Eur J Vasc Endovasc Surg (2016) 52, 119—123

Long-term Clinical Outcome and Functional Status After Arterial Reconstruction in Upper Extremity Injury

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WHAT THIS PAPER ADDS

Long-term functional outcome using the Disabilities of Arm, Shoulder, and Hand (DASH) score after repair of arterial lesions in upper extremity injury is presented. The 30 item DASH questionnaire conceptualizes the upper extremity as a single functional unit, and refers to the patient's everyday activities. High DASH scores indicate high grades of disability of the affected limb. For the first time, significant functional long term deficits, assessed by DASH scores, are shown in two groups of patients (those with associated neurological injuries, and those with initial limb ischemia without neurological concomitants) after repair of upper limb arterial lesions.

Objective/Background: To analyse long term outcome, including functional status and prognostic factors, in patients who have undergone arterial repair of civilian upper limb injury.
Retrospective data analysis of prospectively collected data was performed.
Methods: This was a retrospective data analysis of prospectively collected data. Records of all patients who had undergone repair of traumatic arterial lesions in the upper limb between 1989 and 2010 were reviewed, and clinical follow up was performed. End points were: long term patency, measured by color Doppler ultrasound; vascular re-intervention; limb salvage rate; and long term functional status using the Disabilities of Arm, Shoulder, and Hand (DASH) questionnaire. The DASH questionnaire is an instrument used to identify a patient's disabilities, in which everyday activities are assessed by 30 questions. The DASH answers are summarized and, using a conversion formula, lead to a score between 0 (full recovery) and 100 (severe disability). The DASH questionnaire was sent to all German-speaking individuals for data supplementation after completion of a clinical follow up study.
Results: A total of 117 arterial repairs were performed in 108 patients (87 men, median age 35.7 years). Blunt trauma was the predominant cause of injury ($n = 96$; 82%). Accompanying nerve lesions ($n = 39$; 36%) and/or orthopedic injuries ($n = 65$; 60%) were present in 84 patients (78%). After a median follow up time of 5.3 years (range 0.5—19.7 years), 65 patients (60%) were re-investigated: long-term patency was 97%. The DASH questionnaire was answered by 57 patients (53%). Functional impairment was frequently seen, and determined by neurological injury (including neurological lesions, median DASH score was 40.3 [range 3.5—69.8] vs. 0.8 [range 0—5.8] without; $p < .001$) and ischemia at time of injury (median DASH score with ischemia 4.2 [range 0—16.9] vs. 0.0 [0—1.7] without; $p < .04$).
Conclusion: Favorable long term patency rates after arterial repair in upper extremity injuries can be achieved. Long term functional impairment is a significant problem and determined by associated neurological injury, as well as ischemia at time of injury.

Article history: Received 4 February 2015, Accepted 26 March 2016, Available online 28 April 2016
Keywords: Arterial injury, Functional outcome, Trauma, Upper limb

INTRODUCTION

There is a lack of data in the current literature on long-term functional outcome after repair of traumatic arterial lesions in the upper extremity. To the authors' knowledge, only six series with a follow up >6 months have been published.[1—6]

In summary, these studies have shown that the mechanism of injury is essential: penetrating trauma is usually characterized by limited damage within a limited area and few accompanying lesions; blunt trauma is more frequently associated with neurological and orthopedic injuries and is therefore demonstrated to lead to a significantly higher rate of disability.[1—5,7—14]

The present study is a retrospective outcome analysis aimed at evaluation of functional results using the Disabilities of Arm, Shoulder, and Hand (DASH) score in a

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1078-5884/
http://dx.doi.org/10.1016/j.ejvs.2016.03.028

consecutive series of patients who had undergone arterial repair in upper extremity injuries treated at the Medical University of Innsbruck, Innsbruck, Austria, a level I trauma center. Clinical data of the subgroup of patients with blunt trauma have been reported previously.[15]

MATERIALS AND METHODS

All patients who had undergone repair of arterial injuries as a result of upper limb trauma from 1989 to 2010 at the Medical University of Innsbruck, Innsbruck, Austria, a level I trauma center, were invited for clinical follow up studies, which included physical examination, bilateral segmental blood pressure evaluation and calculation of arterial pressure indices, and duplex ultrasound. In addition, to measure self reported functional disability, all individuals were asked to complete the DASH questionnaire.[16–19] It took some time to receive completed questionnaires from a sufficient number of patients, which delayed the evaluation. The DASH questionnaire was sent to all participants in 2010. Therefore, there was no predefined time interval between injury and answering the questionnaire. The 30 item DASH questionnaire conceptualizes the upper extremity as a single functional unit, and refers to a patient's everyday activities. The questionnaire has been extensively validated and frequently used to assess wrist and hand function in patients with different diseases and injuries.[16–24] The DASH answers are summarized and, using a conversion formula, give a score between 0 (full recovery) and 100 (severe disability). The validated German version of the DASH questionnaire was sent to living, German-speaking individuals ($n = 85$) and was answered by 57 patients (67%).[18]

Data collection included demographic parameters, mechanism of injury, location and type of arterial lesion, presence of ischemia defined by signs and symptoms that are characterized by the six "*ps*" (pulselessness, pallor, pain, poikilothermia, paresthesia, and paralysis), severity of hand ischemia classified according to Rutherford in categories I–III,[25] presence of concomitant injuries (vein, nerve, bone and/or joint), and details of arterial reconstruction. For outcome analysis, long-term patency of arterial repair, vascular re-intervention, limb salvage rate, and functional impairment, as detected by DASH scores, were calculated. Statistical analysis was performed using descriptive statistics, and median and quartiles of DASH scores were calculated. Subgroup analysis and comparison of DASH scores was performed using the Mann–Whitney *U* test, which was considered significant at $p < .05$.

Study design was constructed according to the guidelines of the institutional review board.

RESULTS

A total of 108 consecutive patients (87 men, median age 35.7 years [range 2.5–87.6]) underwent reconstruction of 117 injured arteries of the upper extremity. The majority of lesions ($n = 96$; 82%) were caused by a blunt injuries, 10 by penetrating trauma, and 11 were iatrogenic. Clinical data in the cohort with blunt injuries have been published previously.[15] The left extremity was involved in 64 lesions, the right extremity in 53. Arteries injured included the subclavian ($n = 24$; 20.5%), axillary ($n = 22$; 18.8%), brachial ($n = 53$; 45.3%), radial ($n = 13$; 11.1%), and ulnar ($n = 5$; 4.3%). Forty-three patients (40%) presented with limb ischemia. Accompanying nerve injuries ($n = 39$; 36%) and/or orthopedic injuries ($n = 65$; 60%) were present in 84 patients (78%). Nerve trauma included 21 patients with brachial plexus injuries, and 18 patients with isolated or combined injuries to the median ($n = 13$), ulnar ($n = 8$), radial ($n = 8$), musculocutaneous ($n = 4$), axillary ($n = 1$), and/or suprascapular ($n = 1$) nerve. Orthopedic lesions included 53 fractures and 21 luxations. A total of 14 patients (13%) had severe concomitant injuries to the head or neck ($n = 9$), chest ($n = 5$), abdomen ($n = 3$) and/or vertebral column ($n = 2$).

Within 30 days post-surgery, five patients (with five arterial repairs) died and two patients (with three arterial reconstructions) were amputated (major amputation) at the upper arm level because of severe, life threatening wound infection. At the time of discharge from the hospital, 108 of 109 arterial repairs were patent (secondary patency rate 99%). Patency was measured by color Doppler ultrasound.

Long-term clinical follow up data were available for 65 patients (60%) after a median follow up period of 5.3 years (range 0.5–19.7 years). During this time, 12 patients had died, although none as a consequence of previous upper limb injury. No patient underwent secondary amputation. Amputation was discussed if there were severe functional deficits, but all patients preferred to preserve the limb. None of the patients required vascular re-operation or re-intervention; however, two individuals were detected with occluded arterial repairs and another two patients had a high grade stenosis at the repaired arterial segment during follow up. All patients were asymptomatic and therefore treated conservatively. Long term patency was 97%. DASH scores showed wide inter-individual variations. Subgroup analysis measured higher scores in patients with associated neurological injuries (median + quartiles) (with neurological lesion, the DASH score was 40.3 [range 3.5–69.8] vs. 0.8 [range 0.0–5.8] without neurological lesion; $p < .001$). Among patients with neurological lesions, those with concomitant plexus lesions did not perform worse on the DASH questionnaire than patients with other peripheral nerve injuries. As a consequence of frequently associated neurological lesions, patients with injuries to the subclavian and axillary arteries had higher disability (subclavian and axillary artery [proximal] DASH score 37.2 [range 0–69.6]) than patients with brachial or forearm arterial injuries (brachial artery and forearm artery [distal] DASH score 1.7 [0–6.7]; $p = .017$). In addition, patients presenting with ischemia at time of injury without neurological injuries had higher disability scores (ischemia DASH score 4.2 [range 0–16.9] vs. 0 [range 0–1.7]) than those with no ischemia ($p = .04$). Comparison of DASH scores in patients with blunt ($n = 53$) versus penetrating ($n = 4$) trauma was hampered by the small number of patients with penetrating injuries, which did not allow statistical analysis. On the one hand,

mean ± SD DASH scores were independent of sex (male 21 ± 18 vs. female 29.4 ± 36.5; $p = .401$), age (<30.0 years 17.8 ± 29 vs. >30.0 years 27.6 ± 30.7; $p = .245$) and side of injury (right 23.1 ± 32.1 vs. left 22.6 ± 28.3; $p = .953$); on the other hand, no correlation was found between DASH scores and time of completing the questionnaire during follow up.

DISCUSSION

In contrast to immediate peri-operative results of arterial repair in upper limb injury,[1,4,5,7,11,12,14,26,27] the long term outcome after upper extremity injury with associated arterial lesions is rarely evaluated; previously published data on long term outcome are summarized in Table 1. Only series published since 1990 including >20 patients with follow up of at least 6 months are included.[1–6]

Major end points in the long-term follow up of patients undergoing arterial repair in upper limb trauma include limb salvage, patency of arterial repair and functional outcome. When analysing data from previously published studies,[1–6] long-term limb salvage rates are almost as high as early peri-operative rates; if indicated, limb amputation is usually performed during the early post-operative period. Late amputations are rarely indicated; nevertheless, late amputations are sometimes discussed in patients with total nonfunctional extremity. However, in the authors' experience, in most cases, patients prefer to keep a nonfunctional upper limb. The long-term patency rate after arterial repair is favorable, and only certain individuals develop occlusions and/or stenoses at the site of arterial reconstructions. In the present series, patient surveillance included repeated duplex ultrasound follow up at 3–5 year intervals and two occlusions and two stenoses were detected. The long-term patency rate is 97%, which is slightly lower than the rates of 99–100% given by others.[1,2,6] Of note, those studies do not mention their surveillance programs, whether they included duplex studies, or whether they were based purely on clinical tests.

If functional recovery after upper extremity injury is analyzed, the presence and severity of concomitant neurological trauma is described as the most important factor by numerous groups.[3,5,6,11–14,27–32] This is confirmed by the present data. In the current series, patients with concomitant plexus injury were significantly more likely to suffer from persisting disability. However, as measured by the DASH questionnaire, patients with neurological injury not involving the plexus did not have better functional results.

As confirmed by Changulani et al.[16] the DASH score is recommended for evaluation of patients with disorders involving multiple joints of the upper limb. Use of the DASH questionnaire was advised for assessing outcome in any upper limb pathology, irrespective of the site.[33] In contrast to numerous data on the use of DASH scores in the follow up of patients with isolated musculoskeletal injuries, there are only two reports on DASH outcome measures in patients after complicated upper extremity injuries plus arterial repair.[6,7] Recently, Toepel et al. analyzed 33 patients with arterial repair following upper limb trauma after a median follow up of 42 months.[6] In contrast to the present series, the majority of patients (73%) in the Toepel et al. series had forearm injuries with transected arteries due to cut wounds, and only nine patients had upper arm lesions. DASH scores were correlated with clinical assessment of functional outcome, and patients with neural damage performed most poorly; however, in their statistical analysis, the difference seen in patients with and without concomitant neurological injuries was not significant. Earlier, Joshi et al. presented DASH based data from 17 patients with traumatic arterial injuries to the upper limb:[7] patients with

Table 1. Civilian series of upper extremity trauma with associated arterial injuries and follow up of at least 6 months, published after 1990 and involving more than 20 patients.

Study	Year of publication	Total number of patients (*n*)	Blunt injury	Penetrating injury	Follow up (mo)	Limb salvage (%)	Patency (%)	Functional status determined by
Myers et al.[1]	1990	95	26 (27)	69 (73)	6	100	99	NA
Fitridge et al.[2]	1994	114	52 (46)	62 (54)	14	86 (subclavian or axillary artery), 92 (brachial artery)	100	Associated injuries Location of injury
van der Sluis et al.[3]	1997	25	19 (76)	6 (24)	24	100	NA	Persistent neural deficit joint contractures pain
Manord et al.[4]	1998	46	18 (39)	28 (61)	43	98	NA	Blunt injury ($p < .05$)
Brown et al.[5]	2001	71	21 (30)	50 (70)	6	94	NA	Neurological injury ($p < .05$) Blunt injury ($p < .05$)
Toepel et al.[6]	2009	33	10 (30)	23 (70)	42	98	100	Neurological injury ($p = .085$)
Present series[a]	2016	117	96 (82)	21 (18)	64	98	97	Neurological injury ($p < .001$) Location of injury ($p < .017$) Ischemia at time of injury ($p < .04$)

Note. Data are *n* (%) unless otherwise indicated. NA = not available.
[a] Number of arteries treated.

blunt injuries tended to have higher DASH scores; however, again, the difference was not significant. This may be explained by the small number of patients tested. In contrast to the studies of Toepel et al. and Joshi et al., the present analysis—for the first time—showed significantly higher DASH scores, indicating higher grades of disability, in patients with upper limb arterial lesions plus associated neurological injuries, in patients with subclavian or axillary artery injuries, and in patients presenting with ischemia at the time of injury. DASH scores were independent of sex, age, and side of injury. Of note, these data are long term functional results that were obtained after a median follow up period of >5 years.

Limitations of this study are: incomplete data on duration and severity of ischemia; the lack of systematic assessment during follow up; the different timings of functional assessment after trauma; the low percentage of responders (53%; most likely owing to the fact that the trauma patients were multinational, younger individuals with high mobility and/or non-German speaking residents); and the heterogeneous types of injury (which is typical in patients with upper limb trauma). The different timing of assessments was due to the fact that it was a retrospective analysis of data and DASH questionnaires were sent afterwards. Therefore, correlations between clinical data and DASH scores may be imprecise, as they were not evaluated simultaneously. However, the findings show no significant correlation between time of injury and time of answering the questionnaire during follow up. Manord et al. have stated that final outcome cannot be predicted on the basis of initial clinical presentation.[4] There might be the potential for functional improvement and/or adaptation to the deficit during follow up, for example, if a patient with injury to the dominant right hand uses the left upper extremity for everyday activities. However, when individual patients are assessed, in most cases no great potential for further functional improvement years after initial trauma could be found.

In summary, long-term limb salvage and patency rates after arterial repair in upper extremity injuries are favorable, but functional impairment is a significant problem. The DASH questionnaire is a helpful tool to assess the severity of individual impairment and to compare different subgroups of injuries. Disability is determined by concomitant neurological injury, the presence of ischemia at initial presentation, and the location of injury, with favorable outcome in more distal injuries.

CONFLICT OF INTEREST

None.

FUNDING

None.

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COUP D'OEIL

Infected Aortic Stentgraft Treated with Fresh Cold Stored Arterial Allograft

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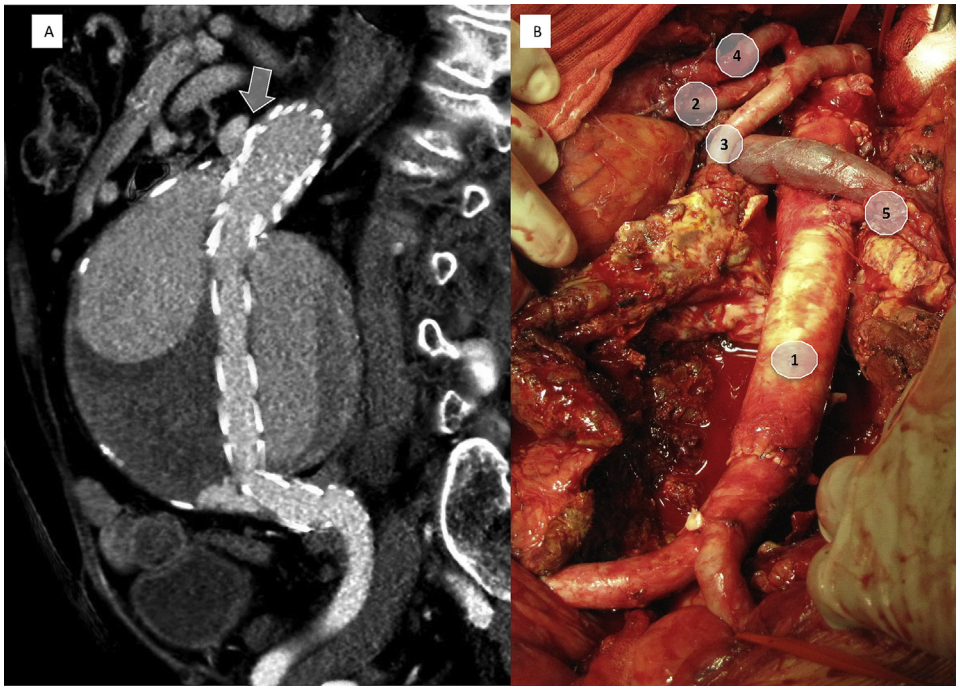

A 68-year-old male was admitted with abdominal pain, fever, and fatigue 7 years after undergoing EVAR. Following a diagnosis of graft infection with endoleak type Ia (A), the patient was managed with stentgraft excision and interposition of a fresh cryopreserved aortic allograft from a cadaveric donor (B). Bypass construction consisted of the main body of allograft (1) with bypass branches between the central main body and the superior mesenteric artery (2), right renal artery (3), and celiac trunk (4). The left renal artery (5) was implanted directly into the main body.

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http://dx.doi.org/10.1016/j.ejvs.2016.04.011