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Original Research

Factors Associated With Prolonged Length of Stay and Failed Lower Limb Prosthetic Fitting During Inpatient Rehabilitation

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KEYWORDS
Amputation;
Amputees;
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Abstract *Objective:* To identify variables associated with rehabilitation length of stay (LOS) and prosthetic fitting success for people with lower limb amputation (LLA).
Design: Retrospective analysis of clinically collected cohort.
Setting: Canadian inpatient rehabilitation hospital.
Participants: Consecutive individuals with LLA (N=103) admitted for prosthetic fitting (mean age, 65.3±10.6y).
Interventions: Not applicable.
Main Outcome Measures: Independent variables included the Lower Limb Amputee Measurement Scale (LLAMS), which is a 31-question tool to predict LOS with items in medical, cognitive, social, physical, activities of daily living, and other subsections; admission FIM; age; sex; level of amputation (below- or above-knee); and time from surgery to admission. LOS was measured as days from admission to discharge. Successful prosthetic fitting was defined as the ability to use a prosthesis on discharge.
Results: The mean LOS was 63.6 ± 33.3 days, and 21.4% of patients failed prosthetic fitting. Higher LLAMS, lower FIM, and above-knee amputation were significantly associated with longer LOS ($P<.001$, $R^2=0.36$). Age, sex, and time from surgery were not significantly associated with LOS or prosthetic fitting. Higher LLAMS was significantly associated with unsuccessful prosthetic fitting ($P=.032$). Of the 31 items in the LLAMS, 5 were associated with prolonged LOS and 5 were associated with failed prosthetic fitting ($P<.10$).
Conclusions: The LLAMS, level of amputation, and admission FIM can be used to predict LOS in lower limb amputees admitted for prosthetic fitting. The LLAMS was weak in identifying patients who failed prosthetic fitting. Future research should consider shortening the LLAMS.

List of abbreviations: AKA, above-knee amputation; BKA, below-knee amputation; DM, diabetes mellitus; LLA, lower limb amputation; LLAMS, Lower Limb Amputation Measurement Scale; LOS, length of stay.

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Health care costs associated with lower limb amputation (LLA) are not available for Canada, but costs have been estimated to be $4 billion per year in the United States,[1] and the number of individuals living with LLA is expected to double over the next 30 years.[2] The primary cause of LLA in most Western countries is complications arising from diabetes mellitus (DM),[3] including peripheral vascular disease. In fact, the risk of LLA is 28.9 times higher for individuals with DM compared with those without.[3] Compromised circulation in the remaining limb, cognitive impairment, and low cardiorespiratory fitness are among the additional challenges faced by amputees with vascular comorbidities who are candidates for prosthetic fitting.[4]

In Canada, approximately one-third of individuals with LLA require admission to an inpatient rehabilitation facility,[5] but this database does not specify whether admissions were for prosthetic fitting. More than 80% of Canadian rehabilitation centers provide inpatient prosthetic rehabilitation.[6] Prosthetic rehabilitation is a resource-intensive process that does not always lead to successful fitting. With most rehabilitation centers providing 4 to 9 weeks of inpatient rehabilitation,[6] it may not be wise to invest resources into prosthetic fitting if the likelihood of a successful outcome is low. Identifying factors that predict prolonged length of stay (LOS) or fitting failure can help avoid unnecessary admissions and streamline the process for individuals with LLA and health care providers.

Consolidated evidence from systematic reviews demonstrates that higher amputation level, advanced age, lower physical fitness, and having multiple comorbidities are the strongest predictors of prosthetic fitting failure.[7,8] Other potential predictors of poor prosthetic candidacy or limited walking ability include cognition or mood disturbances, poor balance, female sex, increased time from surgery to prosthetic rehabilitation, and limited social support.[7-13] Several groups have attempted to develop prediction tools for prosthetic candidacy, walking potential, or long-term prosthetic use.[13-17] Neither tool was specifically designed to predict outcomes for individuals with LLA who were being considered for inpatient rehabilitation.

Developed by an inpatient amputee rehabilitation team, the Lower Limb Amputee Measurement Scale (LLAMS), is the only tool of which we are aware that is designed to predict inpatient LOS before admission for prosthetic rehabilitation. Based on a review of health records, the authors compiled 31 items in 6 subcategories (ie, medical, cognitive, social, physical, functional, other), which they believed could contribute to prolonged LOS.[18] In a sample of 147 individuals with LLA, the LLAMS score was moderately correlated with LOS, but did not predict functional outcome (walking and independence).[18] The analysis did not control for potential confounders such as age and level of amputation. The LLAMS was used to dichotomize patients into either a 6- or 7-week rehabilitation program, but it had not been validated in a rehabilitation program without a predetermined LOS. In addition, because some of the items in the LLAMS have been reported as predictors of prosthetic fitting, we were interested in determining whether the LLAMS could be used clinically to identify individuals likely to fail prosthetic fitting.

The main objective of this study was to identify variables associated with LOS and prosthetic fitting for individuals with LLA undergoing inpatient rehabilitation. The LLAMS was examined along with other variables such as age, sex, time from amputation to admission, admission FIM, and level of amputation. A secondary objective was to explore whether the LLAMS should be shortened from its original 31 items.

Methods

Study design and participants

This was a retrospective analysis of data collected by an inpatient rehabilitation facility in Canada for 105 consecutive individuals with LLA admitted for prosthetic fitting between 2010 and 2017. All patients were screened for prosthetic candidacy by either a multidisciplinary amputee clinic team or the facility intake committee. Patients were included in the database if they were 18 years of age or older, underwent major amputation (above the ankle), and were admitted for first unilateral or bilateral prosthetic fitting. Patients were excluded if they had a previous prosthetic fitting on the same limb (ie, refitting or revision), were discharged within 2 weeks to continue fitting as an outpatient, data were incomplete, or if they were admitted for reasons other than prosthetic fitting. The data were anonymized and collected as part of a quality improvement initiative. Permission to access the database was received from the health authority, and ethics approval was received from the provincial Health Research Ethics Board. Owing to the retrospective nature of the study, informed consent was waived.

Independent variables

Three main subgroups of independent variables were considered: demographic (age, sex, time since surgery), physical and functional status (level of amputation, admission FIM score), and the 31 items of the LLAMS.[18]

Demographic

Because older age has been shown to be associated with increased LOS[5,19,20] and failure of prosthetic fitting,[7] age was included as an independent variable as well as a potential confounder. Sex was included as an independent variable, although the evidence regarding its effect on outcomes has been conflicting.[8,9,12,16,21] Time (in d) from

Table 1 Patient characteristics (N = 103)

Characteristics	Mean (Minimum-Maximum)	SD	Frequency	Percent
Age, y	65.3 (38-90)	10.6		
Sex				
Male			70	68.0
Female			33	32.0
Level of amputation				
BKA			66	64.1
AKA			33	32.0
Bilateral			4	3.9
Amputation etiology				
DM or vascular			93	90.3
Orthopedic			4	3.9
Cancer			1	1.0
Infection			2	1.9
Other			3	2.9
Time from surgery to admission, d	127 (7-592)	119		
LLAMS	10.5 (2-22)	4.6		
Admission FIM	101 (50-124)	14.4		
LOS, d	63.6 (8-184)	33.3		
Prosthetic fitting				
Successful			81	78.6
Unsuccessful			22	21.4

NOTE. Two outliers were removed from the analysis whose time from surgery to admission was more than 3 times the interquartile range above the 75th percentile.

surgery to rehabilitation admission was considered in the model, because earlier initiation of prosthetic rehabilitation has been associated with better outcomes.[12,21]

Physical and functional

Level of amputation, including bilateral, was coded as either below-knee amputation (BKA) or above-knee amputation (AKA) based on the level of amputation being fitted during the admission. Being a bilateral amputee was one of the items included in the LLAMS. FIM scores were completed by rehabilitation team members credentialed in FIM scoring. Admission FIM scores have been shown to predict LOS for amputees in several studies,[19,22] but not successful fitting.[23]

LLAMS score

The LLAMS includes 31 questions (see appendix 1) with binary responses yes and no (coded as 1 and 0).[18] Higher scores are indicative of greater resource needs and poorer health. The LLAMS was completed by the treating physiotherapist (M.C.) on admission and has high inter-rater reliability.[18]

Outcome variables

There were 2 main outcomes, namely LOS (in d) and whether the prosthetic fitting was considered "successful." Successful fitting was coded at discharge by the treating physiotherapist (M.C.) as yes or no (1 or 0), depending on whether the patient was able to use the prosthetic limb for transfers or walking.

Data analyses

Descriptive statistics were summarized using measures of central tendency for continuous variables and frequencies for categorical variables. To examine the associations with LOS, multiple linear regression was conducted with age, sex (male as reference), time from surgery to admission, level of amputation (BKA as reference), total LLAMS score, and admission FIM score as the independent variables. Because prosthetic fitting was a binary outcome, logistic regression was conducted using the same independent variables, with successful fitting as the outcome. A receiver operating characteristic curve was used to assess the ability of the LLAMS to identify patients who failed prosthetic fitting and determine whether there was an appropriate LLAMS cutoff value.

To explore whether the LLAMS should be shortened from 31 items, the associations between each item in the LLAMS and the dependent variables were assessed by separate analyses for each item. Rather than univariate analysis, each item was assessed under the control of the admission FIM, level of amputation, age, sex, and time from surgery to admission. For LOS, items with β greater than 0, a *P* value less than .10 was considered to be associated with prolonged LOS. This process was repeated with unsuccessful prosthetic fitting as the outcome for items with odds ratios less than 1 and *P* values less than .10. A significance level of 90% was chosen for this subanalysis to avoid missing potentially important items in the LLAMS.

Based on a significance level of 0.05, a power of 0.8, with a medium effect size ($f^2 = 0.15$), the sample size was adequate for regression analysis with 6 independent

Table 2 Variables associated with LOS and successful prosthetic fitting

Variables	Model for LOS				Model for Prosthetic Fitting			
	Beta	95% CI	*P* Value	R^2	Odds Ratio	95% CI	*P* Value	Nagelkerke R^2
LLAMS	1.77	0.16-3.39	.032		0.85	0.73-0.99	.032	
Admission FIM	−0.85	−1.41 to −0.29	.004		0.99	0.94-1.04	.56	
Level of amputation	21.4	9.35-33.5	.001		0.40	0.14-1.17	.095	
Age	−0.40	−0.97 to 0.17	.16		1.00	0.96-1.05	.89	
Sex	−7.71	−20.0 to 4.61	.22		0.51	0.17-1.56	.23	
Time from surgery to admission	−0.036	−0.084 to 0.011	.13		1.00	1.00-1.01	.67	
Model summary			<.001	0.36			.12	0.15

Abbreviation: CI, confidence interval.

variables.[24] All analysis was conducted using IBM SPSS, version 25.[a]

Results

Two statistical outliers for time from surgery to admission were removed from the analysis. The sample (n = 103) primarily included older individuals (age, 65.3±10.6y), 68% were men, and 64% were admitted for BKA with the main etiology owing to DM or vascular disease (table 1). Of the 4 bilateral amputees, 2 were admitted for BKA prosthetic fitting after a previous BKA fitting on the contralateral limb, 1 for initial bilateral BKA fitting, and 1 for initial bilateral AKA fitting. On discharge, 21.4% of the patients had a prosthetic fitting attempt that was deemed unsuccessful. These patients spent a total of 1447 days in inpatient rehabilitation.

Variables associated with longer LOS included having an AKA, lower admission FIM, and higher LLAMS (table 2). The overall model explained 36% of the variation in LOS. Figure 1 shows the relationship between LOS and these 3 variables. Age, sex, and time from surgery to admission were not significantly associated with LOS. The LLAMS score was the only variable significantly associated with prosthetic fitting (see table 2). The overall model explained only 15% of the variance in successful fitting. The LLAMS receiver operating characteristic curve was significant ($P = .021$), but the area under the curve for LLAMS was 0.66, indicating that the ability to identify failed prosthetic fitting was poor. Owing to the weakness of the LLAMS in correctly identifying failed prosthetic fitting, an appropriate cutoff value could not be identified.

Within the LLAMS, there were only 5 items that were associated with longer LOS and 5 items that were associated with unsuccessful prosthetic fitting (table 3). There was no overlap between the items associated with LOS and prosthetic fitting.

Discussion

The objective of this study was to examine variables associated with prolonged LOS and unsuccessful prosthetic fitting for individuals with LLA during inpatient rehabilitation. There were 4 main findings. First, despite undergoing prescreening for prosthetic candidacy before admission, 21.4% of the patients were unable to use the prosthesis on discharge, amounting to 1447 inpatient days that did not lead to a successful outcome. Second, the LLAMS tool was associated with LOS and prosthetic fitting, but it was a poor tool for identifying individuals who failed prosthetic fitting. AKA and lower admission FIM were also associated with longer LOS. Third, when deconstructing the LLAMS, only 10 items were associated with either prolonged LOS or failed prosthetic fitting. Items that described cognitive or mental health, clinical judgment, and living situation were most

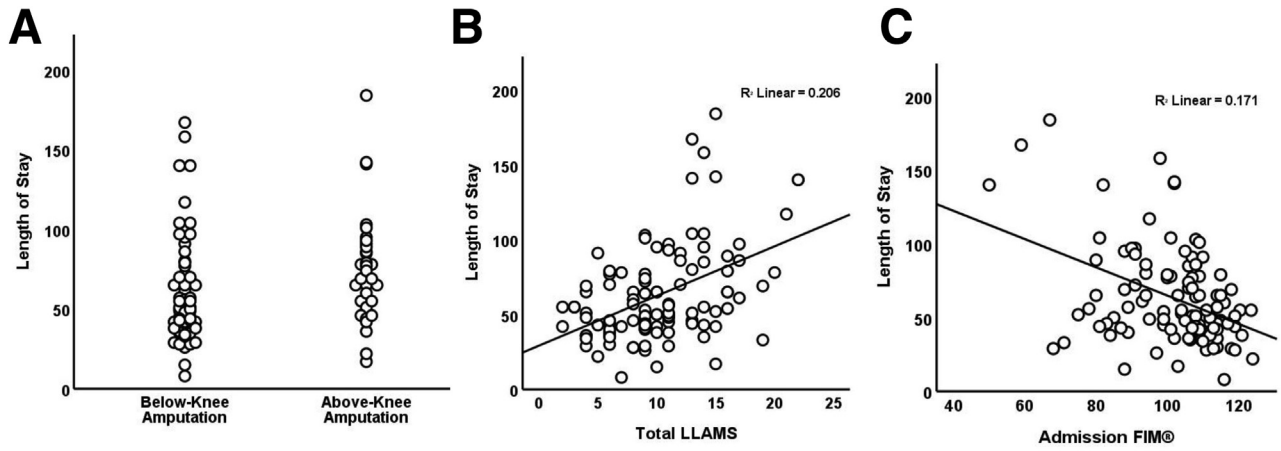

Fig 1 Relationship between LOS (in d) and level of amputation (A), LLAMS score (B), and admission FIM (C).

Table 3 LLAMS items associated with LOS and prosthetic fitting

Description	LOS	
	Beta (95% CI)	*P* Value
History of cognitive impairment/psychiatric illness	26.4 (12.7-40.2)	<.001
Assessor's gut feeling about fitting with a prosthesis (ie, patient will not benefit from receiving prosthetic leg)	23.4 (7.60-39.2)	.004
Lives alone on discharge	17.1 (5.46-28.8)	.004
Incontinence of bowel and/or bladder	15.2 (−1.16 to 31.5)	.068
Lives in inaccessible environment	10.9 (−0.77 to 22.6)	.067
	Successful Prosthetic Fitting	
	Odds Ratio (95% CI)	*P* Value
Requires assistance in dressing	0.19 (0.048-0.78)	.021
Stump not healed, skin ulcer grade 1-4	0.23 (0.068-0.78)	.018
Being a bilateral amputee	0.24 (0.046-1.28)	.095
Skin ulceration on the remaining foot/heel	0.25 (0.084-0.77)	.015
Inability to complete stump bandaging independently	0.26 (0.082-0.80)	.019

Abbreviation: CI, confidence interval.

associated with LOS, whereas functional ability and physical impairments were most associated with prosthetic fitting. Finally, variables that had previously been identified as predictors (ie, age, sex, and time since surgery), were not significantly associated with LOS or prosthetic fitting in this analysis.

The results of this study highlight the need for better management of LOS and improved screening among individuals with LLA being admitted to an inpatient rehabilitation facility. The mean LOS (63.6 days; see table 1) was longer than that of other inpatient rehabilitation centers in Canada (36 days).[5] However, the study sample included only individuals with LLA admitted for prosthetic fitting, whereas those included in the Canadian sample were admitted for various reasons. Most Canadian inpatient rehabilitation facilities provide 4 to 9 weeks of prosthetic rehabilitation for individuals with BKA or AKA.[6] The failed prosthetic fitting rate was also high compared with reports from other countries[12,25] but similar to the rate (23.3%) reported by other Canadian facilities.[6] Although evidence from the United Kingdom and the United States support the delivery of inpatient rehabilitation for individuals with LLA leading to improved outcomes[26,27] and earlier achievement of rehabilitation milestones,[28] identifying and targeting factors that affect outcomes before admission could improve prosthetic candidate selection and improve the likelihood of success. Data supporting the use of screening for amputees are sparse,[29] and further research is required to verify the potential benefits of pre-emptively addressing barriers to successful prosthetic fitting.

Although level of amputation (BKA vs AKA) was not associated with prosthetic fitting success in this study, having an AKA was associated with longer LOS. On average, patients with an AKA stayed 21 days longer (see table 2). Clearly, having an AKA requires greater energy expenditure to walk, and there is an added cognitive requirement to learn to walk with a prosthetic knee.[30] Previous studies have shown that having an AKA may affect walking ability but not necessarily the ability to be fit with a prosthesis.[7] The results presented in this study suggest the same. Although individuals with an AKA did require longer to complete inpatient rehabilitation, they were not significantly less likely to be successfully fit with a prosthesis.

Although FIM is completed for all rehabilitation admissions in Canada, its role in predicting outcomes for individuals with LLA is not clear. As in a previous study involving individuals with LLA,[19] lower admission FIM was significantly associated with longer LOS. However, because admission FIM is typically completed within 72 hours after admission to an inpatient rehabilitation facility, it is not useful in anticipating LOS before admission. Admission FIM score was not associated with prosthetic fitting. This is consistent with a previous finding by Leung et al,[23] although Erjavec et al[22] reported that FIM was a good predictor of prosthetic fitting among transfemoral amputees. FIM has been shown to predict LOS and functional outcomes in other rehabilitation groups such as stroke,[31] but its use for individuals with LLA requires further evaluation.

A key finding in this study was that the LLAMS was significantly associated with outcomes in both models (LOS and prosthetic fitting). For prosthetic fitting, the LLAMS was the only variable significantly associated with the outcome, which highlights the challenges with being able to determine who will be able to successfully complete prosthetic rehabilitation. Despite the statistically significant association, the LLAMS was not strong in discriminating between individuals who were successful or not. We were therefore unable to identify a cutoff value with high sensitivity and specificity for clinical use. When deconstructing the 31 items of the LLAMS, the items associated with LOS did not overlap with those associated with unsuccessful prosthetic fitting. Examining the LLAMS items showed that history of cognitive impairment or psychiatric illness added an average of 26 days to the LOS. Impaired cognition has previously been associated with poor outcomes.[7,8,10,11] Cognitive capacity and motor learning are inherently required to safely walk with a prosthesis.[32] Therefore, patients with cognitive deficits may require longer to gain

competence with tasks such as donning and doffing a prosthesis and prosthetic gait. In a recent systematic review,[11] 15 different cognitive scales were used in 9 studies to predict prosthetic use among older adults with amputation owing to vascular etiology. The authors recommended that a comprehensive cognitive assessment tool accounting for various subdomains (eg, visuospatial ability, memory) should be considered. This would allow researchers to more clearly identify the aspects of impaired cognition that affect rehabilitation of individuals with LLA.

When the assessors' "gut feeling" about prosthetic fitting was negative, the LOS was approximately 23 days longer. This "gut feeling" item in the LLAMS may take into account other factors involved in appraising the patient and making a clinical judgment, such as critically evaluating the patient's ability to match the high metabolic costs of walking with a prosthetic limb.[33] Clinical reasoning involves a complex interplay of memory, anecdotal evidence, and results of objective tests,[34] and was, in this case, a stronger predictor than many other variables. However, it is important to consider that the LLAMS assessors were also sometimes the same clinicians who were providing the interventions such that there was a risk of confirmation bias. Therefore, the assessors could have influenced LOS for patients that they felt would require more rehabilitation effort. Future research should examine the role of clinicians' gut feeling in predicting success in rehabilitation.

This study demonstrated that an individual's living situation on discharge can significantly affect prosthetic rehabilitation LOS. Inadequate social support has previously been associated with poor outcomes.[7] Specifically, individuals who live alone or in an inaccessible environment may require additional support to be discharged home or to another institution if they are not able to be accommodated in the community. This underscores the need to identify and plan for resources required for postdischarge living as early as possible to avoid prolonged LOS.

Although one may expect that comorbidities or cognitive and physical impairments would be major impediments to successful prosthetic fitting, in fact, of all the items included in the LLAMS, functional dependence in dressing reduced the odds ratio for successful fitting to 0.19. Dependence in activities of daily living has previously been associated with poor outcomes for individuals with LLA.[21] In this study, the overall level of function as measured by the FIM was not significantly associated with prosthetic fitting. Dependence in dressing may represent a specific issue for individuals with LLA. If an individual is unable to manage tasks such as dressing, they are likely to struggle with more complex tasks such as donning and doffing a prosthesis and managing changes in limb volume that affect prosthetic fit. To address important functional deficits, rehabilitation teams should include skilled health professionals who are familiar with the specific functional needs of individuals with LLA undergoing prosthetic fitting.[29]

Physical factors in the LLAMS, specifically skin ulceration of the residual limb or the remaining foot, reduced the odds ratio for successful fitting to 0.23 and 0.25, respectively. This is consistent with previous findings[8,12] and warrants examination in individuals being considered for prosthetic fitting. Interventions that improve wound healing should be used to address these issues before initiation of prosthetic fitting.

Shortening the LLAMS may be of value, because only 10 of the 31 items were associated with one of the outcomes. With 31 items, there may be redundancy in the LLAMS. For example, cognitive deficits may affect ability to dress and inability to complete wrapping of the residual limb but could be more related to manual dexterity than to ability to follow instructions. Before recommending changes to the current LLAMS, predictive modeling including all 31 indicators in a single model should be completed to develop a revised LLAMS, which could be validated in a prospective sample. Because the current study was a retrospective analysis with sample size limitations, this was not possible in our study.

Contrary to currently accepted evidence, age, sex, and time from surgery to admission were not associated with LOS or prosthetic fitting in this study. Previous research has reported that advanced age[5,7,19,20] and longer time from surgery to rehabilitation[7,12] negatively affect outcomes, whereas there have been more equivocal findings regarding sex.[7,9] Our findings may also be reflective of both screening for candidacy before admission and the use of short-term outcomes. In addition, the youngest patient in this sample was 38 years old, and the presence of more young adults in the sample could have changed the results. However, our findings suggest that age, sex, and time from surgery to rehabilitation do not always affect longer inpatient rehabilitation LOS and individuals with LLA should not be excluded from consideration for prosthetic fitting on the basis of these variables alone.

Study limitations

Owing to the homogeneity of this sample, findings can only be generalized to populations with major LLA caused by DM or peripheral vascular disease completing prosthetic rehabilitation at an inpatient rehabilitation facility. Because the data were collected on admission, the effects of some variables may have been muted by prescreening for prosthetic candidacy. In this study, the definition of successful prosthetic fitting outcome was subjective and short-term, determined by the treating physical therapist at discharge. As a retrospective analysis, variables were limited to those available for analysis, and potentially important variables were not able to be considered. In addition, a full subanalysis of the LLAMS could not be completed.

Conclusions

The LOS in inpatient rehabilitation for individuals with LLA can be lengthy and does not always lead to a successful prosthetic fitting at discharge. The LLAMS was associated with both LOS and successful fitting. The LLAMS, level of amputation, and admission FIM can be used to predict LOS. Within the LLAMS, history of cognitive impairment or psychiatric illness, clinical judgment, and living alone were associated with longer LOS. Dependence in dressing, incomplete wound healing on the residual limb, and ulceration of the remaining foot were associated with failed prosthetic fitting. Future studies should further investigate shortening the LLAMS and creating separate tools for the prediction of LOS and prosthetic fitting. This study demonstrated that advanced age, sex, and increased

time from surgery to rehabilitation were not associated with LOS or ability to successfully complete inpatient prosthetic fitting in a cohort of prescreened prosthetic candidates.

Supplier

a. IBM SPSS, version 25; IBM Corp.

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