## Title
Lower Extremity Amputations Among Veterans: Have Ambulatory Outcomes and Survival Improved?



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# Lower Extremity Amputations Among Veterans: Have Ambulatory Outcomes and Survival Improved?

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**Background:** We hypothesize among patients undergoing lower extremity amputation, access to pre-, and post operative rehabilitation services; as well as improved medical care, have led to higher rates of postoperative ambulation, and improved survival.
**Methods:** Retrospective single center review of all major lower extremity amputations performed at the Greater Los Angeles Veterans Affairs Healthcare System from 2000–2020 stratified into multiyear cohorts. We abstracted demographics, operative indication, comorbidities, preoperative medical management, perioperative complications, discharge location, and pre and postoperative ambulatory status. Odds of ambulation after amputation were analyzed using multivariate logistic regression. Survival was analyzed using multivariate logistic regression and Kaplan-Meier survival analysis. Multivariate logistic predictors were selected based on prior literature and clinical experience.
**Results:** We identified 654 operations in our study, noting fewer amputations performed in the latest 3 cohort years as compared to the initial cohort (2000–2004). Patients undergoing below-knee amputations (BKA) had 2.7 times ($P < 0.05$) greater odds of postoperative ambulation and 86% ($P < 0.05$) increased odds of survival compared to above-knee amputations (AKA). The odds of ambulation increased by 8.8% ($P < 0.05$) for each consecutive study year. Ambulation post-amputation conferred 13.2 times ($P < 0.05$) greater odds of survival. The odds of survival in "emergent" operations decreased by 48% ($P < 0.05$) compared to an "elective" operation. For each additional comorbidity, the odds of survival decreased by 18% ($P < 0.05$). Patients with any perioperative complication had a 48% ($P < 0.05$) lower odds of survival. Kaplan-Meier survival estimates demonstrated significant survival difference between patients by amputation level and postoperative ambulatory status ($P < 0.05$).
**Conclusions:** Ambulatory status following distal amputation has improved over time and is significantly associated with increased survival post-amputation. Patients undergoing a BKA or discharged home were most likely to ambulate postoperatively. Amputation level, preoperative comorbidities, and perioperative complications remain strong predictors of survival.

Declarations of interest: none.

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## INTRODUCTION

There are approximately, 150,000 lower extremity amputations performed in the United States each year, predominantly in patients with peripheral arterial disease (PAD) or diabetes mellitus (DM).[1,2] Undergoing a major lower extremity amputation portends a poor survival prognosis and adversely impacts a person's functional status. The amputation level at a below the knee (BKA), above the knee (AKA), or through-knee (TKA) site may also influence post operative ambulation which affects a patient's quality of life postamputation. The level of amputation plays a significant role in mortality risk and postoperative functional status.[1] A multicenter study by the Vascular Study Group of New England (VSGNE) reviewed 1-year postoperative functional outcomes in patients who underwent amputation after failed attempts at revascularization. Ambulation with or without assistance was achieved in 65.1% of those who received a BKA, but in only 41.3% of those who received an AKA.[2] This difference has been attributed in part to an increase in energy expenditure required for more proximal amputation.[3] In another study, O'Banion et al. reported that patients undergoing AKAs had nearly a 25% increase in mortality, combined with a lower likelihood of ambulation at a high functioning level, as compared to BKA.[4]

A retrospective review in 2005 by Taylor et al. identified increased risk of nonambulation and decreased 1-year survival in patients of advanced age (>70 years), limited preoperative ambulatory status, proximal level of amputation, and history of end-stage renal disease (ESRD) or advanced coronary artery disease (CAD).[5] Karam et al. corroborated some of these findings among veterans, noting ESRD, advanced age, and level of amputation as factors negatively affecting postoperative 30-day mortality.[6]

The Greater Los Angeles Veterans Affairs Healthcare System offers a multidisciplinary amputee clinic which hosts amputation surgeons, physiatrists, prosthetists, wound care specialists, and social workers. Coordinated services strive to help patients achieve postamputation ambulation with the hope of improving postoperative outcomes, similar to multidisciplinary care teams that have demonstrated a 2-fold increase in survival without subsequent amputation.[7]

We hypothesize that with increased patient access to limb-salvage operations, rehabilitation services, and multidisciplinary amputee care, there should be a concomitant increase in the proportion of patients achieving postoperative ambulation, as well as improved survival. In this retrospective study of lower extremity amputations in the Greater Los Angeles Veterans population, we investigate temporal changes that may affect amputation outcomes and mortality.

## METHODS

We retrospectively reviewed all major lower extremity amputations including BKA, TKA, and AKA performed by the vascular or orthopedic surgery service at the Greater Los Angeles Veterans Affairs Health System from January 1, 2000—December 31, 2020. We abstracted patient demographics, operative characteristics, perioperative complications, length of hospital stay, and length of follow-up, discharge location, and pre- and postoperative evaluations by multidisciplinary amputation teams. Patients with incomplete data were excluded from data analysis. Cohorts were grouped in 5-year intervals, except for 2015—2020, which is inclusive of 6 years.

Referral to amputee clinic is often initiated by one of 3 surgical services; Podiatry, Orthopedics, or Vascular; however, referrals are not limited to the listed services. Our amputee clinic is currently overseen by physical medicine and rehabilitation; evaluation includes observed transfers, and gait training with physiologic testing (transcutaneous pulse oximetry and/or ankle brachial index), and medical optimization completed at the discretion of the lead amputologist.

Operative indications included chronic limb ischemia, acute limb ischemia, infection, trauma, and/or tumor. Secondary to these indications, amputations were classified as elective, urgent, or emergent based upon the patient's clinical severity as defined by leukocytosis, hyponatremia, or evidence of hemodynamic instability. Elective cases were medically stable patients with a nonsalvageable lower extremity not requiring immediate treatment. Urgent cases were classified as medically stable patients requiring imminent amputation. Emergent cases were defined as hemodynamically unstable patients with a presumed life-threatening lower extremity infection requiring immediate amputation. Medically unstable patients requiring amputation underwent initial guillotine amputation. Once medically stable, this was followed by a separate formalization procedure to close the wound. Preoperative medical management included medication regimen within 30 days of operation, and imaging (angiogram, Duplex, CT angiography, MR angiography,

or $TcPO_2$) within 30 days. Perioperative complications were evaluated on a cumulative scale without regard to severity of complication. Discharge location was recorded from patients' discharge notes. Preoperative ambulatory status was abstracted from surgical or perioperative anesthesia provider history and physical notes using a 3-point scale of 1 (ambulatory), 2 (ambulatory with assistance), or 3 (nonambulatory). Assistive ambulation devices included front-wheeled walker, 4-wheeled walker, cane, or crutches. Postoperative ambulatory status was evaluated using notes from physical medicine and rehabilitation specialists or prosthetists notes when the former was unavailable. Primary outcomes were 1- and 5-year survival rates, and postoperative ambulatory status at last amputee clinic follow-up visit. Secondary outcome was hospital length of stay following major amputation.

Odds of ambulation post-amputation were analyzed using multivariate logistic regression with preoperative ambulatory status, amputation level, discharge location, pre- and postoperative multidisciplinary clinic evaluation, and year performed as predictors. Candidate variables were selected from literature review of previously identified risk factors, such as amputation level and discharge location, in addition to variables with suspected clinical contribution to the patient population of the Greater Los Angeles Veterans Affairs, namely preoperative ambulatory status and year performed. Pre-operative evaluation in our amputee clinic was incorporated as a covariate for our multivariate model constructed to predict postoperative ambulation as we hypothesized that earlier evaluation in a multidisciplinary clinic would yield higher odds of ambulation following surgery. Post-operative evaluation in our amputee clinic was incorporated as a covariate for our multivariate model constructed to predict survival as we hypothesized that urgent and emergent amputation may be less likely to have an amputee clinic evaluation preoperatively, however, could be connected with amputation services following surgery which may impact their survival.

Survival was analyzed using Kaplan-Meier survival analysis and multivariate logistic regression with predictors of operative urgency, amputation level, comorbidities (Table I), perioperative complications (Table II), and pre- and postoperative ambulatory status. Similarly, to odds of ambulation, predictors were selected based on prior literature with the addition of pre- and postoperative ambulation to quantify and compare their strengths of association with postoperative survival. Length of stay was analyzed using linear regression with prior ambulatory status, open amputation, case urgency, perioperative complications, and cohort years as predictors. These predictors were grossly selected based on hypothesized influential factors that were specific to the Greater Los Angeles Veterans Affairs Healthcare System. Multivariate logistic regression and linear regression models were constructed utilizing cluster robust standard errors to adjust for the presence of nonindependence in the data due to multiple operations on a single patient due to revisions, bilateral amputations, or more proximal amputation on the ipsilateral extremity. Statistical significance of regression models was measured using a $P$-value $< 0.05$. Significance of Kaplan-Meier survival curves were measured using a $P$-value $< 0.05$.

### Institutional Review Board Approval

This study was deemed exempt by the Greater Los Angeles Veterans Affairs Healthcare System IRB (project # 2021—000,386). Patient informed consent was not required.

## RESULTS

### Demographics

We identified 654 operations performed on 423 patients between January 1, 2000 and December 31, 2020 with fewer patients receiving amputations over time. Patient demographics and operative characteristics are listed in Tables I and II Most patients were male. Chronic limb ischemia and infection encompassed the majority of operative cases with 77% and 71% involving the respective indication. Among cohorts, 209 operations occurred in 2000—2004, 141 occurred in 2005—2009, 168 occurred in 2010—2014, and 135 occurred in 2015—2020. The average age at time of operation was 66 years old standard deviation (SD +/− 10.1). The average age at the time of death was 70 years old (SD +/− 10.1). The average length of stay was 36.8 days (Table III). 482 (73.7%) operations were classified as elective, 96 (14.7%) were urgent, and 76 (11.6%) were emergent. One hundred and forty-nine operations were AKAs, 449 were BKAs, and the remaining 56 were TKAs. Three hundred and sixty-seven operations were performed by orthopedic surgery while vascular surgery performed 286 operations. Among evaluations completed, 52.6% of patients received a preamputation multidisciplinary amputee team evaluation while 90% received a postamputation

**Table I.** Study cohort

| Demographics | |
|---|---|
| Operations, *n* (%) | 654 |
| Above knee amputation | 149 (23) |
| Through knee amputation | 56 (9) |
| Below knee amputation | 449 (68) |
| Patients, *n* | 423 |
| Age at amputation − years: average (S.D.) | 66 (10.1) |
| Age at death − years: average (S.D.) | 74 (10.1) |
| Male, *n* (%) | 650 (99.4) |
| BMI, average (S.D.) | 27 (6.42) |
| Race, *n* (%) | |
| Black/African American | 268 (41) |
| White | 354 (54) |
| Other | 32 (5) |
| Asian | 7 |
| American Indian/Alaskan Native | 11 |
| Native Hawaiian/Pacific Islander | 6 |
| More than one race | 2 |
| Unknown/other | 6 |
| Ethnicity Hispanic, *n* (%) | 92 (14) |
| Ambulatory Status prior to amputation, *n* (%) | |
| Ambulatory | 135 (20) |
| Ambulatory with assistance | 174 (27) |
| Nonambulatory | 345 (53) |
| Co-morbidities, *n* (%) | |
| Peripheral Arterial Disease | 466 (71) |
| Atrial Fibrillation | 77 (12) |
| Myocardial Infarction | 101 (15) |
| Congestive Heart Failure | 135 (21) |
| Coronary Artery Disease | 265 (41) |
| Hyperlipidemia | 265 (41) |
| Hypertension | 561 (86) |
| Cancer | 81 (12) |
| Diabetes | 504 (77) |
| Chronic Kidney Disease | 156 (24) |
| Mental Health Diagnosis | 158 (24) |
| Ever Smoked | 495 (76) |
| Current Smoker | 219 (33) |

evaluation (Supplemental Table I). The average length of long-term follow-up for the entire cohort was 2.7 years (SD +/− 3.8 years). The average length of long-term follow-up was 4.3 years (SD +/− 3.6 years) among patients that achieved post-amputation ambulation with use of a prosthetic, as compared to 1.9 years (SD +/− 2.9 years) for patients that did not ambulate. Two hundred and nineteen (33.5%) patients were ambulatory with the use of a prosthetic following amputation at the last amputee clinic follow-up visit.

The proportion of patients on beta-blocker, antiplatelet, statin or insulin increased over time when comparing the 2000−2005 cohort to the 2015−2020 cohort. Perioperative complications occurred in 24.5% of operations (Table II). Discharge status was as follows: 46% to an acute rehabilitation facility (ARF), 32% to a skilled nursing facility (SNF), 16% to home, 4% died in hospital, and the remaining 2% were discharged to a different inpatient facility (Table III).

The 1-year mortality rates for BKA, TKA, and AKA were 17.2%, 33.6%, and 30.2%, respectively. 5-year mortality rates for BKA, TKA, and AKA were 53.7%, 65%, and 68.2%, respectively.

## Postoperative Ambulation

Patients undergoing BKA had a 2.6 [OR: 2.6, 95% CI: 1.5, 4.6] ($P < 0.05$) times greater odds of

**Table II.** Operative characteristics by cohort year

| Cohort | 2000–2004 | 2005–2009 | 2010–2014 | 2015–2020 |
|---|---|---|---|---|
| Amputations, *n* (%) | 210 | 141 | 168 | 135 |
| Age, years, avg (S.D.) | | | | |
| Amputation | 64 (11) | 66 (11) | 65 (9) | 68 (9) |
| Death | 70 (11) | 71 (11) | 70 (8) | 73 (10) |
| Medications at time of amputation, *n* (%) | | | | |
| Beta-blocker | 93 (43) | 97 (69) | 101 (60) | 62 (46) |
| Aspirin or Plavix | 81 (39) | 71 (50) | 67 (40) | 64 (47) |
| ACEI/ARB | 80 (38) | 84 (59) | 102 (61) | 49 (36) |
| Statin | 69 (33) | 96 (68) | 116 (69) | 97 (71) |
| Insulin | 107 (51) | 82 (58) | 126 (75) | 87 (64) |
| Oral Hypoglycemic | 33 (16) | 22 (16) | 37 (22) | 24 (18) |
| NOAC/Warfarin | 20 (10) | 23 (16) | 8 (5) | 14 (10) |
| Opiate | 82 (29) | 72 (51) | 111 (66) | 63 (46) |
| Amputation level | | | | |
| Above knee | 52 (25) | 36 (26) | 34 (20) | 27 (20) |
| Through knee | 12 (6) | 2 (1) | 14 (8) | 28 (21) |
| Below knee | 146 (69) | 103 (74) | 120 (72) | 80 (59) |
| Case status, *n* (%) | | | | |
| Elective | 143 (68) | 97 (69) | 134 (80) | 108 (80) |
| Urgent | 38 (18) | 24 (17) | 21 (12) | 10 (7) |
| Emergent | 29 (14) | 20 (14) | 13 (8) | 17 (13) |
| Anesthetic technique, *n* (%) | | | | |
| General | 131 (62) | 90 (64) | 124 (74) | 124 (92) |
| Regional | 18 (9) | 46 (33) | 6 (3) | 6 (4) |
| Spinal | 61 (29) | 5 (3) | 38 (23) | 5 (4) |
| Operative time: min, avg (S.D.) | 79.5 (42.5) | 74.8 (37.2) | 102 (37.8) | 104.2 (42) |
| Estimated blood loss; cc, avg (S.D.) | 147.2 (169.7) | 119.4 (135.4) | 168 (147.3) | 219 (206) |
| Intraoperative transfusion, *n* (%) | 19 (9) | 5 (3) | 10 (6) | 9 (7) |
| Operating service, *n* (%) | | | | |
| Vascular Surgery | 151 (72) | 85 (60) | 30 (18) | 21 (15) |
| Orthopedics | 59 (28) | 56 (40) | 138 (82) | 115 (85) |
| Indication, *n* (%) | | | | |
| Chronic limb ischemia | 180 (86) | 112 (79) | 128 (76) | 83 (63) |
| Acute limb ischemia | 0 | 4 (3) | 2 (1) | 1 (<1) |
| Infection | 160 (76) | 122 (87) | 93 (55) | 91 (67) |
| Trauma | 13 (6) | 7 (5) | 8 (5) | 5 (4) |
| Tumor | 1 (<1) | 0 | 3 (2) | 1 (<1) |
| Ambulatory Status, *n* (%) | | | | |
| Pre-amputation | | | | |
| Ambulatory | 124 (59) | 64 (45) | 72 (43) | 49 (36) |
| Nonambulatory | 86 (41) | 77 (55) | 96 (57) | 86 (64) |
| Post-amputation | | | | |
| Ambulatory | 52 (25) | 31 (22) | 82 (49) | 53 (39) |
| Nonambulatory | 158 (75) | 110 (78) | 86 (51) | 83 (61) |
| Perioperative Complication, *n* (%) | | | | |
| Pneumonia | 10 (11) | 1 (3) | 7 (18) | 10 (21) |
| Unplanned intubation | 11 (12) | 3 (9) | 7 (18) | 4 (9) |
| Pulmonary embolism | 1 (1) | 0 | 0 | 0 |
| Deep vein thrombosis | 13 (14) | 1 (3) | 0 | 4 (9) |
| GI bleed | 3 (3) | 1 (3) | 1 (3) | 3 (6) |
| Intubated >48 hr | 22 (24) | 10 (29) | 8 (21) | 6 (13) |
| Acute renal failure | 22 (24) | 8 (24) | 6 (15) | 10 (21) |
| New need for hemodialysis | 3 (3) | 6 (17) | 2 (5) | 3 (6) |
| Stroke | 1 (1) | 0 | 2 (5) | 2 (4) |
| Myocardial infarction | 7 (7) | 4 (12) | 6 (15) | 5 (11) |

**Table III.** Length of stay, survival, and discharge location by cohort year

| Cohort | 2000–2004 | 2005–2009 | 2010–2014 | 2015–2020 |
|---|---|---|---|---|
| Inpatient length of stay | | | | |
| Days, average (S.D.) | 46 (42) | 42 (43) | 37 (52) | 25 (29) |
| Survival, *n* (%) | | | | |
| Alive at 1 year | 152 (72) | 114 (81) | 140 (83) | 99 (73) |
| Alive at 5 years | 93 (44) | 58 (41) | 95 (57) | 29 (21) |
| Discharge location, *n* (%) | | | | |
| Skilled nursing facility | 91 (44) | 37 (26) | 29 (17) | 55 (41) |
| Home | 34 (16) | 20 (14) | 29 (17) | 19 (14) |
| Acute rehabilitation facility | 74 (35) | 70 (50) | 101 (61) | 56 (42) |
| In-hospital death | 11 (5) | 8 (6) | 4 (2) | 1 (<1) |
| Inpatient hospital | 0 | 6 (4) | 5 (3) | 4 (3) |

postoperative ambulation with a prosthetic as compared to those undergoing AKA. Patients undergoing TKA had 15% [OR: 0.85; 95% CI: 0.34, 2.1] decrease in odds of postoperative ambulation with a prosthetic as compared to those undergoing AKA, although this was not statistically significant ($P = 0.72$). Patients who were nonambulatory prior to amputation had a 59% [OR: 0.41; 95% CI: 0.24, 0.69] ($P < 0.05$) decrease in odds of postoperative ambulation with a prosthetic as compared to patients able to ambulate prior to amputation. Patients who were ambulatory but with assistance prior to amputation had an 17% [OR: 0.82; 95% CI: 0.49, 1.40] decrease in odds of postoperative ambulation with a prosthetic, but this was not statistically significant ($P = 0.48$). The odds of postoperative ambulation increased by 8.8% [OR: 1.08; 95% CI: 1.05, 1.13] ($P < 0.05$) for each consecutive year in our study period. Vascular interventions prior to amputation demonstrated a 28% [OR: 1.29; 95% CI: 0.86, 1.94] increase in odds of postoperative ambulation with a prosthetic, however, was not statistically significant ($P = 0.22$). Preoperative evaluation by a multidisciplinary amputation team increased the odds of postoperative ambulation with a prosthetic by 55% [odds ratio OR: 1.55; 95% confidence interval CI: 1.06, 2.27] ($P < 0.05$). Patients discharged to an ARF had a 41% [OR: 0.59; 95% CI: 0.36, 0.97] ($P < 0.05$) reduction in odds of ambulation with a prosthetic as compared to those discharged to home; while those discharged to an SNF had an 82% [OR: 0.18; 95% CI: 0.10, 0.33] ($P < 0.05$) reduction in the odds of ambulation with a prosthetic (Supplemental Table II).

## Postoperative Survival

Patients undergoing BKA had an 86% [OR: 1.86; 95% CI: 1.09, 3.17] ($P < 0.05$) increase in odds of survival when compared to AKA. Patients undergoing TKA had a 3.8% [OR: 1.03; 95% CI: 0.50, 2.14] increase in odds of survival when compared to AKA, but this was not found to be statistically significant ($P = 0.92$). The odds of survival in "emergent" operations decreased by 48% [OR: 0.52; 95% CI: 0.28, 0.95] ($P < 0.05$) when compared to "elective" operations. The odds of survival in "urgent" operations decreased by 35% [OR: 0.65; 95% CI: 0.35, 1.21] when compared to "elective" operations, but this did not reach statistical significance ($P = 0.18$). For each additional comorbidity, the odds of survival decreased by 18% [OR: 0.82; 95% CI: 0.70, 0.96] ($P < 0.05$). Experiencing any perioperative complication conferred a 48% [OR: 0.52; 95% CI: 0.29, 0.95] ($P < 0.05$) decrease in odds of survival. Ambulation with assistance conferred a 38% [OR: 1.38; 95% CI: 0.54, 3.53] increase; while nonambulation conferred a 10% [OR: 0.90, 95% CI: 0.37, 2.17] decrease, in odds of survival as compared to patients able to ambulate prior to amputation, but neither were found to be statistically significant ($P = 0.50$, $P = 0.82$) Ambulation with a prosthetic post-amputation conferred a 13.2 [OR: 13.2, 95% CI: 4.11, 42.36] ($P < 0.05$) times greater odds of survival when compared to nonambulatory status following surgery. All cohort years when compared to initial cohort 2000–2005 were not found to be statistically significant ($P > 0.05$) in predicting postoperative survival (Supplemental Table III).

Kaplan-Meier survival estimates demonstrated survival difference by amputation level and postoperative ambulatory status ($P < 0.05$). By amputation level, 50% of patients undergoing a BKA, TKA, or AKA were expected to survive for an additional 5.3 [95% CI: 4.4, 6.0], 3.5 [95% CI: 0.9, 6.4], or 2.7 [95% CI: 1.5, 4.1] years respectively (Fig. 1). These survival curves begin to intersect near the 10-year postoperative point,

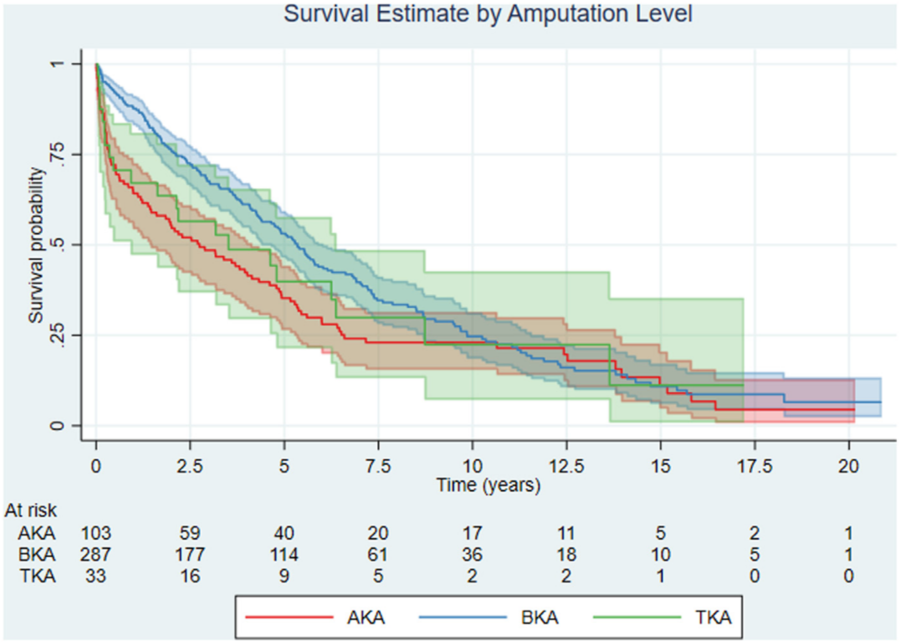


**Fig. 1.** Legend: Kaplan-Meier survival analysis of lower extremity amputations by amputation level. The transparent overlay of the respective curve serves as standard error margins. The survival curve demonstrates a statistically significant median survival length of 2.7, 5.3, and 3.5 years for patients undergoing above knee, through knee, and below knee amputations respectively ($P < 0.05$).

demonstrating a limit to long-term advantage by level. By postoperative ambulatory status, patients ambulating with a prosthesis experienced an increased median survival of 7.9 [95% CI: 6.8, 10.4] years vs. 2.5 [95% CI: 2.0, 3.2] years in non-ambulatory patients (Fig. 2). Those capable of attaining ambulation with a prosthetic following amputation were observed to have an advantage of survival up to the 15-year mark (Supplemental Table IV). Analysis by cohort years were found to have sequentially increasing median survival years of 3.2 [95% CI: 2.2, 4.8], 4.2 [95% CI: 3.2, 5.5], 5.4 [95% CI: 4.3, 6.5] and 5.6 [N/A] years respectively, but this was not statistically significant ($P = 0.16$) with restricted analysis of the 2015−2020 cohort, in part due to limited longitudinal data (Fig. 3).

### Length of Stay

The average hospital stay was 36.8 days (SD +/− 50.3 days) (Table III). Patients who were nonambulatory prior to amputation had an increase of 8.5 [95% CI: −0.40, 17.4] days (SE +/− 4.5 days) in length of stay, though this was not statistically significant ($P = 0.061$). Operative urgency was not statistically associated with length of stay. There was no observed association between length of stay for urgent cases as compared to elective ($P = 0.252$) or when comparing emergent cases to elective cases ($P = 0.748$). The presence of one perioperative complication prolonged the length of stay by an average of 36 [95% CI: 26.0, 47.1] ($P < 0.05$) days (SE +/− 5.4 days) as compared to patients without complications. Comparison between the 2000−2004 and 2015−2020 cohorts demonstrated a reduction in length of stay by 14.4 [95% CI: −23.3, −5.49856] ($P < 0.05$) days (SE +/− 4.5 days) in the latter group.

## DISCUSSION

Major lower extremity amputation remains a morbid procedure and is characterized by significant risk of postoperative decline in ambulatory status and survival. Prior research has predominantly identified comorbidities and operative characteristics that overarchingly worsen patient mortality and postoperative ambulation, which adversely influences a patient's quality of life. Previous research has demonstrated that the likelihood of a proximal lower extremity amputation is most closely correlated to number of comorbid conditions, and physiologic tolerance for lower extremity revascularization such that the unhealthiest patients are

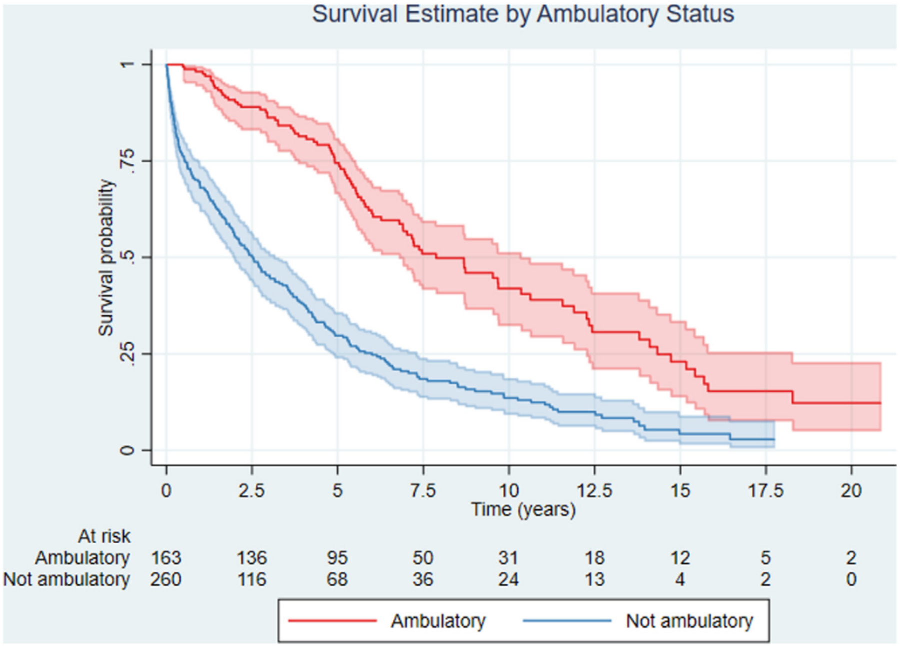


**Fig. 2.** Legend: Kaplan-Meier survival analysis of lower extremity amputations by postoperative ambulatory status. The transparent overlay of the respective curve serves as standard error margins. The survival curve demonstrates a statistically significant increased median survival length of 5.4 years between ambulatory and nonambulatory patients postoperatively ($P < 0.05$).

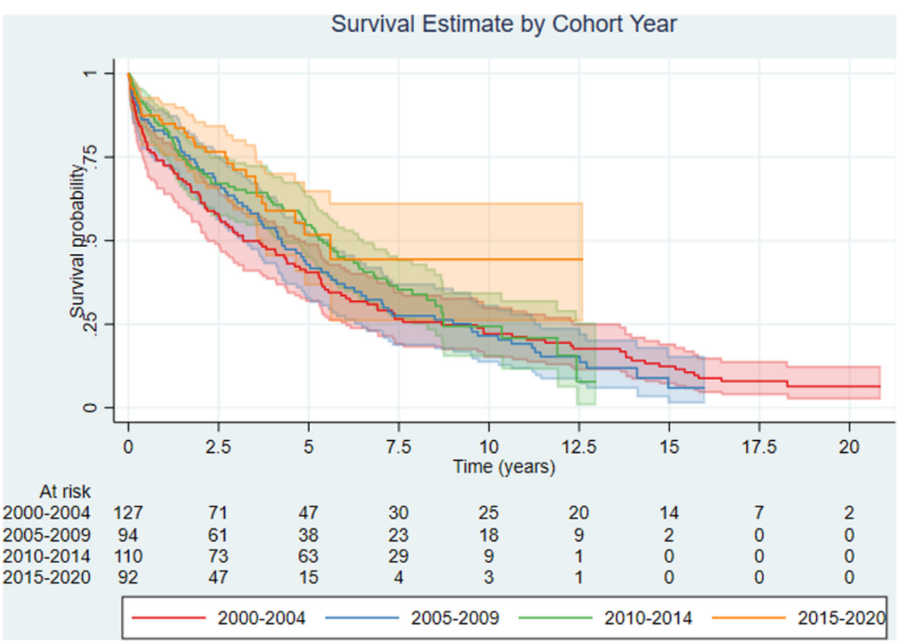


**Fig. 3.** Legend: Kaplan-Meier survival analysis of lower extremity amputations by cohort years. The transparent overlay of the respective curve serves as standard error margins. These curves were found not to be statistically significant ($P = 0.16$).

the most likely to undergo an above knee amputation. This study serves to track how these outcomes have changed over time, corroborate preoperative risk factors, and identify new postoperative factors that contribute to postoperative ambulation and increased survival rates. In this retrospective study of 654 patients undergoing major lower extremity amputations at the Greater Los Angeles VA, we found proximal amputation level, multidisciplinary care teams, and discharge home increased the odds of postoperative ambulation in addition to finding a gradual increase in odds of ambulation yearly. Odds of survival were positively influenced by distal amputation level, fewer comorbidities, no complications, elective operative urgency, and most significantly, achievement of postoperative ambulation with a prosthetic.

Prior studies have identified preoperative nonambulatory status, preoperative comorbidities, and proximal level of amputation as risk factors for poor postoperative ambulatory outcome, findings supported in this study, Impairment in ambulation frequently results in deconditioning and progression of comorbidities, both of which may impede postoperative physical therapy and prosthetic training. As an additive effect, the increased energy expenditure required from more proximal amputation levels results in an even more demanding postoperative recovery period.[5] Improving limb-salvage efforts to avoid poorer postoperative outcomes requires aggressive preoperative care, such as in the form of multidisciplinary care teams, to target the preoperative conditions that put patients at risk for poor operative outcomes. Our study findings demonstrate that evaluation and care by a preoperative multidisciplinary amputation team serves as a positive predictor of achieving postamputation ambulation. Ambulation status improved each progressive year of our study, suggesting gradual improvement in medical care. This may be explained by Chung et al.'s assertion that multidisciplinary care provides improved access to care in the form of ''a more coordinated delivery model,'' earlier interventions, and ''improved surveillance may help to ensure that revascularization efforts are fully maximized,'' potentially lowering the preoperative acuity of these patients.[7]

In contrast to the O'Banion et al. study, which was performed at a private institution, our study demonstrated an increased likelihood of postoperative ambulation in patients discharged home rather than to an acute rehab facility.[6] This difference may be in part due to the policies of government-run institution, where there is greater lenience regarding discharge timeline, permitting Veterans more time with onsite special rehabilitation units in comparison to their civilian counterparts.[8] Our patient population had an average length of stay just over a month. Our observed length of stay is likely multifactorial and influenced by institutional policies as well as disease burden in our patients as compared to the general population. In addition, this study included all eligible patients who received an amputation at the Greater Los Angeles VA from 2000–2020 regardless of initial chief complain; as a result, time to operation was influenced by unrelated indications for admission requiring optimization, trialing conservative therapies, or unexpected clinical deterioration during their admission with many patients receiving an amputation weeks into their hospital admission for a seemingly unrelated diagnosis. Coupled with this extended length of stay, patients that were discharged home may have achieved greater postoperative functional status with additive support of in-home rehabilitation. However, with the limitation of subjective postoperative notation, this value may be conflated with an increase in ambulatory independence with possible assistive resources such as home health to achieve a safe disposition to home. Further studies should seek to ascertain true functional status postoperatively with more objective data.

Our study concurs with previous literature in that the presence of comorbidities, perioperative complications, and proximal amputation level negatively impacted patients' survival, and that outcomes are worse among those undergoing emergent procedures. Each patient approaches the possibility of amputation with a unique set of preoperative conditions. Understanding of how these factors affect postoperative outcomes permit the care team to improve patient-centered care to maximize likelihood of survival and quality of life. We also identified a general increase in the proportion of patients on a beta-blocker, antiplatelet agent, statin, or insulin over time. There exists a robust literature demonstrating the decreased risks of all cause and limb associated mortality when patients are managed with best medical therapy.[9,10] Though we did not demonstrate an association between medical management and long-term survival in our study population, it stands to reason, that increased use of antiplatelet agents and statin therapy has increased survival for our advanced peripheral arterial disease patients.

Postoperative ambulatory status demonstrated the strongest positive association with survival among patients undergoing BKA as compared to those undergoing AKA. This finding reinforces the importance of prioritizing postoperative rehabilitation and mobilization as this is a factor that greatly influences both a

patient's quality of life as well as long-term survival.[6] However, our Kaplan-Meier survival estimates demonstrated that this is ultimately a time-dependent effect, as demonstrated by the eventual intersection of survival curves. Potential explanations for this may include increased severity of comorbidities or age-related functional decline that may be expected towards the end of a person's life. Contrary to our expectations, we also did not find a strong correlation between cohort year of operation and improved odds or estimates of long-term survival. As previously stated, patients of the VA frequently present with significant disease burden that persists postoperatively, possibly standing as a greater obstacle to long-term survival. Analysis of long-term survival was also limited by incomplete data among those within the final cohort who had recently undergone their amputation.

Our study has several limitations. Our study population is limited to Veterans at a single center, reducing external validity to the general population. We were unable to abstract or analyze amputee care received by Veterans outside of our VA health system which may have underestimated the amputations undergone by our patient population. In addition, most patients were white or African-American males, limiting the ability to evaluate differences in primary outcomes based on race, ethnicity, or gender. Nonindependence of data due to multiple revisions and unequal operations per patient permits increased variance in measured estimates, but this was corrected using cluster robust standard errors. Multivariate logistic regression of mortality invited some bias due to censoring of patients with recent operations. However, the survival analysis model aims to provide a more accurate depiction of variables' effects on mortality. When analyzing survival estimates, the latest cohort had the limitation of incomplete data regarding 5-year estimates past 2015.

## CONCLUSION

Our study demonstrates a gradual improvement in survival outcomes as well as length of stay over the course of the 21-year period, suggesting an improvement in medical management, and supports previous research describing amputation level, preoperative comorbidities, and perioperative complications as strong predictors of mortality. One of the greatest predictors of long-term survival rate was postoperative ambulation with use of a prosthetic, suggesting the necessity of ambulation to positively impact postoperative survival. While this appears to be a time-dependent effect, postoperative ambulation has significant impact on quality of life that cannot be underestimated. Further research can expand on optimization of prosthetic training as well as points of care where patients may be lost to follow-up. Moving forward, postoperative follow-up should place an emphasis on ambulation via prosthetic training and physical rehabilitation.

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