Incidence of re-amputation following partial first ray amputation associated with diabetes mellitus and peripheral sensory neuropathy: a systematic review

Sara L. Borkosky, DPM¹ and Thomas S. Roukis, DPM, PhD, FACFAS²*

¹Podiatric Medicine and Surgery Residency Program, Gundersen Lutheran Medical Foundation, La Crosse, Wisconsin, USA; ²Attending Staff, Department of Orthopaedics, Podiatry and Sports Medicine, Gundersen Lutheran Medical Center, La Crosse, Wisconsin, USA

Diabetes mellitus with peripheral sensory neuropathy frequently results in forefoot ulceration. Ulceration at the first ray level tends to be recalcitrant to local wound care modalities and off-loading techniques. If healing does occur, ulcer recurrence is common. When infection develops, partial first ray amputation in an effort to preserve maximum foot length is often performed. However, the survivorship of partial first ray amputations in this patient population and associated re-amputation rate remain unknown. Therefore, in an effort to determine the actual re-amputation rate following any form of partial first ray amputation in patients with diabetes mellitus and peripheral neuropathy, the authors conducted a systematic review. Only studies involving any form of partial first ray amputation associated with diabetes mellitus and peripheral sensory neuropathy but without critical limb ischemia were included. Our search yielded a total of 24 references with 5 (20.8%) meeting our inclusion criteria involving 435 partial first ray amputations. The weighted mean age of patients was 59 years and the weighted mean follow-up was 26 months. The initial amputation level included the proximal phalanx base 167 (38.4%) times; first metatarsal head resection 96 (22.1%) times; first metatarsal-phalangeal joint disarticulation 53 (12.2%) times; first metatarsal mid-shaft 39 (9%) times; hallux fillet flap 32 (7.4%) times; first metatarsal base 29 (6.7%) times; and partial hallux 19 (4.4%) times. The incidence of re-amputation was 19.8% (86/435). The end stage, most proximal level, following re-amputation was an additional digit 32 (37.2%) times; transmetatarsal 28 (32.6%) times; below-knee 25 (29.1%) times; and LisFranc 1 (1.2%) time. The results of our systematic review reveal that one out of every five patients undergoing any version of a partial first ray amputation will eventually require more proximal re-amputation. These results reveal that partial first ray amputation for patients with diabetes and peripheral sensory neuropathy may not represent a durable, functional, or predictable foot-sparing amputation and that a more proximal amputation, such as a balanced transmetatarsal amputation, as the index amputation may be more beneficial to the patient. However, this remains a matter for conjecture due to the limited data available and, therefore, additional prospective investigations are warranted.

Keywords: diabetic foot; hallux; ulceration; osteomyelitis; metatarsal; resection

Received: 8 December 2011; Revised: 2 January 2012; Accepted: 11 January 2012; Published: 20 January 2012
durable, weight bearing residual foot that can be protected in a variety of shoe-gear types with or without bracing. Routinely, to preserve length and integrity to the remaining foot structures, for pathology about the hallux and first metatarsal, the most distal level of resection is usually chosen resulting in a partial first ray amputation. However, recent studies have questioned the reliability of this amputation level (3–9). In some circumstances, it has been shown that a more proximal index amputation level reduces the risk of re-ulceration and need for progressive levels of re-amputation (25). To further investigate this topic, the authors undertook a systematic review of electronic databases to identify relevant material relating to the incidence of re-amputation following partial first ray amputation associated with diabetes mellitus and peripheral sensory neuropathy but without critical limb ischemia.

Methods
The authors performed a systematic review of electronic databases and relevant peer-reviewed sources including Infotrieve-Pubmed/MEDLINE (http://www4.infotrieve.com/newmedline/search.asp). The authors hand searched each identified manuscript for pertinent references. Only manuscripts that involved any form of partial first ray amputation associated with diabetes mellitus and peripheral neuropathy were included.

The authors performed the above systematic review with no restriction on date or language, using an inclusive text word query ‘First ray’ OR ‘Hallux’ AND ‘Amputation’ OR ‘Resection’ AND ‘Diabetes’ AND ‘Neuropathy’ where the all upper-case words represent the Boolean operators employed. Every manuscript was reviewed in their entirety and consensus was met for final inclusion with the lead author being the moderator.

Results
The search for potentially eligible information for inclusion in the systematic review yielded a total of 24 references. All references identified were obtained and reviewed by the authors in September 2010 with additional papers being identified and obtained in May 2011. After considering all of the potentially eligible references, five (20.8%) met our inclusion criteria and were included in this study. Specifically, one evidence-based medicine level I study (4) and four level IV studies met our inclusion criteria (2, 3, 5, 6) (Table 1). The methodological quality of the included studies was generally fair, although one study was designed to be prospective with randomization of patients.

A total of 435 patients with a weighted mean age of 59 years and a weighted mean follow-up of 26 months, were included. The index amputation level included the proximal phalanx base 167 (38.4%) times; first metatarsal head resection 96 (22.1%) times; first metatarsal-phalangeal joint disarticulation 53 (12.2%) times; first metatarsal mid-shaft 39 (9%) times; hallux fillet flap 32 (7.4%) times; first metatarsal base 29 (6.7%) times; and partial hallux 19 (4.4%) times. The incidence of re-amputation was 19.8% (86/435). The end stage, most proximal level, following re-amputation was an additional digit 32 (37.2%) times; transmetatarsal 28 (32.6%) times; below-knee 25 (29.1%) times; and LisFranc 1 (1.2%) time.

Discussion
The purpose of this systematic review was to evaluate the incidence of re-amputation following partial first ray amputation associated with diabetes mellitus and peripheral neuropathy. The goal of any amputation is complete eradication of nonviable tissue optimizing the host’s healing potential while reducing the risk for further breakdown and the need for repeated surgical intervention. To obtain this goal, the level of amputation at initial intervention needs to be chosen with due diligence (3–9, 25). As shown in this study, at a mean follow-up of only 26 months, one out of every five patients who undergo a partial first ray amputation will require a more proximal level re-amputation due to the development of a neuropathic ulceration. Interestingly, the additional level of resection did not occur more proximally along the first ray itself but rather involved a separate digit 32 (37.2%) times, transmetatarsal level 28 (32.6%) times, below-knee level 25 (29.1%) and LisFranc level 1 (1.2%) time.

Weaknesses of this study include the fact that the search for manuscripts that met the inclusion criteria was performed through electronic databases. It is possible that pertinent references may have been inadvertently overlooked or excluded. Moreover, the search did not include a number of potential electronic databases. A more expansive search may have yielded supplementary references for inclusion. Furthermore, the data included in this systematic review spanned nearly 30 years during which the approaches available to treat diabetic neuropathic foot ulceration as well as forefoot amputations has undergone significant change.

However, review of the incidence of amputation is not appreciably different between the earliest and most recent manuscript included in our systematic review. In addition, the inclusion criteria were quite narrow. This produced a small number of manuscripts for evaluation. Many studies included partial first ray amputations along with an additional digit or other surgical intervention. Also, contralateral limb surgery was also performed along with the initial amputation in many studies. Finally, it is possible that some amputations were the result of critical limb ischemia and not solely peripheral sensory neuropathy. This would obviously affect both index amputation healing as well as level of subsequent amputation. With such variety in the description of the procedure, the authors believed it was necessary to define

Citation: Diabetic Foot & Ankle 2012, 3: 12169 - DOI: 10.3402/dfa.v3i0.12169
| Author          | Patients (Number) | Age (Range) | Sex | Original amputation level | More proximal amputations (%) | End stage amputation level (Number; %) | Follow-up (Months) |
|-----------------|-------------------|-------------|-----|---------------------------|-------------------------------|---------------------------------------|-------------------|
| Sizer (3)       | 206               | 56.8        | N/A | Proximal Phalanx Base (166) | 8 (3.9%)                      | Transmetatarsal (15; 7.3%)            | N/A               |
|                 |                   |             |     | 1st Metatarsal Head (40)    | 7 (3.4%)                      | Total: 15 (7.3%)                     |                   |
|                 |                   |             |     |                           |                               |                                       |                   |
| Johnson (4)     | 1                 | 29          | 1M  | Proximal Phalanx Base      | 0                             | N/A                                   | 9                 |
|                 |                   |             |     |                           |                               |                                       |                   |
| Murdoch (5)     | 90                | 56.2 (31–83)| 70M | Partial Hallux (19)        | 14 (15.6%)                    | Digital (10; 11.11%)                 | 36                |
|                 |                   | 58.7 (45–74)| 20F | 1st MPJ Disarticulation (36)| 24 (26.7%)                    | Transmetatarsal (5/5.56%)            |                   |
|                 |                   |             |     |                           |                               | Below Knee (9; 10%)                 |                   |
|                 |                   |             |     |                           |                               | Digital (5; 5.6%)                   |                   |
|                 |                   |             |     |                           |                               | Transmetatarsal (1; 1.1%)            |                   |
|                 |                   |             |     |                           |                               | Below Knee (1; 1.1%)                |                   |
|                 |                   |             |     |                           |                               | Digital (2; 2.2%)                   |                   |
| Dalla-Paola (6) | 89                | 66.3        | 63M | 1st Metatarsal Head (44)   | 8 total (8.99%)                | Digital (6; 6.7%)                   | 16.4              |
|                 |                   |             |     | 1st MPJ Disarticulation (17)|                              | Transmetatarsal (1; 1.1%)            |                   |
|                 |                   |             |     |                           |                               | LisFranc (1; 1.1%)                  | [7–28]            |
| Ahmed (7)       | 49/49             | 58          | 92M | Fillet Flap Hallux (32)    | 0                             | Transmetatarsal (2; 4.1%)            | N/A               |
|                 |                   |             |     | 1st MPJ Disarticulation (17)| 9 (18.4%)                     | Below Knee (7; 14.3%)               |                   |

F, female; M, male; MPJ, metatarsal-phalangeal joint; N/A, not applicable.
narrow inclusion criteria to assure that one procedure was critically analyzed. This did, however, result in a smaller number of manuscripts to be included in the review.

After a systematic review of peer-reviewed literature, the incidence of re-amputation following partial first ray amputation associated with diabetes mellitus and peripheral neuropathy was determined to be 19.8%. This reveals a relatively high rate of re-amputation in a high-risk subset of patients and additional reviews should be undertaken to further evaluate the continued utility of the partial first ray amputation associated with diabetes mellitus with peripheral neuropathy. Furthermore, reviews evaluating the utility and durability of the more proximal level amputations, such as a well-balanced transmetatarsal amputation (25–29), need to be initiated. Only then can a critical comparison, preferably prospective and through appropriately weighted design, be undertaken to define which level of amputation in the distal foot results in the lowest incidence of ulceration and/or re-amputation while maintaining the highest level of function.

**Conclusion**

A systematic review of electronic databases to determine the incidence of re-amputation following first ray amputation associated with diabetes mellitus and peripheral sensory neuropathy was undertaken. Based on the inclusion criteria, a total of five studies (20.8%) were included in the analysis. All of the studies had been published in peer-reviewed journals, although they were of methodologically fair design. The results of these studies reveal a high incidence of re-amputation of 19.8%. Therefore, given the available data, additional prospective investigations are warranted, especially in evaluation and comparison of various levels of partial foot amputation.

**Conflict of interest and funding**

The authors have received no funding or benefits from industry or elsewhere to conduct this literature review.

**References**

1. Lavery LA, Lavery DC, Quebedeaux-Farnham TL. Increased foot pressures after great toe amputation in diabetes. Diabetes Care 1995; 18: 1460-2.
2. Van Damme H, Rorive M, Martens De Noorthout B, Quaniers J, Scheen A, Limet R. Amputations in diabetes patients: a plea for footsparing surgery. Acta Chir Belg 2001; 101: 123–9.
3. Sizer JS, Wheelock FC. Digital amputations in diabetic patients. Surgery 1972; 72: 980-9.
4. Johnson MK, Rybczynski J, Kanat IO. Hallux amputation for diabetic osteomyelitis. J Foot Surg 1987; 26: 141-8.
5. Murdoch DP, Armstrong DG, Dacus JB, Laughlin TJ, Morgan CB, Lavery LA. The natural history of great toe amputations. J Foot Ankle Surg 1997; 36: 204-8.
6. Dalla Paola L, Faglia E, Caminiti M, Clerici G, Ninkovic S, Deanesi V. Ulcer recurrence following first ray amputation in diabetic patients: a cohort prospective study. Diabetes Care 2003; 26: 1874-8.
7. Ahmed ME, Tamimi AO, Mahadi SI, Widatalla AH, Shaver MA. Hallux ulceration in diabetic patients. J Foot Ankle Surg 2010; 49: 2–7.
8. Hodge MJ, Peters TG, Efird WG. Amputations of the distal portion of the foot. South Med J 1989; 82: 1138–42.
9. Light JT Jr, Rice JC, Kerstein MD. Sequelae of limited amputation. Surgery 1988; 103: 294–9.
10. Quebedeaux TL, Lavery LA, Lavery DC. The development of foot deformities and ulcers after great toe amputation in diabetes. Diabetes Care 1996; 19: 165–7.
11. Eneroth M, Apelqvist J, Stenström A. Clinical characteristics and outcome in 223 diabetic patients with deep foot infections. Foot Ankle Int 1997; 18: 716–22.
12. Adler AI, Boyko EJ, Ahroni JH, Smith DG. Lower-extremity amputations in diabetes. The independent effects of peripheral vascular disease, sensory neuropathy, and foot ulcers. Diabetes Care 1999; 22: 1029–35.
13. Rayman G, Krishnan ST, Baker NR, Wareham AM, Rayman A. Are we underestimating diabetes-related lower-extremity amputation rates? Results and benefits of the first prospective study. Diabetes Care 2004; 27: 1892–6.
14. Armstrong DG, Lavery LA, Harkless LB, Van Houtum WH. Amputation and reamputation of the diabetic foot. J Am Podiatr Med Assoc 1997; 87: 255–9.
15. Izumi Y, Satterfield K, Lee S, Harkless LB. Risk of re-amputation in diabetic patients stratified by limb and level of amputation: a 10-year observation. Diabetes Care 2006; 29: 566–70.
16. Kanade R, Van Deursen R, Burton J, Davies V, Harding K, Price P. Re-amputation occurrence in the diabetic population in South Wales, UK. Int Wound J 2007; 4: 344–52.
17. Nehler MR, Whitehall TA, Bowers SP, Jones DN, Hiatt WR, Rutherford RB, et al. Intermediate-term outcome of primary digit amputations in patients with diabetes mellitus who have footseps requiring hospitalization and presumed adequate circulatory status. J Vase Surg 1999; 30: 509–18.
18. Baddeley RM, Fulford JC. A trial of conservative amputations for lesions of the feet in diabetes mellitus. Brit J Surg 1965; 52: 38–43.
19. Moss SE, Klein R, Klein BE. The 14-year incidence of lower-extremity amputation in a diabetic population. The Wisconsin epidemiologic study of diabetic retinopathy. Diabetes Care 1999; 22: 951–9.
20. Van Houtum WH, Lavery LA. Outcomes associated with diabetes-related amputations in The Netherlands and in the state of California, USA. J Intern Med 1996; 240: 227–31.
21. Siitonen OI, Niskanen LK, Laasko M, Siitonen JT, Pyörää K. Lower-extremity amputations in diabetic and nondiabetic patients. A population-based study in eastern Finland. Diabetes Care 1993; 16: 16–20.
22. Ebskov B, Josephsen P. Incidence of reamputation and death after gangrene of the lower extremity. Prosthet Orthot Int 1980; 4: 77–80.
23. Kahn O, Wagner W, Bessman AN. Mortality of diabetic patients treated surgically for lower limb infection and or gangrene. Diabetes 1974; 23: 287–92.
24. Iannucci AJ, Chennell RW, King PL, Farrell DJ. Spontaneous fractures of the lesser metatarsals secondary to an amputated hallux and peripheral neuropathy. J Foot Surg 1987; 26: 66–71.
25. Roukis TS, Singh N, Andersen CA. Preserving functional capacity as opposed to tissue preservation in the diabetic.
patient: a single institution experience. Foot Ankle Spec 2010; 3: 177–83.
26. Roukis TS. Flexor hallucis longus and extensor digitorum longus tendon transfers for balancing the foot following transmetatarsal amputation. J Foot Ankle Surg 2009; 48: 398–401.
27. Schweinberger MH, Roukis TS. Intramedullary screw fixation for balancing of the dysvascular foot following transmetatarsal amputation. J Foot Ankle Surg 2008; 47: 594–7.
28. Schweinberger MH, Roukis TS. Soft-tissue and osseous techniques to balance forefoot and midfoot amputations. Clin Podiatr Med Surg 2008; 25: 623–39.
29. Schweinberger MH, Roukis TS. Surgical correction of soft-tissue ankle equinus contracture. Clin Podiatr Med Surg 2008; 25: 571–85.

*Thomas S Roukis
Gundersen Lutheran Medical Center
La Cross, Wisconsin, USA
Email: tsroukis@gundluth.org