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Segmental surgical exploration for the control of deep soft tissue infection in complicated diabetic foot

Exploración quirúrgica segmentaria para el control de la infección profunda de tejidos blandos en el pie diabético complicado

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Diabetic foot, limb salvage, segmental exploration, plantar ulcer, loss of limb.

Palabras clave:
Pie diabético, salvamento de extremidad, exploración segmentaria, úlcera plantar, pérdida de extremidad.

ABSTRACT

Mexico has the 6th place in diabetes mellitus (DM) in the world, and first place in child and adult obesity, considered as the mains risks for DM. Especially important is diabetic foot since 1 in 6 patients will develop a plantar ulcer, the main risk factor for limb loss. The patient with diabetic foot complicated by deep soft tissue infection can salvage the limb if the diagnosis is done in time, meets adequate inclusion criteria and surgery is complete and resolutive. In the following study, a proposal of surgical treatment is made based on a complete exploration of the foot to avoid extensive incisions that devascularize the tissues, and also allow for the complete drainage of purulent collections, with a high rate of success, at a lower cost, as compared to standard treatment.

RESUMEN

México ocupa el sexto lugar en diabetes tipo 2 en el mundo; el primer lugar en obesidad infantil y adulta considerando esto como el principal factor de riesgo de desarrollar diabetes, con especial importancia de pie diabético, ya que uno de cada seis pacientes presentará pie diabético complicado por una úlcera plantar, el cual representa el principal factor de riesgo de pérdida de la extremidad. El paciente que presenta pie diabético complicado por infección profunda de tejidos blandos es susceptible al salvamento de la extremidad, siempre y cuando su diagnóstico sea oportuno, cumpla con criterios de inclusión adecuados y la cirugía sea completa y resolutiva. En el siguiente estudio se hace una propuesta de tratamiento quirúrgico con base en la exploración completa del pie, a fin de evitar incisiones amplias que devascularicen los tejidos y que además permitan el drenaje completo de las colecciones purulentas o abscesos, teniendo hasta este momento una tasa de éxito alta con un costo menor que el tratamiento estandarizado.

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INTRODUCTION

Type 2 diabetes (DM2) is a global problem with severe socioeconomic implications for developing countries like Mexico, which ranks 6th worldwide and 1st in obesity in adults and children. In 2010 alone, 6.4% of the adult population had diabetes, while in 2012 the figure increased to 9.17% and in 2016 it was estimated at 13.3%.[1] In the United States, it is estimated that the population affected by this disease reaches 23.6 million people.[2]

DM2 continues to be the most common precipitating factor for non-traumatic lower extremity loss.[3] It is estimated that one in six people with DM2 will develop a limb ulcer throughout their lives. A plantar ulcer is the main risk factor for limb loss in diabetic patients, it precedes 85% of all amputations in the United States.[1,4,5]

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Diabetic neuropathy is the most important factor in the development of a plantar ulcer[6-26] and soft tissue infection is the most frequent complication.[8] The incidence of foot infection in people with diabetes ranges from a 4% risk during the rest of their life to a 7% annual risk.[27-32] Infection in a diabetic foot can spread contiguously through the deep tissues with minimal superficial changes, or extend proximally and/or deep into the underlying bone. It can become a severe infection, progress to sepsis, septic shock, multiple organ failure, and death if aggressive infection control is not achieved.[25,30]

As Kaafarani postulates, "surgical exploration is the only real method to differentiate between a benign soft tissue infection and a severe necrotizing soft tissue and skin infection. Intraoperatively, necrotizing skin and soft tissue infection are characterized by pale or necrotic soft tissue/muscle/fascia, absence of bleeding on the surgical cut edge, greyish discharge resembling residual water from a dishwasher machine (dishwasher-like), and the effortless separation of the tissue planes, the gentle sliding of the scanning finger between the muscle layers and fascia, and between the subcutaneous tissue and the fascia (finger test)".[26]

Diagnosis is based on symptoms and clinical signs such as disproportionate pain on physical examination, and description of pain beyond the apparent area of involvement. In many cases, laboratory blood and microbiological studies, as well as radiological studies,[23] are used to make therapeutic decisions.[25] However, both clinical and diagnostic studies[31] have ranges of error that can lead to underestimating the extent of the infection with the consequent progression of tissue damage and increased likelihood of amputation.[28,29] Severe diabetic foot infection is a surgical emergency that justifies immediate and aggressive treatment with hemodynamic support and fluids, broad surgical debridement, and broad-spectrum antibiotics. Amputation of the limb is the radical surgical treatment for severe soft tissue infection, unfortunately, the most frequent treatment in Mexico.[33] A complete surgery with total debridement and drainage of abscesses will not only effectively limit the infection, but will make the process healing faster.[9] Accurate identification of the extent of infection is a priority, and surgery is the best method. We propose a technique involving the segmental surgical exploration of potentially affected areas (areas of clinical suspicion and areas peripheral to the main lesion) to identify and control the extension (to deep planes or neighboring compartments and/or contiguous ligaments), with a low risk of compromising the explored area, and ultimately avoiding or limiting an amputation, especially a major one, altogether resulting in limb salvage, preservation of ambulation, and positive impact on the quality of life.

Research question: is there a transoperative diagnostic method for accurate identification of the extent of severe infection in the diabetic foot? Surgical exploration is the only real method to differentiate between a benign soft tissue infection and a necrotizing infection of the skin and soft tissues,[34] and to achieve total debridement and drainage of the abscesses, and limitation of infection.[9]

Objective: to show how a segmental surgical exploration technique (SSET) of potentially affected areas (areas of clinical suspicion and peripheral areas) and washing reduces the risk of major amputation.

Specific objectives:

- Demonstrate how an SSET identifies areas of extension of severe diabetic foot infection.
- Show that an SSET decreases the number of surgical procedures to control severe infection of the diabetic foot.
- Show that an SSET offers a low risk of compromise of the scanned area during a severe diabetic foot infection.
- Scarring or proper formation of granulation tissue.
- Recurrence or permanence of the septic focus.

Hypothesis: SSET will work in all cases.

Hypothesis: primary result. When performing a segmental surgical exploration technique (SSET) of potentially affected areas to debridement and surgical lavage in severe diabetic foot infection, the number of cases will

decrease, as will the number of cases that will require a major amputation, as reported in the literature (52/299 = 17.4%). [27]

Hypothesis: secondary results. When performing a segmental surgical exploration technique (SSET) of potentially affected areas divided into areas of clinical suspicion and peripheral areas, the areas of severe extension of infection will be identified more than the areas of suspicion in the periphery, and the number of procedures to control severe infection will be reduced. By performing a segmental surgical exploration technique (SSET) of potentially affected areas to debridement and surgical lavage, there will be less than 10% of surgical site infections with a false negative result.

PATIENTS AND METHODS

In Mexico City, at the Surgical Center for Diabetic Foot and Limb Salvage "Salva Pie Diabético" from January 2014 to January 2016, a total of 50 consecutive patients were seen, 18 females and 32 males, with average age of 53.6 years (range from 37 to 86 years), with severe soft and/or deep tissue infection.

The affected feet were: right in 31 patients, the left foot in 19. No patients had both feet involvement. All were admitted with an IDSA (Infectious Diseases Society of America) degree of severe infection and a Perfusion, Extent, Depth, Infection, and Sensation (PEDIS) classification of 4.

Criteria of inclusion

Age or sex were not considered to enter the protocol.

- Previous treatment or without previous treatment.
- No bone compromise on radiography of the affected limb (AP and oblique foot or leg).
- Presence pulses from both, posterior and dorsal foot tibial branches, with distal capillary filling of two to three seconds, and complemented with Doppler ultrasound and/or angio-CT to establish the presence of arterial flow from both branches.

Criteria of exclusion and elimination taken into account

- Vascular compromise identified on initial evaluation with no palpation of pulses of the anterior, posterior, or dorsal tibial arteries, or absent or delayed capillary filling (greater than three seconds).
- Indication of vascular or endovascular treatment from admission.
- Indication of major amputation since admission due to a severe infection that involved a large amount of tissue and/or non-viable tissue.
- Extensive or severe osteomyelitis detected by some other test.
- Subjects who did not accept segmental surgical exploration treatment of potentially compromised or peripheral areas.

Type of study

- Initial assessment, hospital admission.
- Metabolic control (NPH (intermediate)/R (rapid) insulin scheme and subsequently oral hypoglycemic and/or insulin) and comprehensive management of systemic complications.
- Impregnation with a broad-spectrum antibiotic (first-line ceftriaxone 1 g intravenously every 12 hours + metronidazole 500 mg intravenously or in case of having been previously treated with an antibiotic, start with ertapenem 1 g IV every 24 hours).
- Diabetic foot severity classification according to the Clinical and Practical Guide for the diagnosis and treatment of diabetic foot infections: American Society for Infectious Diseases and the International Group on Diabetic Foot *(Table 1)*.[7]

Surgical intervention

- Surgical debridement: the initial approach was performed at the main site of involvement with an incision to achieve wide and complete debridement of the affected and devitalized tissue, removal of tendons and preservation of the irrigation of the main vessels. In

secondary branches vascular ligation in medium-sized vessels is recommended, and avoidance of electrocautery as much as possible.

- Segmental surgical exploration: the segmental surgical exploration consisted of a 2-3 cm superficial incision on the skin, and subcutaneous fatty tissue with mosquito forceps, taking special care not to harm vessels and vascular arches. When finding obvious signs of infection such as suppuration of purulent material, bad odor, or necrotic-looking secretion, the procedure was complemented by extending the incision as necessary. When finding affected tendons, they were removed and the abscesses drained, leaving wounds open for complete drainage. That failing, in case of a proximal rise of the infection the incision was extended to complete the debridement as necessary. If no affectation was observed, a closure was made with two or three 2-0 or 3-0 simple nylon sutures.

The potentially affected areas where the SSET were selected according their characteristics by extension to ligaments or the continuity to deep planes. The area selected was called "area of suspicion", and the characteristics observed were erythema, edema, and/or temperature increase in superficial or deep continuity through the tendon paths. The area of continuity to deep planes through extension by aponeurotic and/or tendon gaps was called "peripheral area". After surgical debridement

Table 1: Classification for Diabetic Foot Infection: American Society for Infectious Diseases and the International Group on Diabetic Foot.

Clinical manifestations of infection	PEDIS	IDSA
No symptoms or signs	1	Not infected
Infection present: defined as the presence of at least two signs: • Erythema • Local pain • Local increase in temperature • Purulent discharge		
Local infection involving only the skin and subcutaneous cellular tissue (without involving deep tissues and without systemic involvement). The erythema should be 5 mm to 2 cm around the ulcer; rule out Charcot foot, fracture, thrombosis, venous stasis, trauma and gout	2	Mild
Local infection (see above) with erythema greater than 2 cm or involving deep structures (fasciitis, osteomyelitis, septic arthritis, abscess) and without systemic inflammatory response syndrome	3	Moderate
Local infection (see above) with systemic inflammatory response syndrome (temperature less than 36 ºC or greater than 38 ºC, heart rate greater than 90 BPM, respiratory rate greater than 20 RPM or $PaCO_2$ less than 32 mmHg, leukocytes greater than 12,000 or less 4,000 cels/ml or more than 10% of immature cells or left shift)	4	Severe

Ischemia can increase the severity of the infection. Severe ischemia is considered a severe infection
Systemic infection can be accompanied by failure of other organs
Abbreviations: IDSA (Infectious Diseases Society of America) $PaCO^2$: arterial CO^2 partial pressure.

Figure 1: *Hospital admission.*

and segmental surgical exploration were completed, conventional mechanical surgical lavage with a superoxidation solution was performed. The wounds were covered with gauze and an anti-edema bandage (Robert Jones bandage).

Surgical management follow-up:

- Wound cleansing 24 hours after surgery with water, surgical soap, and superoxidized solution every eight hours until remission of the infection at the patients' bed.
- When the wound was clean, management was done with special debriding dressings, and reassessment of surgery (washing, debridement, grafting in only two cases).
- When the wound was completely closed:
  - A customized splint (articulated or non-articulated ranch type) for immobilization of the ankle and joint movement between the foot and the leg.
  - Rehabilitation.
- Anti-edema measures (stockings or compression bandage) throughout the post-surgical treatment.
  - Psychological support and metabolic control.

RESULTS

The were 33 surgeries performed with segmental surgical exploration and complete salvage. Fifteen patients underwent minor amputation, 2 had Lisfranc, 6 trans-metatarsals, 3 Chopart, 4 of only one finger.

The closure of the wounds from preservation surgery against amputation was: 6 by first intention, 36 by second intention, and 8 by third intention.

Pus or necrotic material was obtained in 30% of the patients who underwent exploration of suspicious sites (local inflammation data). Pus was found in 15% of the patients who underwent an examination in sites without frank data of inflammation, but peripheral to the affected site.

The average time for complete closure of deep wounds was 150 days (closure by second and third intention; the minimum time was 45 days and the longest was 270 days, the latter being due to lack of adherence to treatment in two patients). For the ambulation with a prosthesis, template with pressure point release or both, average was 170 days. In those patients with closure by first intention, ambulation started at 30 days.

The average weekly cost of postoperative treatment was $ 700 MXN ($ 35 US) with conservative treatment (water, soap, superoxidized solution, and coverage with specialized dressings depending on the requirement of each wound.

The limitation of infection in open wounds was clinically done, with criteria being absence of pus, devitalized tissue, or bad odor, decreased erythema and edema, and increased granulation tissue. Primary closure it was limited to good face-to-face sutures, in absence of exudate, decreased erythema or edema. With the described surveillance of each patient, despite not using sophisticated means of wound closure, a 100% closure was obtained, and in no case did failure occur.

Depression coupled with chronic degenerative diseases was diagnosed in 90% of the patients.

PRESENTATION OF CASES

All the patients underwent surgery under regional anesthesia. Initial management was with a broad-spectrum antibiotic, fluids and electrolytes, metabolic management a rapid insulin regimen. The admission laboratory studies were: complete blood biometry, 27-element blood chemistry, coagulation times, procalcitonin, urinalysis, electrocardiogram, and chest x-rays, to have

Figure 2: *Immediate postoperative.*

Figure 3: *At 60 postoperative days: partial closure by third intention.*

Figure 4: *At 90 postoperative days, total healing and beginning of rehabilitation.*

Figure 5: *Hospital admission.*

Figure 7: *Evolution at 37 postoperative days and closure by third intention.*

Figure 6: *Immediate postoperative: segmental examination.*

the general context of the patient, sepsis, and comorbidities. Joint management was done with internal medicine and critical medicine. The average time to start ambulation was similar to that reported in the international literature for the type of wound (four months in average). In all patients, only one surgical intervention was performed, unlike the international average, which is of two for this type of patient. Wound management by basic and advanced lavage in the middle and late postsurgical period was carried out by the patients themselves and their families after training, thereby significantly reducing the expenses, taking into account that in the United States United the weekly cost for the management of these wounds is between $ 300- $ 3,000 (dollars), while in these cases it was on average $ 1,500.00 MXN ($68 US) weekly, including average medical fees (specialist),

with a visit to the office every two weeks as long as there were no signs of alarm (lack of metabolic control, fever, pus, erythema, pain, volume increase, tissue necrosis and ischemia). Taking into account that the adequate treatment of complicated diabetic foot is extremely expensive in our country and abroad, in our environment it was possible to improve costs while still providing adequate management.

Case 1

A forty-seven-year-old male, with DM of 17 years' evolution, poor metabolic control, a one-week-old plantar ulcer treated with antibiotics without improvement *(Figure 1)*. Upon admission, signs of an inflammatory response, abundant outflow of pus from the plantar region, and the dorsal side of the fourth finger. Impregnation with ertapenem was started, 1 g every 24 hours, as well as hydration, and metabolic control with insulin. Extensive plantar debridement, surgical lavage, and segmental examination of the rest of the foot were done *(Figure 2)*. In the late postoperative period, a third intention closure was done in the plantar wound with 2 single sutures of 2-0 nylon *(Figure 3)*. Ambulation started when all wounds healed.

Figure 8:

At 90 postoperative days and start of rehabilitation.

Figure 9:

Hospital admission: extensive necrosis is observed in the first, second, third and fifth toes.

Figure 10:

Immediate postoperative: segmental examination and trans-metatarsal amputation.

Figure 11:

Evolution 60 days after surgery.

The use of footwear and personalized insoles for diabetics was recommended *(Figure 4)*.

Case 2

Fifty-two-year-old male, 12 years' evolution of DM2, and poor medical control, presented with a one-month-old plantar ulcer. With edema of the foot and erythema of the second toe, who had been treated in a public hospital without improvement *(Figure 5)*. Trans-metatarsal amputation of the affected finger was proposed. After voluntary discharge was requested, he came to us for evaluation. Upon admission, he had a glycemia of 650 mg/dl. Treatment was started with ertapenem 1 g IV every 24 hours, hydration and metabolic control with insulin *(Figure 6)*. He underwent wide plantar debridement and segmental exploration. In the late postoperative period, a third intention closure was done in the plantar wound with 2-0 nylon single sutures *(Figure 7)*. Ambulation started when all wounds healed *(Figure 8)*. Footwear and personalized insoles for diabetics was indicated.

Figure 12:

Start of rehabilitation 110 days after surgery.

Case 3

Forty-seven-year-old male with DM2 of 20 years' evolution and irregular metabolic treatment. He went to a public hospital for a plantar ulcer at the the fifth metatarsal. Upon admission to our unit, he presented with fever and pain. Medical treatment was given, and when presenting data on sepsis and flow of abundant pus, surgical washing and fasciotomies were done *(Figure 9)*. Forty-eight hours later supracondylar amputation was proposed, when he presented with septic shock. Impregnation with ertapenem 1 g IV every 24 hours was started, metabolic control with insulin and fluids were administered. He underwent trans-metatarsal amputation and segmental exploration in the rest of the foot, finding previously unidentified abscesses *(Figure 10)*. Wounds were partially approximated with 2-0 single sutures. Delayed closure was done at the tip of the stump in the late postoperative period with 2-0 nylon *(Figure 11)*. Ambulation was started when all the wounds healed *(Figure 12)*, with footwear, insoles, and a personalized ranch-type splint for diabetics.

CONCLUSION

In this study we show that with a less invasive, but at the same time decisive, surgical technique and conservative post-surgical treatment without sophisticated and expensive means for the management of wounds, we can achieve adequate or acceptable results for the management of this complex and devastating disease that continues to be the leading cause of non-traumatic limb amputation in the world, affecting a greater extent the population with limited economic resources.

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