Decision trees for risk stratification of the diabetic foot

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Article points

1. Delays in referral and intervention are a major issue in diabetic foot care and can, in part, be due to the complexity of risk stratification.
2. Decision trees are clinical diagram algorithms in which clinicians answer a sequence of questions to arrive at a decision.
3. Two examples of decision trees, based on the risk stratifications of the Scottish Diabetes Foot Action Group and NICE, are presented.
4. Decision trees can be used to facilitate correct risk stratifications and referrals of people with diabetic foot complications.

Key words

- Algorithms
- Decision trees
- Delays in care
- Diabetic foot
- Risk stratification

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Delays in referral from primary to specialist care are a common issue in the clinical management of diabetic foot (DF) disease and are associated with worse clinical outcomes. One of the reasons for the delays may be the complexity of risk stratification, which can leave clinicians who are not specialised in the DF uncertain about when to refer patients for specialist assessment. This article illustrates how risk stratification can be simplified with the use of decision trees. Two decision trees are given as examples: one based on the risk stratification system of the Scottish Diabetes Foot Action Group and one based on the National Institute for Health and Care Excellence guideline. Decision trees can be used to facilitate correct risk stratifications and the referral of people with DF complications, and thereby hopefully contribute to improved outcomes for people with DF disease.

Delays in referral from primary to specialist care are a common issue in the clinical management of diabetic foot (DF) disease and are associated with worse clinical outcomes in terms of ulcer healing (Macfarlane and Jeffcoate, 1997; Manu et al, 2018; National Health Service, 2018). An association between delays in referral and major amputations has been reported (Mills et al, 1991). One of the reasons for delays may be the complexity of risk stratification, which leaves clinicians who are not specialised in the management of the DF uncertain about when to refer patients for specialist assessment. This article illustrates how decision trees can be constructed to facilitate risk stratification and, thereby, contribute to more accurate and prompt referrals and interventions.

Risk stratification of the DF

Risk assessment of the DF is a two-step process. In the first step, risk factors (e.g. neuropathy, peripheral arterial disease and ulceration history) from the physical examination and patient history are assessed. In the second step, the results from these assessments are merged into a risk category, which forms the basis for further actions (medical interventions, patient education and referrals). The second step can be complex, as the number of risk factors can be high and they are often given different weights when they are combined to establish a risk category for the patient. Clinical guidelines can be too extensive for risk stratification in clinical practice and, therefore, different algorithms have been constructed to facilitate risk stratification. Some of these algorithms, such as the D-Foot, are electronic (Hellstrand Tang et al, 2017). However, the necessary electronic equipment may not be readily available at all clinics, as the majority of people with diabetes live in low- and middle-income countries (International Diabetes Federation, 2015). Electronic risk stratification algorithms, therefore, need to be complemented with paper-based algorithms.

Many paper-based algorithms take the form of a table, assigning the presence of particular risk factors to a risk category. For example, a table format is used in the risk stratification algorithms of the International Diabetes Federation (Ibrahim, 2017), the International Working Group on the Diabetic Foot (Schaper et al, 2016) and the American Diabetes Association (Boulton et al, 2008). Although the table format is useful, it might in some cases lead to underestimation

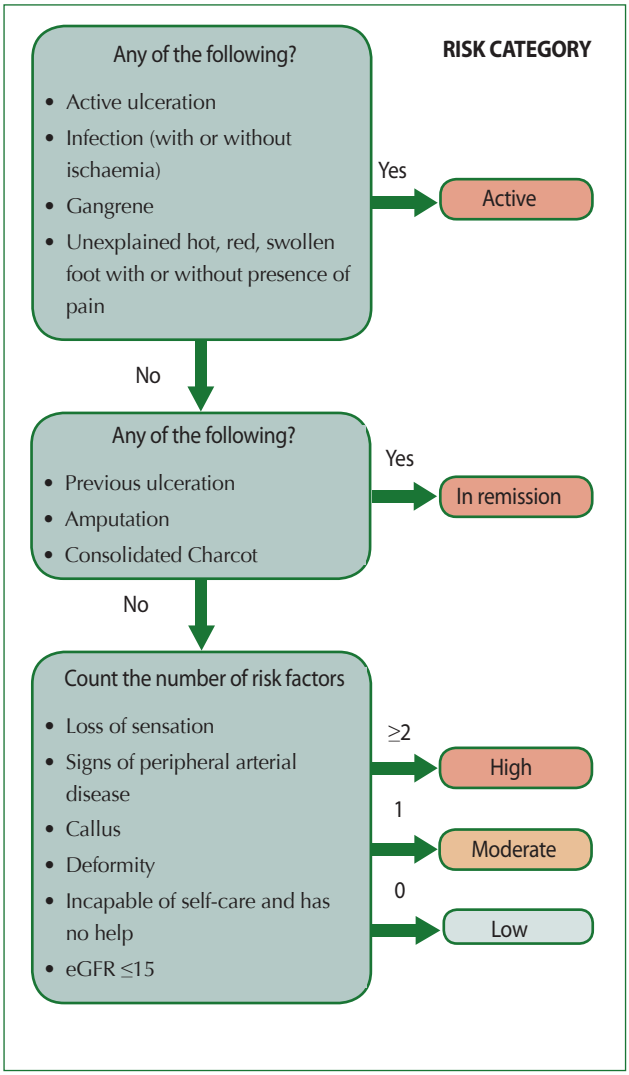

Figure 1. Decision tree for risk stratification based on the Scottish Diabetes Foot Action Group algorithm (Stang et al, 2016).

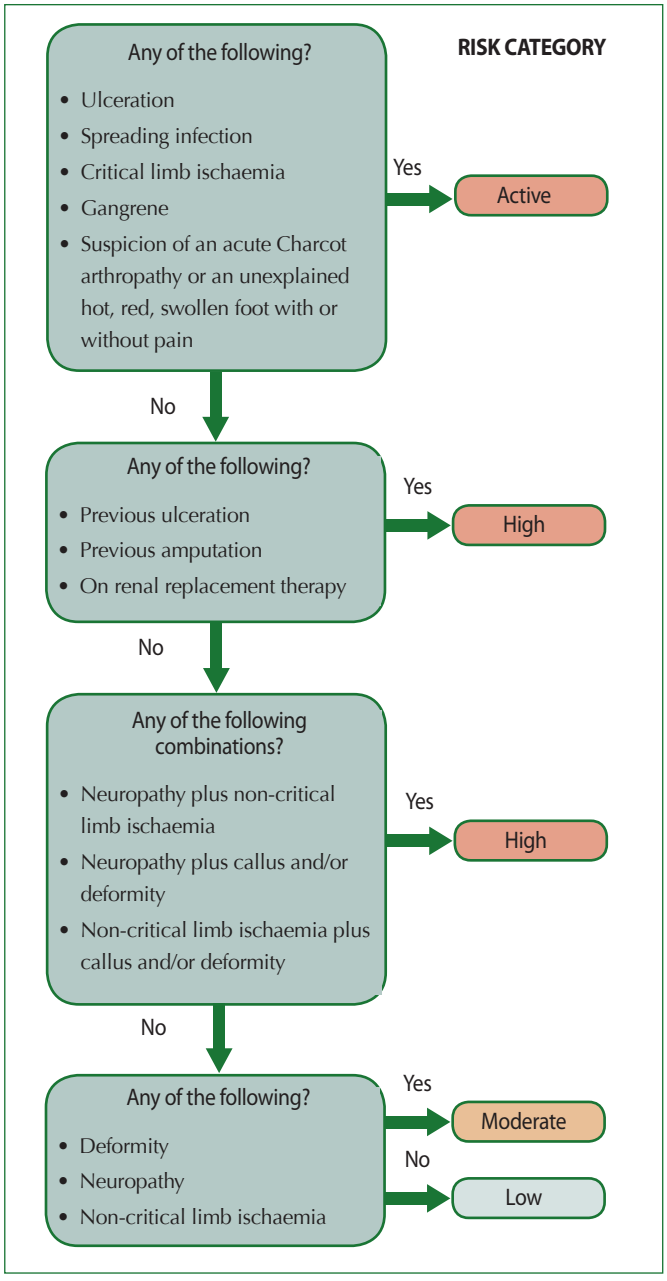

Figure 2. Risk stratification decision tree based on the 2016 NICE guideline.

of the true risk: most tables start with the lowest risk category and if the clinician selects the first category that fits, rather than considering all categories before choosing, too low a risk category may be chosen. As an illustration, consider a clinician using the American Diabetes Association table (Boulton et al, 2008) for the risk stratification of a patient with loss of protective sensation and peripheral arterial disease. If the clinician selects the first risk category that fits, the result will be risk category 1 (defined as loss of protective sensation with or without deformity) instead of the correct risk category 2 (peripheral arterial disease with or without loss of protective sensation). This risk of incorrect categorisation and underestimation of risk is presumably small among clinicians specialised in the DF, but may be larger among clinicians in primary care who have to handle a multitude of different diagnoses, guidelines and algorithms.

Decision trees for risk stratification of the DF

An alternative to the common table-format algorithm is a decision tree. This is a flow chart in which

clinicians answer a sequence of questions until a decision is reached, i.e. a risk category is established for the patient. There are examples of decision trees for DF assessment in primary care (US Veterans Health Administration/Department of Defense, 2003), but they are rare. Two examples are provided here — the Scottish Diabetes Foot Action Group and National Institute for Health and Care Exellence (NICE) — to demonstrate how decision tree algorithms for risk stratification of the DF can be constructed.

The Scottish Diabetes Foot Action Group has constructed a risk stratification algorithm that slightly deviates from the common table format (Stang and Leese, 2016). The algorithm is well known for its visual design, with traffic lights communicating the urgency of the foot health condition to patients and clinicians. The simplicity and clarity of the algorithm is appealing, and its implementation has increased the proportion of patients who have been given a risk stratification in Scotland (Stang et al, 2016). In contrast to the table-format algorithms mentioned previously, the Scottish algorithm starts with the highest risk category, which reduces the risk of clinicians selecting too low a risk category. However, there is still a risk of misclassification, as several risk factors are mentioned three times, making the algorithm unnecessarily complicated. With a decision tree (*Figure 1),* this can be simplified.

The 2016 NICE guideline for DF problems does not provide any algorithm for risk stratification and the risk stratification system can be difficult to comprehend at first glance. The guideline lists 12 risk factors that in isolation or combination influence the risk profile of the patient, and the result of combining different risk factors is not always intuitive. For example, when combining callus with deformity (a moderate risk factor), the result is moderate risk, but when combining callus with neuropathy (another

moderate risk factor), the result is high risk. However, even a somewhat complicated risk stratification system, such as the one by NICE, can be represented by a rather simple decision tree (*Figure 2*).

Discussion

This article demonstrates how risk stratification systems can be transformed into simple decision trees. Two examples are provided. The first decision tree, based on the Scottish Diabetes Foot Action Group decision algorithm, demonstrates that even an already relatively simple system can be simplified even further with a decision tree, without losing information. The second decision tree, based on the 2016 NICE guideline, demonstrates that even quite complex stratification systems can be summarised in a decision tree.

Naturally, decision trees can be created for other DF risk stratification systems as well. For this reason, it might be valuable to point out some general principles for the construction of decision trees.

- First, all relevant risk factors need to be represented in the decision tree to correctly classify all cases
- Second, the categories must be exhaustive and mutually exclusive: every case should fit in one category and one category only
- Third, the decision tree should begin with the most serious risk factors (e.g. ulceration, spreading infection and acute Charcot foot) and end with the least significant risk factors (e.g. callus). The most serious risk factors need to be put first because the presence of any one of them is usually enough to categorise a patient into the highest risk category, while all important risk factors need to be excluded before a patient can be assigned to the lowest risk category. Also, there is an educative reason for putting the most serious risk factors first in the algorithm: this reminds clinicians to always look out for these severe conditions, although some of them are rare, such as acute Charcot foot
- Fourth, the constructor of the decision tree should strive for simplicity to facilitate clinical use. Preferably, the decision tree should fit on a single page, use a simple layout and be intuitive, reducing the need for manuals and instructions.

For some clinicians, decision trees may seem simplistic because they do not take into account all the details that abound in clinical encounters. Decision trees and other decision tools should not replace clinical judgement (Liu et al, 2006). When there are good reasons for departing from the decision arrived at by using the decision tree, the clinician should do so, but this should primarily be when moving patients to higher-risk categories than suggested by the decision tree. For example, a patient may be at low risk according to the decision tree, but the clinician may have specific knowledge about the patient's personal situation (e.g. substance abuse or a history of low adherence) that justify assigning the person to a higher risk category. In contrast, clinicians should be very cautious about moving patients from higher to lower risk categories, because underestimation of the severity of foot disease has been associated with delayed treatment and worse outcomes (Mills et al, 1991).

Some caution is warranted when implementing decision trees for risk stratification. First, risk stratification is only one part of the risk assessment process; appropriate assessment of risk factors has to be conducted prior to the risk stratification, e.g. using Miller's 3-minute DF exam (Miller et al, 2014). Second, the assessment of risk factors and risk stratification are not ends in themselves but should inform the decision on what further actions to take. Thus, decision trees need to be complemented by guidance on what actions to take, which naturally will vary according to the circumstances of the local healthcare organisation. The Scottish Diabetes Foot Action Group system (Stang et al, 2016) illustrates well how recommendations on interventions and referrals can be incorporated in the risk stratification algorithm.

In my clinical practice — in Örebro county, Sweden — we constructed a local guideline for the management of DF disease with a decision tree that summarised the criteria for when and how to refer patients to specialist care. This decision tree has been a useful tool for communication with clinicians not specialised in the DF and hopefully it can help reduce variation in the management of DF disease across Örebro county, Sweden.

With the help of the decision tree that has been used in Örebro county and those suggested in *Figures 1* and *2*, clinicians without specialist knowledge of DF disease can risk stratify all patients using a maximum of three or four decision points. This could potentially facilitate accurate risk stratification and prompt referral of patients. Studies are needed to investigate the

clinical impact of implementing the decision trees (Reilly and Evans, 2006).

Conclusion

Risk stratifications systems of differing complexities can be transformed into simple decision trees that are easy to use in clinical practice. Future studies should investigate whether the use of decision trees in the management of patients with diabetes and at-risk feet leads to more accurate risk stratifications and prompt referrals, thus improving the outcomes for people with DF disease. ■

Boulton AJ, Armstrong DG, Albert SF et al (2008) Comprehensive foot examination and risk assessment: a report of the task force of the foot care interest group of the American Diabetes Association, with endorsement by the American Association of Clinical Endocrinologists. *Diabetes Care* 31(8): 1679–85

Hellstrand Tang U, Tranberg R, Zügner R et al (2017) The D-Foot, for prosthetists and orthotists, a new eHealth tool useful in risk classification and foot assessment in diabetes *Foot & Ankle Online Journal* 10(2): 4

Ibrahim A, Jude E, Langton K et al (2017) *Clinical Practice Recommendation on the Diabetic Foot — 2017: A Guide for Health Care Professionals*. IDF, Brussels. Available at: https://bit.ly/2plM1b7 (12.10.2018)

International Diabetes Federation (2015) *The IDF Diabetes Atlas (7th edn)*. IDF, Brussels. Available at: http://www.diabetesatlas.org/ (accessed 01.10.2018)

Liu J, Wyatt JC, Altman DG (2006) Decision tools in health care: focus on the problem, not the solution. *BMC Med Inform Decis Mak* 6: 4

Macfarlane RM, Jeffcoate WJ (1997) Factors contributing to the presentation of diabetic foot ulcers. *Diabet Med* 14(10): 867–70

Manu C, Lacopi E, Bouillet B et al (2018) Delayed referral of patients with diabetic foot ulcers across Europe: patterns between primary care and specialised units. *J Wound Care* 27(3): 186–92

Miller JD, Carter E, Shih J et al (2014) How to do a 3-minute diabetic foot exam: this brief exam will help you to quickly detect major risks and prompt you to refer patients to appropriate specialists. *J Family Pract* 63(11): 646–54

Mills JL, Beckett WC, Taylor SM (1991) The diabetic foot: consequences of delayed treatment and referral. *South Med J* 84(8): 970–4

National Health Service (2018) *National Diabetes Foot Care Audit — 2014–2017*. Available at: https://digital.nhs.uk/data-and-information/publications/statistical/national-diabetes-footcare-audit/national-diabetes-foot-care-audit-2014-2017 (accessed 01.10.2018)

National Institute for Health and Care Excellence (2016) *NICE Guideline 19. Diabetic Foot Problems: Prevention and Management*. Available at: https://www.nice.org.uk/guidance/ng19 (accessed 01.10.2018)

Reilly BM, Evans AT (2006) Translating clinical research into clinical practice: impact of using prediction rules to make decisions. *Ann Intern Med* 144(3): 201–9

Schaper NC, van Netten JJ, Apelqvist J et al (2016) Prevention and management of foot problems in diabetes: a summary guidance for daily practice 2015, based on the IWGDF guidance documents. *Diabetes Metab Res Rev* 32(Suppl 1): 7–15

Stang D, Leese G (2016) The Scottish Diabetes Foot Action Group 2016 update of the Diabetic Foot Risk Stratification and Triage System. *The Diabetic Foot Journal* 19(4): 182–6

US Veterans Health Administration/Department of Defense (2003) *Clinical Practice Guidelines: Diabetes Mellitus Algorithms-Module F: Foot Care*. Veterans Health Administration, Washington, DC