Understanding Functional and Hemodynamic Outcomes Across Lower Extremity Amputation Levels

Anvitha R Madhavaram, BS, BA[1], Fatima Khan, BS[1], Catherine A. Cash, BS[1], Richard Simman, MD, FACS, FACCWS[2,3].

1) University of Toledo, College of Medicine and Life Sciences, 3000 Arlington Ave., Toledo, Ohio.
2) Department of Surgery, Plastic Surgery, University of Toledo College of Medicine, Toledo, Ohio.
3) Jobst Vascular Institute, ProMedica Health Network, Toledo, Ohio.

THE UNIVERSITY OF TOLEDO

Introduction

Lower extremity amputation (LEA) significantly alters an individual's life, affecting not only functional capabilities but also cardiovascular health. The relationship between amputation levels and subsequent functional and hemodynamic outcomes is complex. Hemodynamic outcome measures -- such as blood circulation, venous return to the heart, stroke volume, and cardiac output -- are ways to assess how well the heart is working and how blood is circulating. Each amputation level varies in degree of changes to these measures, can cause cardiovascular strain, and increases in energy expenditure during ambulation.

A comprehensive review specifically focused on hemodynamic outcomes across different lower extremity amputation levels is currently not readily available. This review aims to examine these outcomes across different levels of LEAs, including hemipelvectomy, hip disarticulation, above-knee amputation (AKA), knee disarticulation, below-knee amputation (BKA), Syme's amputation, Chopart's amputation, Lisfranc's amputation, and toe disarticulation to elucidate these relationships and suggest directions for future research and clinical management.

Methods

This review systematically analyzed English-language studies published between 1970–2024 on functional and hemodynamic cardiovascular outcomes across various amputation levels. A combination of keywords and MeSH terms related to "amputation," "functional outcomes," "hemodynamic outcomes," and "rehabilitation" was used. Eligible studies included observational designs and clinical trials reporting relevant outcomes. Due to heterogeneity, data were synthesized narratively and categorized by amputation level. Key variables included energy expenditure, cardiac strain, mobility, performance of activities of daily living (ADLs), patient satisfaction, and mortality.

Functional Outcomes

Hip Disarticulation and Hemipelvectomy

- Major hemodynamic disruption due to the removal of pelvic structures and large muscle groups; marked increase in energy expenditure and cardiovascular strain during ambulation; prosthetic use is limited; patient satisfaction tends to be low.

Above Knee Amputation (AKA)

- Walking requires 60–100% more energy than in non-amputees; prosthetic attachment is more difficult due to the shorter residual limb.

Functional Outcomes Cont...

Knee Disarticulation

- Preserves femoral condyles; improved prosthetic fit and stability compared to AKA; energy cost of ambulation is lower than AKA but higher than BKA; functional outcomes and patient satisfaction are generally better than AKA.

Below Knee Amputation (BKA)

- More natural gait and effective ambulation due to preserved knee joint; high prosthetic success and independence contribute to strong patient satisfaction.

Syme's Amputation

- Heel pad preservation enables end-bearing and excellent mobility; minimal increase in energy cost during walking; high patient satisfaction and favorable functional outcomes.

Chopart's and Lisfranc's Amputation

- Moderate energy expenditure; longer residual limb supports partial weight-bearing and independent mobility; functional outcomes are good, with moderate patient satisfaction.

Toe Disarticulation

- Medial instability, impaired alignment, and altered gait occur; increase in ulceration risk; least impact on energy expenditure; most patients maintain near-normal ambulation.

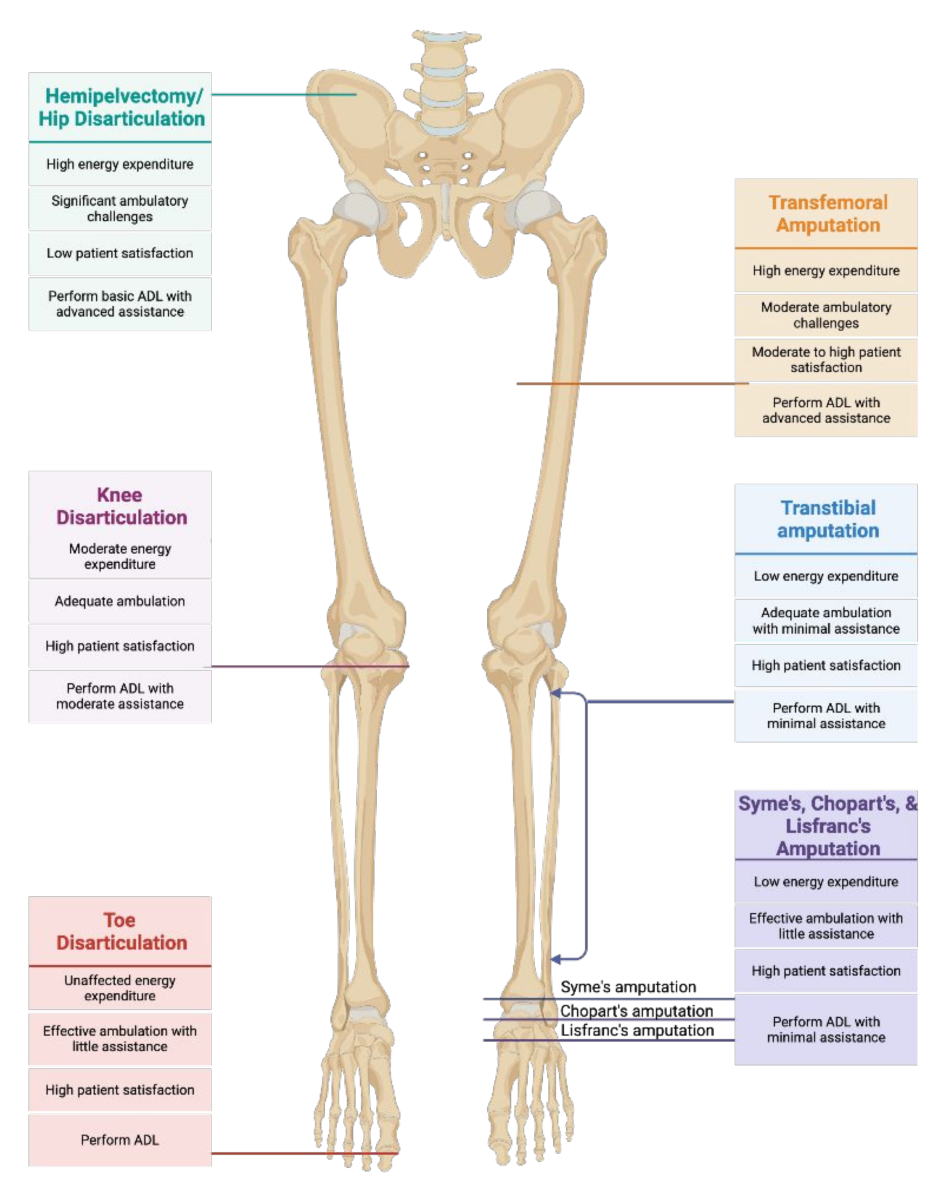

Figure 1. Energy expenditure, ability to ambulate, patient satisfaction, and ideal function by each lower extremity amputation level.

Hemodynamic Outcomes

LEA disrupts vascular integrity, leading to reduced blood flow, decreased venous return, and lower cardiac preload. This cascade results in a reduced stroke volume and cardiac output. To compensate, the heart rate increases to maintain systemic perfusion, which in turn elevates energy expenditure and heightens the risk for cardiovascular diseases such as myocardial infarction, hypertension, and peripheral arterial disease. These hemodynamic changes are more pronounced with higher-level amputations, where alterations in aortic blood flow and shear stress can contribute to arterial remodeling, stiffness, and increased risk for atherosclerosis and abdominal aortic aneurysms. Additionally, factors such as energy cost and comorbidities significantly influence outcomes by amputation level. Patients with higher-level amputations face greater energy demands, and those with underlying conditions—especially diabetes—are at increased risk for poor wound healing, re-amputation, and mortality.

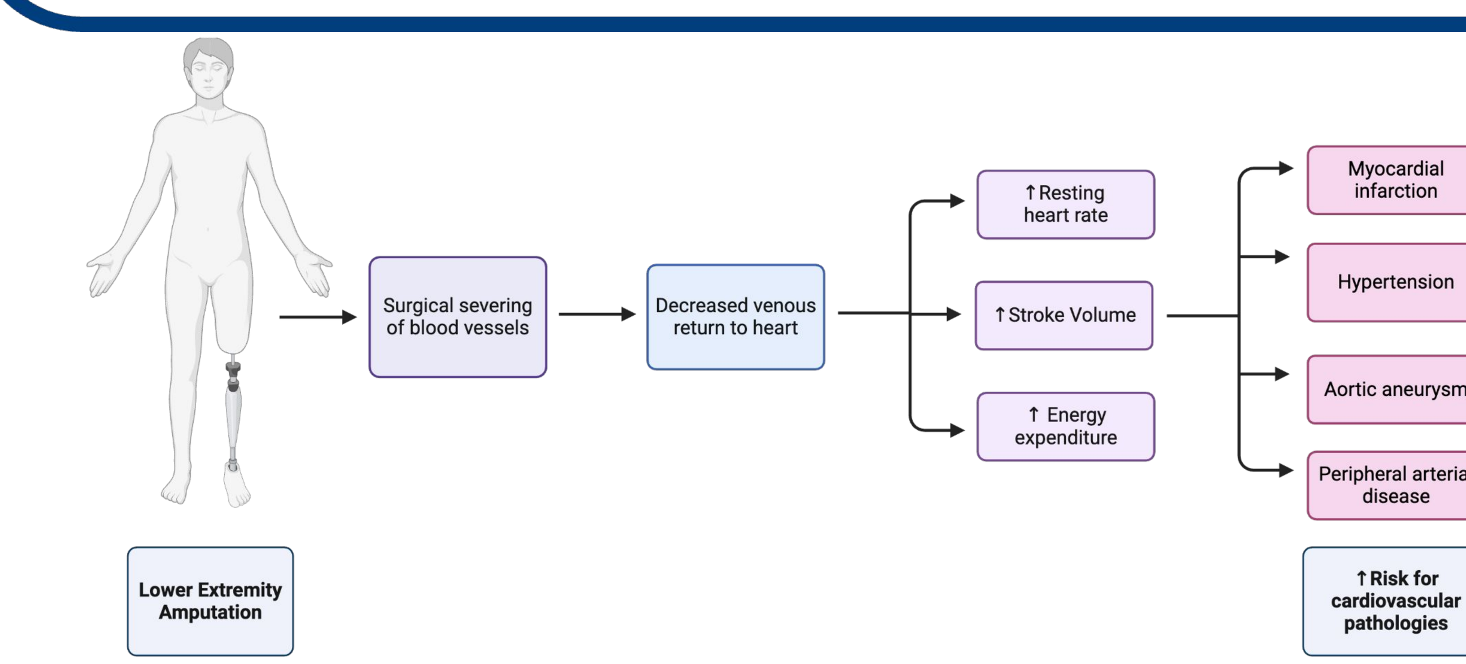

Figure 2: Mechanism of action behind hemodynamic changes of lower extremity amputations.

	Hemipelvectomy/ Hip Disarticulation	Transfemoral Amputation	Knee Disarticulation	Transtibial Amputation	Syme's Amputation	Chopart's/ Lisfranc's amputation	Toe Disarticulation
Mortality	High	High	Moderate	Moderate	Low	Low	Low
	Due to surgery complexity, infection, phantom limb pain, and deep vein thrombosis	Most seen with comorbid conditions (i.e. diabetes, peripheral arterial disease)	Most seen with comorbid conditions (i.e. diabetes, peripheral arterial disease)	Most seen with comorbid conditions (i.e. diabetes, peripheral arterial disease)	Due to the less invasive and complex surgical procedures	Most seen with comorbid conditions (i.e. diabetes, localized infection)	Due to the less invasive and complex surgical procedures
Causes for Reamputation	Typically due to severe underlying health conditions	May require higher level amputations due to complications/ disease progression	Commonly due to wound healing issues/disease progression	Commonly due to wound healing issues/disease progression	Commonly due to wound healing issues/disease progression	Commonly due to complications with initial healing/ disease progression	Commonly seen in diabetic patients with poor wound healing

Figure 3. Mortality rates and causes for re-amputation by each lower extremity amputation level.

Conclusion

LEA level significantly influences functional mobility and cardiovascular health. Higher amputations correlate with increased energy expenditure and cardiovascular strain, while lower-level amputations generally yield better functional outcomes. Patient comorbidities, particularly diabetes and vascular disease, further affect morbidity and re-amputation risks. Future research should focus on optimizing rehabilitation strategies, refining prosthetic technology, and mitigating cardiovascular risks to enhance long-term outcomes for LEA patients.