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Original Research Article

Pediatric arterial injuries of the forearm and hand

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ABSTRACT

Introduction: Traumatic injuries of the arteries are rare in children. Operations due to that kind of damage, inherently difficult, become a challenge for a pediatric surgeon.
Aim: The aim of the study was to present the Center's own experience in treating children with rare penetrating injuries.
Material and methods: A review was completed of 10 patients treated between 2009 and 2012 due to penetrating injuries of the forearm and hand with accompanying damage to the radial and/or ulnar artery.
Results and discussion: There were 9 boys and 1 girl of average age 15.7 years. Injury of the radial artery was reported in 6 patients, of the ulnar in 2, of both arteries in 1 and of the superficial palmar arch in 1 patient. Partial damage was observed in 4, and complete in 7 arteries. In total, 2 patients were treated by ligation, 8 by arterial repair. In each case damage to the arteries was accompanied by injury of the muscles, and in 1 case additionally of the ulnar and median nerves. Postoperative period nerve deficits were observed in 5 patients; 4 patients were submitted to the follow-up. In 2 of these sensory disorders, slightly worse warmth of the limbs was reported.
Conclusions: The treatment of choice in children should be repair of the damaged vessel, nevertheless ligation of single artery does not determine limb ischemia. Concomitant neural damage determines occurrence of transient and permanent loss of limb function.

1. Introduction

Traumatic injuries of the arteries are rare in children.[1–3] Operations due to that kind of damage, inherently difficult, become a challenge for a pediatric surgeon. In the available literature, there are few publications dedicated to this issue.

2. Aim

The aim of this study was to present our own experience of the treatment of arterial injuries of the forearm and hand in children.

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3. Material and methods

We analyzed retrospectively the medical records of 10 patients treated because of penetrating wounds of the forearm and hand with associated arterial lesions. The group was selected from 1 131 children treated between 2009 and 2012 for wounds of the forearm and hand. Age and sex of the patients, mechanism of injury, location and nature of the damage, type of performed surgery, course of postoperative period and treatment after surgery, as well as associated injuries and long-term effects, were evaluated. Children with iatrogenic or digital injuries were excluded from the study.

4. Results

4.1. *General data*

The total number of children hospitalized due to arterial damage distal to the elbow amounted to 10, which represented 0.88% of all penetrating injuries of the hand and forearm. Of these treated patients there were 9 boys (90%) and 1 girl (10%), aged from 12 to 17 years (mean age 15.7 years). The main cause of injury was glass (70%), the other cases involved a razor-blade (a suicide attempt), a circular saw and a fall on the ice. There were no deaths due to injury.

Revisions of the wounds and the repair of the arteries were performed in the operating theater. In 7 patients, the operations were realized under general anesthesia and 3 of the older patients (mean age 16.3 years) were operated under local anesthesia due to the symptoms of intoxication.

Injuries were located on the anterior and antero-medial area of the forearm and hand. Wounds were judged as cut (8 patients), lobe (1 patient), or rugged (2 patients) depending on the mechanism of injury.

4.2. *Injuries of the arteries*

Six patients had isolated damage of the radial artery (2 on the left side and 4 on the right side), 2 children suffered from isolated injury of the left ulnar artery and 1 patient underwent lesion of both arteries of the left forearm (Table 1).

In 1 boy examination revealed damage of the right superficial palmar arch. Complete damage was observed in 7, and partial lesion in 4 arteries (Table 2).

In 7 cases of artery lesion (70%) no pulse was found. In 3 cases (30%) pulse was present despite the injury (1 patient with superficial palmar arch damage, 1 with total radial artery lesion and 1 with partial radial artery injury). In 1 case, due to the long time between injury and initial supply of the wound, the patient was admitted to hospital with symptoms of hemorrhagic shock.

Table 1 – Number of damaged arteries by side.

	Right side	Left side
Radial artery	4	3[a]
Ulnar artery	0	3[a]

[a] As a result of injury to both arteries of the forearm in 1 patient, the total number of damaged arteries exceeds the number of patients with that kind of injury.

Table 2 – Degree of lesion by artery.

	Complete lesion	Partial lesion
Radial artery	5	2
Ulnar artery	1	2
Superficial palmar arch	1	0

4.3. *Associated injuries*

In each case lesions of the arteries were accompanied by partial or complete damage of muscle tendons and/or muscle bellies (Fig. 1). The most commonly injured muscles were the flexor digitorum superficialis, flexor carpalis radialis and palmaris longus.

In 2 patients sensory-motor deficits were observed in the preoperative period. One of them had two wound revisions of the forearm in outpatients, before he was admitted for surgery under general anesthesia. Throughout this period, the radial artery pulse, distal to injury, was palpable. The development of massive hematoma, sensory and motor deficits of the hand and fingers, and the disappearance of the radial artery pulse were an indication for revision of the wound in the operating theater. Examination revealed incomplete damage to the radial artery without lesion of the concomitant nerve structures. The second patient, who suffered a wound of the left forearm from breaking a glass window, as a result of aggression caused by intoxication, was initially supplied directly after the injury. Before the operation the sensory-motor deficits of the median and ulnar nerves were stated. Extensive damage to the nervous structures, muscles and vessels, known as "spaghetti wrist," was revealed intraoperatively (4). Complete damage of both arteries of the forearm, median and ulnar nerves, and flexor muscles of

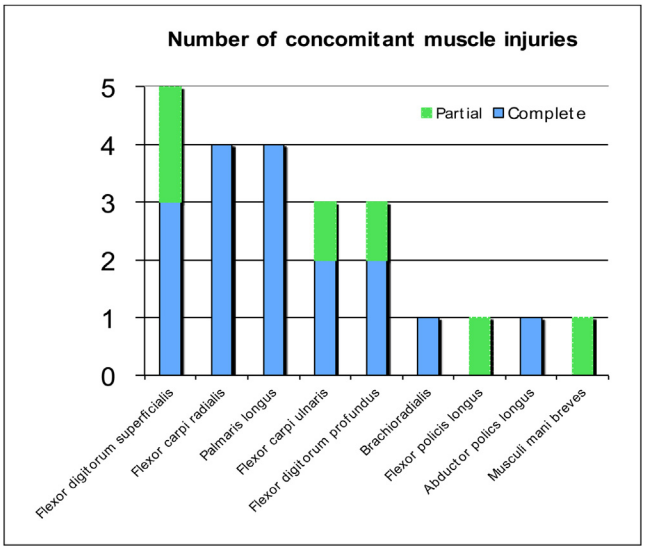

Fig. 1 – Number of muscle injuries associated with arterial injuries. Blue indicates complete lesion of muscle bellies and/or tendons; green indicates partial damage.

the forearm – flexor carpi radialis, flexor carpi ulnaris, flexor digitorum superficialis, flexor digitorum profundus and palmaris longus – was reported.

4.4. *Management of injuries*

Ligation of damaged vessels was performed in 2 patients, in the first patient due to lack of identification of the distal stump of radial artery, with appropriate saturation and clinically proven proper blood supply to the limb, and in the second patient with a superficial palmar arch injury. In the remaining 8 patients sewing of the arteries was performed using single or continuous sutures depending on the preference of the surgeon. Damaged muscle bellies and their tendons were fixed using single sutures or the Kessler technique. Reconstruction of damaged nerves was made using continuous sutures. In the patient with lesion of the arterial superficial palmar arch, two pieces of foreign material (glass) were removed from the hand's soft tissues.

4.5. *Postoperative period*

The average hospital stay was 3.4 days (1–11 days).

In the perioperative period tetanus toxoid (8 patients), cephalosporin of second or third generation (9 patients), low molecular heparins (6 patients) and galantamine (1 patient with ''spaghetti wrist'' injury) were used. In 1 patient with symptoms of hypovolemic shock, 2 units of red blood cells were transfused.

The patient with ''spaghetti wrist'' injury required, a few hours after the operation, surgical decompression of a hematoma causing problems with limb blood supply. No perfusion disorders were observed following this, which was confirmed by Power Doppler ultrasonography showing continuity of the fixed arteries, with presence of blood flow through anastomosis. In the remaining 9 patients, there was no disturbance to the blood supply in the early postoperative period.

In 5 patients (50%) sensory and/or motor nerve deficits were observed in the early postoperative period (Table 3). A nerve conduction study was performed in a patient with paresthesia of fingers I–III (Table 3), which showed abnormal sensory conduction in all three nerves of the forearm and motor conduction abnormalities in the median and radial nerve. No motor deficit was observed in physical examination of this patient. The patient with ''spaghetti wrist'' trauma did not report to a nerve conduction study to which he had been appointed, and resigned from postoperative conservative treatment.

4.6. *Follow-up*

In total, 4 patients (40%) were available for late follow-up. The period from surgical management of arterial lesion to the control ranged from 1 to 4 years. The presence of the pulse distal to injury, the motility of the hand and fingers, warmth in relation to the opposite limb, feeling and the presence of contractures were evaluated. In the patient who underwent ligation of the radial artery no pulse was found in the scar area on physical examination. In the remaining patients pulse was palpable. The motility of limb joints distal to the injury was complete in all patients. The only patient who had surgery for the damaged superficial palmar arch felt less warmth of the hand and hypoesthesia of all fingers. This patient's wounds also took longer to heal than in other cases. Another patient had less warmth in the hand's first interosseus space on examination, despite the absence of subjective sensation in this regard. This patient also reported hypoesthesia of fingers I–III. The remaining patients had symmetrical warmth and no sensory disorders. No contractures caused by scar were observed in any of the patients. Muscle hernia of the forearm was found in one patient. A Power Doppler ultrasound examination was performed for 2 patients, to assess the blood flow through the anastomosis (approval for the study was not obtained in the other 2 cases). Flow through the anastomosis was detected in the ultrasound examination for the patient who had their radial artery reconstructed, and the patient who had his radial artery ligated was also found to have, in the area of the radial artery, a patent vessel with preserved flow.

5. Discussion

The small number of children operated on due to lesion of the arteries of the forearm and hand over four years (0.88% of all penetrating injuries of forearm and hand) suggests that this type of injury is rare in children, and this finding is comparable to material from other authors.[2,4–6]

About 90% of the patients were boys, and the main cause of trauma was glass, which is consistent with reports in the

Table 3 – Nervous disorders in the early postoperative period.

Patient	Motor disorders	Sensor disorders	Early withdrawal
A	–	Hypoesthesia of thumb	+
B	–	Paresthesia of fingers I–III	–
C	Wrist and fingers	Paresthesia of fingers I–V	+
D	–	Hypoesthesia fingers I–V	–
E	In field of n. M and n. U	In field of n. M and n. U	–

Comments: A – Patient with complete damage of the radial artery and the m. brachioradialis, m. flexor carpi radialis, m. flexor digitorum superficialis. B – Patient with complete damage of the radial artery and the m. flexor carpi radialis, m. flexor carpi ulnaris, m. flexor digitorum superficialis, m. flexor pollicis longus and m. palmaris longus. C – Patient with partial damage of the radial artery and with massive hematoma (surgically supplied twice before the proper surgery). D – Patient with damage to the arterial superficial palmar arch. E – Patient with ''spaghetti wrist'' injury.

available literature,[6–8] but the average age of the patients (15.7 years) was higher in comparison to data from other authors.[1,3,4,6]

Some authors report that the most frequently injured artery of the forearm was the radial artery,[2,3,5] while damage of the ulnar artery prevailed in others.[1,4,8,9] In our study 70% of the lesions involved trauma of the radial artery. Accompanying unilateral damage to the radial and ulnar arteries occurred in 1 patient (10%), and is generally much less common than damage to a single artery.[3,4]

As mentioned above, damage to the artery is always accompanied by muscle injury. The most frequently injured muscles were the flexor digitorum superficialis, flexor carpi radialis and palmaris longus (Fig. 1), which is obviously related to the direct proximity of the damaged muscles to the radial artery, which was the most frequently injured artery in our study.

Sensory-motor disorders were reported in 5 patients (50%). Motor deficits were observed in 2 of these, and sensory disturbances were present in all (Table 3). In the first patient with motor and sensory disorders, the cause of deficits was the development of a massive hematoma formation and the consequent pressure on the adjacent neural structures. No anatomical lesions in nerves were observed during the operation, and the removal of the hematoma with the reconstruction of partial arterial damage caused gradual return of function and regression of sensory disorders. In the patient with ''spaghetti wrist'' injury, complete lesion of median and ulnar nerves, and total deficit of the motor and sensory function in the field of their innervation were identified in relation to the lesion (Table 3). Persistent nervous deficits were confirmed in 3 patients (30%) (Table 3), making it difficult to compare with data of the other authors, because they used a different method to assess the scope of the deficit, the time of re-evaluation and the level of return function.[1,4,10] Nerve damage associated with arterial injury observed in 10% of cases in this study represented a smaller percentage than in the works of other authors – Noaman (100% of patients), Evans (67% of damages), and Stanford (47% of damages). Despite the differences between authors, these data are a warning that in every case of wounds with concomitant injury of the artery, it should be expected that not only the lesions of arteries and muscles should be managed, but that damaged nerves will need reconstruction. In these patients sensory disorders and motor deficits might occur and persist, causing loss of limb function.[1,4,9]

There is little data or information about the incidence of complete or partial arterial lesions in children,[11] but it seems to be of great importance in the context of the possibility of partial damage of the artery with palpable pulse distally to injury, which may cause an oversight of the lesion by the surgeon, and thus serious consequences. In our study partial arterial damage was found in 4 cases (36%). In this group 1 patient had palpable pulse distal to the partially injured radial artery until the occurrence of a massive hematoma. Conversely, total damage to the artery does not exclude the occurrence of a palpable pulse from the arterial palmar arches to the distal stump of the injured artery. This occurred in 1 case in our study.

In the available literature two options for supplying isolated arterial damage are considered. Some authors prefer reconstruction of the injured artery, due to a greater percentage of wound infections in the case of ligation.[11] Most authors, however, tend to perform ligation of the injured vessel, because they observed no differences in the long-term effects, whereas prolonged surgery and anesthesia, in the case of reconstruction, indicates ligation.[1,5] In our study, vessel ligation (1 radial artery, 1 superficial palmar arch) was performed in 2 cases (20%). In the remaining 8 patients (80%) the continuity of the vessel was restored. We believe that in case of children, a reconstruction of the injured vessel should be performed, even when a single artery of the forearm is damaged, because the appropriate blood supply, and proper growth conditions for the limb must be ensured during a child's development. In our opinion the best method of anastomosis of the damaged vessel is sewing with single sutures, especially in small children, with regard for the development of the limb and the need to ensure symmetrical growth for the injured artery. However, we agree that continuous suture is a possibility in older children.

In the late follow-up 2 patients had a slight decrease in hand warmth, which in the first place suggests worse blood circulation associated with vascular damage. However, both patients also had sensory disturbances in the fingers. In our opinion, the vascular flow in both patients should be sufficient to ensure proper warmth. In these patients the decreased warmth of the hand may be caused by neurovegetative disorders related to damage of the sensory nerve fibers located in the area of arterial injury.

As mentioned above, the patient, for whom the ligation of the injured radial artery was performed, revealed no pulse in physical examination of the area of post-traumatic scar after four years. Nevertheless the Doppler ultrasound examination showed the presence of patent vessel in the location of the radial artery. This suggests either an error in assessment of the damaged vessel by a surgeon, or the formation of collateral circulation.

6. Conclusions

In conclusion, it should be remembered that every wound with massive bleeding requires a revision and assessment of the neural structures and consideration of the presence of foreign bodies. The treatment of choice in children should be to restore continuity of injured vessel, however ligation does not determine the limb ischemia. In addition, concomitant neural damage conditions occurrence of transient, and permanent, loss of limb function.

Conflict of interest

The authors declare no conflict of interest.

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