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Long-term outcomes after upper limb arterial injuries

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Objective: To assess long-term outcomes in multisystem trauma victims who have arterial injuries to upper limbs.

Design: A retrospective case series.

Setting: Tertiary care regional trauma centre in a university hospital.

Patients: All consecutive severely injured patients (Injury Severity Score greater than 15) with an upper limb arterial injury treated between January 1986 and January 1995. Demographic data and the nature and management of the arterial and associated injuries were determined from the trauma registry and the hospital records.

Outcome measures: Death rate, discharge disposition, residual disabilities and functional outcomes as measured by the Glasgow Outcome Scale.

Results: Twenty-five (0.6%) of 4538 trauma patients assessed during the study period suffered upper extremity arterial injuries. Nineteen of them were victims of blunt trauma. The death rate was 24%. There were 10 primary and no secondary amputations. An autogenous vein interposition graft was placed in 10 patients. Concomitant fractures or nerve injuries in the upper limb were present in 80% and 86% of the patients, respectively. Long-term follow-up data (mean 2 years) were obtained in 16 of the 19 who survived to hospital discharge. The residual disability rate was high. It included upper limb joint contractures, pain and persistent neural deficits (69%). Associated injuries in other body areas also contributed to overall disability. Only 21% of the patients recovered completely or had only minor disabilities.

Conclusions: Associated injuries, rather than the vascular injury, cause long-term disability in the multisystem trauma victim who has upper extremity involvement. Persistent neural deficits, joint contractures and pain are the principal reasons for long-term impairment of function.

Objectif : Évaluer les résultats de longue durée chez les victimes de traumatismes multisystémiques atteints de traumatismes artériels d'un membre supérieur.

Conception : Série de cas rétrospective.

Contexte : Centre régional de traumatologie et de soins tertiaires d'un hôpital universitaire.

Patients : Tous les patients consécutifs victimes de blessures graves (indice de gravité des traumatismes supérieur à 15) et atteints d'un traumatisme artériel d'un membre supérieur qui ont été traités entre janvier 1986 et janvier 1995. Les données démographiques et la nature et le traitement des traumatismes artériels et connexes ont été déterminées à partir du registre des traumatismes et des archives de l'hôpital.

Mesures des résultats : Taux de décès, type de congé, incapacités résiduelles et résultats fonctionnels mesurés selon l'échelle de Glasgow.

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Presented at the Trauma Association of Canada meeting, Halifax, NS, Sept. 26, 1996

Accepted for publication Oct. 30, 1996

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RÉSULTATS : Vingt-cinq (0,6 %) des 4538 patients traumatisés évalués au cours de la période d'étude ont été victimes d'un traumatisme artériel d'un membre supérieur. Dix-neuf d'entre eux ont été victimes d'un traumatisme contondant. Le taux de mortalité a été de 24 %. Il y a eu 10 amputations primaires et aucune amputation secondaire. Dix patients ont reçu une greffe veineuse autogène par interposition. On a constaté des fractures concomitantes ou des traumatismes nerveux du membre supérieur chez 80 % et 86 % des patients respectivement. On a obtenu des données de suivi de longue durée (moyenne de deux ans) sur 16 des 19 personnes qui ont survécu au congé de l'hôpital. Le taux d'incapacité résiduelle était élevé. Ces incapacités comportaient des contractures articulaires du membre supérieur, la douleur et des déficits neurologiques persistants (69 %). Les traumatismes connexes à d'autres parties du corps ont contribué aussi à l'incapacité globale. Seulement 21 % des patients se sont rétablis complètement ou n'avaient que des incapacités mineures.

CONCLUSIONS : Les traumatismes connexes plutôt que le traumatisme vasculaire sont une cause d'incapacité de longue durée chez la victime de traumatismes multisystémiques atteintes aux membres supérieurs. Les déficits neurologiques persistants, les contractures articulaires et la douleur sont les principales raisons du déficit fonctionnel de longue durée.

The operative management of extremity vascular injuries has evolved from ligation to reconstruction largely based on the experience of DeBakey and Simeone.[1] As a result, the immediate limb salvage rate in such injuries currently approaches 95%.[2] Consequently, although death and amputation rates were the original benchmarks of success in this disease process, they are no longer adequate parameters to assess the outcomes of treatment for these injuries. To measure successful treatment, ultimate function of the injured extremity is more germane.

Upper extremity arterial injuries represent about 30% of all cases of arterial trauma.[3] In this disease process, it is clear that functional outcomes are determined not only by vascular damage but also by associated injuries. The purpose of our study was to document and analyse the respective roles of arterial damage and associated injuries on long-term functional outcomes after upper extremity arterial trauma.

METHODS

The trauma registry at Sunnybrook Health Science Centre (SHSC) was used to identify all multisystem trauma patients admitted between January 1986 and January 1995 with an injury severity score (ISS) of 16 or greater and one or more upper extremity arterial injuries. Patients with isolated venous injuries, iatrogenic arterial injuries, arterial injuries of the digits or crush injuries without obvious arterial damage were excluded.

The ISS is an anatomic measure of injury severity and is computed utilizing the Abbreviated Injury Scale (AIS), which categorizes each injury by body area.[4,5] The severity of injury is graded from 0 (no injury) to 6 (fatal injury), and the ISS is calculated by adding the squares of the highest AIS value in each of the three most severely injured body areas. The maximum ISS of 75 represents injuries nearly always incompatible with life and an ISS of 16 or more defines a victim of major trauma.[6]

Demographic data were obtained from the SHSC trauma registry and hospital medical records. The mechanism of injury and the location and management of the arterial injuries were recorded. Associated injuries and injury severity were quantified and measured by the AIS and the ISS. Outcome measures included death rate, duration of hospitalization, discharge destination and the nature and severity of residual disabilities in long-term follow-up. Functional outcome at follow-up was quantified using the Glasgow Outcome Scale (GOS) (1 death, 2 persistent vegetative state, 3 severe disability in which the patient requires help with daily living activities, 4 moderate disability in which the patient is independent but disabled and 5 mild or no disability).[7] This scale was originally designed to be used in head injury research. However, it has since been used to assess physical and mental disabilities in convalescing patients.[8,9] For the purposes of this study, residual disability was assessed at the time of the last recorded outpatient visit for follow-up of either the damaged limb or associated injuries.

RESULTS

Demographics

Twenty-five out of 4538 multisystem trauma patients (0.6%) met the criteria for inclusion in the study. Their mean age was 36 years (range from 18 to 70 years); 21 (84%) were male. Nineteen patients (76%) were referred from other hospitals. An average of 4.3 hours (range from 0.4 to 20.6 hours) elapsed between the injury and admission to the SHSC Regional Trauma Unit.

Nineteen patients (76%) sustained blunt injuries: 16 in motor vehicle accidents and 3 in industrial accidents. The 6 penetrating injuries were caused by a gunshot (1), a stabbing (1), a propeller (2) and machinery (2). The inhospital death rate was 24% (6 patients). Five patients died in the first

24 hours after admission (3 as a result of exsanguination from injuries other than the upper extremity injury and 2 because of head injuries in combination with severe bleeding). The remaining patient died 11 days after admission because of multiple organ failure.

Arterial injuries and treatment

In 10 patients, the arterial injuries were part of such extensive musculoskeletal and soft-tissue trauma that amputation of the mangled extremity had either occurred at the scene or was performed directly on admission to the hospital. Since 1 patient suffered bilateral amputation, this resulted in 11 upper extremity amputations in 10 patients (3 shoulder disarticulations, 3 above-elbow amputations, 4 below-elbow amputations and 1 wrist disarticulation). In 1 patient, the forearm was replanted. Ultimately, this limb became nonviable, resulting in an above-elbow amputation.

Excluding the arterial injuries resulting in immediate amputation, there were 16 patients who sustained injuries to 16 arteries (1 patient with an above-elbow amputation also had an ipsilateral injury of the subclavian artery) (Table I).

The most common method of surgical management was an autogenous vein interposition graft, placed in 10 patients (63%). Only 1 primary end-to-end anastomosis and 1 polytetrafluoroethylene graft were placed (13%). Four patients (25%) did not have vascular surgery; 1 of these patients sustained an injury to a deep branch of the brachial artery, and 1 patient suffered an injury to the radial artery as a result of compression by associated fractures. These 2 patients were successfully treated nonoperatively. The remaining 2 patients died soon after arrival at the trauma centre.

Eight patients (67% of those undergoing revascularization) underwent a fasciotomy because a compartment syndrome was suspected. To evaluate the nature and location of the arterial damage, angiography was performed before or during the operation in only 5 patients (42% of those undergoing revascularization). In 1 patient the initial revascularization procedure failed. However, revision was successful.

Associated injuries

In the 25 study patients, the mean ISS was 35 (range from 17 to 66). Those suffering from blunt trauma had a mean ISS of 34, which was slightly lower than that for patients who sustained penetrating injuries (mean ISS 38). Associated injuries were predominantly in the head and neck area (21 patients) and the chest area (21 patients), whereas a minority had associated injuries of the face (5 patients) and abdomen (4 patients). Twenty-three (92%) patients had external injuries (skin abrasions or lacerations), but these were of minor severity (AIS 1 or 2). All patients had severe injuries of the extremities (AIS of 3 or more). Twelve of the 16 patients who were treated without early amputation suffered serious upper limb fractures or joint dislocations, and 13 of them had concomitant nerve injuries. There were 16 nerve injuries in these 13 patients (Table II). The site of nerve injury was related to the site of arterial injury in every case. In 1 patient, a brachial plexus injury was suspected, but this could not be confirmed because of the patient's early death.

Nearly all nerve deficits resulted from blunt trauma. Only 2 of the brachial plexus injuries were caused by penetrating injury. Ten (63%) of the 16 nerve injuries were found to be severe (no function or minimal nerve function). The remaining nerve injuries showed only moderate function (4 injuries) or could not be assessed because of early death (2 injuries).

One patient underwent primary repair of a damaged radial nerve. Another 3 patients underwent secondary repair at a later date. Two ulnar nerves, 1 radial nerve and 1 median nerve were repaired.

Follow-up

The 19 survivors stayed a mean of 48 days in hospital (range from 10 to 191 days); they were discharged home (5 patients [26%]), to a rehabilitation centre (10 patients [53%]), to an acute care hospital (2 patients [11%]), to a chronic care institution (1 patient

Table I

Upper Extremity Arterial Injuries in 16 Patients

Artery involved	No. (%) of patients
Subclavian	2 (12)
Axillary	3 (19)
Brachial	7 (44)
Ulnar	1 (6)
Radial	3 (19)
Total	16 (100)

Table II

Concomitant Upper Extremity Nerve Injuries

Nerve involved	No. (%) of patients
Brachial plexus	4 (25)
Median	3 (19)
Ulnar	4 (25)
Radial	4 (25)
Unidentified	1 (6)
Total	16 (100)

[5%]) or detained in police custody (1 patient [5%]).

Three of the 19 survivors were lost to follow-up. All were severely disabled at the time of discharge due to prolonged coma in 1 patient and shoulder disarticulation in 2 patients. The 16 patients who were available for long-term follow-up were assessed for an average of 2 years (range from 3 to 78 months) in the outpatient clinic. Fourteen of them had residual functional disabilities (Table III).

None of these 16 patients had any residual vascular compromise from the arterial injury, and there were no secondary amputations. Residual disability in the upper limb predominantly resulted from joint contractures, pain and persistent nerve deficits (11 patients [69%]). Only 2 patients had complete recovery of the injured nerves. The residual deficits were minor in 3 patients (1 ulnar nerve injury and 2 with both ulnar and radial nerve injuries), moderate in 4 patients (2 with brachial plexus injuries, 1 with a median nerve injury and 1 with median and radial nerve injuries), and severe in 1 patient (ulnar nerve injury). None of those who underwent a nerve repair, either primary or secondary, experienced complete recovery of the injured nerve. In 1 patient, the nerve repair was unsuccessful and ultimately a tendon transfer was performed. Since there were no secondary amputations in this series, the amputation rate was not influenced by residual nerve deficits. In the remaining patients, associated injuries in other body areas were the principal reason for residual disabilities.

As measured by the GOS, this group of 16 patients had a high disability rate, even at long-term follow-up (Table IV). Only 4 patients recovered completely or had minor disabilities (GOS 5). Seven patients were moderately disabled (GOS 4) and 5 had severe disabilities (GOS 3). Three patients with a GOS of 3 were disabled because of associated injuries (Table IV): leg amputation and a nerve deficit in the remaining leg in 1 patient, residual cognitive dysfunction in another and cerebrovascular accident in the third. One patient was disabled (GOS 4) as a result of incomplete paraplegia.

Table III

Residual Disabilities in 16 Patients

Location and type of disability	No. (%) of patients
Upper limb	
Joint contractures	10 (63)
Nerve deficits	8 (50)
Pain	4 (25)
Amputation	4 (25)
Lower limb	
Joint contractures	2 (13)
Nerve deficits	1 (6)
Pain	1 (6)
Amputation	2 (13)
Other	
Paraplegia (partial)	1 (6)
Cognitive dysfunction	1 (6)
Pulmonary dysfunction	1 (6)
Cerebrovascular accident	1 (6)
Post-traumatic seizures	1 (6)

Discussion

Vascular injuries occur in approximately 3% of all patients with major civilian trauma.[10,11] One-third of these cases involve the upper limb.[3] Since vascular injuries are potentially life- and limb-threatening, the operative treatment of such injuries has garnered substantial attention.[12–15] This has led to awareness of the urgency of arterial repair and to improvements in the technical ability to revascularize injured extremities, resulting in the low limb-loss rate currently associated with attempted vascular repairs of these injuries. As a result, the major criterion for a positive outcome is no longer simply a successful arterial repair. Rather, the ultimate function of the injured limb with respect to pain, sensation, dexterity and practical function are now the outcomes that need to be assessed in the management of this disease.

Presently there is little documentation regarding the extent and severity of associated injuries in the multisystem trauma victim who suffers a vascular injury. Further, it is unclear to what degree associated injuries influence the functional outcome in these patients. This study is a retrospective review of all consecutive patients who presented to a regional trauma centre

Table IV

Glasgow Outcome Scale (GOS) at Long-Term Follow-up in 16 Patients

GOS	No. (%) of patients	No. (%) of patients with disability due to extremity trauma	No. (%) of patients with disability due to associated injuries
1	0	0	0
2	0	0	0
3	5 (31)	2 (13)	3 (19)
4	7 (44)	6 (38)	1 (6)
5	4 (25)	4 (25)	0
Total	16 (100)	12 (75)	4 (25)

with an ISS of 16 or more and an arterial injury to the upper limb during a 9-year period (1986 to 1995). The location and management of the arterial injuries and the nature and severity of concomitant nerve injuries were determined. Long-term follow-up over an average of 2 years was obtained to assess the overall degree of disability in the survivors.

The 25 study patients comprised only 0.6% of all severely injured patients treated at our institution during the study period. This suggests that although this injury has dire long-term consequences, it is uncommon in a trauma centre that mainly treats victims of blunt trauma. Seventy-six percent of the patients in the study suffered blunt trauma, a proportion that is consistent with reported European series (73% to 95%) of vascular trauma.[12,16,17] However, many large urban trauma centres in the United States evaluate a higher percentage of penetrating trauma and report blunt trauma in only 2% to 16% of patients with vascular injuries.[15,18] Upper extremity vascular trauma is far more common in these centres than in our experience. However, the extent of significant associated injuries in this study is higher than that reported by high-volume penetrating trauma centres in the US.[19,20] This may be a reflection of our study inclusion criteria, which allowed only trauma victims with an ISS of 16 or more entrance into the study.

The high proportion of associated injuries in victims of blunt trauma combined with the relative infrequency of upper limb vascular trauma may lead to a concern-causing delay in the diagnosis of arterial injuries. Early recognition and treatment of these injuries are mandatory to achieve satisfactory outcomes. Therefore, physicians dealing with multisystem trauma victims need to be cognizant of these injuries in the initial assessment of the patient. This is particularly true when one realizes that at least 10% of all patients with arterial injuries of the upper extremities will have palpable distal pulses due to extensive collateral vascular beds.[21] Indeed, some authors suggest that 40% of patients with proximal arterial injuries will have palpable distal pulses due to substantial collaterals in the axilla.[18,22] In this scenario, however, it is unlikely that these patients will have an immediate limb-threatening vascular injury.

In this case series, all arterial injuries were identified without delay. Primary repair (end-to-end anastomosis or lateral suture) was initially considered. However, if the injured segment was too extensive, an interposition graft was used. In a patient with blunt trauma, the possibility of primary repair is less likely than with penetrating trauma, and this is reflected in the high proportion of vein grafts utilized in our patients.

Once the arterial deficit had been repaired, the vascular injuries were relatively unimportant in determining short and long-term outcomes. Neither the high amputation rate (40%) nor the high death rate (24%) in this study could be attributed to the arterial injury alone. Extensive musculoskeletal and soft-tissue damage to the upper limb and severe head injuries contributed largely to the overall morbidity and mortality.

Amputation rates related to upper extremity vascular trauma recorded in the recent literature vary from 9% to 40%.[12,16,17,19,23,24] However, these figures may not be comparable to ours because of differences in the proportions of blunt versus penetrating trauma in the various studies and the differences in the severity of the sustained injuries (minor versus major trauma). Our high amputation rate is not surprising, since our study patients were severely injured, and those patients whose upper limb amputations occurred at the scene of the injury were included in the analysis. The 24% death rate in our severely injured patients is consistent with those in other studies with a high mean ISS.[9,25]

From a technical standpoint, all arterial repairs were carried out successfully, although one revision procedure was required. Secondary amputations were not necessary, and none of the patients had symptoms related to arterial insufficiency. Unfortunately, those who sustained injuries to the brachial plexus or peripheral nerves did not fare as well. The majority of these injured nerves were associated with impaired long-term function, whether they were treated operatively or not. There was no clear advantage to early or late nerve repair in this study.

In general, injuries to nervous tissue account for approximately 40% to 50% of the associated injuries in vascular trauma[22] and are twice as likely to occur in the upper limb as the lower limb.[10,26] Previous studies have shown that nerve injuries account for the majority of the 27% to 49% of patients who continue to experience long-term disability from upper limb vascular trauma.[10,11,15,18,19,27] In the present study, permanent nerve deficits, joint contractures and chronic upper limb pain (causalgia) incurred substantial long-term functional impairment. The latter findings may have been underreported in previous studies.[26,27] In addition, associated injuries in other body areas were important contributors to overall disability. This reinforces the degree of severity of the initial injuries in our series.

These patients incurred a high long-term disability rate, since only 4 of the 16 long-term survivors (25%) recovered completely or had minor

disabilities. On average, 70% of multisystem trauma patients show complete recovery or have only minor disabilities.[8,9] This serves to further emphasize the suggestion that severe injuries to the upper extremities lead to long-term disability due to persistent nerve deficits, joint contractures and pain in spite of the successful treatment of associated vascular injuries.

This study is limited because of its retrospective design and has the biases and potential for confounding inherent with this methodology. In addition, even though the primary outcome measure utilized (GOS) is useful in retrospective studies, a more sensitive, disease-specific measurement tool may have provided a more accurate assessment of functional impairment. Even with these limitations, this study describes important long-term outcome results and may serve to stimulate further research in this area.

In conclusion, precise revascularization of an injured extremity is readily achievable. However, further improvements in the long-term outcomes for these patients appear to rely on the development and application of new techniques of nerve repair, since the presence of vascular damage is no longer the rate-limiting step toward recovery from such injuries.

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