COST OF OWNERSHIP OF UPPER LIMB PROSTHESES: A RETROSPECTIVE ANALYSIS

Anthony Chan[1,2], Ezra Kwok[1], Petcharatana Bhuanantanondh[1]
[1]Biomedical Engineering Program, University of British Columbia; [2]Biomedical Engineering Technology, British Columbia Institute of Technology

INTRODUCTION

An external limb prosthesis is an externally-applied medical device to replace entirely, or partly, any absent or deficient limb segment [1]. Prostheses for functional restoration of a compromised limb can be body-powered (BP) or externally-powered. A BP prosthesis relies on intentional body motion to create functional activities [2]. An externally-powered prosthesis uses signals initiated by the amputee to control actuators in the prosthesis. A myoelectric (Myo) prosthesis is an externally-powered prosthesis using myoelectric signals from the patient as control input. Electric motors and batteries are common actuators and power sources [3,4].

Healthcare funding and insurance agencies often hold mandates to fund the provision, training, and ongoing maintenance of prostheses for injured workers. Keeping up with the latest technology and determining which prosthesis is appropriate for an individual at a reasonable cost becomes a growing challenge for case managers of these organizations [5,6]. There are very few reported studies on life-cycle cost analysis, maintenance requirements, and reliability of upper limb prostheses. An assessment platform to evaluate performance and reliability of Myo prostheses in laboratory setting was developed and reported [7]. Blough reported the average 5-year projected unilateral upper limb prosthetic cost to be US$31,129 and US$117,440 respectively for veterans from the Vietnam conflict (1961−1973) and from the Operation Iraqi Freedom/Operation Enduring Freedom conflicts (2000−2008) [8]. Biddiss in 2011 reported the average costs of prosthetic components and their annual maintenance to be US$9,574 and US$1,936 respectively [9].

This paper reports the results of a retrospective data analysis on upper limb prostheses prescribed to adult workers who underwent upper limb amputations subsequent to work-related injuries. Information on life-cycle costs and service patterns of BP and Myo prostheses are analyzed and presented.

AMPUTEE PROFILE

In the province of British Columbia, WorkSafe BC (WSBC) is the provincial statutory agency on workers' compensation. Twenty eight WSBC workers with upper extremity amputations between the year 2004 and 2010 were studied. The medical sections in the case files of these amputees documented from the time of injury to November 3, 2011 were retrieved and analyzed. These workers are unilateral upper limb amputees with the majority of them suffering from transradial (TR) and transhumeral (TH) amputations. Prosthetic prescription data, service patterns, acquisition and maintenance costs extracted from invoices and service requests submitted by prosthetists were analyzed and reported in the next section.

Of the 28 amputees reviewed, 6 (21%) are female and 22 (79%) are male. There are 14 (50%) workers with TR amputation, 12 (43%) with TH amputation, 1 (4%) with transcarpal (TC) amputation and 1 (4%) with shoulder disarticulation (SC). The majority (23 or 82%) of the amputees received both body-powered (BP) and externally-powered (Myo) prostheses, 2 (7%) have only BP prostheses, 1 (4%) has only Myo prosthesis, and 1 (4%) is without any prosthesis.

RELIABILITY AND SERVICE PATTERNS

Reliability is indicated by the frequency of demand maintenance due to malfunctioned parts, out of alignments, and worn-out components. From each amputee case file, the number of repairs, adjustments, and component replacements are recorded. The costs associated with these services are compiled. The frequency of repair is calculated by the total number of repairs divided by the number of years of possession of the prosthesis. Other service frequencies as well as their associated costs are similarly calculated. Figure 1 is the "Box and Whisker" Plot (Box Plot) of the annual repair frequencies of this study group arranged by prosthetic types and levels of amputation. The sample mean is also shown (diamond tic-marks) in the plot.

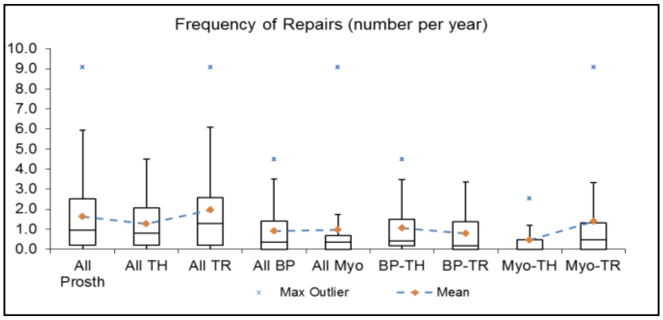

Figure 1 - Frequencies of Repair by Type of Prostheses

The analysis shows that the average number of prosthetic repairs per amputee is 1.64 ± 0.22 (mean ± SEM) per year. A TR amputee has more problems with his/her prostheses than a TH amputee (1.96 ±0.37, versus 1.26 ± 0.32). When grouped into prosthetic types, the number of repairs per year of BP versus Myo prostheses is 0.90 ± 0.14 and 0.98 ± 0.23 respectively. On average, within the group of TR amputees, Myo prostheses require twice as much repair as BP prostheses (1.39 versus 0.78 times per year); whereas, for TH amputees, the repair requirements are reversed (0.45 for TR versus 1.05 for TH per year). It is also noted that the frequency of repair for TR Myo prostheses is over three times that of TH Myo prostheses (1.39 versus 0.45 times per year). However, due to the small sample size, these differences are not statistically significant.

Other than repair work, prostheses require occasional adjustments (e.g., cable and harness adjustment for BP prosthesis) to maintain their functional effectiveness. In addition, worn out components (parts and accessories such as gloves and liners) will need to be replaced. The data collected on prosthetic adjustments and components replacements were similarly analysis. Figure 2 compares the means frequencies of repair, adjustment, and replacements between different types of prostheses. The total demand maintenance frequencies are also shown.

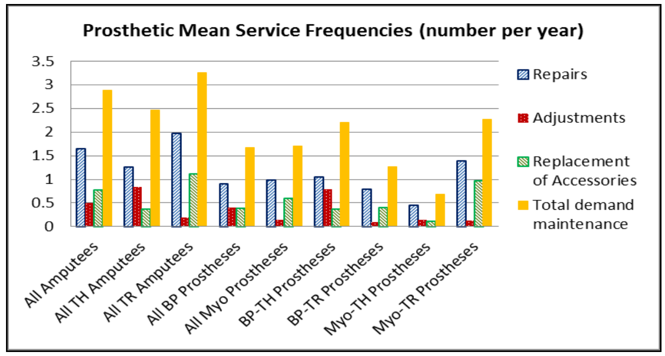

Figure 2 –Prosthetic Service Frequencies

Figure 2 shows that, on average, an upper limb amputee needs to adjust his/her prostheses once every 2 years (frequency = 0.49 per year). BP prostheses need more adjustments than Myo prostheses; and TH prostheses need more adjustments than TR prostheses. Replacement accessories are primarily consumable such as gloves and liners from wear and tear, and from soiling. TR prosthetic users shows a higher component replacement frequency which indicates that TR amputees are likely using their prostheses more than the TH amputees. From the collected data, TR amputees required more maintenance on their prostheses than TH amputees. Surprisingly, the overall demand maintenance requirements for BP and Myo prostheses are roughly the same.

COST-OF-OWNERSHIP ANALYSIS

When a worker is injured leading to upper limb amputation, resources provided by funding agencies includes medical care, financial compensation, rehabilitation, training, workplace and home modification, and prosthetic costs. Although some of the above listed costs are related and may affect others, cost analysis in this study is only focused on the last item, i.e., prosthetic costs. These costs are reported in Canadian funds.

From the medical files, in particular from the prosthetic claims, the prosthetic history of each amputee is reviewed. For each amputee, the cumulative expenses of BP and Myo prosthesis as well as the combined prosthetic expenses are compiled and tabulated. These expenditures are normalized against the overall combined cumulative prosthetic costs and plotted against time. Figure 3 shows an example of such a plot. The horizontal axis is the year from the date of the first prosthesis. Each point on the graph is a prosthetic claim. In this example, the worker was injured in October 2004, underwent TR amputation in April 2005, and received his first BP prosthesis in November 2005. The cumulative total cost over time of the BP prosthesis is represented by the lower line (square tic-marks). The worker was prescribed his/her first Myo prosthesis in January 2007, about 14 months after his BP prosthesis. The cumulative cost over time of the Myo prosthesis is shown in the middle line (triangular tic-marks) The combined cumulative total prosthetic cost is represented by the upper line (diamond tic-marks). In this case, six years of history was recorded. At the cut-off date (November 2011), the total cumulative prosthetic expenses was $52,029. From the reliability analysis in the previous section, the frequency of demand maintenance for a Myo prosthesis is 1.67 times per year. As there was no prosthetic claim on the Myo prosthesis for this worker in the most recent 3.6 years, it is reasonable to suggest that this worker has not been using his/her Myo prosthesis. On the other hand, the regular maintenance of the BP prosthesis indicates that the amputee has been using the BP prosthesis consistently. Using this observation, we establish a criterion that a prosthesis has been abandoned when there was no maintenance activity for over two years.

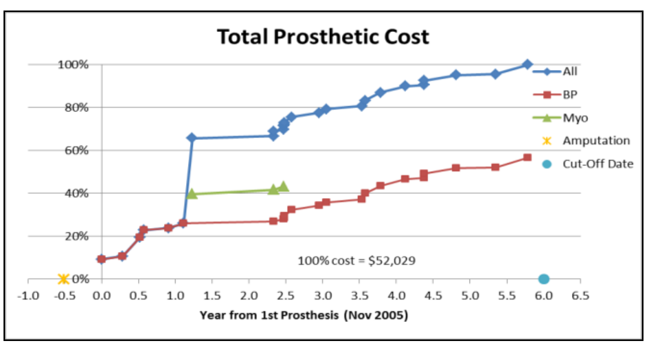

Figure 3 - Total Prosthetic Cost against Time Plot

The total cumulative prosthetic costs for all 28 amputees in this study are charted. Among the cases, 20 (74%) amputees have been given prostheses for over three years. Using the abandonment criterion, 12 out of 20 (60%) have not been using either or both of their prostheses. Four out of 20 (20%) amputees have stopped using all prostheses. Among them, 3 out of 4 (75%) are TH amputees and 1(25%) is a TR amputee. Of the 12 who have abandoned their first prosthesis, 8 (67% out of 12) were BP prosthesis and 4 (33%) were Myo prosthesis. When considering the costs of these abandoned prostheses, $305,922 could have been saved if appropriate prostheses were prescribed in the first place.

To provide a better picture of the prosthetic cost distribution with time, the annual total prosthetic costs for the first five years are plotted in Figure 4. As shown the Box Plot, the average first year cost was substantially higher than the annual costs of the remaining years. For example, the first year cost ($34,840) is 38% more than the second year cost ($13,121), and is 53% of the total cumulative 5-year cost ($65,520±$10,751). The differences between the average first year cost and those in the subsequent years are found to be statistically significant ($p < 0.01$).

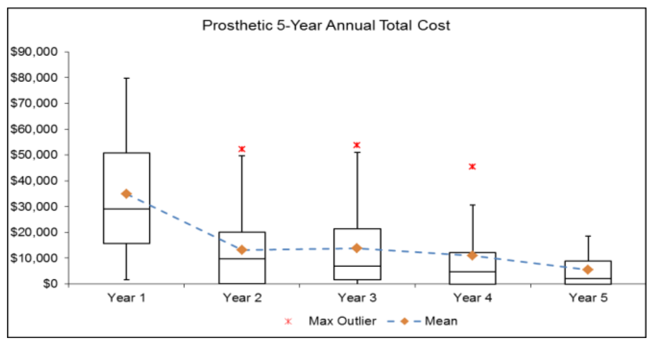

Figure 4 -.Five-Year Annual Total Prosthetic Cost

To study the cost differences between the types of prostheses, data from BP and Myo prostheses were separated. The average annual total prosthetic cost, the average annual prosthetic componentry cost, and the average annual prosthetic operating cost for the different types of prostheses are compared in Figures 5, 6, and 7 respectively. Prosthetic componentry costs include the initial prosthesis and all subsequent acquisition of prosthetic components such as additional terminal devices, adaptive devices, etc. Operating costs encompasses the remaining costs which include refitting, maintenance, and supplies.

The values in Figures 5, 6, and 7 clearly show that, among this group of amputees, the total 5-year life-cycle cost, as well as the componentry and operating costs are much higher for Myo prostheses than those for BP prostheses.

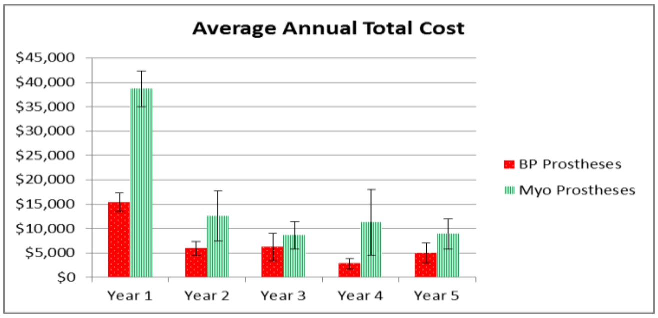

Figure 5 - Average Annual Total Prosthetic Cost

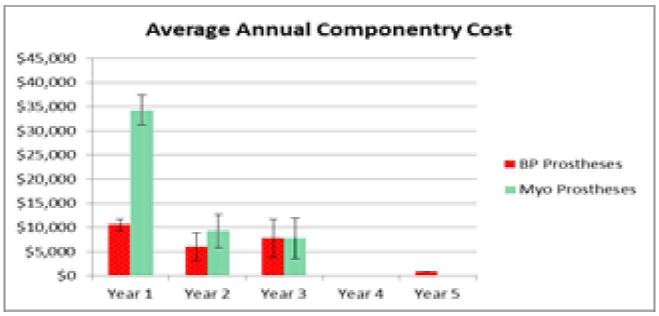

Figure 6 - Average Annual Prosthetic Componentry Cost

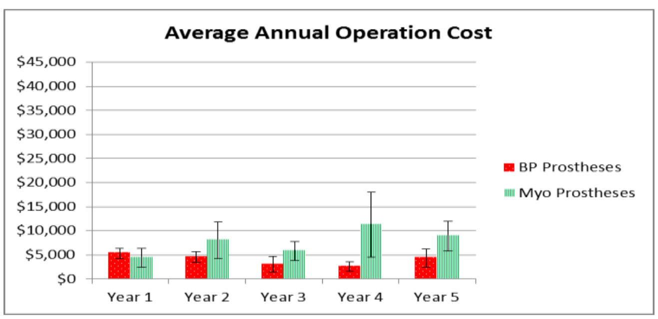

Figure 7 - Average Annual Prosthetic Operating Cost

CONCLUSIONS AND RECOMMENDATIONS

This retrospective amputee case study reveals the prosthetic cost of ownership and their life-cycle cost distribution. The average total cumulative 5-year prosthetic cost per upper limb amputee is found to be $65,520, of which 53% was spent in the first year. The results also provide knowledge in prosthetic reliability as well as patterns of technical service requirements. In addition, the service pattern may be used as an indicator for prosthetic utilization and abandonement. This information will benefit rehabilitation practitioners and funding agencies in appropriate selection of prosthetic devices to amputee workers. However, the findings are from data mining only 28 amputee case files supplied by WSBC. In order to improve the statistical relevance of the findings, additional cases should to be included in the analysis. It will be interesting and helpful to analyze similar data sets from other workers' compensation boards within the same period of time. Better designed and consistent reporting structures will benefit funding agencies and researchers to collect relevant data, study outcomes, and extract performance indicators for ongoing analysis and quality improvement.

ACKNOWLEDGEMENTS

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