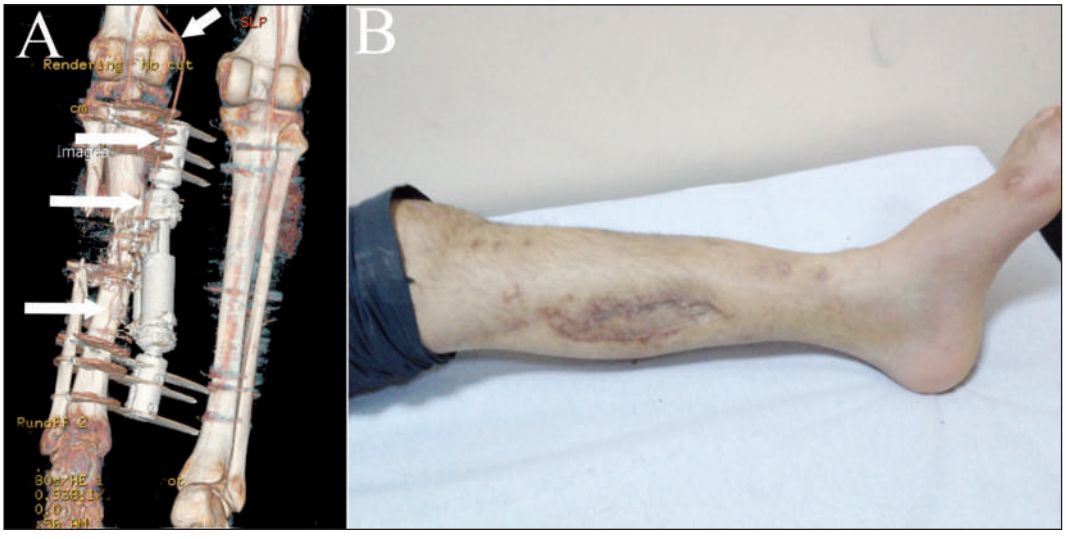

FIGURE 3: A) Postoperative 3rd month computerized tomography angiography control of the same patient in Figures 1 and 2. Arrows shows the patent vena saphena magna graft between popliteal artery and posterior tibial artery. **B)** Postoperative 12th month control of the same patient. The patient has a motor deficit.

vision for achieving tibial stability. The median hospital stay was 11 days (8-15 days). Mean bleeding into surgical drains was 430 ml within the first day after the operation. The drains were removed when the volume got below 25 ml per day. None of the patients had systemic infections whereas two patients had local wound infections. Complete recovery was achieved with appropriate antibiotic treatment and wound care.

All patients had fragmented tibial fractures, and 6 patients had also fibula fractures. Peripheral nerve injury was present on surgical exploration in 5 patients. Four of them had a primary nerve repair. Four patients achieved improvement in limb functions whereas the remaining 5 patients had permanent neurologic impairment during follow-up. These 5 patients were the ones who had both the tibia and fibula fractures as well as nerve injury.

Because all wounds were seriously contaminated on admission, all patients initially received an external fixation. Two patients had complete bone healing with external fixation alone. The external fixators were removed at 6th and 9th months after the operation. The remaining seven patients received intramedullary and external cortical plaque stabilization procedures to achieve recovery.

TABLE 1: Preoperative characteristics of the patient group.

	Patient group (n=9)
Age	28 ± 9 years
Male	9 (100%)
Chronic disease	1 (11.1%)*
Tobacco use	6 (66.6%)
Time until admission	3.1 ± 2 (1-5 hours)

TABLE 2: Symptoms and clinical findings on admission.

	Patient group (n=9)
Blood pressure	
- Systolic	91.2±25.4 mmHg
- Diastolic	44.3±19.8 mmHg
Hypovolemic shock	2 (22.2%)
Glasgow coma score	13
Pulsatile bleeding	9 (100%)
Paralysis	7 (77.7%)
Paresis	6 (66.6%)
Ischemia	9 (100%)

In all patients, the damage to the arteries was confined distal to the popliteal artery. The posterior tibial artery was the most commonly injured artery (8 patients). Five patients had double arterial and 4 patients had triple arterial damage. The

locations of the damaged vessels are given in Table 3. All patients also had a venous injury adjacent to the involved artery.

Four patients received primary revascularization to the extremity, 3 received autologous graft interposition with great saphenous vein, and 2 received distal bypasses with the popliteal artery being used as the inflow source. The distal anastomoses were placed on distal posterior tibial artery, at the level of the ankle.

The venous injuries were repaired primarily in 7 patients and using autologous vein interposition grafts in 2 patients. In the postoperative period, one patient was complicated with popliteal venous thrombosis.

DISCUSSION

In this cohort, we had good results -in terms of prevention of amputation- by using distal arterial revascularization at calf level in patients presented with concomitant open fragmented leg fractures and vascular damage due to close range gunshot injuries. The operative planning was based on a multi-disciplinary approach, and we made every effort to save the affected limb. The vascular revascularization procedures were pertinaciously undertaken to keep the viability of the already threatened limb.

Vascular injury frequently occurs in lower extremity gunshot wounds. These injuries are associated with a high risk of amputation if accompanied by severe bone fractures and soft tissue damage.[5,6] The arterial injury is one of the most important factors that predict a future amputation of the affected limb.[6,7] Rapid diagnosis and early surgical intervention are essential to decrease the rate of amputation, and achieve a functional recovery.[6,8]

The patients a primary repair was performed were the ones suffered somewhat less extensive damage to the limb compared to the others. The patients in whom we performed autologous veins either interposed or used for distal bypass had a greater damage at the calf. High risk of future infection in a large wound might also affect the patency and integrity of the repaired vessel, and this was why we proceeded with distal bypass technique in those two patients. The treatment strategy should be to save the individuals' life in patients with severe hemodynamic instability or progressive hypovolemic shock, therefore amputation may be the initial option in this group. Limb salvage and major reconstruction of the leg should be performed after conservative medical treatment (including volume replacement, inotrops or vasoconstrictors etc.) in patients with mild to moderate hypovolemic shock. Additional life threatening pathologies such as chest or brain trauma should be taken into account prior to reconstructive surgery. Anticoagulation with heparin is required during vascular reconstruction, and additional pathologies (intracranial bleeding, hepatic injury etc.) may be a contraindication for anticoagulation. Conserva-

TABLE 3: The distribution of the arterial injuries.

Patient no.	Posterior tibial artery	Anterior tibial artery	Peroneal artery
1	+	+	+
2	+	+	-
3	-	+	+
4	+	+	+
5	+	-	+
6	+	-	+
7	+	+	+
8	+	+	-
9	+	+	+
Total	8 (88.8%)	7 (77.7%)	7 (77.7%)

tive treatment and amputation may be a better option in these cases. The accurate treatment choice should be decided for each patient considering additional pathologies, contraindication for anticoagulation, extensive tissue loss or very low limb salvage expectation.

There are diagnostic tips to determine the vascular consequences of the injuries. Although some authors suggest that pulsatile bleeding and ischemic signs are highly specific and sensitive for the diagnosis of an acute arterial injury, many centers use conventional angiography because it shows the localization of the injury and the presence of arteriovenous fistulas.[9-11] It was shown that the costs substantially increased when the angiography was performed in cases who presented without obvious clinical signs of vascular injury.[12] Multidetector computed tomography angiography (MDCTA) is useful for both assessing the extension of the damage, and locating and measuring the vascular injury. Recent studies suggest that this technique may be preferred over the conventional angiography in cases of acute injuries.[13] Rapidly performing MDCTA on admission, we obtained three-dimensional images for evaluation of both vasculature and bone structure. We think that, besides its technical and diagnostic advantages, the images provided by MDCTA also allow us to envisage the repair before we began to the operation, and thus we achieved a rapid surgery. Given its lower cost than conventional angiography, rapid availability and non-invasiveness, MDCTA has already been suggested to be used in this group of patients.[14]

The cases in the present study were not subjected to low velocity civilian "gunshot" injuries, but they were the victims of "shotguns" which also have relatively low velocity but the damage induced to the affected part of the body is relatively high.[15] From the point of "wound ballistics", wounds are classified according to the amount of energy induced to the wound as follows; high energy (>1,000 J), medium energy (250-1,000 J), and low energy (<250 J).[16] This classification forms the basis of the classification provided by Gustilo-Anderson.[3] Ordog et al. divided the shotgun injury severity into three main categories with 3-7 meters of range being defined as "close-range", and 0-3 meters as "point-blank".[17] The proximity of the range was reported to be associated with serious consequences such as development of acute compartment syndrome, compound fractures and severe contamination.[18] The shotgun pellets have distinct features based on their higher powder charge and stuffing, the damage they cause further increases.[15,19]

CONCLUSION

The wound complications occurred in the minority of our patients, and they improved with appropriate care and antibiotic treatment. We think that the rigorous approach we followed to prevent the spreading of the contamination and to maintain the surgical antisepsis throughout the operation brought this outcome. In addition, rapid evaluation and treatment of the patient allowed prevention of prolonged ischemia which is known to be the most important cause of poor outcome in this group of patients.[4]

Conflict of Interest

Authors declared no conflict of interest or financial support.

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