Vascular Injuries of the Upper Arm

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Abstract

Twenty eight patients who had subclavian, axillary, and brachial artery injuries were studied. Sixteen (57%) sustained blunt trauma and 12 (43%) sustained penetrating trauma. Motor cycle accidents were the most common cause of injuries (43%). Twenty patients (71.4%) were transferred from other hospitals. Nine patients (32%) were in shock on arrival. All patients had radial pulse abnormalities (3 decreased, 25 absent) of the affected limbs. Eighteen patients (64%) had associated injuries to other parts of the body. Eighteen patients (64%) also had associated nerve injuries, 7 of them had complete brachial plexus injuries from motor cycle accidents. Twelve patients (43%) had preoperative angiography. Twelve patients (43%) had brachial, 10 (35.7%) had axillary, 2 (7%) had axillary-subclavian, and 4 (14%) had subclavian artery injuries. Eight patients (28.6%) had concomitant venous injuries. Resection of the injured artery and reversed saphenous vein graft were performed in 23 patients (82%). The remaining had resection and end to end anastomosis in 3 patients (10.7%), lateral repair in 2 patients (7%), and ligation in 1 patient (3.6%). Concomitant venous repairs were performed in 5 patients. Fasciotomies were performed in 2 patients (7%). Excellent results of vascular repairs were obtained in all patients. Long-term disability occurred in patients who had associated nerve injuries. Avulsion injury of the brachial plexus usually resulted in severe impairment of limb function.

Vascular injuries of the upper extremity from blunt and penetrating trauma are not uncommon(1-4). According to Sitzmann et al(5), arterial injuries to the arm may be classified into upper and lower arm arterial injuries. Upper arm arteries include the subclavian, axillary, and brachial arteries. Lower arm arteries include the radial, ulnar, and interosseous arteries. Generally, upper arm arterial injuries are more difficult to manage and more of a threat to life than lower arm arterial injuries. Furthermore, associated brachial plexus and/or high radial, median, and ulnar nerve injuries which frequently occur in axillary-subclavian vascular injuries usually result in severe disabling and poor outcome despite successful vascular repair(3,6-13).

A retrospective evaluation of upper arm arterial injuries was carried out in order to examine the results of management of this entity.

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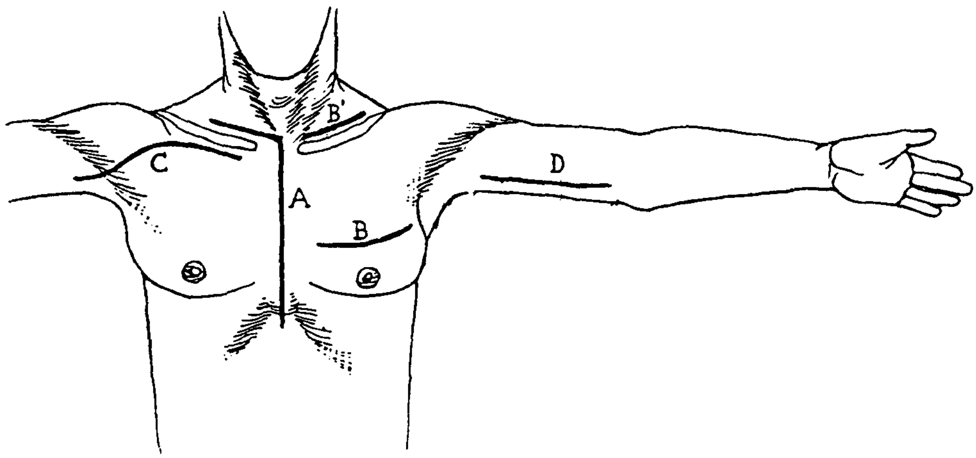

Fig. 1. Various incisions that provide optimal exposure of the upper arm arteries. A, median sternotomy with supraclavicular extension for right subclavian artery. B and B', third interspace thoracotomy combined with supraclavicular incision for left subclavian artery. C, infraclavicular incision with lateral extension for axillary artery. D, medial arm incision for brachial artery(5).

PATIENTS AND METHOD

The medical records of patients who sustained vascular injuries to the upper arm and were admitted to Chulalongkorn Hospital, Bangkok, Thailand between February 1991 and January 1996 were reviewed. Arterial injuries were suspected from the following findings: coolness of the involved arm, diminished or absent radial pulse, proximity of an open or penetrating wound to the major arteries, and impairment of motor function and/or sensation of the involved arm. Preoperative angiography was performed in selected cases. All patients were operated upon and diagnosis was confirmed in the operating room.

When patients first arrived in the emergency room, patency of the airway, adequacy of breathing, and circulatory status were routinely evaluated and treated if any abnormalities were detected. Fluid resuscitation was performed with crystalloid, colloid, and blood if indicated. Exsanguinating and hypotensive patients were immediately taken to the operating room. Patients who had open wounds and suspected of having vascular injuries were also taken to the operating room without preoperative angiography. Preoperative angiography was performed only in stable patients who were under clinical suspicion of a vascular injury.

In the operating room, proximal control of the injured artery was performed using incisions described in the Fig. 1. Distal subclavian artery injury was approached by supraclavicular incisions with resection of medial half of the clavicle if necessary. Proximal control of injuries to proximal left subclavian artery was performed through 3rd or 4th intercostal space anterior thoracotomy incision. Proximal control of injuries to proximal right subclavian artery was performed through median sternotomy with supraclavicular extension. Axillary and brachial artery were approached through incisions along the course of the arteries. When proximal and distal control of the injured artery were accomplished, the damaged arterial segment was resected, thrombus in the proximal and distal artery, if presented, was removed with Fogarty catheter, and revascularization was performed by end to end anastomosis or reversed saphenous vein graft depending on the length of the resected artery. When only a small defect at the arterial wall is found, lateral repair may be performed. Associated venous injuries were repaired whenever possible.

Associated injuries to the brachial plexus which frequently occur in axillary-subclavian arterial injuries were classified as incomplete brachial plexus injury and complete brachial plexus injury.

Incomplete brachial plexus injury refers to partial injury to the spinal roots, trunk, and cords. Complete brachial plexus injury refers to severe damage of the brachial plexus resulting in a totally paralyzed, insensate limb. Disability after vascular repair which usually results from associated nerve injuries was classified into mild, moderate, and severe. Mild disability was defined as a minimal loss of limb function which did not disturb daily life style. Moderate disability was defined as a definite impairment of limb function, however, some useful motor movement remained. Severe disability was defined as a useless limb or a totally paralyzed, insensate limb.

Shock in this study was defined as a systolic blood pressure of less than 90 mmHg.

RESULTS

Twenty-eight patients were entered in this study. Twenty-six (93%) were males and 2 (7%) were females. The age ranged from 15 to 39 years, mean 24 years. Sixteen patients (57%) sustained blunt trauma and 12 (43%) sustained penetrating trauma. Causes of injury are shown in Table 1. Motor cycle accidents were the most common cause of injury. Twenty patients (71.4%) were transferred from other hospitals, only 8 patients (28.6%) were sent directly from the scene of the event. Nine patients (32%) were in shock on arrival. No patient had normal radial pulse at initial examination. The radial pulses were diminished in 3 patients (10.7%), and absent in 25 patients (89.3%). Eighteen patients (64%) had impairment of motor function and/or sensation from associated nerve injuries, 7 of them had totally paralyzed, insensate limbs. Associated injuries remote from the site of vascular injury were present in 15 patients as shown in Table 2.

Preoperative angiography was performed in 12 patients (42.8%). The preoperative time ranged from 1 to 50 hours, mean 10 hours. Brachial artery was the most common injured artery (12 patients, 43%); followed by axillary artery (10 patients, 35.7%), subclavian artery (4 patients, 14%), and axillary-subclavian artery (2 patients, 7%). Twenty-three arteries (82%) were treated by resection of the damaged segment and reversed saphenous vein interposition graft, 3 (10.7%) by resection of the damaged segment and end to end anastomosis, 2 (7%) by lateral repair, and 1 (3.6%) by ligation (Table 3). The only patient who had axillary artery ligation sustained gunshot wounds to the chest. He arrived in the emergency room in profound shock and underwent emergency room thoracotomy which revealed injury to the heart causing cardiac tamponade. He also had injuries to the axillary artery and vein, both vessels were ligated. He died shortly after the operation. Eight patients (28.6%) had concomitant venous injuries, 3 were treated by saphenous vein interposition graft, 2 by lateral repair, and 3 by ligation (Table 4).

Peripheral nerve injuries were noted during vascular repair in 18 patients (Table 5). Seven of them had complete brachial plexus injuries, they had severe damage to the brachial plexus with avulsion of the nerve roots from the cervical cord, all of them were victims of motor cycle accidents. Four patients had incomplete brachial plexus injuries. Four patients had isolated radial or ulnar or median nerve injuries (2 had median, 1 had radial, and 1 had ulnar nerve injuries). Three patients had more than 1 peripheral nerve injury (1 had radial and ulnar, 1 had ulnar and median, and 1 had median, ulnar and radial nerve injuries). During the initial operations for vascular repairs, no attempted

Table 1. Causes of injury.

Causes	Number of patients (%)
Motor cycle accident	12 (42.8)
Car accident	3 (10.7)
Pedestrian accident	1 (3.6)
Stab wound	4 (14.3)
Cut wound	4 (14.3)
Gunshot wound	4 (14.3)
Total	28 (100)

Table 2. Associated injuries remote from site of arterial injury.

Injuries	Number of patients (n = 15)*
Multiple fractures	13
Chest injuries	7
Head injuries	2
Hepatic injuries	2
Spinal cord injury	1
Maxillo-facial injury	1
Kidney injury	1

* = some patients had more than one injury.

Table 3. Details of arterial injuries and treatments.

Injured arteries	Number of patients	Treatments			
		RSVG*	End to end anastomosis	Lateral repair	Ligation
Subclavian	4	4	-	-	-
Axillary-subclavian	2	2	-	-	-
Axillary	10	7	1	1	1
Brachial	12	10	2	-	-
Total	28	23	3	1	1

*= reversed saphenous vein graft

Table 4. Concomitant venous injuries.

Injured veins	Number of patients	Treatments		
		Saphenous vein graft	Lateral repair	Ligation
Subclavian	2	1	1	-
Axillary	3	-	1	2
Brachial	3	2	-	1
Total	8	3	2	3

repair was performed in all brachial plexus injuries. Three out of 4 patients who had median nerve injuries underwent primary repair .of the injured nerves. Of the 3 patients who had radial nerve injuries, 1 of them underwent primary repair. Of the 4 patients who had ulnar nerve injuries, none of them underwent primary repair.

Impairment of motor function and sensation of the involved limbs were found in all patients who had associated nerve injuries in the postoperative period (Table 5). All patients who had complete brachial plexus injuries and 2 out of 4 patients who had incomplete brachial plexus injuries had severe disability. Two patients who had incomplete brachial plexus injuries had moderate disability. Regarding patients who had injuries to the radial, ulnar or median nerve; moderate disability was found in patients who had more than 1 nerve injury and mild disability was found in patients who had isolated single nerve injury.

Two patients (7%) had fasciotomy performed at the forearm after a successful vascular repair. No amputation was required in this study. Only one patient died from associated heart injury (mortality 3.8%). The hospital stay ranged from 3 to 95 days, mean 20 days, excluding 1 patient who died and 2 patients who were transferred to other hospitals shortly after a successful initial operation. In blunt trauma patients, the mean hospital stay was 27.3 days. For those who had penetrating trauma, the mean hospital stay was 6.5 days. The hospital stay of patients who had associated nerve injuries was 23.6 days. For those without associated nerve injuries, the mean hospital stay was 5.3 days.

DISCUSSION

Injuries to vascular supply of the upper extremity have a variety of presentations depending on causes and mechanisms of injury. Blunt trauma usually results in intimal tear, thrombosis, or even

Table 5. Associated nerve injuries and results of treatments.

Injured nerves	Causes of injuries (No. of patients)	Injured arteries (No. of patients)	Mean hospital stay (days)	Disability (mild, moderate, severe)
Avulsion injury of brachial plexus	MCA (7)	Subclavian(2) Axillary-subclavian(2) Axillary(3)	27	severe
Partial brachial plexus injuries	MCA(1) CA(1) GSW(2)	Axillary(1) Subclavian(1) Subclavian(1) Axillary(1)	15	severe severe moderate moderate
Median, ulnar, and radial n.	SW(1)	Brachial(1)	26	moderate
Median and ulnar n.	CW(1)	Brachial(1)	6	moderate
Ulnar and radial n.	SW(1)	Axillary(1)	4	moderate
Median n. only	CW(2)	Brachial(2)	4	mild
Ulnar n. only	MCA(1)	Brachial(1)	26	mild
Radial n. only	SW(1)	Axillary(1)	9	mild

MCA = motor cycle accident; CA = car accident; GSW = gunshot wound;
SW = stab wound; CW = cut wound; n. = nerve

avulsion of the injured vessels. As observed in our study, most avulsion injuries from blunt trauma did not result in exsanguinating hemorrhage owing to rapid formation of thrombus in both ends of the injured vessels and tamponade effects of the surrounding musculoskeletal and connective tissue. On the other hand, penetrating injuries may result in thrombosis or exsanguinating hemorrhage depending on causes of injury. Gunshot wounds may produce thrombosis or false aneurysms, while cut wounds may cause a lot of bleeding(14).

Thrombosis and complete avulsion with thrombosis were common findings in this study. Severe ischemia following acute occlusion of the upper arm arteries is uncommon owing to abundant collateral vessels around the shoulder(10). This allows the attending surgeons a period of time for a careful evaluation. The relatively prolonged preoperative time (mean 10 hours) with no amputation in our study confirms this observation. Although it has been generally accepted that a diminished or absent distal pulse is a reliable sign of acute arterial occlusion, the presence of a palpable distal pulse does not exclude a vascular injury(9,10). Up to 40 per cent of patients with arterial injuries of the upper arm will have a palpable distal pulse(5,7,9). In our study, decreased or absent radial pulses were found in all patients, approving the usefulness of a careful basic physical examination.

The decision to do preoperative angiography depends on clinical presentations and expected site of arterial injury. Angiography is performed in order to identify an arterial injury in patients with abnormal physical findings or to establish the anatomy and precise location of injury. Early angiography is also indicated in patients who have signs of a brachial plexus injury with or without signs of vascular injury[12]. Surgery should be performed without angiography in cut or penetrating wounds with active bleeding. In such circumstances, angiography may delay treatment. Furthermore, site of injury can be roughly located by the appearance of external wounds or bullet pathways making proximal and distal control of the injured vessels relatively safe without preoperative angiography. Angiography is recommended in stable patients with suspected subclavian or axillary artery injuries[8,10,12,13]. Proximal control of subclavian and axillary artery can be safely performed when site of injury is precisely located by preoperative angiography. Although exploration of the distal axillary or brachial artery can be safely performed by an experienced vascular surgeon without preoperative angiography, accurate location of injury obtained from angiography will save time and lessen unnecessary dissections.

Expeditious repair of all arterial injuries remains a sound surgical principle. Almost all of the injured arteries in this study (23 out of 28) were successfully treated by resection of the damaged segment and revascularization with reversed saphenous vein interposition graft. Practically, primary repair with either end to end anastomosis or lateral repair is easier and more convenient to perform and was frequently the initial procedure of choice[5,9]. However, when a significant segment of artery is resected, an interposition graft is recommended to prevent excessive tension at the suture line as was frequently found in this study. Generally, saphenous vein grafts are used in most circumstances. When saphenous vein is not available or not suitable, a prosthetic graft such as polytetrafluorethylene (PTFE) was employed with a satisfactory outcome [9,12,15]. In some situations when vascular repair is not an appropriate procedure owing to the presence of other life-threatening conditions, ligation of the injured subclavian or axillary artery may be performed with a certain risk of amputation from severe ischemia. During World War II, when arterial ligation was routine, the amputation rate of upper arm arterial injuries was about 26-43 per cent[16].

In patients with a pulseless but viable limb who sustain a root avulsion type brachial plexus injury proved by myelography, nonoperative management of suspected axillary-subclavian artery injury has been advocated by some investigators with an acceptable outcome[13]. The explanation for such management based on the fact that it has little to do with the damaged neural elements and limb viability remains *via* extensive collateral vessels around the shoulder. However, this practice should be undertaken with great caution owing to a risk of subsequent extremity ischemia from distal embolization of the proximal thrombus[8].

Management of concomitant venous injuries depends on location, associated injuries, and patients' condition. Some investigators suggested a need for venous repair of all major injuries[17]. The main objective of venous repair is to improve venous return, decrease limb edema, and probably enhance successful arterial repairs. However, the procedures are tedious and difficult and obvious advantages remain controversial. Furthermore, long term patency of a venous repair is uncertain. Meyer et al[18] documented that 59 per cent of venous repairs thrombosed within 14 days and that thrombosis was not necessarily associated with clinically evident edema of the affected extremity. Timberlake et al[19] reported on a series of 73 venous injuries managed by ligation, including 21 at the popliteal level. With the liberal use of fasciotomies and elevation of injured extremities, no amputation was necessary in this series. No patient was discharged with edema of the extremity. We recommend venous ligation if the patient's condition does not allow for a delicate venous repair. However, repairing of injuries to large veins should be performed whenever possible. In patients who have severe soft tissue injuries where maximal venous return is necessary, venous repair is also recommended.

Regarding the necessity to perform fasciotomy, only 2 patients in our study underwent fasciotomy of the forearm. One of them had brachial artery injury, the other had subclavian artery injury. Both of them had concomitant venous injuries which were treated by ligations. Fasciotomy of the forearm is performed in order to prevent compartment syndrome which may ultimately lead to a Volkmann's ischemic contracture. Symonds et al and Adar et al both stressed the importance of fasciotomy in patients with suspected compartment syndrome of the forearm to salvage the limb with a successful vascular reconstruction[20,21]. Fasciotomy should be considered when one or more of the following are encountered: the limb is diffusely swollen after revascularization, prolonged ischemia, concomitant venous injuries are ligated, associated severe soft tissue and skeletal injuries, or compartmental pressure exceeds 40 mmHg.

Despite excellent results of vascular repairs in our study, poor long-term functional results of the upper arm vascular injuries occurred in patients who had associated major proximal nerve injuries. This observation is in agreement with previous reports(6,8-13). The most severely disabled group sustained spinal nerve roots avulsion and complete transection or severe contusion of proximal nerve trunks and cords of the brachial plexus (6,10-13). This type of injury usually occurs in blunt trauma. The most common pattern of injury to the brachial plexus in our study is the stretch-contusion injuries from motor cycle accidents. Motor cycle accidents causing severe damage to the brachial plexus have been previously reported (22,23). Poor prognosis for recovery is anticipated. Bonney(24) reported on 19 patients with complete brachial plexus injuries who were followed for 2 years. There was little return of function, and if recovery did occur, it was delayed for 12 to 18 months and limited to the proximal shoulder muscles. In addition to motor and/or sensory deficits, some patients are incapacitated by causalgia. Persistent extremity pain resulting in repeat hospitalization or treatment has been reported to be as high as 80 per cent of patients(25). Several operative procedures performed by neuro, plastic, or orthopedic surgeons in order to improve limb function have been attempted with varying outcome(26-33).

SUMMARY

Vascular injuries of the upper arm may occur following blunt and penetrating trauma. Blunt trauma, especially motor cycle accidents, usually produces a more severe injury than penetrating trauma. Decreased or absent radial pulse of the affected extremity is a reliable sign of the subclavian, axillary, and brachial artery injury. However, a normal pulse does not exclude the possibility of an arterial injury. Severe ischemia rarely encountered in upper arm vascular injuries owing to extensive collateral vessels around the shoulder. Angiography is a timely investigation for definite diagnosis and precise location of arterial injury in stable patients. Resection of the injured artery and reversed saphenous vein interposition graft were the most frequent procedures employed in this study. Despite a high rate of successful vascular repair, long-term disability frequently occurred in patients who had associated nerve injuries. Avulsion injury of spinal nerve roots and severe injury of the trunks and cords causing a complete brachial plexus injury were factors contributing to a poor prognosis.

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ภยันตรายต่อหลอดเลือดส่วนต้นที่เลี้ยงแขน

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ได้รายงานการบาดเจ็บต่อหลอดเลือดแดงส่วนต้นที่ไปเลี้ยงแขน อันได้แก่ หลอดเลือดแดง subclavian, หลอดเลือดแดง axillary, และหลอดเลือดแดง brachial ในผู้ป่วย 28 ราย ที่มารับการรักษาที่โรงพยาบาลจุฬาลงกรณ์ ในช่วงเวลา 5 ปี ตั้งแต่เดือนกุมภาพันธ์ 2534 ถึงเดือนมกราคม 2539 ผู้ป่วย 16 ราย (ร้อยละ 57) ได้รับบาดเจ็บชนิดทู่ (blunt trauma) ผู้ป่วย 12 ราย (ร้อยละ 43) ได้รับบาดเจ็บจากการถูกแทง, ถูกยิงและถูกของมีคมบาด อุบัติเหตุรถจักรยานยนต์เป็นสาเหตุการบาดเจ็บที่พบบ่อยที่สุด (ร้อยละ 43) ผู้ป่วยส่วนใหญ่ได้รับการส่งต่อมาจากโรงพยาบาลอื่น (ร้อยละ 71.4) ผู้ป่วย 9 ราย (ร้อยละ 32) อยู่ในภาวะช็อคเมื่อมาถึงโรงพยาบาลจุฬาลงกรณ์ ผู้ป่วยทุกรายมีความผิดปกติของชีพจร radial ที่ข้อมือแขนข้างที่ได้รับบาดเจ็บโดย 3 ราย (ร้อยละ 10.7) มีชีพจรเบาลงและ 25 ราย (ร้อยละ 89.3) คลำชีพจรไม่ได้ ผู้ป่วย 18 ราย (ร้อยละ 64) มีการบาดเจ็บร่วมที่ส่วนอื่นของร่างกาย ผู้ป่วย 18 ราย (ร้อยละ 64) มีการบาดเจ็บต่อเส้นประสาทที่ไปเลี้ยงแขนร่วมด้วยโดยในจำนวนนี้ 7 ราย เป็นการบาดเจ็บรุนแรงต่อ brachial plexus (complete brachial plexus injury) จากอุบัติเหตุจักรยานยนต์ ผู้ป่วย 12 ราย (ร้อยละ 43) ได้รับการยืนยันการวินิจฉัยโดยการฉีดสารทึบรังสีเข้าหลอดเลือดแดง ผู้ป่วย 12 ราย (ร้อยละ 43) ได้รับบาดเจ็บต่อหลอดเลือดแดง brachial, 10 ราย (ร้อยละ 35.7) ได้รับบาดเจ็บต่อหลอดเลือดแดง axillary, 2 ราย (ร้อยละ 7) ได้รับบาดเจ็บต่อหลอดเลือดแดง axillary และ subclavian, และ 4 ราย (ร้อยละ 14) ได้รับบาดเจ็บต่อหลอดเลือดแดง subclavian ผู้ป่วย 8 ราย (ร้อยละ 28.6) มีการบาดเจ็บร่วมต่อหลอดเลือดดำที่อยู่ข้างเคียง ผู้ป่วยส่วนใหญ่ได้รับการรักษาหลอดเลือดแดงที่ได้รับบาดเจ็บโดยการตัดส่วนที่ได้รับบาดเจ็บออกและต่อโดยใช้ reversed saphenous vein graft (23 ราย, ร้อยละ 82) ผู้ป่วย 3 ราย (ร้อยละ 10.7) ได้รับการรักษาโดยตัดหลอดเลือดแดงส่วนที่ได้รับบาดเจ็บออกและต่อแบบ end to end anastomosis ผู้ป่วย 2 ราย (ร้อยละ 7) ได้รับการเย็บซ่อมแซมหลอดเลือดแดงที่ได้รับบาดเจ็บแบบ lateral repair และผู้ป่วย 1 ราย (ร้อยละ 3.6) ได้รับการผูกหลอดเลือดแดงที่ได้รับบาดเจ็บ หลอดเลือดดำข้างเคียงได้รับการซ่อมแซมด้วยในผู้ป่วย 5 ราย ผู้ป่วย 2 ราย (ร้อยละ 7) ได้รับการทำ fasciotomy ร่วมด้วย ผลการรักษาหลอดเลือดที่ได้รับบาดเจ็บอยู่ในเกณฑ์ดีโดยไม่มีผู้ป่วยรายใดต้องได้รับการตัดแขนหลังจากการรักษาการบาดเจ็บต่อหลอดเลือดแดงเลย แต่ผู้ป่วยที่มีการบาดเจ็บร่วมต่อเส้นประสาทมักมีความทุพลภาพตามมาโดยกลุ่มผู้ป่วยที่มีการบาดเจ็บรุนแรงต่อ brachial plexus ร่วมด้วยมีความทุพลภาพมากที่สุด

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