Vascular Injuries of the Axilla

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Between January 1970 and December 1980, 65 patients sustaining 85 vascular injuries of the axillary artery and/or vein were managed at the Ben Taub General Hospital in Houston, Texas. Concomitant injuries of the subclavian and/or brachial vessels were noted in 34 per cent of patients. A variety of exposure techniques was used in approaching the axillary vessels. Emphasis upon preservation of collateral vessels led to an increased use of substitute vascular conduits over end-to-end anastomosis. The ready availability of prosthetic conduits, absence of graft infection, and excellent short-term patency have made them a primary choice for axillary arterial reconstruction in our recent experience. Associated brachial plexus injury (35%) accounted for the most significant long-term morbidity. The operative mortality was 3.1%, and one patient required upper extremity amputation following failure of repeated revascularization attempts.

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PENETRATING AND BLUNT INJURIES of the shoulder are frequent and often innocuous appearing wounds. In close proximity, however, lies the anatomic axilla and a host of neurovascular structures. Although providing considerable coverage and protection, the surrounding bone and muscular girdle may obscure physical signs of vascular injury and hinder rapid operative exposure and vascular control. The intimate proximity of the brachial plexus and the presence of an extensive collateral network to the upper extremity demand accuracy of dissection. A systematic approach to the evaluation and management of axillary vascular injuries is required. In the following report, the management and morbidity of axillary vascular injuries in a civilian population are reviewed.

Materials and Methods

Between January 1970 and December 1980, 65 patients sustaining 85 vascular injuries of the axillary artery and/or vein were managed at the Ben Taub General Hospital in Houston, Texas. Fifty-eight patients were male and 17 were female. Their ages ranged from 16 to 61, with an average age of 22.2 years. Axillary vascular injuries were caused by gunshot wounds in 39 patients, stab wounds in 16 patients, shotgun wounds in 7 patients, and blunt trauma in 3 patients (Table 1).

Results

Thirty-one arterial, 14 venous, and 20 combined arteriovenous wounds were managed. The axillary artery is defined as that continuation of the subclavian artery from the lateral border of the first rib to the lateral border of the teres major muscle. Its three anatomic divisions are defined by the overlying pectoralis minor tendon (Fig. 1). The 51 axillary arterial injuries were evenly distributed between the three divisions, with 13 injuries involving multiple segments or the entire artery (Table 2). Complete or subtotal transection was present in 47% of arterial and 24% of venous injuries. In 24 patients (47%) with axillary artery injury, distal arterial pulses were absent or markedly diminished. In 19 patients, positive arteriograms were obtained, 14 via retrograde brachial and five via arch aortogram techniques. Axillary artery injury was not initially recognized in two patients. One patient was discovered to have a traumatic axillary arteriovenous fistula one week following repair of a concomitant subclavian vein injury. A lateral axillary artery injury was missed in another patient at the time of the original exploration. Re-exploration and repair of the false aneurysm three weeks following injury was required. Twenty-three patients (35%) in this series had evidence of injury to the brachial plexus, while two patients had injury to the spinal cord. One patient was found to have a hemispheric cerebral neurologic deficit. Concomitant vascular wounds were the most frequent associated injuries (Table 3). Subclavian or brachial arterial injuries were present in 22 patients (34%), including one patient with simultaneous subclavian, axillary, and brachial artery injuries.[6]

A variety of operative exposures was used (Table 4). In most patients, the initial incision was in either the

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infraclavicular or anterior axillary region. Options for extension of either wound to attain proximal or distal vascular control or to expose adjacent concomitant vascular wounds were frequently used. In addition, division of the pectoralis major and/or minor tendon(s) was selectively performed to aid exposure. In one patient, the proximal axillary artery was exposed following thoracotomy by resecting the first and second ribs. Two patients having large shotgun wounds were explored by extending the original wound defects. In more proximal axillary vascular wounds, supraclavicular exposure of the subclavian artery was occasionally used for vascular control.

Rapid resuscitation and early exposure of axillary and associated vascular wounds permitted repair of all arterial injuries (Table 5). In 61% of arterial wounds, a substitute vascular conduit of either autogenous saphenous vein, Dacron velour, or Gore-Tex®* ranging from 2 to 6 cm in length was used. Axillary vein injuries were generally repaired by lateral venorrhaphy. Prosthetic grafts were not used in the venous position, but three injuries were treated by segmental resection and end-to-end anastomosis. Ligation was used only in patients with extensive venous wounds. One patient sustaining extensive brachial and axillary arteriovenous injuries following a shotgun wound subsequently required amputation. Revascularization was attempted used a saphenous vein graft from the axillary artery to the distal brachial artery. Recurrent graft thrombosis, despite repeated attempts at thrombectomy, and graft revision ultimately led to distal extremity gangrene and infection. Patients having axillary vein repair or ligation experienced minimal or only temporary problems with arm edema. Aside from the two previously described instances of delayed diagnosis, no additional vascular related complications occurred. There have been no early or late graft infections. Graft failure or vascular occlusion has not been observed. Each patient had a palpable distal pulse at the time of discharge and at follow-up two weeks following discharge. Although long-term follow-up has been incomplete, no instance of late vascular occlusion has been recorded.

Two patients expired from complications of numerous associated injuries. One patient died of respiratory insufficiency and pneumonia two weeks following surgery for multiple gunshot wounds of the chest and abdomen. The second patient died of complications of cerebral injury incurred as a result of blunt trauma.

* W. L. Gore and Associates, Inc., 555 Paper Mill Road, Newark, DE 19711.

TABLE 1. *Mechanisms and Location of Axillary Vascular Injuries in 65 Patients*

Etiology	Artery	Artery & Vein	Vein	Total
Gunshot wounds	19	12	8	39
Stab wounds	8	2	6	16
Shotgun wounds	1	6	0	7
Blunt trauma	3			3
Total	31	20	14	65

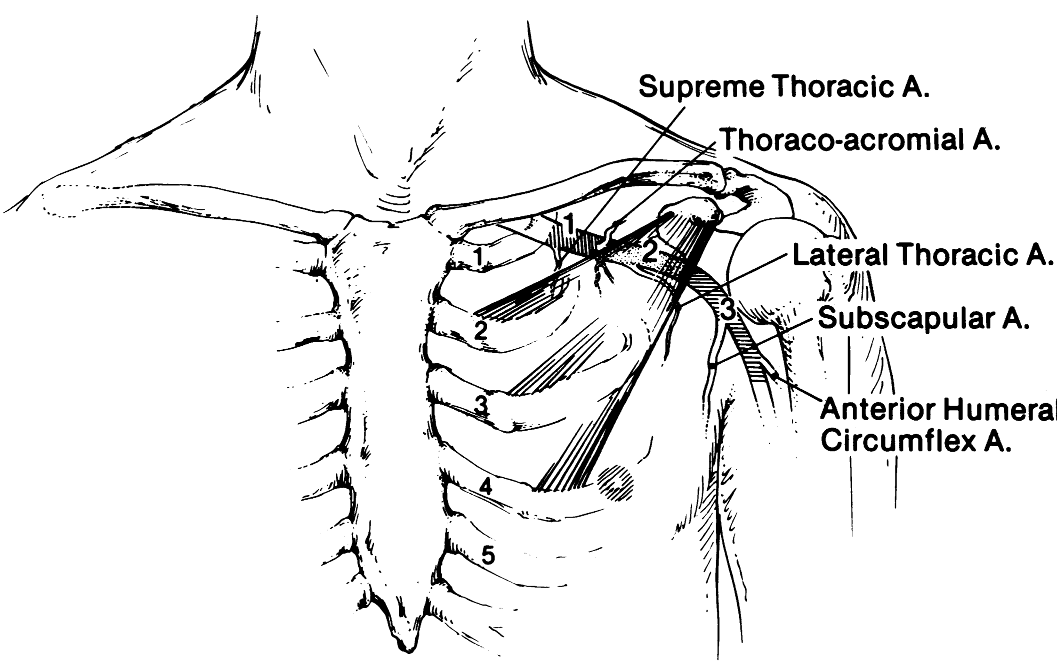

FIG. 1. The three anatomic divisions of the axillary artery and their branches.

TABLE 2. *Location of Axillary Artery Injuries*

Location	Number of Injuries
First division	12
Second division	14
Third division	12
Combined divisions	13
Total	51

Pulmonary insufficiency developed in three surviving patients, and severe cerebral sequelae of an associated head injury were noted in one patient. The most severe and permanent disability was experienced by 25 patients (39%) having associated brachial plexus or spinal cord injury. Immediate repair of lacerated or transected nerve roots and cords was not performed. Proximal and distal nerve ends were marked with nonabsorbable suture for possible future identification and when possible the nerve ends were approximated to prevent retraction. Three patients (12%) having brachial plexus contusion were observed to regain appreciable neurologic function. Delayed conventional epineural end-to-end union was performed in six patients, but without significant neurologic or functional return. Causalgia or persistent extremity pain led to repeat hospitalization or therapy in 20 patients (80%) and subsequent elective amputation in one patient for a useless painful extremity.

Discussion

Although wounds to the axilla appear to be innocuous in many patients, axillary vascular injuries may lead to severe disability, loss of limb, or death.[1,3,8,9,14,19] The incidence of axillary artery trauma among major arterial injuries has been similar in both civilian and military series, ranging from 2.9 to 9.0%.[1,3,4,10,12,14,19] With the escalating use of firearms in our society, the occasional trauma surgeon needs to be familiar with the recognition and management of such injuries.

The classic signs and symptoms of arterial injury are usually well recognized and include (among others) pain, pulselessness, pallor, paresthesia, and paralysis.[11,16] Following injury of the axillary artery, some or all of these "classic" signs may be absent.[6,7] The explanation for this apparent paradox lies in the extensive anastomotic network of collateral vessels around the shoulder. As a result, patients having traumatic transection or surgical ligation of the axillary artery may maintain not only a viably extremity but a palpable distal pulse.[4,12,13] Other well-described manifestations of arterial injury are usually present. These may include active arterial bleeding, expanding hematoma, continuous thrill, and a diminished pulse pressure when compared to the opposite arm. Loss of peripheral pulse, a large or expanding hematoma, or a positive arteriogram were the major indications for surgical exploration in this experience.

Patients with penetrating wounds in proximity to the axillary vessels should undergo arteriography if other criteria for operative exploration are absent. In this experience, no false negative study was obtained; however, one false positive arteriogram was seen. The accuracy of arteriography in the diagnosis of arterial injury has been documented elsewhere and depends upon

TABLE 3. *Associated Injuries Among 65 Patients with Axillary Vascular Trauma*

Location	Number of Patients
Vascular	
Subclavian artery	9
Subclavian vein	5
Brachial artery	13
Brachial vein	7
Neurologic	
Brachial plexus	23
Spinal cord	2
Brain	1
Bones	
Clavicle	3
Humerus	7
Scapula	2
Other	
Thoracic duct	1
Lung	19

TABLE 4. *Operative Exposure in 65 Patients*

Incision	Number of Patients
Infraclavicular	54*†
Axillary	8
Thoracotomy with first and second rib resection	1
Extension of original wound	2

* Division of pectoralis major (10) and/or minor (19) muscle tendons to aid exposure.

† Concomitant anterior thoracotomy and upper median sternotomy for repair of subclavian vessels (9).

TABLE 5. *Operative Repair of 85 Axillary Vascular Injuries*

Surgical Procedure	Artery	Vein
Ligation	0	9
Primary repair	10	22
Segmental resection and repair with		
End-to-end anastomosis	10	3
Saphenous vein graft	13	0
Dacron graft	14	0
Gore-Tex[R]	4	0

the quality of the study and the experience of the viewer.[16,17] In most instances, a retrograde brachial arteriogram was performed by the surgeon himself shortly after initial evaluation and resuscitation (Fig. 2). Equally as important are arteriograms obtained in patients suspected of having concomitant subclavian vascular injuries.[6] Associated proximal vascular injury should be considered when supraclavicular hematoma formation or extension is present. Arteriograms delineating anatomy in this area usually require transfer to an arteriographic suite with percutaneous Seldinger selective techniques. Many patients are too unstable to permit such detailed evaluations. In these cases, the surgeon must immediately proceed to exploration and be ready to achieve adequate proximal vascular control.

Approximately 22–27% of reported vascular injuries occur in the venous system.[5,15] Although venous injuries represented 40% of axillary vascular trauma in this series, they probably occur more frequently than clinically recognized. It may be hypothesized that many isolated venous injuries may not produce sufficient evidence of vascular injury to warrant exploration, and the sequelae of small unrepaired injuries are negligible. Fifty-nine per cent of the venous injuries in this series were encountered at the time of exploration and repair of an arterial injury. Venous injury alone may produce sufficient hematoma formation or external bleeding to warrant operative exploration. In these patients, the presence or absence of an associated arterial injury may not be known until full exposure and exploration has been performed. Many suspected axillary venous injuries, however, require only careful observation and may only cause problems when associated arterial injury cannot be ruled out.

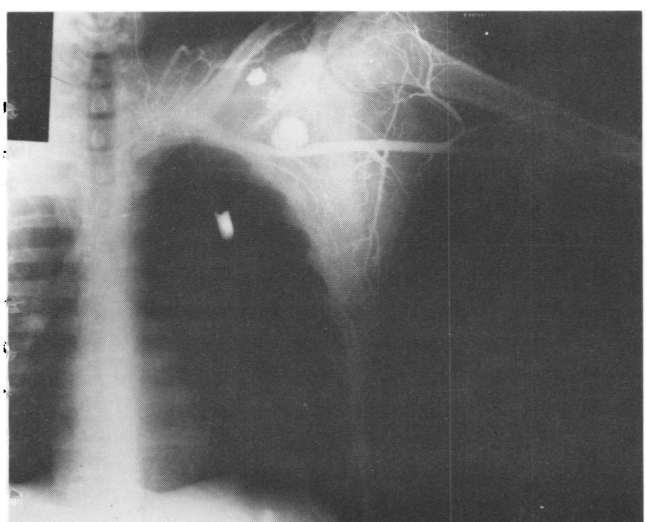

FIG. 2. Retrograde brachial axillary arteriogram demonstrating axillary artery injury.

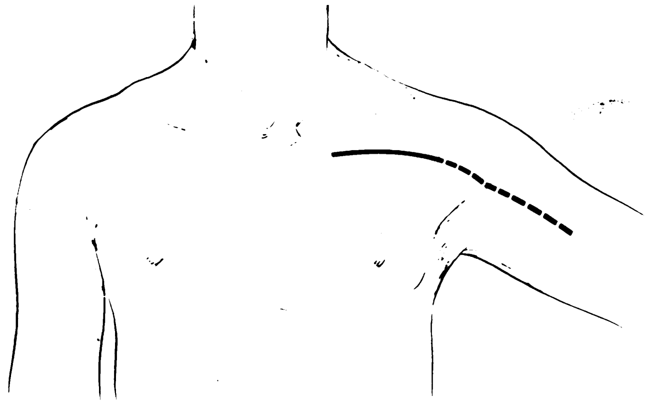

FIG. 3. Incision for infraclavicular exploration of the axilla (solid line) and possible extension (dotted line) for additional exposure of the distal axillary and brachial vessels.

The operative management of axillary vascular injuries begins with the placement of intravenous lines and the proper positioning of the patient for exploration. Peripheral or central venous lines on the side of suspected vascular injury are contraindicated. In most instances, a lower extremity intravenous line should be placed. The patient should be positioned supine with the involved extremity abducted 90°. The entire anterior chest, abdomen, and neck should be prepped and draped within the operative field to allow for possible thoracic and cervical exploration. The arm should be

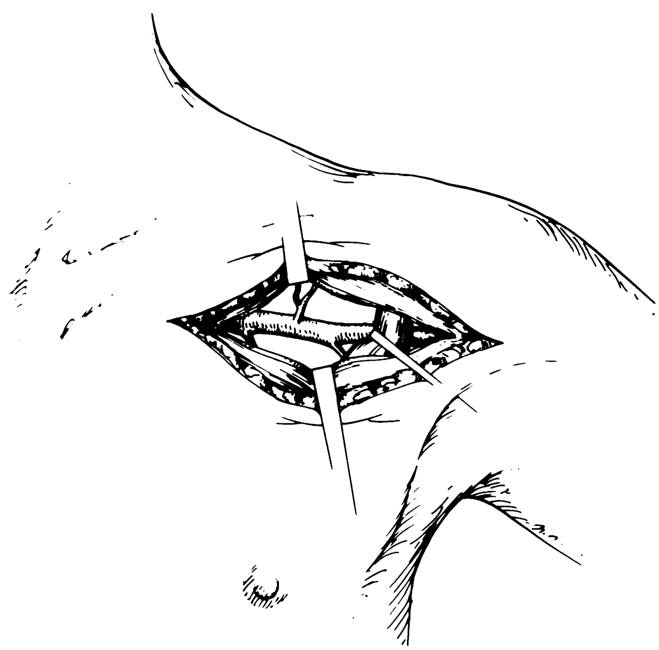

FIG. 4. Exposure of the axillary artery following separation of the pectoralis major muscle fibers and lateral retraction of the pectoralis minor tendon.

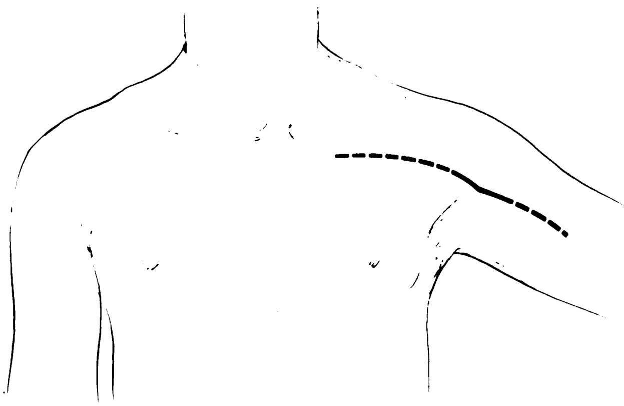

FIG. 5. Lateral exposure of the axilla via an anterior axillary incision (solid line) with possible infraclavicular and brachial extension (dotted lines).

similarly prepared to the wrist to allow for repositioning and palpation of brachial pulses.

Exposure of the axilla via an infraclavicular approach affords the widest exposure. The incision begins inferior to the medial third of the clavicle and is carried laterally to the delto-pectoral groove. The incision may be extended onto the proximal arm to gain additional exposure of the third portion of the axillary artery and the brachial artery (Fig. 3). Fibers of the pectoralis major muscle are then separated, and the underlying pectoralis minor muscle tendon retracted medially or laterally (Fig. 4). When additional exposure is needed, the pectoralis major and/or minor tendons may be divided near insertion, and the muscles retracted inferiorly. Patients having distal axillary artery injury may be approached laterally via an incision in the axilla along the delto-pectoral groove. Options for medial or distal wound extension exist (Fig. 5). The pectoralis muscle tendons are then retracted medially or divided for additional exposure (Fig. 6). By definition, the axillary artery is extrathoracic in location and not exposed via median sternotomy or thoracotomy. Supraclavicular exposure and control of the subclavian artery may be required in some patients when proximal control of the axillary artery cannot be attained via the infraclavicular incision. Division or resection of the clavicle was infrequently performed in this experience and, in general, found to add little to axillary exposure. Regardless of the choice of incision, the extensive collateral network about the shoulder and the intertwining proximity of the brachial plexus demand careful but rapid dissection. All efforts should be extended to preserve collateral branches and avoid additional nerve injury. The site of arterial injury may usually be digitally compressed to maintain hemostasis as the dissection proceeds. The frequent association of concomitant subclavian (14%) or brachial artery (20%) injury demands that the surgeon be familiar with the limits of the various incisions used for exposure of the axillary vessels. Extended approaches to exposure of the right and left subclavian arteries are available and have been previously described.[7]

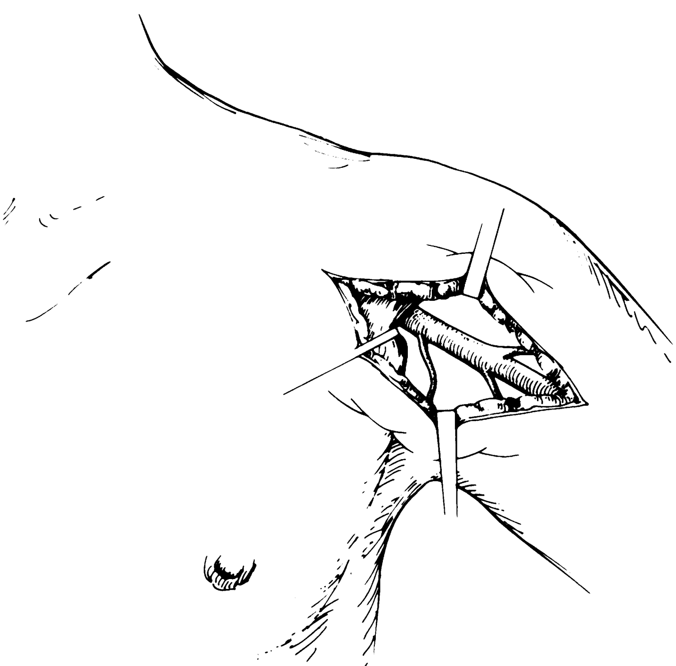

FIG. 6. Exposure of the axillary artery following medial retraction of the pectoralis muscle tendons.

Repair of the axillary vascular wound is dependent upon the nature of the injury and size of the defect. In most instances of venous injury, lateral repair may be performed (65%). Larger defects may be ligated with impunity, as no morbidity was observed in this experience from such treatment. Although venous end-to-end anastomosis may be accomplished and short-term patency may be demonstrated (Fig. 7), little if any additional benefit may be recognized. Although no patient in this series underwent axillary artery ligation, this alternative could be used in the profoundly hypotensive patient with multiple associated injuries.[8,14] The low rate of limb amputation in this (1.6%) and other series reflects improved techniques of arterial repair and avoidance of arterial ligation.[8,14] In the past, ligation of the acutely injured axillary artery has been associated with an amputation rate of 9.0 to 43.2%.[1,3] Lateral arteriorrhaphy is reserved for cutting wounds that produce simple, incomplete arterial disruption. Most complex arterial wounds, such as those produced by gunshot wounds, have extensive intimal disruption and require complete transection at the site of injury and debridement of each open end. The choice of reconstruction in these injuries may then be end-to-end anastomosis or interposition of a substitute vascular conduit. Collateral branches should not be sacrificed to allow adequate mobilization of arterial ends to perform an end-to-end anastomosis. With such an approach, the use of substitute vascular conduits (81%) will be greater than in repair of other peripheral arteries, but the collateral network about the shoulder will be maintained. Autogenous saphenous vein grafts were preferentially used as a substitute vascular conduit early in this experience. The necessity of performing an additional incision at a remote or separate site from the original injury and the time required for harvesting and preparation have always been problems in an acutely traumatized patient. In addition, clinical observations and laboratory investigations at this institution have revealed an increased propensity toward disruption and hemorrhage of an infected saphenous vein graft as compared to synthetic grafts when infected.[2,9] During the past four to five years, prosthetic grafts have been routinely used for all peripheral vascular wounds requiring relatively short (2–6 cm) segmental replacement. At present, the choice of synthetic graft is expanded polytetrafluoroethylene (Gore-Tex).[20] This preference is based upon its availability in smaller sizes (4–6 mm), and a high degree of resistance to infection following placement into grossly contaminated wounds at this institution. The short-term patency rates for both saphenous vein and prosthetic interposition grafts in this study have been equal. Although peripheral pulses were palpable at the time of hospital discharge, patients having late occlusion of vascular grafts may well remain asymptomatic.[14] Although previous long-term studies of patency for small 4–6 mm prosthetic grafts have been discouraging, their use in the patient with severe traumatic wounds may be justified. In patients sustaining symptomatic late graft occlusion or in the event of prosthetic graft infection, the saphenous veins have been preserved and may be utilized for elective vascular reconstruction.

The incidence of concomitant brachial plexus and axillary artery injury in the Vietnam experience was 92%.[14] The 39% incidence seen in this series may reflect the more limited nature of civilian wounds. Residual neuropathy in Vietnam also accounted for most postoperative morbidity, including late amputation of one upper extremity that was without motor or sensory function.[14] Although the results for repair of brachial plexus injuries have been discouraging in the past, current techniques of microvascular funicular repair may prove rewarding.

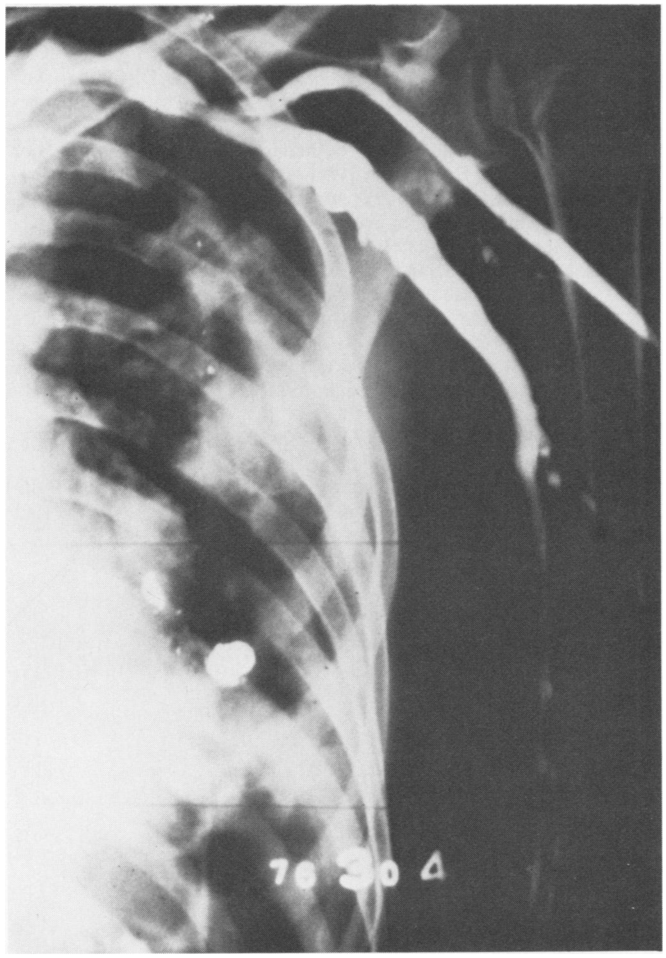

FIG. 7. Postoperative venogram two weeks following segmental resection and end-to-end anastomosis of the axillary vein.

Conclusion

Injuries of the shoulder may not be as innocuous as commonly thought. Axillary vascular wounds are accompanied by associated injury of the subclavian and/or brachial vessels in 34% of patients. Preservation of collateral vessels is essential in operative exposure and repair. Associated brachial plexus injury accounts for the majority of long-term morbidity.

References

1. Bailey H, ed. Wounds of the neck. In: Surgery of Modern Warfare. Edinburgh: E & S Livingston, 1944.
2. Bricker D, Beall AC, DeBakey ME. The differential response to infection of autogenous vein versus Dacron arterial prosthesis. 1970; Chest 58:566–570.

3. DeBakey ME, Simeone FA. Battle injuries of arteries in World War II: an analysis of 2,471 cases. 1946; Ann Surg 123:534-579.
4. Drapanas T, Hewitt RL, Weichert RF, Smith AD. Civilian vascular injuries: a critical appraisal of three decades of management. 1970; Ann Surg 172:351-360.
5. Gaspar MR, Treiman FL: The management of injuries to major veins. Am J Surg 1960; 100:171-182.
6. Graham JM, Feliciano DV, Mattox KL. Combined brachial axillary and subclavian artery injuries of the same extremity. J Trauma 1980; 20:899-901.
7. Graham JM, Feliciano DV, Mattox KL, et al. Management of subclavian vascular injuries. J Trauma 1980; 20:537-544.
8. Hughes CW. Arterial repair during the Korean War. Ann Surg 1958; 147:555-561.
9. Lau JM, Mattox KL, Beall AC, DeBakey ME. Use of substitute conduits in traumatic vascular injury. J Trauma 1977; 17:541-546.
10. Makins GH. Gunshot Injuries to the Blood Vessels. Bristol, England: John Wright and Sons, 1919.
11. Perry MO. The Management of Acute Vascular Injuries. Baltimore: Williams & Wilkins, 1981.
12. Perry MO, Thal ER, Shires GT. Management of arterial injuries. Ann Surg 1971; 173:403-408.
13. Phillip ML, Rich NM, Hutton JE. Collateral circulation in arterial injuries. Arch Surg 1971; 102:391-399.
14. Rich NM, Baugh JH, Hughes CW. Acute arterial injuries in Vietnam: 1,000 cases. J Trauma 1970; 10:359-369.
15. Rich NM, Hughes C. W. Vietnam vascular registry: A preliminary report. Surgery 1969; 65:218-229.
16. Rich NM, Spencer FC: Vascular Trauma. Philadelphia: WB Saunders, 1978.
17. Snyder WH, Thal ER, Bridges RA, et al. The validity of normal arteriography in penetrating trauma. Arch Surg 1978; 113:424-428.
18. Thal ER, Perry MO. Peripheral and Abdominal Vascular Injuries. In: Rutherford R, ed. Vascular Surgery, Philadelphia: WB Saunders, 1977.
19. Treiman RL, Doty D, Gaspar MR. Acute vascular trauma: a fifteen-year study. Am J Surg 1966; 111:469-473.
20. Vaughan GD, Mattox KL, Feliciano DV, et al. Surgical experience with expanded polytetrafluoroethylene (PTFE) as a replacement graft for traumatized vessels. J Trauma 1979; 19:403-408.