DAYTON ARTIFICIAL LIMB
Lower Extremity Specialists

Tracking Long-Term Functional Development with a Prosthesis: A Case Report

Erin Sutton[123], Robert Hoskins[12] B.S. BME

[1]Dayton Artificial Limb, Dayton, Ohio; [2]Prosthetic Design, Inc., Dayton, Ohio; [3]University of Dayton Department of Mechanical and Aerospace Engineering, Dayton, Ohio

I. Introduction

The goals of prosthetic rehabilitation are to improve the new amputee's functional capability and to successfully reintegrate the patient into their community. Function can affect more than just mobility; in a study of 25 transtibial and transfemoral amputees, Deans et al. found that there was a significant relationship between amputees' functional ability and their physical, psychological and social well-being[1]. While there are many advanced technologies that claim to improve patient function, often the research is inadequate in terms of experimental design and ecological validity[2]. In fact, a national meeting to assess the research needs in prosthetics and orthotics cited outcomes research as the highest ranked area of need[3]. To combat this lack of knowledge, a prosthetist or physical therapist can perform qualitative functional assessments to gauge the effectiveness of various interventions and components with an individual patient. A previous case report has outlined this procedure to quantify the impact of prosthetic knee choice on balance confidence[4]. This type of assessment protocol allows the prosthetist to see which components have the greatest positive impact on the patient's function, making it instrumental to the patient's successful reintegration into the community and overall quality of life.

However, very little has been studied about functional development after major limb amputation. Munin et al. studied the predictive factors for early ambulation among lower-limb amputees but ended data collection after the patients were discharged from inpatient rehabilitation[5]. This showed that early prosthetic training can be beneficial in the short term, but did not consider the long term effects. Another study assessed the functional abilities of transtibial amputees one year after amputation, and those results were used to show that longer residual limbs can be associated with improved mobility[6]. While valuable for comparison, a cross-sectional study like this one does not consider the way in which the patients reached independence, nor does it include the components used by each patient. More valuable to a prosthetist would be a study showing how a group of similar patients progresses functionally through the prosthetic process. Furthermore, where research on patient function following amputation does exist, the outcome measures used are standard gait protocols with limited ecological validity to assess community mobility[2]. Therefore, valid, quantitative research is needed to illustrate how a patient progresses through the recovery process.

With regard to amputee rehabilitation, each phase has distinct challenges, goals and outcomes (Table 1). This case report shows the functional development of one patient from prosthetic training to follow-up, assessing his functional status at intervals.

Table 1. Phases of amputee rehabilitation[7]

Phase	Hallmark
Preoperative	Assess body condition, patient education , surgical level discussion, prosthetic plans
Amputation Surgery & Reconstruction	Length, myoplastic closure, soft tissue coverage, nerve, handling, rigid dressing
Acute Post Surgical	Wound healing, pain control, proximal body motion, emotional support
Pre-prosthetic	Shaping, shrinking, increase muscle strength, restore patient locus of control
Prosthetic Prescription	Team consensus on prosthetic prescription and fabrication
Prosthetic Training	Increase prosthetic wearing and functional utilization
Community Integration	Resumption of roles in family and community activities, emotional equilibrium and healthy coping strategies, recreation
Vocational Rehabilitation	Assess and plan vocational activities for future, many need further training or job modification
Follow-up	Lifelong prosthetic, functional, medical assessment and emotional support

II. Case Presentation

The patient is a 74 year old male. He is 6 feet tall and weighs 143 pounds. He was non-diabetic. After a post-operative blood clot led to gangrene in January 2010, the patient underwent amputation of his right leg at the transtibial level. No other vascular symptoms have been reported. He is osteoporotic. Also of note, the patient had a total knee replacement on his left knee in 1999 and right knee in 2001. He smokes three small cigars daily and does not drink alcohol. He was retired and lived in a two story home with his wife but did not use stairs daily. Prior to the amputation, he required no assistive devices to ambulate independently and enjoyed camping and yard work.

The patient works with a prosthetist and physical therapist at Dayton Artificial Limb in Dayton, Ohio. He received a patella tendon bearing (PTB) socket in March 2010, but experienced sharp pain at distal patella and distal tibial prominence accompanied by persistent redness at those areas. The prosthetist added dense pads to the patellar region and distal end of the socket, but little improvement was seen. The clinician and physical therapist agreed that the patient was a good candidate for a vacuum prosthesis, because it could relieve the areas of high pressure on the patient's limb by evenly distributing forces over a total surface weight bearing socket[7]. He began wearing the vacuum system prosthesis (Fig. 1) in May 2010, and the clinician evaluated his functional status at the two month, three month and 15 month landmarks in the training and community integration stages of his rehabilitation process with the vacuum system.

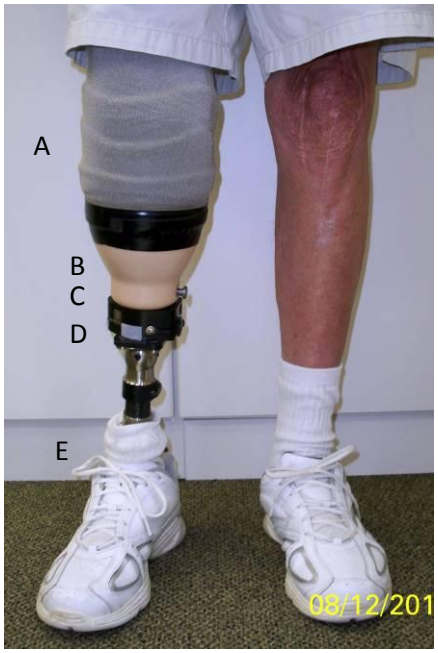

Figure 1. Patient's vacuum system prosthesis: silicone liner (not visible), sealing sleeve (A), thermoplastic socket (B), EV locking system (C), electronic pump (D), foot (E). Details of this prosthesis are in Appendix i.

III. Assessment

An attempt was made to implement the most reliable and ecologically valid instruments for the patient's functional assessment (Appendix ii-iii). First, the patient self-reported his functional capabilities with the Locomotor Capabilities Index 5 (LCI5), a measure of a lower limb amputee's perceived capabilities with a prosthesis. It was originally developed as part of the Prosthetic Profile of the Amputee questionnaire and consists of 14 basic and advanced activities on a five-point ordinal scale. Analyses show that it demonstrates good internal consistency, test-retest reliability, and construct validity when used with adults with lower limb amputation[9-11]. It has been shown to be able to detect changes in functional limitations throughout rehabilitation[6,11], making it appropriate for this report.

The second assessment was the Instrumental Activities of Daily Living (IADL) index, which is a tool used to measure functional independence in a wide range of patient groups[12]. While not a measure of locomotor ability, it does yield information about a patient's general ability to perform daily tasks. It is especially useful for this patient, because the researcher hoped to compare his performance to non-amputees in his age group and age-matched norms are well established for IADL. Both assessments were given in an interview so that the researcher could clarify any questions the patient had about the measures.

IV. Outcome

On the patient's first visit since agreeing to participate in the case study, two months after receiving the vacuum prosthesis, he was administered the LCI5 and IADL assessments (Table 2). While considering his vacuum prosthesis and using a cane, he scored 24 points in general activities and 16 points in advanced tasks. His IADL score reflects an inability to do light housekeeping tasks.

Table 2. Patient's Functional Assessment Results

Duration of EV Use	LCI5 Score (56 possible)	IADL Score (8 possible)
2 months	38	6
3 months	36	8
15 months	41	8

After three months of wearing the prosthesis, the patient came into the clinic for a routine check of his prosthesis and functional evaluation. He walked using a cane and expected to remain doing so. He reported that sometimes he doffs the prosthesis if it begins to ache within the first twenty minutes of donning, but usually re-dons it after his residuum "calms down" and from that point wears it for 4-6 hours without pain. The redness he experienced with the PTB socket had largely disappeared, and his limb appeared healthy, even showing hair re-growth at the distal end (Fig. 2). Again, the clinician administered the LCI5 and IADL assessments. His LCI5 score decreased for advanced two tasks: going up a few stairs without a handrail and walking while carrying an object. He indicated that he would only perform those tasks if someone was nearby. His IADL score improved because he felt more confident performing light household work like putting away dishes. No major component changes were initiated because the patient's progress seemed to be adequate with current components.

Figure 2. Three month follow-up. Medial view of patient's residual limb immediately after wearing prosthesis for four hours. Hair growth visible at distal end, previously a painful high pressure area in the PTB socket system.

The patient was evaluated for a third time in August 2011. The researcher photographed the patient's limb, which appeared healthy, with no evidence of poor circulation or redness (Fig. 3,4).

Figure 3. 15 month follow-up. Anterior view of residual limb immediately after wearing the prosthesis for four hours.

Figure 4. 15 month follow-up. Lateral view of residual limb immediately after wearing the prosthesis for four hours.

At that 15 month follow up, the patient expressed that he still occasionally needed to doff the prosthesis shortly after donning if it felt unbearably tight. He usually re-donned the prosthesis after thirty minutes. The patient had experienced pain around the medial and lateral femoral condyles of his affected side, so the prosthetist attempted to relieve some of the pressure around those areas with reliefs cut out of the patient's outer, rigid socket (Fig. 5). The patient felt an improvement in fit and expressed no increased instability. Functionally, the patient improved significantly in the 12 months since the second evaluation. He said that he was able to perform the majority of the tasks on the LCI5 either unaided or alone with a cane. Qualitatively, he said that he was unable to camp, a hobby that he had enjoyed before the amputation. However, the patient was excited about an upcoming family reunion where he would be responsible for grilling enough food for forty people. He was also able to mow one acre on land weekly using a tractor.

Figure 5. 15 month follow-up. Patient wearing new socket design with EV prosthesis

V. Discussion

While this patient's quantitative functional growth did not show improvement between the two month and three month appointments, the health of his limb improved dramatically when compared to its condition with the PTB socket system. Hair re-growth was unexpected and has not been officially documented, but the prosthetist suspects that it is due to reduced vertical movement in the prosthetic socket during gait, a phenomenon that has been recently shown with vacuum patients[13,14]. The decrease in redness of the limb that the patient experienced with the use of the vacuum prosthesis was likely due to even distribution of force in the total surface bearing socket compared to the PTB version.

The lack of improvement from month two to month three has been seen in other cases, and it seems to indicate that the patient became more realistic with his estimation of his abilities with the prosthesis. Since the LCI5 asks the patient to imagine himself or herself doing several activities and how well they think they could perform them, it is likely that this patient's optimism led him to overstate his capabilities at first.

This patient's results can be compared to both amputee and non-amputee populations. His LCI5 scores are consistent with the means reported in several studies, even when the average age was much younger than this patient's[11,15]. It should be noted that 35.3% of all independent, non-institutionalized adults his age also have at least one IADL limitation[15], and results from a study of similarly-aged non-amputees found an average score of 4.08[17]. The specific tasks that this patient was not able to perform after 15 months of training, namely hiking and camping, are in line with Nissen's work that cited recreational activities among the most negatively affected areas of mobility[18]. That study also found community mobility limitations to be common among lower limb amputees[18], an area in which this patient excelled. Finally, a study defining "successful outcome" in patients with transtibial amputation found that only 56% of patients were ambulatory one year post-amputation, a statistically significant result[19]. Therefore, this patient's functional level can actually be considered above average compared to amputee adults and non-amputee adults of his age.

There are several factors that likely contributed to this patient's long-term functional success with a prosthesis. First, this patient participated in immediate post-operative physical therapy and began prosthetic training three months after the amputation was performed. While not suitable for all patients, early use of a prosthesis has been shown to predict a successful prosthetic outcome[5]. He also had high preoperative activity levels, which has been shown in younger amputee populations to predict successful outcome. The appropriate prescription of prosthetic components is extremely important to patient sucess[7], and likely contributed to this patient's success. While the patient's function was not measured with a PTB socket, his residual limb health improved after the transition to an EV system with a total surface weight-bearing socket. The patient also experienced reduced pain with the EV prosthesis. Both of these effects have been seen in preliminary studies with the technology[8,20], and both may have contributed to this patient's excellent functional development.

Additionally, the inner socket had higher medial and lateral trimlines to stabilize the patient's knee joint, but because it was made of a more flexible material than the outer socket, it did not cause the patient pain at the femoral condyles.

VI. Conclusion

Statistics indicate that this patient is fairly typical considering his age, health, and cause and level of amputation[2,7]. However, his high scores on standard functional assessments are above average compared to amputees his age. With early physical therapy and on-going prosthetic training, he was able to gradually reduce the use of a cane and take on more responsibility in his household. While the pace and extent of functional recovery varies greatly between patients, this patient was able to regain his pre-operative activity level within 15 months of amputation with only occasional assistive device use. This case report is evidence that standard functional assessments are clinically viable tools to measure long-term abilities with a prosthesis.

Some consideration should be given to the limitations of this report. As with any case report, the conclusions can be applied only to a limited group of patients. This report showed how one patient performed with a vacuum system, but we make no claim that the technology is solely responsible for this patient's success. Instead, large-scale, longitudinal, comparative research must be performed in order to investigate the many claims present in literature regarding its positive effects. How do changes in the prosthetic components affect long-term patient function? While short term biomechanical effects have been documented for a few types of components (feet, knees), long-term comparative studies between components are absent in the literature. Vacuum system technology could have the potential to improve the quality of life of hundreds of thousands of amputees if it can be applied successfully to patients like the one in this report.

V. Consent

Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review from the Editor-in-Chief of this journal.

References

1. Deans SA, McFadyen AK, Rowe PJ. Physical activity and quality of life: A study of a lower-limb amputee population. *Prosthet Orthot Int* 2008;32:186-200.

2. Van der Linde H, Hofstad CJ, Geurts AC, Postema K, Geertzen JH, van Limbeek J. A Systematic Literature Review of the Effect of Different Prosthetic Components on Human Functioning with a Lower-Limb Prosthesis. *J Rehabil Res Dev* 2004;41:555-570.

3. Research in P&O: Are we addressing clinically-relevant problems? Report on the State-of-the-Science Meeting in Prosthetics and Orthotics; 2006; Chicago, Illinois. Northwestern University Feinberg School of Medicine; 2006.

4. Philip SM, Carson R. Case report: Using the activities-specific balance scale to quantify the impact of prosthetic knee choice on balance confidence. *J Prosthet Orthot* 2007;19:114-116.

5. Munin MC, Espejo-De Guzman MC, Boninger ML, et al. Predictive factors for successful early prosthetic ambulation among lower-limb amputees. *J Rehabil Res Dev* 2001;38:379-384.

6. Arwert HJ, van Doorn-Loogman MH, Koning J, et al. Residual-limb quality and functional mobility 1 year after transtibial amputation caused by vascular insufficiency. *J Rehabil Res Dev* 2007;44:717-722.

7. Esquenazi A. Amputation rehabilitation and prosthetic restoration: From surgery to community reintegration. *Disabil Rehabil* 2004;26:831-836.

8. Beil TL, Street GM, Covey SD. Interface pressures during ambulation using suction and vacuum-assisted prosthetic sockets. *J Rehabil Res Dev* 2002;39:693-700.

9. Gauthier-Gagnon C, Grise MC: Prosthetic profile of the amputee questionnaire: Validity and reliability. *Arch Phys Med Rehabil* 1994;75:1309-1314.

10. Franchignoni F, Giordano A, Ferriero G, et al. Rasch analysis of the locomotor capabilities index-5 in people with lower limb amputation. *Prosthet Orthot Int* 2007;31:394-404.

11. Frachnignoni F, Orlandini D, Ferriero G, Moscato T. Reliability, validity, and responsiveness of the locomotor capabilities index in adults with lower-limb amputation undergoing prosthetic training. *Arch Phys Med Rehabil* 2004;85:743-748.

12. Lawton MP, Brody EM. Assessment of older people. *Gerontol* 1969;9:179-186.

13. Papaioannou G, Mitrogiannis C, Tsiokos D, et al. Transtibial prosthetics kinetics during prolonged strenuous activities of daily living, measure by internal gait analysis instrumentation. Proceedings of the 37th Meeting of the American Academy of Orthotists and Prosthetists; 2011; Orlando, Florida.

14. Wood J, Papaioannou G, Fiedler G, et al. Effect of elevated vacuum sockets on residual limb-socket motion in prolonged strenuous activities. Proceedings of the 37th Meeting of the American Academy of Orthotists and Prosthetists; 2011; Orlando, Florida.

15. Larsson B, Johannesson A, Andersson IH, Atroshi I. The locomotor capabilities index; Validity and reliability of the Swedish version in adults with lower limb amputation. *Health Qual Life Outcomes* 2009;44

16. Centers for Disease Control and Prevention. Limitations in activities of daily living and instrumental activities of daily living 2003-2007. Available at: http://www.cdc.gov/nchs/health_policy/ADL_tables.htm. Accessed August 8, 2011.

17. Vittengl JR, White CH, McGovern RJ, Morton BJ. Comparative validity of seven scoring systems for the instrumental activities of daily living scale in rural elders. *Aging Ment Health* 2006;10:40-47.

18. Nissen SJ, Newman WP. Factors influencing reintegration to normal living after amputation. *Arch Phys Med Rehabil* 1992;73:548-51.

19. Taylor SM, Kalbaugh CA, Cass AL, et al. :"Successful outcome" after below-knee amputation: An objective definition and influence of clinical variables. *Amer Surgeon* 2008;74:607-613.

20. Ferraro C. Outcomes study of transtibial amputees using elevated vacuum suspension in comparison with pin suspension. *J Prosthet Orthot* 2011;23:78-81.

Appendix i. Details of Patient's Prosthetic Components

Component	Manufacturer	Part #
SealMate™ Liner	Prosthetic Design	SM-BK4
TT Thermoplastic Socket w/ Flex Inner	Prosthetic Design	BK6
EVLS™ Lock Kit	Prosthetic Design	EVLS-CAUC
Limb Logic® Vacuum Suspension	WillowWood	LLV-1600-T
½" Offset Plate	Prosthetic Design	OP1/2-4C4TCF-1/2"
Pyramid	Prosthetic Design	PYR
Tube Clamp	Prosthetic Design	TC30
30mm Carbon Fiber Tube	TiMed	A-200HD
Tube Clamp	Prosthetic Design	TC30-1/2
Echelon Foot	Endolite	Ech-27R-3

Appendix ii. The Locomotor Capabilities Index – 5

"Are you able to ___ with your prosthesis on?"	Score (0-4)
1. Get up from a chair	
2. Pick an object up from the floor from standing*	
3. Get up from the floor (if you fell)*	
4. Walk in the house	
5. Walk outside on even ground	
6. Walk outside on uneven ground (grass, gravel, slope)*	
7. Walk outside in inclement weather (rain, snow, ice)*	
8. Go up the stairs with a handrail	
9. Go down the stairs with a handrail	
10. Step up a sidewalk curb	
11. Step down a sidewalk curb	
12. go up a few steps without a handrail*	
13. Go down a few steps without a handrail*	
14. Walk while carrying an object*	

* indicates advanced task

Answer	Score
No	0
Yes, if someone helps me	1
Yes, if someone is nearby	2
Yes, alone, with an assistive device	3
Yes, alone, without an assistive device	4

Appendix iii. Instrumental Activities of Daily Living

A. Telephone Use

Operates telephone on own initiative; looks up and dials numbers, etc.	1
Deals a few well-known numbers	1
Answers phone but does not dial	1
Does not use telephone at all	0

B. Shopping

Takes care of all shopping needs independently	1
Shops independently for small purchases	0
Needs to be accompanied on any shopping trip	0
Completely unable to shop	0

C. Food Preparation

Plans, prepares and serves adequate meals independently	1
Prepares adequate meals if supplied with ingredients	0
Heats, suerves and prepares meals or prepares meals but does not maintain adequate diet	0
Needs to have meals prepared and served	0

D. Housekeeping

Maintains house alone or with occasional assistance	1
Performs light daily tasks such as dishwashing, bed making	1
Performs light daily tasks but cannot maintain acceptable level of cleanliness	1
Needs help with all home maintenance tasks	1
Does not participated in any housekeeping tasks	0

E. Laundry

Does personal laundry completely	1
Launders small items	1
All laundry must be done by others	0

F. Transportation

Travels independently on public transportation or drives own car	1
Arranges own travel, but does onot otherwise use public transportation	1
Travels on public transportation when accompanied by another	1
Travel limited to taxi or automobile with another	0
Does not travel at all	0

G. Medication

Is responsible for taking medication in correct dosages at correct time	1
Takes responsibility if medication is prepared in advance in separate dosage	0
Is not capable of dispensing own medication	0

H. Finances

Manages financial matters independently, collects and manages income	1
Manages day-to-day purchases, but needs help with banking, major purchases, etc.	1
Incapable of handling money	0