Modeling Long-Term Costs of Traumatic Lower-Limb Amputation in the Workplace

Andrea B. Wanamaker[1], Rebecca R. Andridge[2], and Ajit M.W. Chaudhari[1,3]

[1]Department of Biomedical Engineering, [2]College of Public Health, [3]School of Health and Rehabilitation Sciences, The Ohio State University

Introduction

- Assessing total costs of living with an amputation is difficult as costs are typically borne by many different entities

- The Ohio Bureau of Workers' Compensation (BWC) covers any medical and lost-wage costs associated with workplace injury from the time of initial injury until death [1]
  - Includes:
    - Physical, mental health, and vocational therapies
    - Prostheses and associated expenses (repairs, liners, socks, etc.)
    - Any and all hospital associated costs
    - Prescription and over-the-counter medications
    - Assistive technology (wheelchairs, auto/home modifications, etc.)

- Medicare classifies five activity levels for amputees to determine which prosthesis should be prescribed [2] (Table 1)

Table 1. Medicare classification of activity level and associated prosthesis [2]

Level	Description	Prosthetic Knee
K0	Not able and lacks potential to ambulate or transfer safely without assistance; prosthesis would not enhance their quality of life or mobility	None
K1	Limited or unlimited household ambulator - able or has potential to use a prosthesis for transfers or ambulation on level surfaces at fixed cadence	Single axis; constant fiction
K2	Community ambulator - able to transverse low-level environmental barriers such as curbs, stairs, or uneven surfaces	Single axis; constant friction
K3	Community ambulator able to ambulate with variable cadence – can transverse most environmental barriers and may have vocational, therapeutic, or exercise activity that demands prosthetic use beyond walking	Fluid and pneumatic control
K4	Athlete, active adult, or child - prosthetic ambulation needs that exceeds basic ambulation skills, exhibiting high impact, stress, or energy levels	Any

- Little research has been completed to determine the long-term costs associated with living with an above-knee amputation

- The BWC database allows us to determine the healthcare costs per year associated with each level of prosthesis (K1-K4 devices) and determine the frequency at which transitions occur between prosthetic devices and associated activity levels

PURPOSE: To use the BWC database to build Markov decision models to estimate long-term costs (10, 15, 20 years) associated with above-knee amputation after receiving a prosthesis

Methods

Obtaining the Data

- Anonymized data from 1993-2013 obtained from BWC's database on traumatic workplace lower-limb amputees obtained September 2014 through a Freedom of Information Act request (330 male, 31 female)

- Data restricted to above-knee amputees who received a prosthesis
  - 62 above-knee workers (7 female)
  - Age at initial injury: 42.0 ± 13.3 years

Methods Cont.

Organizing the Data

- Over 400,000 insurance claims reimbursed totaling over $122 million
- Claims organized into 7 main categories: prosthetic limbs, prosthetic equipment, vocational therapy, mental health therapy, physical therapy, narcotic pain medication, non-narcotic pain medication, non-pain medication, assistive technology, and hospital
- All costs were adjusted to January 2014 USD

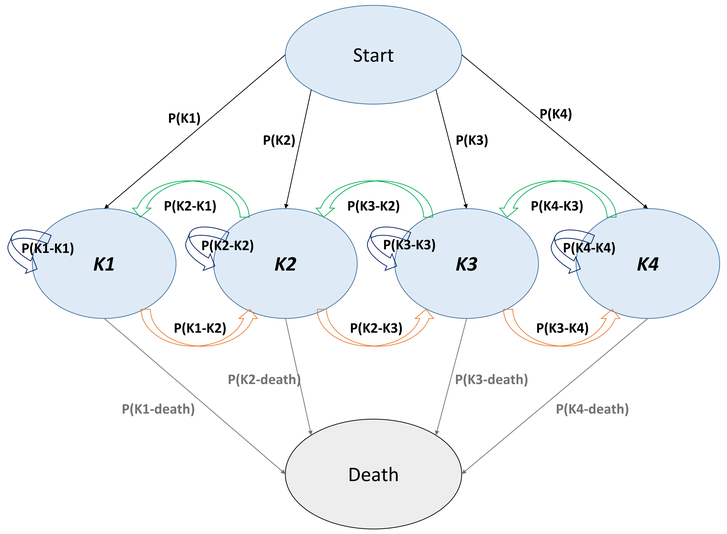

Figure 1. Depiction of the Markov decision model. P(K#) indicates the probability of beginning the first cycle in that state. P(K#-K#) indicates the probability of transition between states or remaining in that state.

Determining Transition Probabilities and Cost Penalties for States

- Markov States were defined as the Medicare K-Levels and Death
- Estimating the transition probabilities between states:
  - Examined data after worker received prosthesis (claims prior to receipt of prosthesis were not included)
  - Determined the K-level of prosthesis received by each worker
    - Normally the K-level is determined and then a prosthesis is prescribed
    - The reverse must be done here: determine the K-level by examining the prosthesis as we do not know anything regarding physical capabilities
  - Determined time history of K-Levels for each worker
  - Combined time histories for the cohort to determine how frequently workers shifted or stayed in K-Levels over the span of one year
- Estimating the cost penalties for states:
  - Determined cost per year per K-level for each worker
  - Averaged cohort together to create table of costs based on K-Level and year within K-Level
    - First year in K-Level is most expensive as it includes cost of the prosthesis
    - Subsequent years are less expensive as prosthesis associated costs are solely from maintenance and supplies
- Assumptions:
  - Cycle length = 1 year
  - Can only move up or down 1 K-Level, or remain in same state, per cycle
  - Each transition is independent of the previous transitions
  - Death treated as a terminal state, with probability of death determined by National Vital Statistics Reports [3]

Methods Cont.

Running the Markov Model

- Model construction and computation done by custom MATLAB code
- Cycle length was set to 10, 15, and 20 years to determine long-term costs of living with an amputation
- Cost incurred at each state for each cycle was determined by sampling from a normal distribution based on observed costs in the BWC data
- Random walk analysis (n = 1000) used to determine average total cost incurred over cycle length

Results

Table 2. Results of 1000 random walks through the Markov model with cycle lengths of 10, 15, and 20 years.

Cycle Length	Average Total Cost	Standard Deviation
10 years	$236,762	$41,697
15 years	$363,134	$57,360
20 years	$488,902	$71,349

Discussion and Future Work

- Previous work has been completed that explores the costs of living with an amputation, but has been based on expert panel advice [4] or limited to solely examining prosthetic costs [5]

- The results presented here use insurance information from a large cohort of above-knee amputees in order to create a Markov model that includes all healthcare associated costs and transition probabilities determined from actual real-life data

- Results agree with previous work based on expert panel advice [4], but both sets of results require additional refinement and development to be truly indicative of long-term costs of amputation

- Future work will focus on developing a higher order model so that state transitions are dependent on previous state transitions
  - The probability of remaining in or transition out of a K-Level is dependent on how long you have been in that state
  - The cost incurred within each K-Level is also time dependent

References and Acknowledgements

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1. www.bwc.ohio.gov
2. www.cms.gov
3. National Vital Statistics Reports, **64**, 2015
4. Blough, et al. *JRRD*. **47**:384-402, 2010
5. Brodtkorb, et al. *Arch Phys Med Rehabil,* **89**:24-30, 2008

OSU Sports Biomechanics Laboratory