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Assessment of Functional Outcomes Related to the Revascularization Role in Management of the Delayed Limb Ischemia after Trauma

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Abstract: Delayed ischemia of the limbs after traumatic injury is a serious vascular emergency, and the main therapeutic measure to maintain the limbs and restore their functions to the original state is revascularization. The current study aimed at determining the functional outcomes relating to revascularization in individuals with delayed ischemia of the limbs due to trauma. The study is a cross-sectional one that involved 105 patients with delayed limb ischemia due to trauma that received revascularization surgery. Information was received concerning patient demographics, injury characteristics, procedural details, early complications (0-30 days), and functional outcomes in the 6 and 12 months. Such outcomes as limb salvage rates, mobility ratings (Lower Extremity Functional Scale), pain ratings (Visual Analog Scale), return-to-work, quality of life (SF-36), and long-term complications were considered. The 6 and 12-month overall limb salvage rate was 84.8 and 81.9 percent. The patients, upon treatment with less than 6 hours, reported better limb salvage (93.5%), mobility (77.4%), and returning to their jobs (58.1%), compared with the treatment of the patients who were late and treated after 12 hours (62.5%, 34.4%, and 15.6%, respectively). The 6 and 12-month overall limb salvage rate was 84.8 and 81.9 percent. The patients, upon treatment with less than 6 hours, reported better limb salvage (93.5%), mobility (77.4%), and returning to their jobs (58.1%), compared with the treatment of the patients who were late and treated after 12 hours (62.5%, 34.4%, and 15.6%, respectively). There is a strong correlation between early revascularization (within 6 hours) and patients with delayed limb ischemia after trauma, with enhanced limb salvage, better functional recovery, and lower complication rates. Old age, high comorbid status, high level of injury, and a long period of time in ischemia also become significant predictors of negative outcomes.

Keywords: delayed limb ischemia, trauma, post-operative complications, and quality of life.

INTRODUCTION

Background

Traumatic injuries have been one of the leading causes of illness and death in the world. Vascular injuries, particularly those that lead to limb ischemia, have deteriorating consequences (Siddique, M. K. *et al.*, 2014). Limb ischemia may present itself several hours or days following trauma (Jagdish, K. *et al.*, 2014). The only way to restore circulation and save limbs is by revascularization; surgery can accomplish it either via bypass in case of a surgical approach or endovascular in case of a hybrid approach. (Kobayashi, L. *et al.*, 2020)

The ischemia of the limbs is usually caused due to a damage to the vessels directly or because of clotting or secondary clotting caused by the trauma. In the acute cases, the diagnosis and treatment is required within a short time frame as this saves the destruction of tissues and amputation is avoided (Sun, Y. F. *et al.*, 2015). Delayed limb ischemia manifests at a period which appears stable and is normally occasioned by enlarging clots or spasms, or previously ignored injuries. In such cases, the time frame of successful revascularization is smaller due to permanent damage of muscles and nerves in long ischemia. (Hafez, H. M. *et al.*, 2001)

Open surgery, bypass grafting, or thrombectomy is a good fix with a risk of infection and a prolonged recovery time (Swiontkowski, M. F. *et al.*, 2002). Less invasive methods, such as endovascular (thrombolysis, angioplasty, stenting), are more likely to heal faster, but may not be effective in cases of severe dissection or large blockages. Endovascular repair with surgical exposure or vice versa is becoming widespread in addressing complicated wounds. (Moini, M. *et al.*, 2008; Joshi, S. S. 2016)

The results are predetermined by a variety of factors, including duration of the ischemic period of the limb, quality of collateral vessels, and the presence of other diseases such as diabetes and atherosclerosis (Malcom, O., and Perry. 1993). Prolonged ischemia longer than 12 hours normally precipitates the reperfusion damage, and inflammation, as well as compartment syndrome. This may necessitate other procedures like fasciotomies. The process of success does not

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concern purely the technical process purely; effective anticoagulation, re-blockage control, and rehabilitation are contributory factors. (Baghi, I. *et al.*, 2015; MacKenzie, E. J. *et al.*, 2002)

There are new tools that enhance precision in the treatment of delayed ischemia; they are catheter-directed thrombolysis and intravascular ultrasound. Decisions and results are refined and results enhanced by multidisciplinary trauma teams, which consist of vascular surgeons, interventional radiologists, and critical-care doctors. (Martin, G. E. *et al.*, 2018)

METHODOLOGY

The study was designed as a cross-sectional study to assess the functional outcomes of revascularization having the procedures in patients who presented with delayed limb ischemia after traumatic injury. The main goal was to identify the effectiveness of surgical revascularization to rescue the limbs and regain the functional capacity, and the secondary goals were to find out risk factors of poor progress. The patient group included 105 sequential cases of patients who have received a revascularization of timely limb ischemia (presentation more than 6 hours after injury) in one of the tertiary trauma services within the time frame of 12 months of follow–up in different hospitals in Iraq.

To gather that data, medical records, operative reports, and outpatient clinic files were reviewed. The variables were extracted and packaged in theme tables as under: a) patient demographics and characteristics of injury: age, sex, mechanism of injury, Injury Severity Score (ISS), involved part of the body, and comorbid injury; b) procedural: what was used to revitalize the vessels, How it was done, what was used, operative time, d) early postoperative outcomes (30 days to follow-up): vascular, infectious, and other complications, and re-operation; and d) functional outcomes: measured at 6 and 12.

The stratifying of patients according to time since injury to revascularization was used to compare and contrast them into three categories: less than 6 hours, between 6 and 12 hours, and more than 12 hours. The statistical analysis included the descriptive statistics of the demographic data (frequencies, percentages). Multivariate logistic regression was also used to determine independent risk factors of poor functional outcomes (major amputation or poor mobility/quality of life scores), where adjusted odds ratios (OR) along with 95% confidence intervals (CI) were calculated in variables such as age, comorbidities, injury severity, and time-to-surgery. All the data was analyzed and planned using SPSS, version 24.0.

RESULTS

Table 1. Preoperative and clinical features outcomes.

Characteristic	Patients [n = 105]	Percentage (%)
Age Class		
20-30 years	28	26.7%
31-45 years	35	33.3%
46-60 years	27	25.7%
>60 years	15	14.3%
Gender		
Male	73	69.5%
Female	32	30.5%
Mechanism of Injury		
Motor Vehicle Accident	48	45.7%
Industrial Injury	23	21.9%
Fall from Height	19	18.1%
Crush Injury	15	14.3%
Time to Presentation		
<6 hours	31	29.5%
6-12 hours	42	40.0%
>12 hours	32	30.5%

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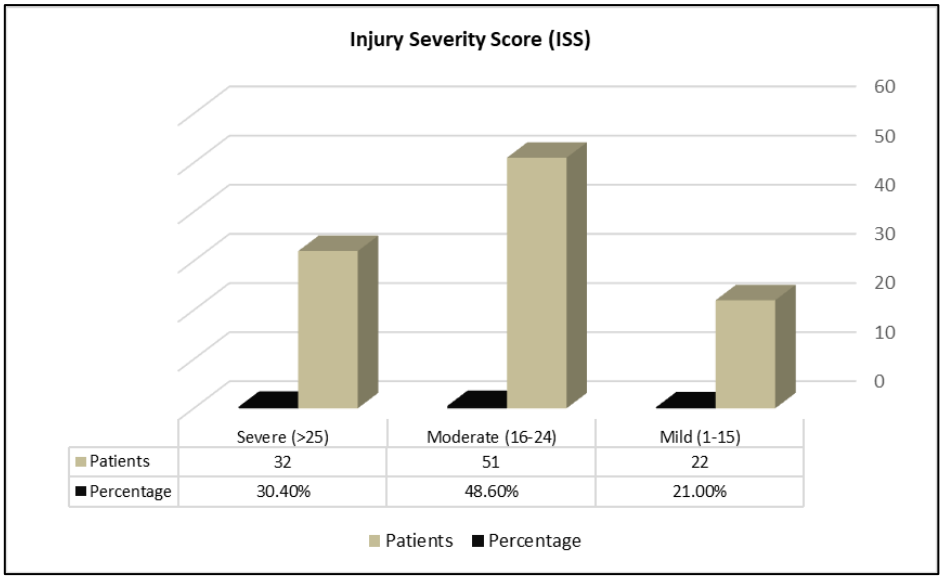

Figure 1. Assessment of injury severity in 105 patients using the ISS scale.

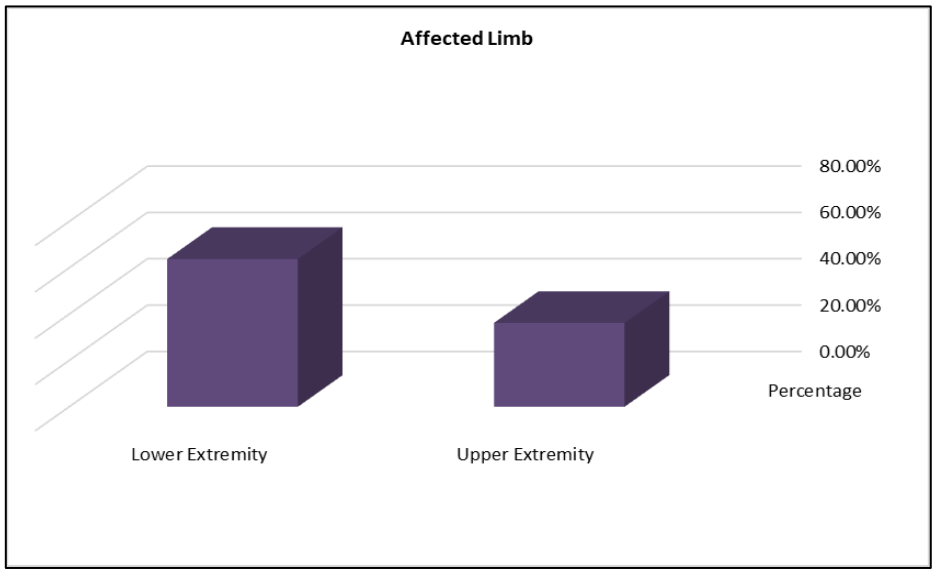

Figure 2. Distribution affected limb on the patients.

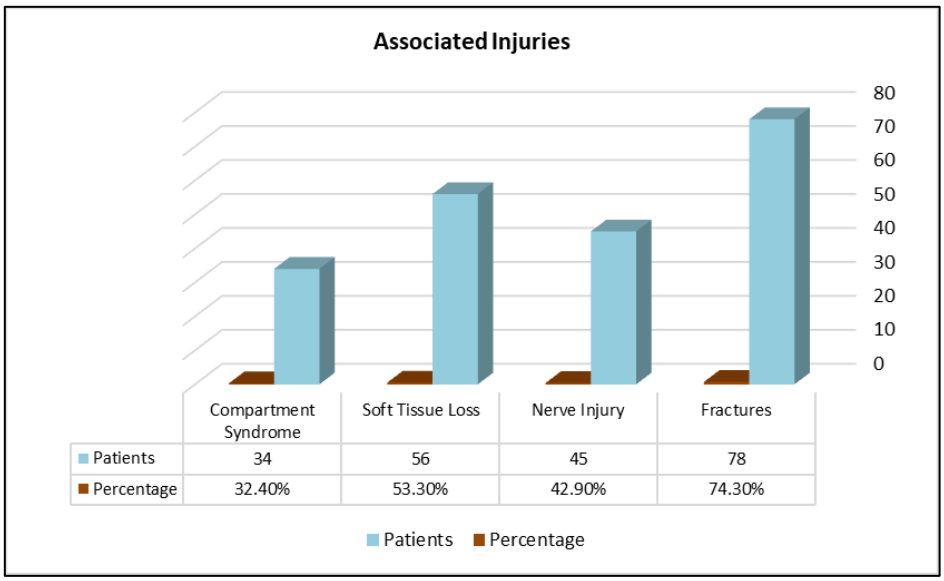

Figure 3. Prevalence mechanisms of injury in the patients.

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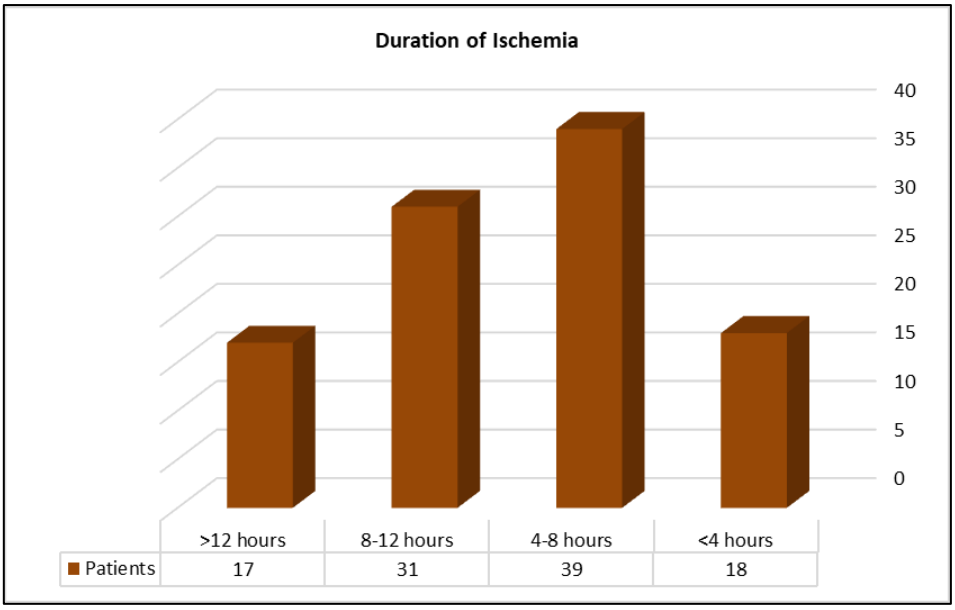

Figure 4. Determining the duration of limb ischemia in the 105 patients.

Table 2. Clinical outcomes of revascularization techniques.

Clinical outcomes	Patients, (n = 105)	Percentage (%)
Procedure Type		
Primary Arterial Repair	29	27.6%
Interposition Graft	43	41.0%
Bypass Graft	25	23.8%
Thrombectomy + Repair	8	7.6%
Surgical Approach		
Open Surgery	89	84.8%
Endovascular	12	11.4%
Hybrid Approach	4	3.8%
Graft Material Used		
Autologous Vein	52	49.5%
Synthetic Graft (PTFE)	16	15.2%
No Graft (Primary Repair)	37	35.3%
Procedure Duration		
<2 hours	24	22.9%
2-4 hours	58	55.2%
>4 hours	23	21.9%

Table 3. Post-intervention complications during 30 days.

Complications	**Number of patients (n = 105)**	**Percentage (%)**
Vascular Complications		
Graft Thrombosis	12	11.4%
Pseudoaneurysm	5	4.8%
Arteriovenous Fistula	3	2.9%
Hemorrhage Requiring Intervention	8	7.6%
Infectious Complications		
Superficial Wound Infection	18	17.1%
Deep Wound Infection	9	8.6%
Graft Infection	4	3.8%
Sepsis	6	5.7%
Other Complications		
Compartment Syndrome (Post-op)	14	13.3%

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Acute Kidney Injury	11	10.5%
Wound Dehiscence	7	6.7%
Re-operation Required		
Revision of Repair	15	14.3%
Fasciotomy	22	21.0%
Amputation	9	8.6%

Table 4. Assessment of functional outcomes in post–operative patients during 6 months.

Outcome Measure	**n**	**Percentage (%)**
Limb Salvage Status		
Limb Salvaged	89	84.8%
Major Amputation	13	12.4%
Minor Amputation	3	2.8%
Mobility Score (Lower Extremity Functional Scale)		
Excellent (75-80)	28	26.7%
Good (60-74)	35	33.3%
Fair (40-59)	26	24.8%
Poor (<40)	16	15.2%
Pain Level (VAS Score)		
No Pain (0-2)	32	30.5%
Mild Pain (3-4)	41	39.0%
Moderate Pain (5-7)	24	22.9%
Severe Pain (8-10)	8	7.6%
Return to Work Status		
Full Duty	38	36.2%
Light Duty	29	27.6%
Unable to Work	25	23.8%
Not Applicable (Retired/Student)	13	12.4%

Table 5. Assessment of functional outcomes in post–operative patients during 12 months.

Outcome Measure	**n**	**Percentage (%)**
Long-term Limb Salvage		
Limb Salvaged	86	81.9%
Late Amputation (6-12 months)	3	2.9%
Total Amputations	19	18.1%
SF – 36 QoL questionnaire		
Excellent (>50)	34	32.4%
Good (40-50)	38	36.2%
Fair (30-39)	22	21.0%
Poor (<30)	11	10.4%
Functional Independence		
Independent Ambulation	71	67.6%
Assistive Device Required	24	22.9%
Wheelchair Dependent	10	9.5%
Chronic Complications		
Chronic Pain Syndrome	27	25.7%
Chronic Venous Insufficiency	19	18.1%
Neuropathic Pain	22	21.0%
Contractures	15	14.3%
Graft Stenosis	8	7.6%

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Table 6. Enroll post-operative clinical outcomes according to time to revascularization.

Outcome	**<6 hrs (n=31)**	**6-12 hrs (n=42)**	**>12 hrs (n=32)**	**p-value**
Primary Outcomes at 12 Months				
Limb Salvage Rate	29 (93.5%)	37 (88.1%)	20 (62.5%)	<0.001
Amputation Rate	2 (6.5%)	5 (11.9%)	12 (37.5%)	<0.001
Functional Outcomes				
Excellent/Good Mobility	24 (77.4%)	28 (66.7%)	11 (34.4%)	<0.001
Independent Ambulation	26 (83.9%)	30 (71.4%)	15 (46.9%)	<0.001
Return to Full Work	18 (58.1%)	15 (35.7%)	5 (15.6%)	<0.001
Complication Rates				
Graft Thrombosis	1 (3.2%)	4 (9.5%)	7 (21.9%)	0.024
Infection Rate	3 (9.7%)	8 (19.0%)	10 (31.3%)	0.042
Re-operation Rate	4 (12.9%)	9 (21.4%)	11 (34.4%)	0.038
Quality of Life Measures				
Excellent/Good QOL	23 (74.2%)	29 (69.0%)	20 (62.5%)	0.527
Chronic Pain Syndrome	5 (16.1%)	10 (23.8%)	12 (37.5%)	0.047

Table 7. Univariate analysis of risk factors causing poor outcomes.

Risk Factors	**Good Outcome n (%)**	**Poor Outcome n (%)**	**Odds Ratio (95% CI)**	**p-value**
Age-Related Factors				
Age < 45 years	51 (81.0%)	12 (19.0%)	Reference	-
Age >= 45 years	22 (52.4%)	20 (47.6%)	3.87 (1.68-8.92)	0.002
Comorbidities				
Diabetes Mellitus	12 (48.0%)	13 (52.0%)	4.23 (1.72-10.4)	<0.001
Peripheral Vascular Disease	8 (44.4%)	10 (55.6%)	5.12 (1.85-14.2)	<0.001
Smoking History	28 (62.2%)	17 (37.8%)	2.54 (1.15-5.61)	0.021
Hypertension	24 (66.7%)	12 (33.3%)	1.89 (0.82-4.35)	0.134
Injury Severity				
ISS < 25	58 (79.5%)	15 (20.5%)	Reference	-
ISS >= 25	15 (46.9%)	17 (53.1%)	4.38 (1.85-10.4)	<0.001
Associated Nerve Injury	25 (55.6%)	20 (44.4%)	3.20 (1.45-7.06)	0.004
Treatment Delay				
Time to Surgery < 6 hrs	27 (87.1%)	4 (12.9%)	Reference	-
Time to Surgery 6-12 hrs	32 (76.2%)	10 (23.8%)	2.11 (0.62-7.18)	0.231
Time to Surgery >12 hrs	14 (43.8%)	18 (56.2%)	8.68 (2.56-29.4)	<0.001

DISCUSSION

The current paper compared the functional outcomes, which were related to revascularization in treating delayed limb ischemia after a traumatic event. In 105 patients in our cohort of patients, the overall limb salvage rate was 84.8 and 81.9 at 6 months and 12 months, respectively, which highlights the importance of early surgical intervention. But these results are greatly influenced by various critical variables, the paramount of them being the length of ischemia before being resuscitated. The limb salvage rate of patients who are revascularized within 6 hours was 93.5 percent, but it drastically decreased to 62.5 percent in patients who were revascularized after 12 hours ($p<0.001$). This observation is very consistent with the developed concept in vascular trauma of the golden period that irreversible necrosis of muscle starts 6-8 hours of warmth-induced ischemia. (Neary, P., and Redmond, H. P. 1999; Shi, L. 2013; Spitler, C. A. *et al.*, 2022; McHenry, T. P. *et al.*, 2002)

Other than salvage, functional recovery that is arguably the more patient-centric measure, was also a time-sensitive measure. Good or excellent mobility in 12 months occurred only in 77.4% of the early intervention group (less than 6 hours), but in only 34.4% of the delayed group (more than 12 hours). Although technically, a limb can be salvaged, it is its functional value that can be significantly impaired by the presence of prolonged ischemia, probably caused by

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reperfusion injury (Singh, D., and Pinjala, R. K. 2005; Fowler, J. *et al.*, 2009; Hornez, E. *et al.*, 2015), compartment syndrome, and permanent neuromuscular damage.

Certain studies discovered that functional outcomes, which can be denoted by scales such as the Lower Extremity Functional Scale (LEFS), are more sensitive measures of success than salvage itself. (Williams, T. K., and Clouse, W. D. 2016; Byerly, S. *et al.*, 2020)

Risk-factor analysis clarified a multidimensional situation that has an impact on prognosis. Significant poorer outcomes were independently related to advanced age (45 years), high Injury Severity Score (ISS 25), or pre-existing comorbidities, especially diabetes mellitus (OR 4.23) and peripheral vascular disease (OR 5.12). The observation that a greater complication profile was correlated with synthetic graft usage than with autologous vein grafts is a reflection of the old surgical ad maxim of using venous conduits in contaminated traumatic areas. (de Silva, W. *et al.*, 2011; Fox, N. *et al.*, 2012)

We have a complication profile with a rate of early graft thrombosis of 11.4 percent and an infection rate of 17.1 percent, which is similar but slightly lower than previously published series of delayed traumatic ischemia. This could indicate improvements in the care provided during the perioperative period, such as conservative aggressive anticoagulation regimens and the multidisciplinary approach to wound management. The gunning prevalence of chronic sequelae, however, including chronic (25.7) and neuropathic pain (21.0) at one year, is a wake-up call of the realization that the end of recovery is so far beyond the first year of postoperative. (Sharma, A. *et al.*, 2015; Alam, H. B., and DiMusto, P. D. 2015; Feliciano, D. V. 2017) These chronic disabilities have a considerable effect on quality of life and rate of return to work, 36.2% of our group ever returned to full occupational duty at 6 months.

CONCLUSION

Delayed limb ischemia Revascularization has positive limb salvage (81.9) and satisfactory functional outcomes. The most important modifiable factor with respect to the outcomes is time to revascularization. Under 6 hours of intervention leads to a great way of salvaging limbs, better functional recovery, and fewer complications.

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