

Case report

Return to run after partial amputation of the ankle: clinical assessment and instrumental evaluation

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Abstract. *Background and aim of the work:* the traumatic amputation or partial amputation of a portion of the lower limb is one of the most serious and not so rare road accident and job injury. There are few cases reported of replantation of the lower extremities rather than amputation surgery. This work describes a case of partial amputation of the right ankle. *Methods:* the emergency treatment consisted of rigorous lavage and debridement, reduction, stabilization of the ankle and restoreation of the neurovascular and soft tissues lesions. Because of cutaneous necrosis another surgical treatment of reverse rotation flap was needed. The good outcome has been documented with foot pressure analysis, stabilometric evaluation and gait and jump analysis based on measurements of acceleration. *Results:* after seven months of personalized rehabilitation program the patient walks without devices, has recovered functional of range of movement and had no neurological deficit or subjective problems. Currently the subject has returned to his job and runs without pain. *Conclusions:* emergency foot salvage treatment was possible thanks to a close collaboration among different physicians with specialized skills, good emergency management and an adequate infrastructure. (www.actabiomedica.it)

Key words: Ankle amputation, reverse rotation flap, stabilometric evaluation, accelerometer, gait analysis.

Introduction

The traumatic amputation or partial amputation of a portion of the lower limb is one of the most serious and not so rare road accident and job injury. There are few cases reported of replantation of the lower extremities rather than amputation surgery. The reason is linked to the high rate of complications and, at the present, the satisfactory possibility of good prosthetic substitution (1, 2). The skills of the surgical team, the infrastructure available, the surgeon's experience and available recovery programs affect the outcome of the replantation. Decision-making in the case of severe lower limb injury involves judgement relating to the method of fixation, the possibility of re-establishment of vascular supply if required, the timing of reconstruction and type of flap for soft tissue lesions, the likelihood of reconstruction producing a functional outcome superior to the amputation (3) and future functionality. The Gustillo-Anderson classification of open fractures can help guide the decision and direct subsequent treatment (4). Over time, several scoring systems have been developed in attempt to quantify the severity of trauma and to establish guidelines for decision-making. Mangled Extremity Severity Score (MESS) is the most used scoring system in combat studies due to its simplicity (amputation for MESS score > 7); the others are Predictive Salvage Index (PSI) or Limb Salvage Index (LSI). They incorporate bone fracture, soft tissue damage, vascular, nerve and tendon lesions (5, 6). Indications for primary amputation should be included not only the extremity variables but also patient and associated variables (age, chronic diseases, mechanism of injury, neurovascular injuries, ISS, etc). Flap failure in free flap, or partial necrosis in local flap and infection leading to non-union are the main complications leading to secondary amputation after reconstructive surgery (3). The last two decades have seen advances in reconstructive techniques, combined with good collaboration between plastic, orthopedic and vascular surgeons (7-9). In this study we present the clinical case, the decision-making, the surgical interventions, and the outcome after surgical replantation in a 21-years-old man whose right foot was partially amputated at the ankle during an road accident. The postoperative conditions were assessed with clinical, radiographic and instrumental evaluations.

Figure 1. First ankle X-ray

Materials and Methods

Clinical evaluation

A 21-years-old man, was struck by a car while riding a motorcycle on August 27th 2011. This event resulted in the subamputation of the right ankle. He was admitted to the Emergency Room where he was assessed clinically and radiographically, got his antalgic and broad-spectrum antibiotic therapy (gentamicin, metronidazole and ampicillin with sulbactam), antidiphteric and tetanus vaccine and was evaluated from both orthopaedics and vascular surgeons. The injury resulted in a displaced plurifragmentary open fibula fracture with dislocation of the ankle (Fig. 1), neurovascular and tendon injuries (Fig. 2, 3). At the first clinical evaluation it was clear that the ability to extend the toes was lost, the sensitivity was difficult to assess because of the pain. The vascular surgeon, confirmed the absence of foot's ischemic signs at present. The Doppler Study detected the presence of the posterior tibial artery at the dorsal arch near the first toe. The radiographs confirmed the type of fracture: a three fragment fracture of peroneal diaphysis and dislocation of the ankle. In consideration of this situation, salvage appeared to be possible. Emergency

Figure 2. Partial subamputation of the ankle

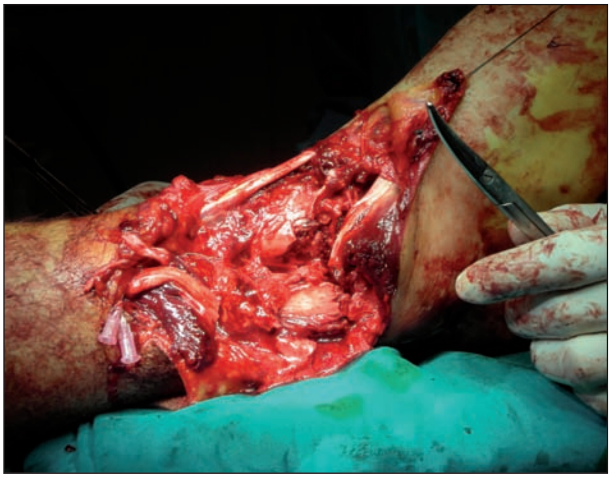

Figure 3. Intraoperative image

surgery was performed the same day.

Treatment

The patient was anesthetized via femoral nerve block and a tourniquet was applied at the base of the thigh. The evaluation of the dorsal wound showed a deep and extensive lesion involving the anterior articular capsule, the extensor hallucis longus, extensor digitorum longus, peroneus longus and brevis muscles, the medial dorsal nerve and the dislocated ankle with a displaced plurifragmentary fracture of the fibula and the terminus of the tibia. After an extension of the original wound, a rigourous lavage, debridement and removal of foreign bodies (gravel and asphalt) was performed. With a fluoroscope, the fibula was reducted and stabilized with a K-wire, as well the tibiotalar joint. The injured tendons, nerve, extensor retinaculum and the skin were stitched with a non absorbable suture. A boot gutter cast was made. The same day, an arteriography was performed and showed the plantar artery acted as the main supply for the foot. Antibiotic therapy was continued and anticoagulant therapy was administered post-operatively and carried on until complete weight bearing was achieved. The salvage was successful and the patient was discharged after 20 days.

He started a personalized rehabilitation program at our department and continued until the recovery of the ankle function.

In a second surgical time, an anterior cutaneous necrosis with tendons exposition was treated with reverse rotation flap in prone position under spinal anesthesia. An epidural catheter was inserted for postoperative analgesia. The VAS score (0 to 10) was used to evaluate the pain. The score was always under 4 when at rest and under 5 during motion. The low concentration of local anesthetic in association with opioids based drug allowed a differential block, which permitted earlier mobilization of the patient. The catheter was removed after 7 days following a blood coagulation test.

Follow-up

During the follow-up, at our outpatient clinic, a period of 20 days of pulsed electromagnetic field therapy (Gauss 100, Hertz 50) was prescribed to help the healing of the fracture: then the wound was healed. Then patient started hydrokinesis and after 14 weeks the X-ray showed a good bone callus. Seven months post-operation, the fracture healed so the patient could bearing weight completely without any aiding devices (Fig. 4). The skin was healed and the foot re-

Figure 4. Ankle X-ray: 6 months after the trauma

gained complete sensation. At the clinical examination, the anterior drawer test was negative with a good plantar and dorsal flexion (Tab.1, Fig. 5, 6, 7).

After 13 months the patient returned to work and was able to run without pain. At the last follow-up, 14 months after the trauma, the American AOFAS ankle and hindfoot score was 69.

Table 1. Comparison between patient and normal ankle Range Of Motion

Range Of Motion degrees	Patient	Normal range
Extension	0-11	0-20
Flexion	0-40	0-50
Inversion	0-3	0-5
Eversion	0-2	0-5

Figure 5. Plantar flexion of the ankle

Figure 6. Extension of the ankle

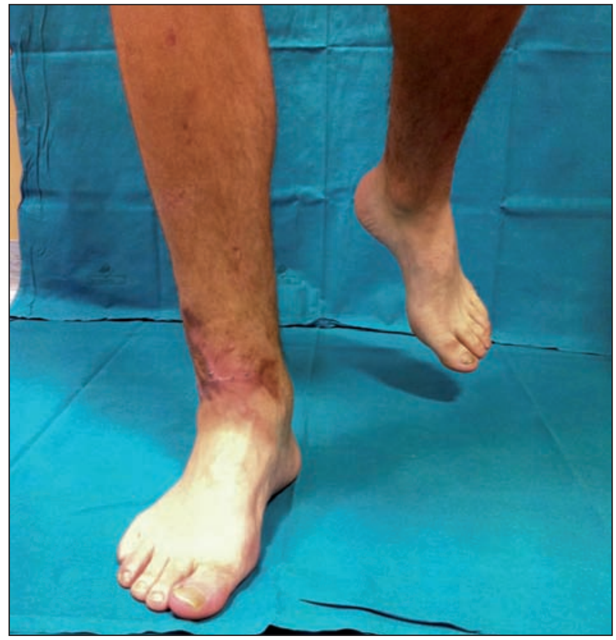

Figure 7. Single leg stance on affected ankle

Instrumental evaluation

Eighteen months after the trauma, postural evaluation and simultaneous assessment of kinematics, kinetics, and plantar pressure on foot subareas was also carried out. Data were quantitatively recorded in static position and during gait using a baropodometric-stabilometric platform (EPS/C® LorAn-Engineering, Bologna, Italy). This force platform presented an active surface of 40x48 cm with 4096 capacitive sensors. Foot pressure analysis provided qualitative data of total pressure applied to the foot, the percentages of pressure distribution in the segments of hindfoot, midfoot, and forefoot, maximum pressure values and total contact area (10). Stabilometric evaluation provided displacements of the center of pressure, postural oscillation, ground contact area of the feet and peak contact pressure (11). In static examination patient was standing upright barefeet for 30 seconds with the minimum movement possible on platform, once with eyes opened and once with eyes closed. The same evaluation was carried out in bilateral single leg stance (SLS). For dynamic examination the patient walked on the platform until 10 valid footmarks (5 for each foot) were recorded. Gait symmetry and regularity was assessed by means of an inertial sensing unit (Free4Act®, LorAn-Engineering, Bologna, Italy). It is a triaxial sensor, consists of a small case of 78x48x20 mm weighting 48 g only, easy to use, requires no specialized equipment, does not interfere with regular walking, and could be used to analyze walking in clinical practice. The accelerometer, placed on a semi-elastic belt covering the L4-L5 intervertebral space, transmitted the data to a PC via Bluetooth. The sensitive axes of the sensing unit were automatically aligned along the anatomical vertical, medio-lateral, and antero-posterior axis. The patient walked at normal speed for 10 meters. At last the vertical component of acceleration was assessed with FreePower® accelerometer (Sensorize, Rome, Italy). It is a triaxial sensors, consists of a small case of 88x51x25 mm weighting 93 g and not interfere with normal jump. The accelerometer, placed on an elastic belt covering the L5-S1 intervertebral space, transmitted the data to a PC via Bluetooth. The patient made countermovement jump (CMJ) in double (B-CMJ) and single (M-CMJ) leg start position to assess vertical elevation (12-17).

Results and Discussion

Baropodometric evaluation suggested normal plantar pressure distribution in both feet: in double leg stance (DLS) with eyes opened (EO) was 50.8% for left foot (LF) and 49.2% on right foot (RF), with eyes closed (EC) pressure distribution remained in normal range (LF: 52.3%, RF: 47.7%) even if greater in LF. Patient presented pelvic rotation (EO: 7.48°, EC: 6.58°) that was probably due to a posterior kinetic chain muscles shortening as a consequence of the scar on right lower limb. However Max Pressure was greater in RF (LF-EO: 148.3 Kpa, RF-EO: 193.3 Kpa, LF-EC: 142.8 Kpa, RF-EC: 183.8 Kpa) probably because the rehabilitation program after trauma was focused on pressure redistribution. The Arch Index (AI) assessed normal foot both in EO and in EC. There are not significant variations between different segments of feet, neither between LF-AI (EO: 22.3%, EC: 21.94%) and RF-AI (EO: 27.55%, EC: 27.08%). However RF-AI was at upper limit of normal foot (28%), tending to light flat foot. This is probably due to the trauma and consequent reconstruction. Some troubles have occurred during SLS-RF evaluation: the patient was not able to maintain the position for 30 seconds with EC. A possible explanation for the instability is an isolated proprioceptive sensory loss as a consequence of the trauma. SLS requires a high neuromuscular demand to control displacements and frequent inversion/eversion of the ankle.

The analysis of the morphological and functional variation of the baropodometrical footprint during gait suggested that the contact feet surfaces in LF and RF are different (LF:127,4 cm^2, RF:157,4 cm^2). Dynamic foot pressure analysis also described a different duration (LF:1165.2 msec, RF:1052.2 msec). In this context it is indispensable to highlight that during gait RF-AI assessed a normal foot (24.14%) with a normal distribution in the segments of hindfoot, midfoot and forefoot. Therefore during gait RF act like a physiological foot unlike from static evaluation.

Stabilometric evaluation suggested that reduced vision could lead to greater oscillation, as visual informations contributes to balance control. With eyes closed greater oscillations about the vertical axis and larger Center of Pressure (CoP) displacements and velocity are observed (Tab. 2).

Gait analysis, based on measurements of acceleration, shows an excellent overlapping between left and right stride, however the patient has an increased time of double support (Fig. 8). This fact may be attribute to needs to promote stability of the body.

B-CMJ elevation (0.33 m) was greater than M-CMJ, but it is important to emphasize that LF and RF M-CMJ elevation are exactly alike (0.22 m), nevertheless RF-peak force (RF-PF) and RF-peak power (RF-PP) were lower than LF (LF-PF=7.07 N7Kg, RF-PF=5.99 N/Kg, LF-PP=9.60 W/Kg, RF-PP=7.62 W/Kg). The RF-displacement was greater than LF, as a consequence concentric work was higher (LF=4.17 J/Kg, RF=4.32 J/Kg) (Fig. 9).

Conclusions

Emergency foot salvage treatment was possible thanks to a close collaboration among the physicians

Table 2. Stabilometric evaluation with eyes open and closed. Legend: DLS:Double leg stance, SLS:Signle leg stance, EO:Eyes Open, EC:Eyes Closed, LF:Left Foot, RF:Right Foot, CoP: Center of Pressure

	Stabilometric evaluation (DLS)		Stabilometric evaluation (SLS)			
	EO	EC	EO		EC	
			LF	RF	LF	RF
CoP X (mm)	0.1	0.4	-0.3	-0.5	-0.4	missing
CoP Y (mm)	-1.5	-1.6	-1.6	-1.5	-0.8	missing
CoP displacement (mm)	78.6	169.9	184.3	301.7	408	missing
Standard Deviation X	1.754	2.282	3.063	4.767	9.955	missing
Standard Deviation Y	1.962	4.378	5.730	6.617	7.473	missing
CoP velocity (mm/sec)	3.9	8.5	9.2	15.1	20.4	missing
CoP Surface (mm2)	53.41	153.18	307.75	565.76	1533.55	missing
Left CoP Surface (mm2)	10.75	40.85	0	565.76	0	missing
Right CoP Surface (mm2)	7.70	16.30	307.75	0	1533.55	missing

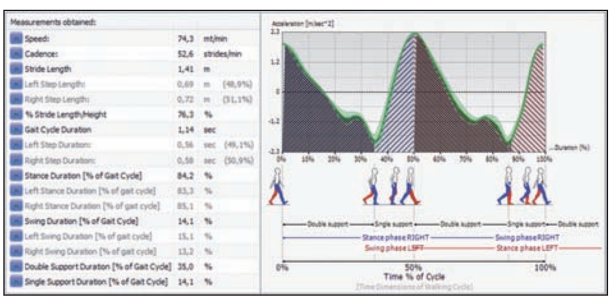

Figure 8. Gait analysis based on measurements of accelerometer

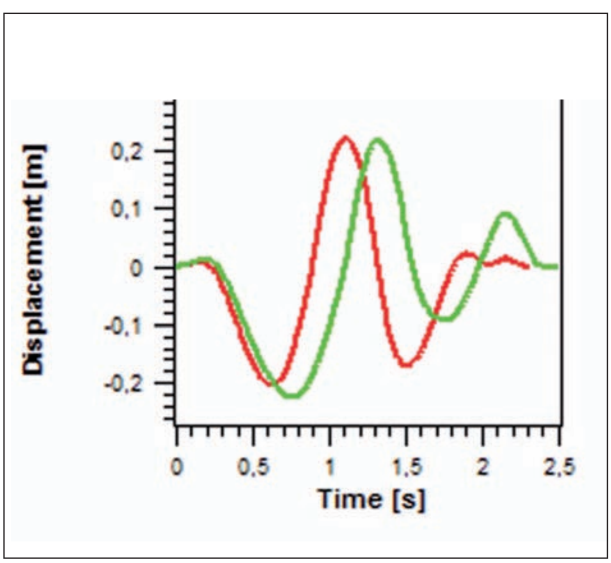

Figure 9. M-CMJ displacement, left foot (red) compared with right foot (green) start position

involved. The primary stabilization after surgical debridement and functional reconstruction was successful a week after surgery. Cutaneous necrosis of the distal third of the limb with extensor tendons exposition occurred. This complication has been successfully treated by plastic surgeons with a reverse rotation flap. The patient's compliance allowed for well-timed treatment and the personalized rehabilitation program allowed for the excellent clinical and radiological outcomes. The positive outcome has been exhibited by instrumental evaluations and from the daily life activities achieved during recovery. Weight bearing on the damaged foot has been restored. The positive outcome confirmed the medical decision making and the patient restart to run without pain.

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