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Limb salvage in diabetic foot disease: A classification to aid successful reconstruction

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Summary Diabetes is a global epidemic. If poorly managed, innocuous injury in a diabetic foot leads to intractable ulceration, bone and joint destruction and subsequent major amputation. It is estimated that every week in the UK there are 100 lower limb amputations of which 80 could have been prevented had diabetes been better managed. It is widely recognised that prevention is critical; nonetheless diabetic foot lesions continue to increase in prevalence.
Reconstruction of diabetic foot lesions has a dismal reputation despite promising published work. Reconstruction in the correctly chosen patient can be successful. Multiple classification systems and scores have been published, but these do not guide the clinician as to which lesions are reconstructible, and those in which attempts to salvage are futile. These patients would be better served with primary amputation.
A tertiary referral centre's experience of diabetic foot reconstruction over 7 years is presented in a series of 22 consecutive patients who were assessed using a new classification system. Twenty-four flaps were performed all of which were either complex ($n = 7$) or complicated ($n = 17$) wounds as per our classification. Five patients (22%) had donor site healing problems, but only one flap (5%) in the series failed. Average follow-up was 23 months (range 4-75 months) and all patients were ambulant at discharge.

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Our simple classification system and aggressive approach to excision and reconstruction of diabetic foot lesions is a useful adjunct to existing systems, and helps promote the cause that limb salvage is warranted in these challenging cases when appropriately managed.

Introduction

Diabetes continues to increase in prevalence and is becoming a global epidemic. Both Type 1 and Type 2 diabetes are becoming more prevalent. The global population continues to grow in both numbers and in age resulting in older patients with chronic disease including diabetes. It is believed that every 30 s a lower limb is lost somewhere in the world as a consequence of diabetes.[1] It is also estimated that 100 lower limbs undergo a below-knee amputation in the UK each week, of which 80 are preventable.[2]

The triad of neuropathy, vasculopathy and foot deformity leads to a hostile substrate for the reconstructive surgeon. Diabetic foot reconstruction has a reputation of technical difficulty and of poor outcomes. If poorly managed, innocuous injury to the foot will develop into intractable ulceration often over weight-bearing surfaces. Left untreated, this in turn will lead to destruction of bone and joint, rendering the foot unreconstructable. The prevention of a trans-tibial amputation then becomes unrealistic[2].

Without safe, efficacious clinical pathways for management in diabetic foot disease the rates of morbidity and mortality increase.[1] As the wound progresses, so the quality of life reduces,[3] which also results in higher costs to both the patient and healthcare provider.[1,4] The vast majority of surgical diabetic foot disease is attributable to peripheral neuropathy, and is therefore preventable[5]. Peripheral vascular disease compounds the prevalence and capricious nature of ulceration in diabetic feet. This can be both micro-vascular as well as macro-vascular disease.[1] Assessment of the peripheral vascular tree is thus essential when assessing these patients and planning treatment.[6,7] Overcoming vascular stenosis either by angioplasty or by major vascular reconstruction will be a prelude to ulcer treatment in those patient in whom debridement, pressure relief and healing by secondary intention has not been, or is not likely to be successful.[8,9] Once arterial inflow has been improved the options for ulcer care must be decided upon. If the ulcer is superficial then an off-loading cast may be used after efforts to promote blood flow.[10]

A contentious issue is the grading and classification of diabetic foot ulcers. There are many classification systems available.[11] The aim of all of these systems is to help health professionals in treating these wounds.[11] Surgical excision of diabetic foot wounds beyond the margins of the ulcer ('tumour-like' excision) is now an accepted practice.[12,13] This leads to the production of larger areas to heal with the concept that this aggressive excisional surgery leads to a more robust reconstruction.[13] However, knowing when to attempt reconstruction as opposed to performing a major amputation is a persistent challenge that is not guided by currently used classification systems.

Should there be composite tissue resection (skin, tendon and bone), the defect becomes a greater challenge for reconstructive surgeons. Advances in tissue transfer using microsurgical techniques have allowed plastic surgeons to offer tissue reconstruction in such cases, and promising results have been published suggesting that attempts at reconstruction and limb salvage are not futile.[14,15] The challenge in these cases is selecting which patients are appropriate for aggressive excision and reconstruction, and at what point to do this. This requires accurately assessing when the patient is no longer physiologically capable of healing their wound without surgical intervention, but before the infection has destroyed the foot so extensively as to make salvage unfeasible.

A single institution's experience of limb salvage in diabetic foot disease over 7 years in a tertiary referral setting is presented below. Some of the more common classification and scoring systems for diabetic foot disease are discussed, and a simple, new classification is suggested to identify those patients suitable for an aggressive reconstructive approach to limb salvage.

Methods

A retrospective cohort study was performed in line with the STROBE guidelines. The tertiary referral centre holds a database of all lower limb reconstructions performed in the unit dating back to February 2011 ($n = 1030$). This database was interrogated and all patients with diabetes mellitus were identified ($n = 85$) over the 7 year period of the database. Diabetic patients who presented with acute traumatic injuries were excluded, as were patients having reconstruction of areas other than the foot and ankle. Twenty-two patients were identified to have had 24 reconstruction of defects of the foot and ankle due primarily to diabetic foot disease.

The wounds to be reconstructed were classified using the following system:

1. Simple – skin ulceration but no exposure of underlying structures (Figure 1).
2. Complex – exposed but not destroyed structures (Figure 2).
3. Complicated – exposed and destroyed structures +/- deep infection where wound excision would retain a functional foot (Figure 3).
4. Unreconstructable – destruction of structures such that excision would not leave a functional foot (Figure 4).

The notes of these patients and electronic records were thoroughly investigated to supplement information in the

Figure 1 Simple diabetic foot lesion.

Figure 2 Complex diabetic foot lesion – note structures exposed but intact.

database. Supplementary and missing data were sourced by directly contacting the patients themselves.

Results

Twenty-two patients underwent 24 flaps during the described period (2% of flaps in database).

By definition, all patients had either complex ($n = 7$) or complicated ($n = 17$) wounds as per our classification. Simple wounds did not require surgical reconstruction, and attempts to salvage 'unreconstructable' wounds was deemed futile and thus not attempted. All patients underwent

Figure 3 Complicated diabetic foot lesion – note the loss of 2nd and 3rd toes and exposure of metatarsals. Excision and reconstruction can preserve tripod of foot, thus leaving a functional foot.

tumour-like excision of the wound and subsequent reconstruction with autologous, vascularised tissue.

The average age of diabetic foot patients was 55 years (range 37–74 years). Pre-operative HbA1c (normal range 51–59 mmol/L) was an average of 65 mmol/L (range 39–121 mmol/L) suggesting that these patients were already at a higher risk for developing diabetic foot complications. All patients showed improvement in their HbA1c post-operatively to a lesser or greater extent.

Following wound excision the width of defects ranged from 3–12 cm, length ranged from 3–18 cm, with an average defect size of 79.7 cm^2. The majority of reconstructions ($n = 20$) were with free tissue transfer (83%) with the remaining four flaps being pedicled medial plantar flaps used to resurface weight bearing areas on the heel (17%).

One patient (5%) required a return to theatre within 24 h of surgery. This patient had a systolic blood pressure $>$200 mmHg in recovery and developed a haematoma. The patient was taken immediately back to theatre, the haematoma was evacuated and the flap was salvaged. Average inpatient stay was 26 days (range 7–93 days).

In total 6 patients (27%) had donor site problems, ranging from delayed/incomplete healing at the 6 week post-operative clinic review through to total loss of skin graft. Three complications were in medial plantar donor sites which had been closed with split skin grafts, two were partial dehiscence of scapular flap donor sites, and one was a partial loss of full thickness graft in a radial forearm flap donor site.

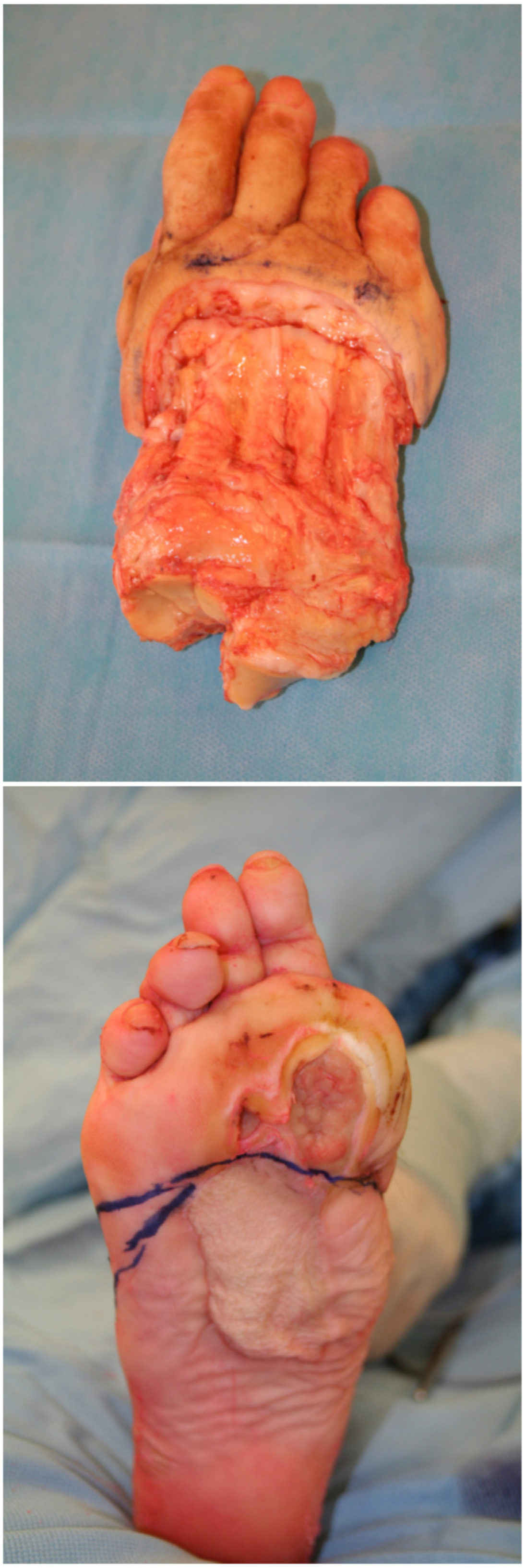


Figure 4 Unreconstructable diabetic foot lesion - note erosion of metatarsal heads through plantar skin. Destruction of the forefoot required transtarsal amputation.

One flap was lost (5%) in the immediate post-operative period. This patient had a pedicled medial plantar flap which became infected and failed, as did the adjacent split skin graft on the primary donor site. The subsequent defect required a free scapular flap to cover the defect which healed uneventfully and the foot was salvaged. Diabetes is a recognised risk factor for wound healing problems and our results show similar rates compared to the published literature.[13-15]

Patients were kept non weight bearing for 2 weeks post-operatively and then allowed to fully weight bear with guidance from physiotherapists and occupational therapists with no restrictions.

One patient required below knee amputation at 2 years post free flap reconstruction of their left heel following excision of calcaneal osteomyelitis. The same patient had previously had a right BKA for diabetic foot disease. Due to persistent infection in the reconstructed limb it was amputated.

Follow-up of patients was an average of 23 months (range 4–75 months) and so far only 3 patients have developed further ulceration in their reconstructed foot. In all cases, the flap reconstructions remained intact, however the adjacent skin ulcerated. One patient required excision of the ulcer and split skin graft at 9 months post reconstruction, which subsequently healed. The other 2 patients, reviewed at 18 months and 5 years post reconstruction respectively were treated non-operatively and their wounds healed without further surgical intervention (Table 1).

Modified Enneking scores were obtained during clinic appointments and the average score was 68% (range 47.5–82.5%) which compared favourably with the average score for all-comers in the database of 57%. All patients, including the bilateral below-knee amputee (on prosthetics), were ambulant at discharge from follow-up.

Discussion

The burden of diabetes is becoming globally epidemic. The lifetime risk of a diabetic person developing a foot ulcer is believed to be as high as 25%,[1] and in a European study, neuropathy accounted for both the majority of foot ulcers and the highest incidence of microvascular complications.[5] Neuropathic ulcers are highly preventable when appropriate screening, education and treatment programs are implemented.[16] Sadly, patients risk vast personal, social, medical and economic costs if they develop what is one of the most preventable long-term complications of diabetes.[17]

As the incidence of Type 2 diabetes, particularly, is on the increase, the incidence of diabetic foot disease is also set to rise. Contributory factors of diabetic foot disease such as neuropathy and peripheral vascular disease are present in 10% of patients at time of diagnosis,[18] and the first year following diagnosis is a particular danger time for development of ulcers and subsequently requirement for amputation.[19] Eight out of ten non-traumatic amputations are due to underlying diabetes, and 85% of these have a pre-existing ulcer.[1]

The economic costs of lower limb amputation are well documented and make a strong case for limb salvage. The initial costs of limb salvage seem high; however, the

Table 1 Diabetic foot reconstruction patients.

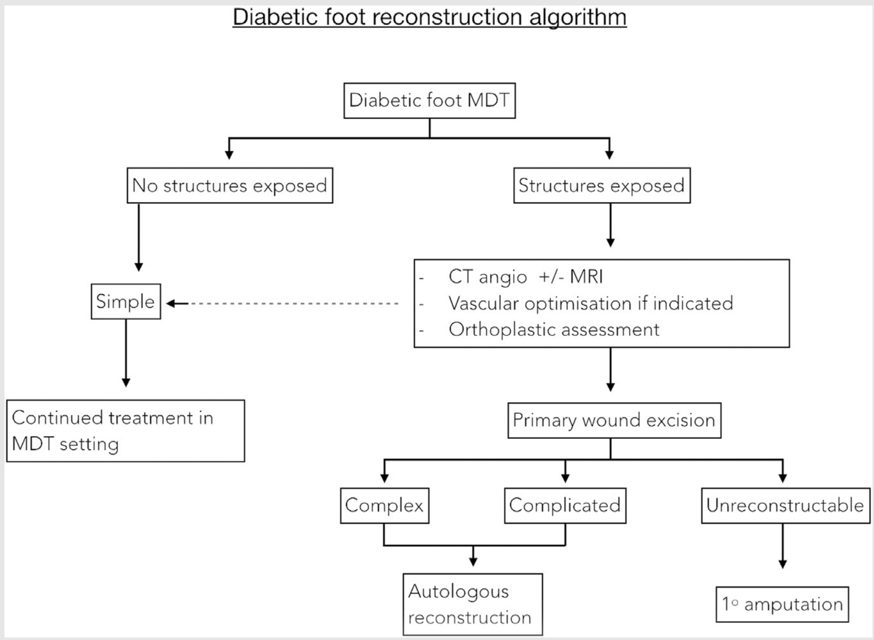
Patient ID	Age	ASA grade	Type of diabetes	Other co-morbidities	Smoker	Preop HbA1c	Site	Classification	Defect width	Defect length	Type of flap	Flap	Donor site closure	Flap survival (%)	Donor site outcome	Enneking score (%)	Days of admission	Other complications	Ambulant at discharge
1	52.5	2	2		N	62	L heel	Complex	7	7	Free	RFF	FTSG	100	Healed	75	8		Y
2	37.8	3	1	Obese	N	78	R foot	Complicated	8	10	Free	ALT	Direct	100	Healed	67.5	28	Further ulceration (not of flap) requiring STSG	Y
3	54	3	1	Peripheral neuropathy	N	52	R foot	Complicated	7	15	Free	ALT	Direct	100	Healed	67.5	16		Y
4	62.3	2	2		N	42	R foot/ankle	Complicated	6	10	Free	Gracilis	Direct	100	Healed	60	35		Y
5	44	2	1	R BKA previously for diabetic foot disease	N	67	L heel	Complicated	7	12	Free	ALT	Direct	100	Infected seroma	55	51	BKA for persistent infections 2yrs post recon - bilateral amputee but ambulant on prosthetics	Y
6	74.4	2	2	AF (pacemaker), CKD3	N	39	R foot	Complicated	4	8	Free	RFF	SSG	100	Healed	47.5	9	Further wound problems lateral to flap (2nd MTPJ) 5 years post op	Y
7	66.6	4	2		N	70	R heel	Complicated	12	14	Free	Scapular	Direct	100	Dehiscence 4/52 post-op - resutured	67.5	93		Y
7	66.6	4	2		N	70	R heel	Complicated	12	14	Pedicled	MPF	SSG	100	Dehiscence 4/52 post-op - resutured	67.5	93		Y
8	44.4	3	1	Hypertension, hypercholes-terolaemia	N	46	R heel	Complex	6	7	Pedicled	MPF	SSG	0	Flap donor broke down leading to 1st MT osteomyelitis	70	9	Infection lead to loss of flap, SSG and 1st MT osteomyelitis. Required further excision and free scapular flap (see below)	Y
9	65.3	2	2	Psychosis, catatonic	N	52	R heel	Complex	8	8	Pedicled	MPF	SSG	100	Healed	60	13		Y
8	44.6	3	1	Hypertension, hypercholes-terolaemia	N	46	R foot/heel	Complex	6	17	Free	Scapular	Direct	100	Healed	70	27	See above (Patient ID 8)	Y
10	49.3	2	2		N	60	R foot	Complicated	12	18	Free	ALT	SSG	100	Healed	75	26		Y
11	42.3	2	1	Peripheral neuropathy, previous MI	N	81	L foot	Complicated	4.5	8	Free	RFF	FTSG	100	Delayed healing, partial loss of full thickness skin graft	82.5	7		Y

(*continued on next page*)

Table 1 (*continued*)

Patient ID	Age	ASA grade	Type of diabetes	Other co-morbidities	Smoker	Preop HbA1c	Site	Classification	Defect width	Defect length	Type of flap	Flap	Donor site closure	Flap survival (%)	Donor site outcome	Enneking score (%)	Days of admission	Other complications	Ambulant at discharge
12	64.5	2	2	Hypertension	N	60	R foot	Complex	7	15	Free	Scapular	Direct	100	Healed	80	16		Y
13	53.3	2	2	Hypertension	Y		R foot	Complicated	3	6	Free	RFF	SSG	100	Healed	77.5	9		Y
14	63	3	2	Alchool dependency	N	48	L foot	Complicated	8	5	Free	ALT	Direct	100	Healed	70	30		Y
15	64.4	2	2	Severe PVD, psoriatic arthropathy	N	61	R foot	Complicated	5	7	Free	ALT	Direct	100	Healed	70	18		Y
16	53.5	2	2	Hypertension	Y		R foot	Complicated	3	6	Free	Fibula	Direct	100	Healed	72.5	57		Y
17	54.5	3	2	Hypertension, obesity	N	121	R foot	Complicated	8	15	Free	ALT	Direct	100	Healed	75	13	Ulceration native skin lateral edge of flap 18 months post recon. Healed by secondary intention	Y
18	58.9	2	2		N	113	L foot	Complex	10	15	Free	ALT		100	Healed	57.5	25		Y
19	42.6	3	1	IV drug abuse	Y	67	L foot	Complicated	12	18	Free	Scap/Parascap	Direct	100	Partial dehiscence scapular wound 2/52 post-op - resutured	55	28		Y
20	45.8	3	2	Lymphoedema	Y	85	R heel	Complex	3	3	Pedicled	MPF	SSG	100	100% graft loss - healed by secondary intention	60	10	Return to theatre from recovery – BP >200 mmHg eating to haematoma under flap and donr. Washed out and flap salvaged. STSG subsequently lost	Y
21	54.8	3	2	Obesity	N	48	R foot	Complex	4	6	Free	Gracilis	Direct	100	Healed	62.5	44		Y
22	54.1	3	2		N		L foot	Complicated	8	15	Free	ALT	Direct	100	Healed	77.5	23		Y

Table 2 Surgical treatment algorithm for diabetic foot lesions.



lifetime costs when compared with maintenance of an amputation stump and prostheses, as well as other associated healthcare problems, are significantly lower.[1,4] As such, whilst prevention should remain the flagship for management of diabetic foot disease, reconstructive strategies should be closely examined.

Optimisation of the patient's physiology prior to any intervention is critical. In particular, close control of HbA_{1c} is known to decrease some of the sequelae of diabetes; a 1% increase in the HbA_{1c} leads to a 25% increase lifetime risk of peripheral vascular disease.[20]

It is known that the relative importance of factors involved in the development of diabetic foot problems can vary in both their presence and severity between patients and lesions. This may be one of the reasons why outcomes seem to vary centre to centre and why some treatments may seem more effective in some people than others. No single system is currently in widespread use, although a number have been published.[11] The lack of consensus is explained partly by the varying presentation of diabetic foot lesions and partly because the specification of a classification depends on its intended use.[21] The most appropriate classification or scoring system can be chosen dependent on need - clinical care, research or audit – but this leads to difficulty in comparison of results across studies using different criteria.

The Meggitt-Wagner system is one of the most early systems for classification of diabetic foot lesions. It describes a six-grade linear description starting with a healed or pre-ulcerative lesion (Grade 0) through to extensive gangrene of the foot (Grade 5).[22] It is simple to use and correlates with prognosis, but is limited by its inability to differentiate between depth of wound, infection and vascular disease.

The University of Texas (UT) classification is a validated system that categorises the ulcer by using four grades on a scale from 0 to 3. Beside these grades, there are four stages to classify the presence of infection and/or lower-extremity ischaemia.[23] It has been shown to correlate well with the Wagner system in the prediction of major amputation, but is superior to the Wagner system in the prediction of wound healing.[24] Neuropathy is not included as part of the classification as the authors considered neuropathy as an already pre-existing condition necessary to produce the majority diabetic foot wounds, its effects being negated if the patient is adequately offloaded.[25] However, neuropathy has been associated with adverse outcomes in studies from non-US centres,[26,27] and a significant number of patients in diabetic foot clinics may not have neuropathy.[28] UT also does not take into account the cross-sectional area of the wound. The baseline factors that significantly predicted healing were cross-sectional area, site and depth and the presence of infection and/or ischaemia.[29] As such, this classification may lack universal applicability.

At the present time the SINBAD system[30] appears to be the best validated system for clinical practice and audit.[31] Its simplicity in clinical practice has led it to being the system chosen for the UK national diabetic foot audit.[32] It is an evolution of the S(AD) SAD score[33] and has been validated in three different continents, reliably predicting healing time. It comprises the same five clinical features as S(AD)SAD (ischaemia, neuropathy, (bacterial) infection, area and depth) but with the addition of site of lesion (forefoot vs hindfoot). Each is graded in a simple, binary fashion as either present or absent (0 or 1), giving a simple scoring system of severity with a maximum score of 6. It is a reproducible descriptive tool offering prognostic information but does not provide

Figure 5 Angiosomal excision of complex diabetic foot lesion – note preservation of extensor tendons.

Figure 6 Post-operative result following free tissue reconstruction of complex diabetic foot lesion.

a clinical indication of which lesions are surgically reconstructable and which are unsalvageable.

Development of our practice

Surgical management of diabetic foot disease is challenging. The patient group have physiological differences that make their general care more complicated compared with traumatic injuries. This other major patient group requiring foot and ankle reconstruction are generally younger and fitter with fewer comorbidities. Thus the surgery in diabetic foot disease is technically more difficult than in non-diabetic patients and the rate of complications is traditionally higher.

Ian Taylor introduced the angiosome concept, separating the body into distinct three-dimensional blocks of tissue fed by source arteries. Understanding the angiosomes of the foot and ankle and the interaction between their source arteries is clinically useful in surgery of the foot and ankle, especially in the presence of peripheral vascular disease.[12]

The concept of angiosomal resection provides a useful insight into the extent of resection required to ensure adequate removal of non-viable tissue.[12,13] More recent publications have questioned how purely the clinical findings correlate with Taylor's original cadaveric angiosomal model.[34] Nonetheless, whether the lesion is purely affecting one angiosome or traversing more than one, it remains prudent to excise the lesion carefully and widely in order to ensure that the remaining wound edges are viable. The result of finding a healthy flap surrounded by native skin that has progressed to further necrosis due to inadequate initial excision is disheartening, and perhaps explained by the angiosomal resection concept.

In this unit's experience, the surgical management of diabetic foot disease has shown promising results using a multidisciplinary approach to pre-operative optimisation, and an aggressive, 'tumour-like' excision and reconstructive strategy. Despite the higher risks there is a cohort of patients in whom the challenge of reconstruction should be considered.

We use the following algorithm to stratify how to manage patients and to guide their surgical pathway (Table 2).

All patients undergo a CT angiogram prior to any decisions about surgical management as this will help to delineate structures, assess vascular inflow to the foot and inform choices for reconstruction. Where indicated, patients undergo further assessment by the vascular service to ascertain whether vascular reconstruction is possible. If so, this could upgrade a previously unreconstructable limb into a potentially salvageable one.

Simple wounds should be managed in the multidisciplinary setting such as a diabetic foot clinic with availability of techniques like topical negative pressure therapy, pressure-relieving casting and, if deemed appropriate, split

Figure 7 Complex diabetic foot lesion involving plantar surface of heel as well as exposed achilles tendon.

skin grafting. Acellular dermal matrices and hyperbaric oxygen have also been described in the treatment of these wounds, however they do not form a regular part of this unit's practice.

Complex wounds should undergo staged excision of non-viable tissue, followed by autologous tissue reconstruction (Figures 2, 5, and 6). In our series, the majority of these were free tissue transfer; however, there are instances where pedicled flap reconstructions may be considered. A particular example is the glabrous medial plantar flap to reconstruct defects on the weight-bearing surface of the heel. This flap provides a robust, sensate surface which is superior to other donor sites in those individuals without peripheral neuropathy. In larger, more complicated defects, this can also be used alongside free tissue transfer (Figures 7-9).

Complicated wounds present somewhat more of a challenge in the excisional phase. Care needs to be taken to ensure complete excision of any non-viable tissue whilst maintaining the essential function of the foot. If the tripod of 1st and 5th metatarsal heads and calcaneum can be preserved, a functional foot can be salvaged. The aim of surgical management is to convert the complicated wound into a complex one which can then be reconstructed, usually with free tissue transfer (Figures 3, 10, and 11)

If the function of the foot cannot be preserved, then the foot should be deemed unreconstructable and the patient should be considered for amputation at the most appropriate level viable (Figure 4).

Figure 8 Defect following angiosomal excision of complex heel diabetic foot lesion.

Figure 9 Post-operative result following pedicled medial plantar and free scapular flap reconstructions of complex diabetic foot lesion.

We propose this simple classification that can be applied to all diabetic foot wounds. It can be used as an adjunct to other, more descriptive classifications of scoring systems. Where the SINBAD system, for example, would accurately describe the wound, our classification further adds information as to whether attempts to salvage the limb should be undertaken or whether a major amputation should be considered.

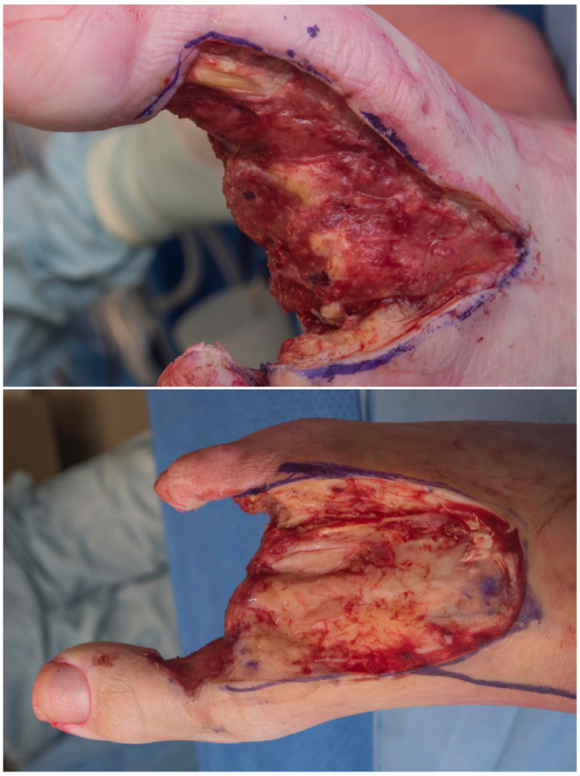


Figure 10 Post angiosomal excision of complicated diabetic foot lesion – note preservation of the transverse metatarsal ligament.

Figure 11 Post-operative result following free tissue reconstruction of complicated diabetic foot lesion.

Conclusion

Reconstruction of diabetic foot disease has traditionally had a dismal reputation. This series highlights a cohort of patients in whom reconstruction can and should be considered. With a staged approach, aggressive excision of devitalised tissue and autologous reconstruction, excellent results in keeping with outcomes for non-diabetic patients can be achieved. We propose this simple classification of wounds to guide surgical excision and reconstruction.

Conflict of interest

None to declare.

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