

# Functional Outcomes of Major Upper Extremity Replantation: A Scoping Review

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**Background:** Traumatic upper limb amputations proximal to the carpus are devastating injuries. Existing literature on outcomes following replantation is limited. Our objective was to perform a scoping review of (1) functional outcomes; (2) return to work data; and (3) secondary surgeries required following proximal to carpus replantation.

**Methods:** A literature search of MEDLINE, EMBASE, Cochrane, and CINAHL was performed according to PRISMA guidelines. All studies reporting on functional outcomes, return to work, or secondary surgeries following replant of traumatic proximal to carpus amputation were included.

**Results:** Of the 753 articles, 13 studies were included, accounting for 136 major upper extremity replants (0 shoulder, 36 arm, 14 elbow, 86 forearm). Average age was 35 (24-47) years, with average follow-up of 8 years (2-18). Chen's Functional Criteria was the most common tool for reporting outcomes (10/13). Level of injury was related to functional outcome, with excellent to good Chen scores for replants distal to elbow, and poor Chen scores for replants at or proximal to elbow. Return to work correlated with level of replantation, with successful return for 65% of forearm, 43% of elbow, and 32% of arm replants. A mean of 2.4 secondary procedures were required.

**Conclusions:** This study provides insight into major upper extremity replantation, to assist in patient counseling and surgical decision making. Good functional outcomes and successful return to work are directly related to level of injury following major upper extremity replant. Patients should be counseled that more than 1 secondary procedure may be required. (*Plast Reconstr Surg Glob Open* XXX;8:e3071; doi: 10.1097/GOX.0000000000003071; Published online 27 October 2020.)

## INTRODUCTION

Traumatic major upper extremity amputations are life-altering injuries. These amputations are defined as “major” when they occur as transections through the limb at or proximal to the wrist.<sup>1</sup> Given the impact on quality of life and functional limitations with a lost limb, major upper extremity replantation is commonly pursued.<sup>2</sup> In the last 20 years, we have made strides in the delivery of microsurgical care and postoperative rehabilitation regimes, which have invariably had a positive impact on the viability and functional outcomes of these replantation injuries.<sup>3</sup> Several reviews on digital replants already

exist. A similar review for major upper extremity replants has not yet been performed.<sup>4,5</sup>

The purpose of this study was to perform a scoping review of upper extremity replantation proximal to the wrist, specifically seeking to identify which functional outcomes have been reported and how the level of injury impacts the functional outcome. Return to work data and secondary surgeries performed are also assessed.

## METHODS

The objectives, inclusion criteria, and methods for this scoping review were developed a priori and are reported in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analyses guidelines. To satisfy the inclusion criteria, studies included (1) adult patients over the age of 18 (2) with complete traumatic amputations of the upper limb (3) proximal to the wrist. Studies also had to either include outcome data of any kind, discussion of secondary procedures, or return to work information. Only studies published from the year 2000 and onwards were included, to reflect the microsurgical

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advancements in the last 2 decades.<sup>6</sup> Studies reporting on partial amputations or complete amputations through the wrist crease or distal to the wrist crease were excluded. Non-English language and pediatric studies, case reports, letters, conference proceedings, abstracts, and textbook chapters were also excluded.

An electronic literature search of MEDLINE (via Ovid), EMBASE (via Ovid), CINAHL (via EBSCO), Cochrane Database of Systematic Reviews (via Ovid), and Cochrane Central Register of Controlled Trials (via Ovid) was conducted to identify relevant studies published from January 2000 to January 2019. Comprehensive searches for each database were created with the assistance of a medical librarian (Z.P.). The searches included keywords and subject terms, where available. The records were downloaded, and deduplicated using EndNote X8. Studies were reviewed independently by two authors (M.R. and A.K.S.), and disagreements were resolved through discussion and achieving consensus with senior author (J.Y.) when needed. Reference lists of the included articles were scanned for additional studies that satisfied the inclusion criteria.

Data extraction was completed by two reviewers (M.R. and A.K.S.) using a spreadsheet determined a priori. Study characteristics collected include age, sex, mechanism of injury, level of injury, ischemia time (hours), and length of follow-up (years). Reported functional outcomes, return to work data, and frequency and type of secondary procedures were reviewed. Where functional outcomes were reported consistently in the literature, summary data were generated.

## RESULTS

The primary search identified 753 unique articles. After title and abstract review, followed by full-text article review, a total of 13 articles fulfilled the inclusion criteria (Fig. 1).<sup>1,4-15</sup> Study designs consisted of 12 retrospective reviews and 1 case series. A total of 136 replanted limbs were included in the analysis. When reported, mean patient age was 35 (24–47) years and the male-to-female ratio was 8:1.

Average ischemia time was 4.8 hours (2.0–10.7) and average follow-up recorded was 8 years (range 2–18 years). Mechanism of injury was equally divided among crush (N = 42, 32%), avulsion (N = 50, 38%), and sharp (N = 41, 31%) injury patterns. The majority of replants involved the forearm (63%). There were no shoulder-level replantations. Level of injuries included 36 (26%) arm replantations, 14 elbow replantations (10%), and 86 forearm replantations (63%). When specified, in 70 of 86 forearm replants, 23% (16) were proximal injuries, 41% (29) were mid-forearm injuries and 36% (25) were distal forearm injuries. Demographic data are summarized in Tables 1 and 2.

Functional outcomes reported were highly variable. An estimated 10 of 13 studies evaluated outcomes by way of Chen's functional criteria. This scoring method relies on the surgeon's assessment of the patient's use of the limb, based on 4 objective criteria: sensation, range of

motion, Medical Research Council (MRC) power grade, and global use of the affected extremity.<sup>15,16</sup> Replantations are then rated as grade I (excellent), grade II (good), grade III (fair), and grade IV (poor). A summary of the Chen criteria can be found in Table 3. Most of the forearm replants in this review were rated with an excellent to good rating, whereas a majority of elbow and arm replants had a fair to poor outcome (Table 4).

A single study reported outcomes using the TAMAI scoring. The TAMAI score involves a multicategorical scoring that is made up of 100 points. The TAMAI score involves the measurement of joint range of motion, ability to perform activities of daily living, subjective symptoms, patient overall satisfaction, and job status.<sup>16,17</sup> Of the 11 cases graded using the TAMAI scoring, 1 patient had a poor outcome (9%), 5 with a fair outcome (45%), and 5 more with a good outcome (45%).<sup>14</sup>

The only validated patient-reported outcome used was the DASH score, which was captured in 3 of 13 studies.<sup>8,10,12</sup> The mean DASH score reported for any major upper extremity replant, at any level was 40.4 (range 4.5–94.8).

With regard to return work, 65% of forearm-level replant patients were able to return employment, with 23% returning to their original preaccident employment. For elbow-level replants, 43% of patients returned to employment, with 14% returning to original preaccident employment. Finally, for arm-level replants, 32% of patients returned to work, with only 3% returning to their former employment (Fig. 2). Time required before return to work is not well reported. A single study comments that of the 36 patients included in their review, social integration was obtained at an average of 8 months and average time for overall treatment and return to a normal lifestyle was 1.5 years<sup>6</sup> (Table 5).

Five studies document the need for performing secondary procedures to optimize use and functional outcome of the replanted extremity.<sup>1,2,4,5,8</sup> Among 43 patients reviewed in these 5 studies, approximately 105 secondary procedures were performed. This accounts for 2.4 secondary procedures per patient. Most performed procedures were soft tissue resurfacing with skin graft or local flap, followed by tenolysis. Other procedures included nerve grafting, tendon transfers, digit joint release, replacement, and wrist arthrodesis. Two studies also comment on the need for performing free functioning muscle transfer to augment volitional range of motion with gracilis or latissimus free flap transfer.<sup>6,8</sup> This was performed in 5 patients (Fig. 2).

## DISCUSSION

Our study provides a review of major upper extremity replants published from the year 2000 onwards. Replant level is organized by the forearm (distal, mid, proximal), elbow, arm, and shoulder. As mentioned, no replants at the shoulder are documented in this review. There is a broad variability in functional outcomes reported in the literature for major upper extremity replants, making it difficult to collate results.

The most consistently reported outcome was Chen's functional criteria. As expected, more distal injuries

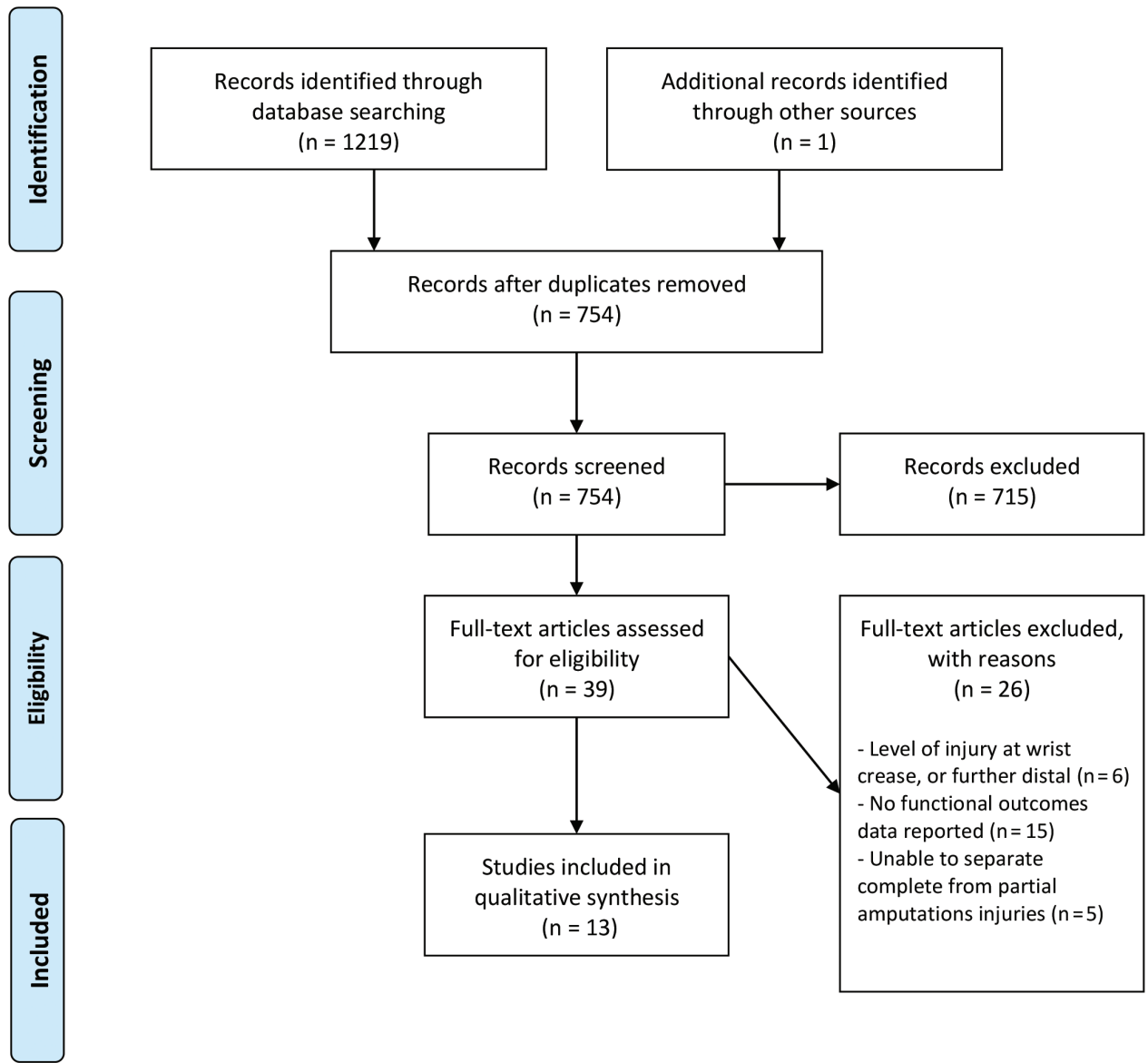


Fig. 1. PRISMA flow diagram.

involving the forearm were largely found to have an excellent to good outcome. Proximal injuries involving the elbow, a major joint of the upper extremity, as well as the arm had a majority of fair to poor outcomes.

Although frequently used, the Chen scoring has limitations as a classification system. It relies exclusively on the surgeon’s assessment of the injury and does not consider patient perspective through patient-reported outcomes. Furthermore, it is unclear from the published literature as to whether failure to meet one of the four criteria is enough to change the grade of outcome from one level to the next.

Secondary procedures are often required in major upper extremity replant patients. Of the 43 patients, more than 100 procedures are listed, with each patient receiving an average of 2.4 procedures following replant. Given this, surgeons can convey to patients at the time

of replantation that subsequent surgical procedures will likely be required, with the possibility of 2 or more procedures. These secondary procedures aim to augment volitional control, range of motion, and reliable coverage of the replanted limb and can contribute to the overall functional outcome.

Return to work data identified in this review can be used to counsel patients on likelihood of return to work following replantation of the upper extremity. It would be reassuring for a patient to know that a majority of patients with forearm replantation (65%) will return to the workforce and nearly a quarter (23%) will even return to their preaccident job-level work. For more proximal injuries, less than half will be gainfully employed in an alternative job following their injury (31% of arm and 43% elbow replants). The reason for this is not elaborated on in the literature, but could be due to a myriad of reasons, including lack of

**Table 1. Patient and Injury Characteristics**

Patient Characteristics (N = 136)	
Age, y (mean)	35
Male-to-female ratio	8:1
Upper extremity injury characteristics (N = 136)	
Ischemia time, h (mean)	4.8 (2.0–10.7)
Follow-up, y (mean)	8 (2–18)
Mechanism of injury (N = 133)	
Crush	42
Guillotine	41
Avulsion	50
Level of upper extremity replantation (N = 136)	
Shoulder	0
Arm	36
Elbow	14
Forearm	86

**Table 2. Level of Forearm Replantation (n = 70)**

Proximal forearm	16 (23%)
Mid forearm	29 (41%)
Distal forearm	25 (36%)

meaningful function of the replanted limb, chronic pain, and mood instability. Finally, returning to former employment with an arm-level replantation is rare (3%). The statistics reported here may help promote realistic patient expectations for employment following replantation. It should be noted that our study includes a large number of replantation following crush or avulsion (92/133). The functional results for these patients should be interpreted accordingly. It is likely that overall functional outcomes would be even more optimistic for guillotine-type injuries.

In the absence of replantation, amputation with prosthesis is challenged with its own shortcomings. Prosthesis can range from simple cosmetic hands to complex, functional myoelectric limb and access to these are impacted by regional availability, local expertise, ability to pay, and level of injury. Patients with upper extremity replantation have similar chances of return to work when compared with those with upper extremity amputation and a prosthesis. A study

**Table 3. Chen’s Functional Criteria**

Grade 1 (Excellent): (1) ability to resume original work with critical contribution from the reattached parts; (2) collection joint ROM exceeds 60% of normal, including the joint immediately proximal to the reattached part; (3) recovery of sensibility to a high grade without excessive intolerance to cold; and (4) muscular power of 4–5

Grade 2 (Good): (1) ability to resume some gainful work but not for original employment; (2) range of joint motions exceeds 40% of normal; (3) recovery of near normal sensibility in the median and ulnar nerve distributions without severe intolerance of cold; and (4) muscular power of Grades 3–4

Grade 3 (Fair): (1) independence in activities of daily living; (2) range of joint motions exceeds 30% of normal; (3) poor but useful recovery of sensibility; and (4) muscular power of grade 3

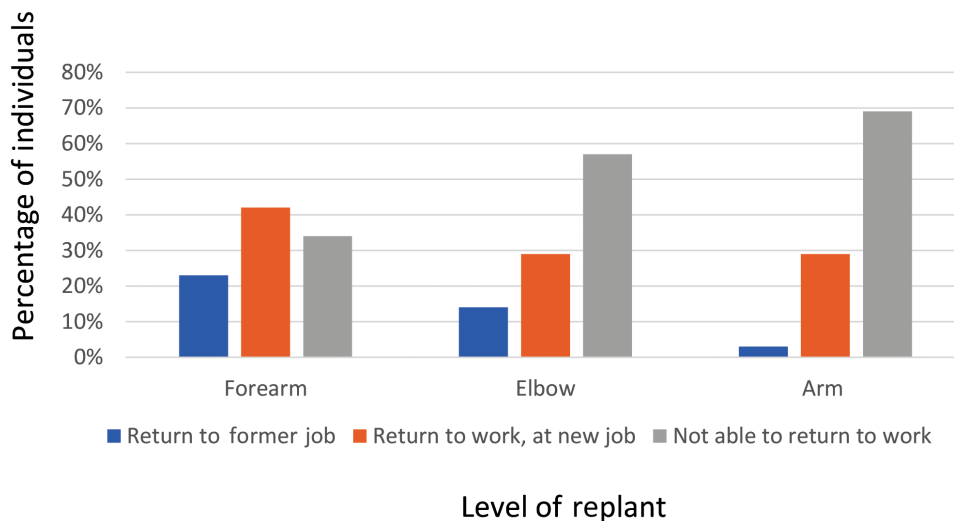
Grade 4 (Poor): (1) tissue survival with no recovery of useful function

**Table 4. Chen’s Functional Criteria for Replant Level**

Level of Injury	Excellent (I)	Good (II)	Fair (III)	Poor (IV)
Forearm	15 (23%)	27 (42%)	13 (20%)	9 (14%)
Elbow	2 (14%)	4 (29%)	5 (36%)	3 (21%)
Arm	1 (3%)	10 (29%)	18 (51%)	6 (17%)

by Jang et al<sup>18</sup> reported that following amputation, 40% of patients were unable to return to work of any kind, which is similar to our study, wherein 39% of replant patients were unable to return to work following injury. Their study reports no statistically significant difference in the extent of return to occupation based on prosthesis type or level of injury.<sup>18</sup>

A substantial limitation of prosthesis however, when compared with replant, is related to the aesthetic loss of limb and the sense of continued disfigurement by the patient. In fact, a systematic review, performed by Otto et al<sup>19</sup> sought to compare outcomes between replanted limbs and upper extremity amputation with prosthesis. Their review found



**Fig. 2.** Return to work, based on replant level. Return to work date for major upper extremity replants, based on level of replant.

**Table 5. Return to Work, Based on Replant Level**

Level of Injury	Return to Original Work	Return to Work, New Job	Not Able to Return to Work
Forearm	15 (23.4%)	27 (42.2%)	22 (34.4%)
Elbow	15 (14.3%)	4 (28.6%)	8 (57.1%)
Arm	15 (2.9%)	10 (28.6%)	24 (68.6%)

that replantation at any level yielded a high level of satisfaction specifying sensation and psychological well-being as two significant advantages of replant over prosthesis.<sup>19</sup>

An outcome not addressed in this systematic review is the higher cost of upper extremity replantation compared with amputation. Friedrich et al<sup>20</sup> reported that replantation is associated with an average hospital stay of 5.8 days and hospital charges of \$42,561, whereas patients receiving amputation stay are associated with an average of 3.5 days with total charges of \$27,541. When combining the need for repeat surgeries, extended rehabilitation, and days of work lost, replantation is more expensive than amputation.<sup>20</sup> What costs are not accounted for here however are visits made with the prosthetist and the prosthesis itself.

A limitation of this scoping review is the low-quality evidence of the existing literature. The studies featured suffer from small patient numbers, publication bias, and mixed follow-up duration. Furthermore, given that the literature presents variable outcome measures, it was challenging to draw reliable conclusions. Many studies had to be excluded, as there were inconsistencies in clear identification of the level of injury and in terms of whether the injury was complete or partial. This contributed to a lower number of cases captured.

## CONCLUSIONS

Outcomes following major extremity replantation vary by level of injury. Inconsistent methods for reporting functional outcomes and a lack of patient-reported outcome measures following major upper extremity replantation make it difficult to compare functional success across studies. Consistently reported validated patient-reported outcome measures would increase our ability to critically assess functional outcomes following major upper extremity replantation in the future.

Functional outcomes following upper extremity replantation remain optimistic. While most patients do not return to their preaccident employment, up to one-third of patients return to meaningful work. Patients with higher level amputations should be cautioned that return to work may be less likely. An average of 2.4 secondary procedures may be required to achieve optimal functional results.

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