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Is lower limb salvage worthwhile after severe open tibial fractures in a developing country? An analysis of surgical outcomes, quality of life and cost implications

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A B S T R A C T

Introduction: Open tibial fractures are rare and difficult-to-treat injuries because of the involvement of bony, skin and neuromuscular injury along with co-morbidities. Often, during the management of very severe cases these injuries, the question arises, should we amputate or salvage the limb? This question has been explored previously in civilian and military contexts in the US and UK but remains unstudied in the alternative sociocultural and economic context of the developing world.

Methods: We studied 78 adult patients with severe open tibial fracture that presented to our institution, a Level 1 trauma center in India, from February 2018 to June 2019. 20 patients underwent above-knee amputation (AKA), 16 underwent below-knee amputation (BKA), and 42 underwent limb salvage. We assessed injury severity using [our institution's] Open Injury Severity Score (GHOISS), which has separate sub-scores for bony injury, skin injury, neuromuscular injury and co-morbidities, and patients were only included with GHOISS $>$ 13. We assessed functional outcome measures as well as economic costs as primary cost levied by our institution and other secondary costs.

Results: Salvage (LEFS: mean=51, SF-12 PCS: mean=48, SF-12 MCS: mean=49) provided better outcomes to BKA (LEFS: mean=39, p=0.005, SF-12 PCS: mean=40, p=0.003, SF-12 MCS: mean=43, p=0.052) and AKA (LEFS: mean=31, $p<0.001$, SF-12 PCS: mean=34, $p<0.001$, SF-12 MCS: mean=43, p=0.043). Primary costs were higher for limb salvage (index: mean=$3100, total: mean=$4400) than both BKA (index: mean=$2500, p=0.012, total: mean=$2600, $p<0.001$) and AKA (index: mean=$2800, p=0.020, total: mean=$3200, $p<0.001$). Secondary costs were higher for limb salvage than both BKA and AKA ($p<0.001$). Patients who underwent salvage were more likely to return to work at 36 months post-injury compared to below-knee amputees (adjusted OR=0.11, p=0.010).

Conclusions: Limb salvage results in better functional outcomes compared with amputation at a higher upfront cost but a likely lower lifetime cost. Unlike other literature on the topic, amputation carries a heavy mental and physical toll in India, likely due to sociocultural differences and stigma. Amputation is a difficult decision for patients to accept and results in poorer outcomes; therefore, we believe that limbs should be aggressively salvaged in our developing country.

Study design: Therapeutic Level II Prospective Cohort Study

Introduction

Open tibial fractures are rare and difficult-to-treat injuries because of the involvement of bony, skin, and neuromuscular injury along with co-morbidities. Often, during the management of these injuries, the question arises, should we amputate or salvage the

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limb? This question has been previously explored in both civilian and military settings in the United States and the United Kingdom [1–3]. In the short-term, these studies suggest that amputation, with a good prosthesis, can achieve better clinical outcomes than salvage; in the long-term, outcomes, though poor in general, appear no different between groups.

These injuries are both more common and more severe in the developing world because road traffic accidents (RTAs) are intensified by the problems of unsafe driving, poor vehicle design, and weak traffic laws [6]. RTAs are epidemic in these regions and constitute the most important cause of loss of life and limbs. For example, in India, there are an average of more than 180,000 deaths (one death every three minutes) with a large number of cases requiring amputations and resulting in permanent limb disability [7]. Moreover, the costs associated with salvage in developing nations, both the primary cost of surgery and the secondary costs of the inpatient stay and other indirect costs, are disproportionally lower than those in the developed nations [8,9]. The costs and outcomes of amputation are tied to the choice of locally manufactured prostheses. Affordable prostheses do not provide functional outcomes on par with more expensive high-functioning prostheses found in the developed world [10,11]. Patients in the developing world are also often more price-sensitive, as they are often uninsured and self-paying, and more sensitive to a local cultural stigma against amputees [12]. Therefore, the question of amputation versus salvage is pertinent in this setting, yet unstudied, as previous studies do not take into account these contextual differences.

The objective of this study is to evaluate differences in functional outcomes and economic costs in open tibial fractures treated with amputation versus limb salvage in the developing world. We conduct this study in the setting of a high-volume specialty hospital in India.

Methods

We surveyed 87 patients who came to our institution's outpatient department for follow-up after open tibial fracture between February 2018 and June 2019 in this retrospective cohort study. This study was approved by our institutional review board. Inclusion criteria were history of open tibial fracture, injury severity (defined below) > 13 points, follow-up > 12 months, treatment complete (fracture union), and age > 18 years. Exclusion criteria were initial management of injury done at an outside institution and patient cognitive deficit. Patients with bilateral limb-threatening injury were also excluded because of small sample size and given the variable nature of the subpopulation [13]. Patients groupings were defined as either amputation, below- (BKA) or above-knee (AKA), or limb salvage at the time of follow-up.

For all patients, we classified injury severity using [our institution's] Open Injury Severity Score (GHOISS) system intraoperatively. In short, the system has subscores for injuries to the bone, skin and muscle and a subscore for co-morbidities – with higher scores corresponding to more severe injuries (Table 1) [14]. In addition, we classified patients by the, more general, Gustilo-Anderson classification of open injuries intraoperatively. All patients were scored based on pre-operative photos and radiographs of the injury by a blinded observer. We noted the laterality of injury, site of injury, and mode of injury. We noted post-operative complications of infection and fracture mal- or non-union. Using serial radiographs, we noted time between injury and fracture union.

To evaluate outcomes following treatment, we utilized both lower-extremity functional scale (LEFS), specific to the function of the lower extremity, and Medical Outcomes short form 12 (SF-12), about general health condition, patient-reported outcome measures (PROMs). LEFS is a 20-question survey about a patient's ability to perform everyday activities [15]. SF-12 is a 12-question survey about general health, which provides both a physical component subscore (PCS) and mental component subscore (MCS). EQ-5D quality-of-life (QOL) indices were derived from SF-12 data using a previously published formula [16]. Both surveys were either administered in-person or via telephone via a translator in the patient's local language of either English, Tamil, Hindi, or Malayalam.

To evaluate financial burdens following treatment, we assessed both primary and secondary costs. Rather than report aggregate costs, we provide modular cost outcomes that can be interpreted based on relative local pricing, because relative pricing of transportation, prostheses, hospitalization and other costs vary widely in our region and throughout the developing world. For primary cost, we totaled the costs of all hospitalizations, including the cost of both the surgeries themselves and associated hospital stays – these costs are reported in both Indian Rupees (INR) and United States Dollars (USD). For amputees, we also noted the cost of their prostheses. For secondary costs, we noted the total length of hospitalization, number of surgeries, and number of outpatient visits. We also noted time to return-to-work (RTW) and evaluated RTW at 6, 12, 24, and 36 months after injury in a subset of patients during follow-up (51 of 78, 65%). Outpatient visits consisted of follow-up care with orthopaedic surgeons, plastic surgeons and physical rehabilitation specialists for both amputee and salvage groups of patients; though amputee patients also had additional outpatient visits with prostheses retailers for prosthesis fitting, maintenance and physical rehabilitation which were not captured by this analysis. Physical rehabilitation in our population sample was largely done by patients at-home, with in-hospital demonstration of exercises and techniques.

Statistics

We used ANOVA, Kruskal-Wallis, and Chi-squared tests to evaluate differences in demographics and patient characteristics between treatments. We used multivariate regression to assess effects of treatment on outcomes and financial burdens, adjusted using injury severity as a covariate. We used multivariate regression to assess relationships between other variables using injury severity as a covariate and Pearson or Spearman regression to assess these relationships without covariates. P-values less than 0.05 were considered significant. The minimum clinically important difference (MCID) of LEFS is 9 points; no MCID for SF-12 PCS nor MCS has been reported in the literature for open injuries [15]. All statistical analysis was done using R (version 3.6.0, R Foundation for Statistical Computing, Vienna, Austria).

Results

Of the 78 patients in our study, 42 (54%) received limb salvage treatment, 16 (21%) received BKA, and 20 (26%) received AKA (Table 2). Our patient cohort varied widely in age (range: 18-88) and patients in the salvage group were younger than those in amputation groups (p=0.006). Most patients were male in all groups. All injuries were mostly due to road traffic accidents (RTAs), but a small portion of BKA (31%) and salvaged (2%) patients had injuries due to other causes like workplace accidents and falls from height. There were no differences in laterality between patients of different treatment options (p=0.754), but patients with BKA and AKA were more likely to have injuries in the distal and proximal 3rd of the tibia, respectively (p<0.001). Most injuries were of Gustillo-Anderson Type IIIB (94%) and injuries were more severe in the BKA and AKA groups compared to limb salvage, in terms of total GHOISS score (p<0.001), though GHOISS subscores were not significantly different across groups (p>0.05, Table 2, Supplemental Table 1). Salvaged patients were more likely to have a post-

Table 1
GHOISS subscores, striated by treatment group with demographic details and associated MESS.

	GHOISS	GHOISS Subscore				MESS	Demographics	
		Bone	Skin	Muscle	Comorbidities		Age (Years)	Sex
Above-Knee Amputation	14	5	4	3	2	3	27	M
	14	5	4	1	4	4	43	M
	15	1	5	5	4	7	42	F
	15	3	5	3	4	4	46	M
	15	4	4	3	4	7	61	F
	15	5	4	4	2	8	61	M
	15	2	5	4	4	5	65	F
	15	3	5	3	4	8	75	M
	16	4	4	2	6	4	32	M
	16	5	4	3	4	5	36	M
	16	5	4	3	4	5	52	M
	16	4	5	5	2	6	56	M
	17	4	4	5	4	7	40	M
	17	5	4	4	4	5	45	M
	17	2	4	5	6	5	52	M
	18	3	5	4	6	5	27	M
	19	5	5	5	4	5	41	F
	19	5	5	5	4	5	50	M
	19	4	4	5	6	5	64	M
	20	5	4	5	6	7	60	M
Below-Knee Amputation	14	3	5	4	2	7	20	M
	15	5	4	4	2	6	33	M
	15	4	5	2	4	4	39	M
	15	3	5	3	4	7	48	F
	15	4	5	2	4	6	56	M
	15	5	4	2	4	8	70	M
	15	3	5	3	4	6	77	M
	16	4	5	5	2	4	34	M
	17	3	5	5	4	5	21	M
	17	4	4	5	4	4	41	F
	17	2	4	5	6	6	53	M
	17	5	4	2	6	7	66	M
	17	3	5	5	4	6	67	M
	17	2	4	3	8	7	88	M
	18	3	5	4	6	4	40	M
	18	5	4	3	6	7	68	M
Salvage	14	4	4	4	2	3	20	F
	14	4	4	4	2	5	22	M
	14	3	4	3	4	5	22	M
	14	4	5	3	2	3	22	M
	14	5	5	4	0	3	22	M
	14	3	4	3	4	3	24	M
	14	5	4	3	2	4	27	M
	14	3	4	5	2	3	28	M
	14	5	4	3	2	3	29	M
	14	5	4	3	2	4	30	M
	14	3	4	3	4	4	30	M
	14	5	4	3	2	4	31	M
	14	3	4	3	4	4	33	M
	14	5	4	3	2	4	36	M
	14	2	4	4	4	7	53	M
	14	2	4	4	4	5	54	M
	14	5	5	2	2	5	55	M
	14	3	5	2	4	4	56	M
	14	4	5	3	2	5	56	M
	14	5	4	3	2	4	59	M
	14	3	5	4	2	5	60	M
	14	3	4	3	4	4	61	M
	15	4	5	4	2	3	18	M
	15	3	5	5	2	5	18	M
	15	4	4	3	4	3	22	M
	15	5	4	4	2	3	25	M
	15	3	4	2	6	5	33	M
	15	3	4	4	4	4	36	M
	15	5	4	4	2	4	38	M
	15	5	4	4	2	4	45	M
	15	3	5	1	6	5	50	M
	15	4	4	3	4	5	62	M
	15	4	4	3	4	5	69	M
	16	3	4	5	4	7	22	M
	16	3	4	5	4	3	23	M
	16	3	4	3	6	3	24	M
	16	3	4	5	4	5	56	M
	16	4	4	2	6	5	75	M
	17	1	5	5	6	3	25	F
	17	2	4	5	6	4	42	M
	19	5	4	4	6	4	28	M
	20	4	4	4	8	4	40	M

Table 2
Demographics and descriptive statistics of our patient cohort. ANOVA, Kruskall-Wallis, and Chi-squared tests $p<0.05$ are bolded.

		Amputation AKA	BKA	Salvage	*p*-value
N		20	16	42	
Age, Years (Mean, Range)		49 (27 - 75)	51 (29 - 88)	38 (18 - 75)	**0.006**
Sex (N, % Female)		4 (20)	2 (13)	2 (5)	0.171
Followup, Months (Mean, Range)		24 (12 - 62)	21 (14 - 32)	30 (12 - 100)	0.090
Mode of Injury (N, %)					**<0.001**
	RTA	20 (100)	11 (69)	41 (98)	
	Workplace	0	0	1 (2)	
	Fall From Height	0	5 (31)	0	
Laterality (N, %)					0.754
	Left	8 (40)	6 (38)	13 (31)	
	Right	12 (60)	10 (63)	29 (69)	
Site (N, %)					**<0.001**
	Distal 3rd	2 (10)	16 (100)	11 (26)	
	Middle 3rd	5 (25)	0	11 (26)	
	Proximal 3rd	8 (40)	0	9 (21)	
	Segmental	5 (25)	0	11 (26)	
Gustillo-Anderson Type (N, %)					0.386
	IIIA	1 (5)	0	0	
	IIIB	18 (90)	16 (100)	39 (93)	
	IIIC	1 (5)	0	3 (7)	
GHOISS (Median, IQR)		16 (15 - 17)	17 (15 - 17)	14 (14 - 15)	**<0.001**
	Bone	4 (3 - 5)	4 (3 - 4)	4 (3 - 5)	0.450
	Skin	4 (4 - 5)	5 (4 - 5)	4 (4 - 4)	0.060
	Muscle	4 (3 - 5)	4 (3 - 5)	3 (3 - 4)	0.413
	Comorbidities	4 (4 - 5)	4 (4 - 6)	4 (2 - 4)	0.072
Infection (N, %)		1 (5)	3 (19)	18 (43)	**0.005**
Mal-/Non-Union (N, %)				18 (43)	
Time to Union, Months (Mean, Range)				17 (5 - 44)	

Table 3
Outcomes following open tibial injury with amputation versus salvage treatment. Summary statistics are reported unadjusted for injury severity as mean ± standard deviation. Multivariate linear and logistic regression β and adjusted odds ratio (OR) are reported as estimates with 95% confidence intervals. $P<0.05$ are bolded. *No salvage patients used prostheses, so β-values compare differences between BKA and AKA.

		Amputation AKA	BKA	Salvage	Salvage-AKA β	p	Salvage-BKA β	p
N		20	16	42				
LEFS		31 ± 11	39 ± 17	51 ± 13	-20 [-28–13]	**<0.001**	-13 [-21–5]	**0.002**
SF-12								
	PCS	34 ± 7	40 ± 11	48 ± 6	-13 [-19–10]	**<0.001**	-8 [-13–3]	**0.002**
	MCS	43 ± 6	43 ± 7	49 ± 9	-6 [-12–1]	**0.022**	-7 [-12–1]	**0.022**
	EQ5D Index	0.70 ± 0.07	0.76 ± 0.11	0.87 ± 0.09	-0.17 [-0.22–.0.11]	**<0.001**	-0.12 [-0.18–0.06]	**<0.001**
Cost of Index Hospitalization	*in 1000s INR*	194 ± 153	173 ± 107	213 ± 91	-19 [-89–+51]	0.588	-40 [-113–+32]	0.271
	in 1000s USD	2.8 ± 2.2	2.5 ± 1.5	3.1 ± 1.3	-0.3 [-1.3–+0.7]		-0.6 [-1.6–+0.5]	
Cost of Index Hospitalization	*in 1000s INR*	225 ± 215	183 ± 110	309 ± 114	-84 [-174–+7]	0.068	-125 [-219–32]	**0.010**
	in 1000s USD	3.2 ± 3.1	2.6 ± 1.6	4.4 ± 1.6	-1.2 [-2.5–+0.1]		-1.8 [-3.1–0.5]	
Cost of Prosthesis*	*in 1000s INR*	130 ± 183	80 ± 86		-50 [-175–+74]	0.413		
	in 1000s USD	1.9 ± 2.6	1.1 ± 1.2		-0.7 [-2.5–+1.1]			
Hospitalization Length, Days		15 ± 10	17 ± 10	40 ± 20	-25 [-34–16]	**<0.001**	-23 [-33–14]	**<0.001**
Number of Hospitalizations		1.2 ± 0.4	2.0 ± 1.1	4.3 ± 2.1	-3.2 [-4.0–2.3]	**<0.001**	-2.3 [-3.3–1.4]	**<0.001**
Number of Outpatient Visits		8 ± 2	9 ± 5	22 ± 8	-15 [-18–11]	**<0.001**	-14 [-17–10]	**<0.001**
Time to RTW					**Adjusted OR**	**p**	**Adjusted OR**	**p**
	6 Months, %	0	0	0		1.000		1.000
	12 Months, %	33	10	13	2.58 [0.34-18.64]	0.340	0.67 [0.03-5.56]	0.739
	24 Months, %	44	30	56	0.88 [0.16-4.92]	0.885	0.39 [0.72-1.78]	0.239
	36 Months, %	56	30	81	0.42 [0.07-2.57]	0.330	0.11 [0.02-0.55]	**0.010**

operative infection (p=0.005). Mean follow-up was 26 (range: 12 - 100) months and was not significantly different between groups (p=0.090). One patient in each of the AKA and BKA groups had amputation within 1 month following an unsuccessful salvage attempt.

AKA (β=-20 [-28 – -13], $p<0.001$) and BKA (β=-13 [-21 – -5], p=0.002) both resulted in worse extremity-specific functional outcomes, by LEFS, than limb salvage (Table 3, Fig. 1A). Similarly, in a more general measure of physical functioning, patients with AKA (β=-13 [-19 – -10], $p<0.001$) and BKA (β=-8[-13 – -3], p=0.002) both scored significantly lower on SF-12 PCS than those with limb salvage. LEFS and SF-12 PCS scores were moderately correlated (r^2=0.30). Patients with BKA (β=-6 [-12 – -1], p=0.022) and AKA (β=-7 [-12 – -1], p=0.022) both scored significantly lower on SF-12 MCS compared to those with limb salvage (Fig. 1B). SF-12 MCS scores were very weakly correlated with both LEFS (r^2=0.15) and SF-12 PCS (r^2=0.08) functional outcomes. Patients with AKA (β=-0.17 [-0.22 – -0.11], $p<0.001$) and BKA (β=-0.12 [-0.18 – -0.06], $p<0.001$) both had lower EQ-5D quality-of-life indices than those with salvage. Complications, such as infection and malunion or nonunion, did not significantly worsen any outcomes at final follow-up ($p>0.05$). Cost of prosthesis was not associated with better or worse outcomes when adjusted for injury severity ($p>0.05$).

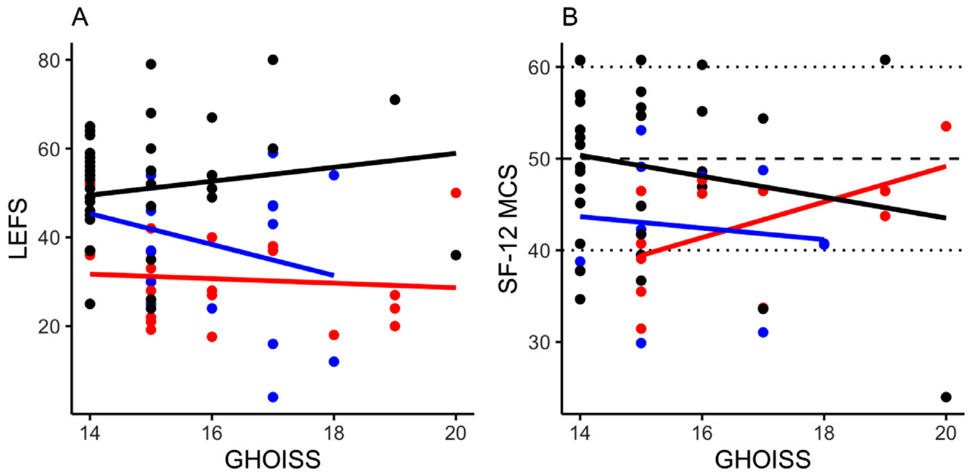

Fig. 1. Relationship of (A) functional outcomes, LEFS, and (B) mental health outcomes, SF12 MCS, to injury severity, GHOISS, by group. Population mean for SF-12 MCS is represented as the dashed line and population standard deviation is represented by the dotted lines. Black: Limb Salvage; Blue: BKA; Red: AKA.

The cost of index hospitalization (AKA: p=0.020, BKA: p=0.012) was not different between groups (p>0.05) but the total cost of all hospitalizations was higher for salvaged patients compared to below-knee amputees (p=0.010). The cost of prostheses tended to approach half the level of in-hospital cost-savings. Patients with amputations needed fewer (AKA: β=-3.2 [-4.0 – -2.2], p<0.001, BKA: β=-2.3 [-3.3 – -1.4], p<0.001) hospitalizations and a shorter overall length of hospitalization (AKA: β=-25 [-34 – -16], p<0.001, BKA: β=-23 [-33 – -14], p<0.001) than those with salvage. Patients with amputations also needed fewer outpatient visits (AKA: β=-15 [-18 – -11], p<0.001, BKA: β=-14 [-17 – -10], p<0.001) than those with salvage. Patients with amputation were not significantly less likely to return to work by 6, 12, or 24 months after injury (p>0.05); however, patients with BKA were less likely to return to work (adjusted OR: 0.11 [0.02-0.55], p=0.041) compared to those with salvage at 36 months after injury, though the same was not seen in patients with AKA (p>0.05).

Discussion

This study is the first to compare outcomes following amputation and limb salvage in a setting outside of Europe and North America and in the developing world. We hope that these results shed light on practical differences for surgeons practicing in developing contexts that are, not only resource-poor, but also home to patients with different sociocultural understandings of treatment options.

In India, as in many developing countries, there is a cultural stigma against amputees, and we hypothesized that this would result in poorer mental health-related outcomes for this patient population, as compared to salvaged patients. Our results support our hypothesis that amputees in India also carry an emotional toll resultant from sociocultural stigma. The lower-extremity assessment project (LEAP) and studies in military populations found no significant difference in mental health between amputees and salvaged patients [1–3]. Bosse et al. (LEAP) and Doukas et al., both in the US, observed generally poor mental health outcomes in their cohorts in both amputation and salvage groups, with over 40% of patients in total having mental health scores representing severe disability and nearly a third of patients reporting depressive symptoms [1,4]. This is in contrast to reports by Ladlow et al., in the UK, that found that both salvaged patients and amputees had mental health outcomes near population norms and were likely to re-integrate into society [5]. Our cohort reports similar results to the UK cohort with SF-12 MCS outcomes for all groups being satisfactory, being within 1 standard deviation of population averages. The authors in the US postulate that post-traumatic stress disorder (PTSD) is prevalent among their population post-injury and that that may explain poor outcomes. PTSD after a traumatic event is more than twice as prevalent in high- as compared to low-income countries, so this protective effect may have bolstered overall mental health outcomes in our cohort [17].

We also observe functional deficits in limb-specific function, general function, ability to work and quality-of-life in amputees as compared to salvage patients. This contrasts with reports from studies in the military which have shown that amputees have better functional outcomes that salvaged patients [4,5]. In the civilian context, LEAP showed no significant difference between amputees and salvage patients regarding functional outcomes, though they did note worse function in above- as compared to below-knee amputees [1–3]. LEAP also showed no significant difference between amputees and salvage patients in return-to-work as far as out to 84 months [18]. We believe that this functional deficit is contextual, as the local environment – public spaces, workplaces, walkways and bathrooms – is not well suited to available prostheses.

Although we did not see a significant relationship between prosthesis cost and outcomes, previous studies have shown that more functional, expensive prostheses afford patients with better functional outcomes [10,11]. Patients from our institution frequently used expensive, imported prostheses rather than either not using a prosthesis or using inexpensive, non-functional prostheses provided by the government and non-governmental organizations. In this light, we view outcomes in our patient cohort as a “best-case” scenario for amputees in the developing world as they have access to high-quality prostheses but must traverse a prosthesis-unfriendly environment. We postulate that, in other centers and throughout the developing world, when patients do not have access to or cannot afford high-quality prostheses, they will have poorer outcomes than what we have described.

In-hospital cost was much greater for patients undergoing limb salvage, owing to an increased number of and longer hospitalizations. However, some amputation cost-savings are lost when selecting a high-quality prosthesis to regain function, and analysis of lifetime costs from LEAP show that prosthesis maintenance costs are also high for amputees which may offset total cost-savings over a longer period [19,20]. Beyond primary costs, patients undergoing salvage have a large secondary cost burden: they, and their families, need to travel back and forth between a large tertiary center and their home, which can often be hundreds of kilometers away, for many outpatient visits and inpatient hospitalizations.

While we report that amputees required 14-15 fewer outpatient visits than salvaged patients, these patients will additionally need to have outpatient visits with a prosthesis retailer which were not captured by our study design and, so, actual differences in travel may be less obvious. Secondary costs are often not considered as part of the total healthcare cost burden for patients, but these costs significantly affect patient decision making in developed and even more so in developing nations [21–23].

Patients, in our population, universally prefer to salvage whenever possible, driven by the social stigma around amputation. Surgeons, too, should favor salvage because of better outcomes and potentially lower lifetime costs. However, it is important to counsel patients during the early stages of treatment about large upfront primary costs and secondary costs, like transportation and accommodation, involved in salvaging a limb.

As opposed to the other studies comparing amputation and salvage, we stress that there are also many strengths of our analysis. Our study robustly adjusts for injury severity (which includes adjustments for polytrauma, associated injuries and co-morbidities), only includes patients with severe injuries that are on the brink between amputation and salvage, and only includes a single category of injury: open tibial fractures. Further, our injury severity score allows us to select injuries near our clinical decision-making thresholds for amputation, whereas previous studies more broadly included limb-threatening injuries [1–3]. We also observed that patients in the amputation cohort had more severe injuries and were older, however, we have included these variables in our injury severity score. This strength allows us to more accurately assess differences in outcomes between groups by having fewer potential confounders. The key weakness of our study is its lack of longitudinal, uniform and long-term follow-up. These are the key strengths of LEAP but are common weaknesses among the literature surrounding comparisons of amputation and salvage. This level of follow-up has shown useful trends, such as the degradation of outcomes over time for both salvaged patients and amputees, and therefore we posit that longitudinal and long-term follow-up should be studied in the developing context to understand if trends from LEAP also apply outside of developed nations. Our study also categorizes secondary amputees – where an initial attempt at salvage had been made – alongside primary amputees, so our study compares prognoses of successful salvage with successful amputation in a borderline injury severity; surgeons will still need to evaluate each patient to understand the probability of success and mortality risks of the salvage procedure, even though we demonstrate a morbidity benefit given procedural success. Further scholarship should be powered sufficiently to explore subgroup differences in outcomes between primary and secondary amputees and understand if the benefits of salvage can persist in more severe injuries to counterbalance the risk of secondary amputation. Lastly, contrasting our study with those prior suggests that differences exist between outcomes in different contexts and we can only postulate mechanisms through our data and clinical experience, but our study does not quantify those differences; therefore, future work should further elucidate the magnitude of differences between contexts and delineate clear mechanisms for these differences.

Conclusion

Even in a best-case scenario in the developing world, salvage maintains better outcomes than amputation when correcting for injury severity. We postulate that this advantage multiplies in cases where there are qualified surgical staff, but environments are less hospitable to amputees and good-quality prostheses are not available. However, though likely a lower lifetime cost, salvage still maintains a large upfront cost-burden with similarly large secondary costs. Weighing the evidence, we recommend that surgeons in developing countries continue to aggressively salvage limbs when possible.

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