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INVITED REVIEW

The care of transmetatarsal amputation in diabetic foot gangrene

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Abstract

Diabetic foot ulcerations may determine minor or major amputation, with a high impact on patients' life expectation and quality of life and on economic burden. Among minor amputations, transmetatarsal amputation (TMA) appears to be the most effective in terms of limb salvage rates and in maintaining foot and ankle biomechanics. In spite of this, TMA needs particular pre- and postoperative management in order to avoid the frequent failure rates.

A systematic review was undertaken of studies concerning TMA and its care in diabetic foot gangrene. Studies were identified by searching the MEDLINE, Scopus and Science Direct databases until 13 January 2016. All studies were assessed using the Downs and Black quality checklist.

Of the 348 records found, 86 matched our inclusion criteria.

After reading the full-text articles, we decided to exclude 35 manuscripts because of the following reasons: (1) no innovative or important content, (2) no multivariable analysis, (3) insufficient data, (4) no clear potential biases or strategies to solve them, (5) no clear endpoints and (6) inconsistent or arbitrary conclusions. The final set included 51 articles.

In the current literature, there are less data about TMA, indication for the selection of patients, outcomes and complications.

Generally, the judgment of an experienced physician is one of the best indicators of subsequent healing. Ankle brachial indices, toe pressures, laser Doppler skin perfusion pressures, angiography and Doppler assessment of foot vasculature may help physicians in this decision.

In any case, despite the presumed lower healing rate, it is reasonable to pursue a TMA in a patient with a higher likelihood of continued ambulation.

Furthermore, tailored wound closure, adjuvant local treatments and the choice of the most appropriate antibiotic therapy, when infection occurs, are pivotal elements for the success of TMA procedures.

TMA is a valuable option for diabetic foot gangrene that can prevent major limb loss and minimise loss of function, thus improving the quality of life for diabetic patients.

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Introduction

Diabetic foot is considered a syndrome because of several aspects of diabetic disease, such as peripheral arterial disease, both microangiopathy and macroangiopathy and peripheral neuropathy leading to foot ulcerations that affect one in ten diabetics during their lifetime (1). Diabetic foot ulcerations may determine minor or major amputation, especially when wound infection or osteomyelitis is involved, with a high impact on patients' life expectation and quality of life and on economic burden. Furthermore, studies have shown that about 50% of patients with diabetic foot infections treated with distal amputations expire within 5 years (2).

These data are also alarming because the incidence and prevalence of diabetes is rising in last years. Therefore, it is important to prevent diabetic foot and its complications, such as ulcers and infection, acting primarily on the risk factors: close monitoring of hyperglycaemia, smoking and obesity (3,4). Moreover, complete and careful foot care is also needed through daily foot checks, removing callosity because of diabetic neuropathy, daily foot hydration, regular toenail cutting and appropriate or custom-made footwear (5,6).

For many patients with infection or distal foot gangrene, a transmetatarsal amputation (TMA) is the last hope for partial foot salvage. The preservation of a sensitive heel is desirable for maintaining ambulatory function. However, wound healing of TMA is frequently a major challenge. Although transtibial amputations heal more reliably than TMAs, patients are often resistant to this procedure, and subsequent ambulation with a prosthesis is often more difficult than ambulation on the native heel and forefoot (7,8).

The poor ambulatory performance of atherosclerotic patients with transtibial amputations is well documented. Therefore, despite the accepted lower healing rates, it is reasonable to pursue a TMA in patients with a higher likelihood of continued ambulation. It is often difficult to determine this preoperatively because most patients express a wish to walk again. So, for patients in whom ambulation is clearly a reasonable future goal, TMA is an optimal option despite its low healing rate and the need for additional operations and hospitalisations. For the superior functional outcomes of patients with successful amputation healing, TMA should be offered to patients with favourable prospects for postoperative ambulation. In patients with poor rehabilitation prospects, TMA may lead to additional procedures and hospitalisations, and a more proximal amputation with a higher likelihood of healing may be preferable (9).

Moreover, advanced wound care is required to improve diabetic ulcer healing and TMA outcome.

Key Messages

- this review article deals with the major issues around TMA, also providing the best evidence-based information on the main characteristics and the outcomes of this procedure in the management of diabetic foot gangrene
- currently, no specific preoperative measures are able to accurately predict which patients would go on to achieve healed TMAs, so clinical judgment still remains an important factor in deciding who should be offered this operation in order to avoid the failure of a TMA
- for patients in whom ambulation is clearly predictable, TMA is an optimal option; otherwise, in patients with poor rehabilitation prospects, TMA may lead to additional procedures and hospitalisations, and a more proximal amputation with a higher likelihood of healing may be preferable
- after performing a TMA, advanced wound care is required to improve diabetic ulcer healing and TMA outcomes
- tailored wound closure, adjuvant local treatments and the choice of the most appropriate antibiotic therapy, when infection occurs, are pivotal elements for the success of TMA procedures

Methods

This systematic review was conducted and is reported in accordance with the PRISMA guidelines.

Inclusion and exclusion criteria

We decided to include all the studies conducted about TMA in diabetic foot. Randomised trials, cohort studies and reviews were contemplated in order to give a breadth of clinical data. Only publications in English were considered. We excluded all the studies with insufficient statistical analysis, possible biases and contradictions, no clear endpoints and inconsistent or arbitrary conclusions.

Search strategy

Two members of the research team (MA, LB) performed a comprehensive literature search using terms identified and agreed on by the authors. Medline, Scopus and Science Direct were searched from January 2006 to April 2016 using the keywords 'Transmetatarsal amputation and diabetic foot'.

Data extraction and risk of bias assessment

Two review authors (SdF, RS) independently assessed both titles and abstracts of potentially eligible studies found in Medline, Scopus and Science Direct. In case of an ambiguous or unclear result, the study was retrieved in full and assessed further by all authors independently and included if pertinent. All studies were assessed using the Downs and Black quality checklist (10,11).

Results

Study selection

A total of 348 records were found, and 86 matched our inclusion criteria (Figure 1).

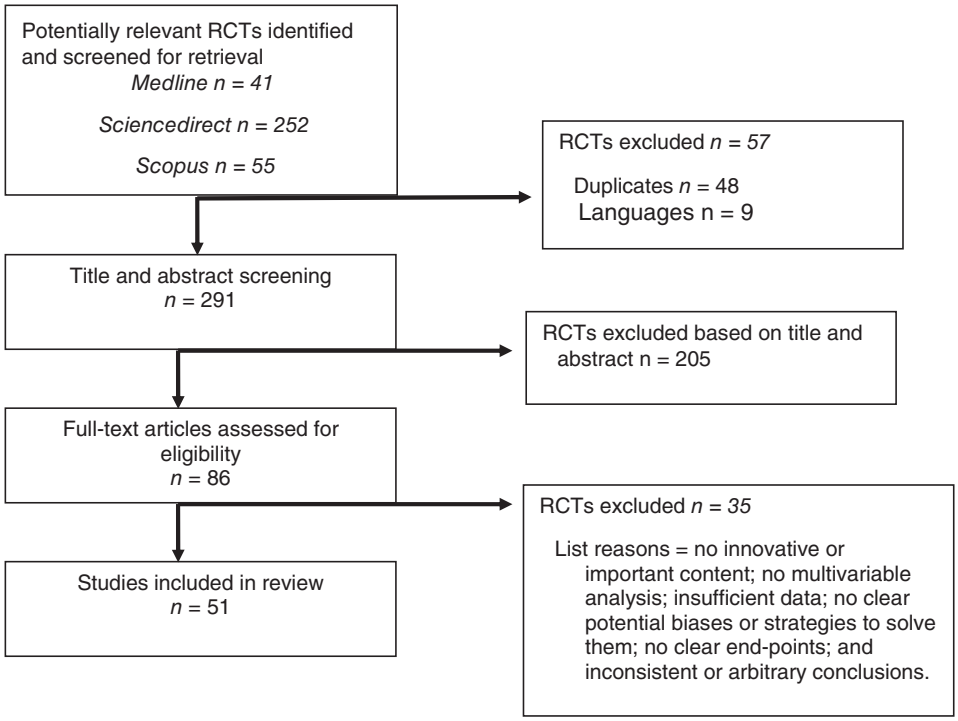

Figure 1 PRISMA diagram.

After reading the full-text articles, we decided to exclude 35 manuscripts because of the following reasons: (i) no innovative or important content, (ii) no multivariable analysis, (iii) insufficient data, (iv) no clear potential biases or strategies to solve them, (v) no clear endpoints and (vi) inconsistent or arbitrary conclusions. The final set included 51 articles.

Diabetic foot epidemiology

The term 'diabetic foot' will be taken to encompass any foot lesion occurring as a result of diabetes and its complications. Globally, the diabetic foot remains a major medical, social and economic problem that is seen in every country. People at the greatest risk of ulceration can easily be identified by careful clinical examination of the feet; education and frequent follow-up is indicated for these patients. When assessing the economic effects of diabetic foot disease, it is important to remember that rates of recurrence of foot ulcers are very high, being greater than 50% after 3 years. Costing should therefore include not only the immediate ulcer episode but also social services, home care and subsequent ulcer episodes. A broader view of total resource use should include some estimate of the quality of life and the final outcome. An integrated care approach with regular screening and education of patients at risk requires low expenditure and has the potential to reduce the cost of health care (12,13).

However, the reported frequencies of amputation and ulceration do vary considerably as a consequence of the different diagnostic criteria used as well as regional differences (14,15).

Up to 25% of patients with diabetes will develop a foot ulcer sometime during their lives, and up to 2% of patients may already have undergone amputation. Diabetes remains the major cause of non-traumatic amputation in most Western countries; rates are as much as 15 times higher than in the non-diabetic population (16,17).

It is difficult to make a direct comparison between studies/countries for methodological issues. First, the definition as to what constitutes a foot ulcer varies, and secondly, surveys invariably include only patients with previously diagnosed diabetes, whereas in type 2 diabetes, foot problems may be the presenting feature. In one study from the United Kingdom, for example, 15% of patients undergoing amputation were first diagnosed with diabetes on that hospital admission (18,19).

Such observations clearly indicate the need for all diabetes services to have a regular screening programme to identify such high-risk individuals. It is well recognised that a number of contributory factors working together ultimately result in the final pathway to foot ulceration in diabetic patients. The most common component in this pathway include peripheral neuropathy, foot deformity, external trauma, peripheral vascular disease and peripheral oedema (20,21).

With the exception of trauma, none of the abovementioned risk factors will cause ulceration in isolation. Ethnicity and gender also have associations with neuropathy. In Western countries, foot ulcers are more common in male patients, and in mixed populations, foot ulceration is more common among those of European origin when compared to Asians and African–Caribbeans (22,23).

An important prospective study evaluated in detail the predictive factors for limb salvage in patients with diabetic foot problems in Singapore: comorbidities, infections, complications, sensory neuropathy, gangrene and pathogens (24).

However, the greatest single risk factor for foot ulceration is a past history of either ulceration or amputation (20,21).

Much progress has been made in the last 20 years in our understanding of the pathogenesis and management of diabetic foot problems, and the volume of research activity in this area is rapidly increasing. However, the current 'epidemic' of type 2 diabetes that is being witnessed throughout the world is resulting in an ever-increasing population of diabetic patients with lower limb complications. The challenge in the years before the next international meeting is to continue increasing the awareness of diabetic foot problems, their causes and management.

Functional impact of TMA

Risk factors associated with TMA were male gender, physical impairment, cardiovascular complications, smoking, obesity, nephropathy, peripheral arterial disease characterised by intermittent claudication and impaired peripheral pulses, neuropathy, previous diabetic ulcers, gangrene and contralateral amputation (25).

Several authors consider TMA better than transtibial amputation because of its ability to preserve the ankle and a part of the foot, permitting independent gait and avoiding a prosthetic device (26,27).

After TMA, there are several patho-mechanical changes in the amputated limb that cause abnormalities of gait; among these, a shorter and deformed foot, with loss of toes, plantar aponeurosis, intrinsic muscles and toe proprioceptors, causes an inadequate plantar flexor lever arm and forces patients to walk with reduced gait velocity and decreased ankle moments. Furthermore, higher pressures over the mid-foot of the amputation limb because of reduced surface area are detected (28).

As a result of these factors, the patients had remarkable difficulty in any activity that required shifting weight to the forefoot, like climbing stairs and picking up something from the floor.

Indeed, the contralateral limb shows greater ankle moments and heel high pressure, causing an asymmetrical ankle during the gain, which can undergo a plantar tissue injury (29,30).

Patients should wear regular shoes and toe fillers to improve function and to prevent skin breakdown. Mueller *et al.* recommend the full-length shoes, total-contact insert and a rigid rocker-bottom sole for almost all patients (31).

Outcomes and complications

In the current literature, there are less data about TMA outcomes and complications. Unfortunately, no preoperative measures were able to accurately predict which patients would go on to achieve healing of their amputations, so clinical judgment still remains an important factor in deciding who should be offered this operation.

TMA was first described as a method of partial foot preservation by McKittrick *et al.* in 1949 (32). Preservation of a sensitive heel is desirable for maintaining ambulatory function. However, wound healing of TMA is frequently a major challenge. Wound-healing rates from multiple series range from approximately 40% to 70% (33–39) .

Clearly, patient choice becomes an important factor because patients in general wish to preserve as much of their limb as possible. Below-knee amputation is still a stigmatised procedure that patients will most likely defer as long as possible and at all reasonable cost. However, several similar studies demonstrate the importance of tempering expectations. Patients need to be aware of the relatively low likelihood of the success of this operation. Although this awareness is not likely to dissuade patients from pursuing it, at least patients will be informed of the tenuous nature of limb salvage in their particular situation. It is human nature to believe that bad outcomes will happen to someone else and not them, but armed with the knowledge that their operation has a relatively low likelihood of success, patients may be more likely to be compliant with the prescribed postoperative care recommendations, not the least of which is maintaining a non-weight-bearing status until the amputation site has healed.

Although transtibial amputations heal more reliably than TMAs, patients are often resistant to this procedure, and subsequent ambulation with a prosthesis is often more difficult than ambulation on the native heel and forefoot. Given the difficulty in the healing of TMA, however, it would be desirable to predict which patients are less likely to heal and to possibly avoid the prolonged periods of medical care for these patients.

Typically, the judgment of an experienced physician is one of the best indicators of subsequent healing. Other adjunctive measures, such as ankle brachial indices, toe pressures, laser Doppler skin perfusion pressures, angiography and Doppler assessment of foot vasculature, are occasionally used to assist in this decision (35,40–42).

Detailed data by Landry *et al.* showed that TMA should be pursued in patients with good rehabilitation potential. In this study, 62 TMAs were performed in 57 patients. On univariate analysis, significant predictors of mortality included renal failure (74% mortality in patients with renal failure versus 40% in patients without renal failure), non-ambulation (62% versus 36%), non-independent living (79% versus 21%) and pre-TMA revascularisation (64% versus 31%). Multivariate predictors of mortality included renal failure [odds ratio (OR), 4·85; 95% confidence interval (CI), 1·01–23·30] non-independent living [OR, 17·80; 95% CI, 3·03–104·80] and need for preoperative revascularisation (OR, 4·80; 95% CI, 1·24–18·50). The mean survival of the entire patient cohort was 16·5 months (range, 0–94 months) (43).

Other researchers, such as Pollard *et al.*, suggest that TMA is associated with high complication rates in a diabetic and vasculopathic population. In this study, 90 patients underwent 101 TMAs. A healed stump was achieved in 58 cases (57·4%). Post-surgical complications developed in 88 cases (87·1%). Patients were examined for any postoperative complications associated with TMA. Complications were defined as hospital mortality occurring less than 30 days postoperatively, stump infarction with or without more proximal amputation, postoperative infection, chronic stump ulceration, stump deformity in any of the three cardinal planes, wound dehiscence and equinus and calcaneus gait. The χ^2 tests of association were used to determine whether diabetes, a palpable pedal pulse, coronary artery disease, end-stage renal disease, cerebral vascular accident or hypertension were predictive of or associated with healing. A documented palpable pedal pulse was a predictor of healing and of not requiring more proximal amputation (38).

Postoperative management of TMA

The aim of TMA is to stem forefoot infection by dislodging all necrotic and infected tissues in order to assist healing and to rescue the mid-foot and rearfoot, keeping limb function to walk and bear the load. Therefore, adequate and optimal postoperative management is essential (44–46). If the amputation is subsequent to an infection, antibiotic therapy should be continued (47); evidence has shown that Gram-positive (e.g. *Staphylococcus aureus*) and Gram-negative (e.g. *Pseudomonas aeruginosa*) bacteria react to adverse environments, producing a biofilm that protects them against the host's immune response, (48) and it accounts for peripheral arterial disease and ischaemic gangrene (49). In this way, a good choice of antibiotics, 'the most active' and not 'the most easy' (48), is necessary to obtain a rapid improvement of symptoms in patients with infected chronic ulcers. However, antibiotic treatment is often blocked by antibiotic resistance, making stump management difficult in the post-amputation period (48,50).

Primary closure by the plantar flap is indicated when a plentiful arterial network, arising from the plantar artery, is present, and closure without skin tension and a satisfactory capillary fill time is needed to prevent wound dehiscence and ischaemia (51,52). Surgical wound closure generally consists of non-absorbable, simple, interrupted sutures, and deep sutures are not required because of the possible of dysvascularity (53,54). If a plantar flap is not available, other options for closure should be explored (55,56), such as the use of skin flaps and grafts on the basis of the available skin tissues. Local flaps, characterised by skin without the presence of local necrosis and infection, and the transposition of neighbouring vascularised soft tissue allow coverage of a large defect (34,57). The split-thickness skin graft may be used with meshing that allows coverage of a larger area and decreases complications, such as a seroma or haematoma (58–60). Sometimes, delayed primary closure is a valid option (61); diabetic post-amputation wounds, in fact, tend to heal often by second intention, and the main disadvantage is the high complication rates in wound healing that range from approximately 40% to 70% (38,43,62,63). Failure to heal occurs because of decreased vascularity, increased pressure, hyperglycaemia and concomitant infection (28,64,65).

Several approaches have been proposed to improve wound healing in diabetic patients with TMA. Negative pressure wound therapy (NPWT), the delivery of intermittent or continuous subatmospheric pressure through a specialised pump connected to a resilient, open-celled, foam-surface dressing covered with an adhesive drape to maintain a closed environment, heals a higher proportion of post-amputation wounds, ensuring a faster time to wound closure, a more rapid and robust granulation tissue response and a potential trend towards reduced risk for a second amputation (66–68). Studies on the restoration of tissue integrity have shown the involvement of platelets in the wound-healing process. Platelet activation can modulate wound healing by interacting with molecular signals, primarily cytokines and growth factors (GFs) (69,70). Serra *et al.* documented that in 96·15% of patients, PG promoted the functional recovery of physiological tissue reparation after a TMA procedure. Therefore, PG application may be an effective adjuvant treatment to improve wound healing in diabetic dysvascular patients (70).

Discussion

The primary goal of a TMA is the removal of nonviable tissue and the subsequent maintaining of limb function by preserving the ankle joint and limb length, (44) and undoubtedly, a well-healed TMA provides excellent function over time. Therefore, careful consideration of performing a TMA should take into account several factors such as the assessment of skin perfusion and foot vasculature as well as the likely ability of the patient to undergo successful rehabilitation (71). In fact, in this way, we can identify which patients are less likely to heal and to maintain the functionality of a TMA (34,39–41) as it was also observed that limited mobility at the ankle joint with increased plantar pressure puts the post-TMA diabetic patient at a high risk of tissue breakdown and major amputation (72).

After performing a TMA, wound closure is a pivotal element that must be tailored according to the wound's and the patient's conditions, and when appropriate, adjuvant local treatments must be considered (skin grafting, NPWT, application of PG) in order to speed up and maintain wound healing (58–60,66–68,71).

Furthermore, the choice of the most appropriate antibiotic therapy, in the case of infection, improves stump management in the post-amputation period and avoids TMA failures (47,48,50).

TMA is a valuable option for diabetic foot gangrene that may prevent major limb loss and minimise loss of function, thus improving the quality of life for diabetic patients. Furthermore, interdisciplinary cooperation among the wound specialists (73) is needed in order to obtain the best results in terms of global health.

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