Retrospective Review of Air Transportation Use for Upper Extremity Amputations at a Level-1 Trauma Center

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Abstract

Introduction Air transportation to tertiary care centers of patients with upper extremity amputations has been utilized in hopes of reducing the time to potential replantation; however, this mode of transportation is expensive and not all patients will undergo replantation. The purpose of this study is to review the appropriateness and cost of air transportation in upper extremity amputations.

Materials and Methods Consecutive patients transported by aircraft with upper extremity amputations in a 7-year period at a level-1 trauma center were retrospectively reviewed. The distance traveled was recorded, along with the times of the injury, referral, transportation duration, arrival, and start of the operation. The results of the transfer were defined as replantation or revision amputation.

Results Overall, 47 patients were identified with 43 patients going to the operating room, but only 14 patients (30%) undergoing replantation. Patients arrived at the tertiary hand surgery center with a mean time of 182.3 minutes following the injury, which includes 105.2 minutes of transportation time. The average distance traveled was 105.4 miles (range, 22–353 miles). The time before surgery of those who underwent replantation was 154.6 minutes. The average cost of transportation was \$20,482.

Discussion Air transportation for isolated upper extremity amputations is costly and is not usually the determining factor for replantation. The type of injury and patients' expectations often dictate the outcome, and these may be better determined at the time of referral with use of telecommunication photos, discussion with a hand surgeon, and patient counseling.

Level of Evidence III.

Keywords

- ▶ air transport
- ▶ upper extremity amputation
- ▶ digit amputation
- ▶ replantation

Introduction

Emergent referral to tertiary care centers of patients with upper extremity amputations for potential replantation is common. Friedrich et al recently describe 8,567 patients in a 3-year period

with finger amputations in the United States resulting in 27% of thumb and 12% of finger amputations being replanted.¹ Air transportation for these injuries has been utilized to reduce the time to potential surgery. While survival and discharge disposition have been shown to improve with air transportation in

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critically ill patients,² ground transportation revealed equivalent outcomes in stroke victims who already receive thrombolytic treatment.³ There have been few studies reviewing the use of air transportation in the setting of upper extremity amputations. In 2010, Ozer et al found a considerable portion of patients transported via air did not undergo replantation surgery.⁴ With the high cost of transportation and refinement of replantation, indications for the use of air transportation should be further evaluated.⁵ The purpose of this study is to review the appropriateness and cost of air transportation in upper extremity amputations.

Materials and Methods

After institutional review board approval, consecutive patients from April 2004 to September 2011 with upper extremity amputations seen at a level-1 referral center were retrospectively reviewed. Using International Classification of Diseases-Ninth Revision codes for upper extremity amputations, 918 patients were identified. Those who were transported by helicopter or fixed wing aircraft were included in the study. Patients with an additional life or limb-threatening injury were excluded.

Chart review provided basic demographics such as sex, age, hand dominance, occupation, smoking status, history of diabetes, and if the injury was work related. Injury levels were divided into flexor zones I–V, forearm, elbow, or humerus. The mechanism was recorded as clean cut, crush, or avulsion.

The time from the traumatic injury to arrival at the tertiary hospital was recorded. Transportation time was determined as the time when the air transportation was requested by the referring institution to arrival at the tertiary hospital, while presurgery time was defined as the time from arrival at the tertiary hospital to the beginning of the operation. The duration from injury to the beginning of the procedure was recorded as ischemia time. The distance the patient traveled from the referring institution to the tertiary hospital was also recorded.

The results of the transfer were defined as replantation, revision amputation in the operating room, or revision amputation in the emergency department. A successful replant was defined as the patient being discharged with a viable replanted limb.

From 2008 to 2011, the medical billing was analyzed for average cost of air transportation, emergency department care, and total hospitalization. These costs were the hospital charges independent of insurance status. Before 2008, the financial records were not detailed in a manner that allowed for accurate comparisons.

Results

A 7-year review at a tertiary referral center with specialized hand surgeons found 918 patients with upper extremity amputations. A total of 57 (6%) underwent air transport, and 47 (5%) of these met our inclusion criteria. Patient demographics are shown in ► **Table 1**. This group comprised 36 men and 11 women with a mean age of 39.0 ± 19.9 years. Overall, 11 patients (23%) had zone I injuries, 22 (47%) with zone II injuries, and 8 (17%) with injuries proximal to the

wrist. Out of the 47 patients, 13 patients (28%) had clean-cut amputations while 34 patients (72%) sustained avulsion or crush injuries.

A total of 43 patients went to the operating room with 14 patients (30%) undergoing replantation. Four patients had revision amputations in the emergency room and were discharged home after the procedure. Six patients on arrival had missing amputated digits. Of the 14 patients who underwent replantation, 9 procedures (19%) were considered successful as they were discharged from the hospital with a viable appendage. None of the three attempted replants proximal to the wrist survived to discharge. Three patients had a good functional outcome at time of last follow-up as reported by the attending surgeon. One patient had partial use of the digit. Four of the nine replanted patients had poor function of replanted digits. Two patients eventually underwent amputation of the replanted digit due to poor function and pain. One patient was lost to follow-up.

A hand surgeon was contacted before transportation on 23 (49%) occasions. Ten of these patients (43%) underwent replantation versus 4 of 15 (27%) and 0 of 9 patients, when emergency physicians or emergency medical technicians made the decision to transfer, respectively. The reasons cited for needing air transportation to the tertiary center were that the patient was a candidate for replantation (55%), there was no available hand surgeon at the referring institution (30%), or the significant complexity of the injury (13%).

Patients were brought by aircraft to a tertiary hand surgery center with a mean time of 182.3 minutes (range, 57–661 minutes) following the traumatic upper extremity injury, which includes 105.2 minutes of transportation time. The average distance traveled was 105.4 miles (range, 22–353 miles). A total of 19 patients were flown directly from the scene directly to the tertiary hospital. The presurgery time of those who underwent replantation was 154.6 minutes compared with 237.5 minutes for those that were revised in an operating room.

The average cost of transportation by a fixed wing aircraft or helicopter was \$20,482. The emergency department cost was \$5,124 for isolated upper extremity injuries or \$7,593 for patients requiring evaluation to rule out substantial other traumatic injuries. Excluding transportation, the total cost of hospitalization for these patients was \$52,477.

Discussion

Our study found the main reasons for transferring a patient with an upper extremity amputation to a tertiary center was for potential replantation or the lack of an available hand surgeon at the referring institution. These two factors are appropriate initial considerations for transfer for replantation purposes. A Tennessee study showed that only 7% of hospitals have a hand surgeon on call at all times, 18% have a hand surgeon on call occasionally, and 42% do not have a hand surgeon.⁶ Patients were subsequently flown to a hospital for evaluation and treatment by a hand surgeon. Ultimately, 70% of these patients did not undergo replantation, including 9% (4/47) that were able to be revised in the emergency department. Ozer et al had similar results with 62.5% of patients not

Table 1 Patient and injury characteristics of replanted versus revised upper extremity amputations

Characteristics	Replanted		Revised				All patients	
			OR		ED			
Number of patients	14	29.8%	29	61.7%	4	8.5%	47	
Age (y)	35.3 ± 18.9		40.4 ± 20.0		41.7 ± 27.0		39 ± 19.9	
Male:female	9:5		23:6		4:0		36:11	
Health status								
Smoker	6	4.9%	11	37.9%	1	25.0%	18	38.3%
Diabetes mellitus	0	0.0%	1	3.4%	2	50.0%	3	6.4%
Occupation								
Laborer	9	64.3%	16	55.2%	2	50.0%	27	57.4%
Sedentary	0	0.0%	5	17.2%	0	0.0%	5	10.6%
Student/unemployed/retired	5	35.7%	6	20.7%	1	25.0%	12	25.5%
Unknown	0	0.0%	2	6.9%	1	25.0%	3	6.4%
Workers' compensation	8	57.1%	7	24.1%	1	25.0%	16	34.0%
Mechanism of injury								
Clean cut	5	35.7%	7	24.1%	1	25.0%	13	27.7%
Crush	3	21.4%	7	24.1%	2	50.0%	12	25.5%
Avulsion	6	42.9%	15	51.7%	1	25.0%	22	46.8%
Level of amputation								
Zone I	1	7.1%	7	24.1%	3	75.0%	11	23.4%
Zone II	7	50.0%	14	48.3%	1	25.0%	22	46.8%
Zone III	1	7.1%	1	3.4%	0	0.0%	2	4.3%
Zone IV	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Zone V	2	14.3%	2	6.9%	0	0.0%	4	8.5%
Forearm	1	7.1%	3	10.3%	0	0.0%	4	8.5%
Elbow	0	0.0%	1	3.4%	0	0.0%	1	2.1%
Humerus	2	14.3%	1	3.4%	0	0.0%	3	6.4%
Transfer characteristics								
Injury to arrival at tertiary center (min)	197.6 ± 123.4		189.1 ± 152.1		100.3 ± 38.0		182.3 ± 138.7	
Transport time (min)	117.1 ± 74.9		105.6 ± 75.9		64.5 ± 18.3		105.2 ± 72.3	
Presurgery time (min)	154.6 ± 75.9		237.5 ± 173.0				209.9 ± 151.9	
Ischemia time (min)	348.1 ± 117.7		429.6 ± 209.7				406.3 ± 190	
Distance traveled (miles)	104.7 ± 97.4		104.7 ± 73.1		113.0 ± 96.8		105.4 ± 80.9	
Reason for referral								
No hand surgeon	4	28.6%	9	31.0%	1	25.0%	14	29.8%
Replant candidate	9	64.3%	16	55.2%	1	25.0%	26	55.3%
Complexity of injury	1	7.1%	3	10.3%	2	50.0%	6	12.8%
Unknown	0	0.0%	1	3.4%	0	0.0%	1	2.1%
Length of stay (d)	7.2 ± 5.5		3.1 ± 4.1		1.5 ± 1.0		4.2 ± 4.8	

Abbreviations: ED, emergency department; OR, operating room.

receiving replantation after air transportation.⁴ These results bring to question the appropriateness of air transportation in the transfer of patients with upper extremity amputations. With increasing emphasis on cost efficiency in medicine,

proper triage of upper extremity amputations may reduce costs and improve resource utilization.

Air transportation cost on average \$20,482, with only 62% being paid by the patient or insurer. Moreover, the average

total cost of the hospitalization was \$52,477 without the added expense of transportation, which is comparable to Friedrich et al cost of \$42,561 for the hospitalization following replantation.¹

Despite the additional cost for air transportation, it is not clear that it meets its objective of expediting transfer to optimize viability of the amputated appendage for replantation. Although Lin et al, showed successful digital replantation after 24 hours of ischemia, the length of ischemia time is particularly important in proximal replantation, of which none survived to discharge.⁷ This time dependence is likely related to the muscle content in the proximal amputations. On average, it took over 3 hours from the time of injury for the patient to be evaluated at the tertiary center. Transportation time in minutes was similar to mileage travelled to the tertiary center raising questions on how much slower an ambulance would be. One potential reason for this is that many referring institutions do not have easily accessible aircraft and must wait for one to arrive before being able to transfer the patient. An ambulance may be more universally available and provide a comparable transportation time.

Following patient arrival, there are still delays in getting the patient to the operating room. On average, the time from hospital arrival to incision was 2.5 hours for those undergoing replantation. The presurgery time in our study for replantation is reasonable at 154.6 minutes considering the many steps to be completed before beginning an operation. Evaluation must be completed for the candidacy for potential replantation by the hand surgeon at the tertiary center and then preparations may be made for replantation. This includes further evaluation by an anesthesiologist and multiple nursing assessments. However, if the patient is not a candidate for replantation, there is less of an urgency as shown by a nearly 4-hour delay in those being revised.

The main reason cited in this study for not replanting was a crush or avulsion mechanism for 70% (23/33) of patients. Although communication with a hand surgeon before transport was noted 49% of the time, an accurate verbal description of the injury may be difficult for nonhand specialists. Scher et al revealed a paucity of hand pathology and treatment knowledge among emergency and internal medicine residents.⁸ While Lifchez et al demonstrated improved hand knowledge among residents who completed a hand surgery rotation,⁹ the use of telecommunications may be more practical. Good sensitivity and specificity has been shown using images transmitted from a camera-phone between a remote hand surgeon and on-site hand surgeon to distinguish injuries with reasonable replant potential.¹⁰

In addition to a crush or avulsion mechanism of injury, Ozer et al found patient refusal secondary to a delay in return to work as a common reason for not attempting replantation.⁴ As that study recommends, appropriate preoperative counseling on the functional outcomes after a prolonged treatment course reduced the number of patients wanting replantation. While this statistic was not directly addressed by our study, patients' wishes were included in the decision to proceed with a revision amputation. However, if this counseling was per-

formed by the referring institution, the cost of transfer may have been greatly reduced without the urgency.

The goal of this study was to analyze the utilization of air transportation in patients who have suffered an upper extremity amputation. While the study is retrospective with a small series of patients, analysis reveals that there is a significant amount of money unnecessarily spent on air transportation that might be saved with appropriate transfers. Another potential weakness of the study is the lack of comparison to transfers by land vehicles; however, our study wanted to focus on the way to reduce transportation costs and not specific differences between groups. Ground transportation timing is difficult to assume, thus, making a comparison to the air transportation time useless. Regardless, air transportation was not as fast as expected as nearly half of the patients did not arrive sooner than a normalized transportation time of 1 minute/mile.

Air medical transportation for isolated upper extremity amputations is costly and is not usually the determining factor for replantation. The type of injury and patients' expectations often dictate the decision to attempt replantation, and these could be better determined at the time of referral with use of telecommunication photos, discussion with a hand surgeon, and patient counseling. We suggest a hand surgeon should be involved in the decision-making process regarding air versus ground transportation. Based on our observations, upper extremity amputations proximal to the wrist and those farther than 2 hours from the tertiary center may be the most appropriate to consider for air transportation.

Note

This study did not receive any funding. For this type of study a formal consent is not required.

Conflict of Interest

None.

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