Surgery in Africa - Monthly Review

Vascular Trauma

Introduction

Trauma, both blunt and penetrating, is extremely common in Africa. As a result, trauma to major vessels, in particular arteries, is a not uncommon clinical occurrence. Some of the pathologic consequences of arterial injury including bleeding and occlusion with tissue ischemia, are acute events demanding immediate intervention to save life and limb and precluding any attempt at transfer or referral. Therefore, the particular specialized surgical skills, techniques and materials for the care of these patients need to be at the disposal of the non-specialist African general surgeon. It is the purpose of this Review to discuss these questions. While it will focus on the treatment of injured arteries, attention will be given to those venous injuries which require surgical repair rather than simple ligation. Finally photographs from the author's personal experience are presented in "Clinical cases".

Epidemiology

The literature is full of epidemiological studies describing the features of vascular trauma in various countries (1 - 9). There is wide variation in the incidence, cause and mechanism of injury depending on the local conditions. In a civilian population in Australia (5;9) vascular injuries represent 1-2% of total trauma patients. However they account for 20% of all trauma related death (5). Deaths from vascular injury vary considerably with anatomic location and mechanism of injury. Thoracic and abdominal injuries routinely have death rates between 30-50%; vascular injuries to extremities are significantly lower

in the range of 5%.
In an unparalleled large study from Vietnam Rich (10) reported a total death of only 1.7% for all vascular injuries. It may be that life-threatening vascular injuries were pre-selected by their failure to survive transport. In the current warfare conditions of the American intervention in Iraq and Afghanistan (11) vascular trauma represents 7% of total battle injuries, 88% of these were extremity injuries. The amputation rate was only 8% after vascular repair.
In North India (3), with a low risk of personal violence, blunt injuries, mostly motor vehicle accidents, account for 84% of vascular injuries. Whereas in Medellin, Columbia (6) 93% of vascular injuries are penetrating and in Georgia (2) they represent 85% of the total. Surprisingly, in the European experience (8), up to 40% of vascular injuries are iatrogenic, as a result of vascular and other surgical interventions. Kuwait (1) strikes a middle ground with 41% penetrating, 23% a result of road traffic accidents (RTA) and 22% iatrogenic. In Malaysia (4), over 50% of vascular injuries occur as a result of RTAs.
As far as anatomic site of injury is concerned, variability is less. In Australia (5;9) injuries are split almost equally between thorax, abdomen and upper and lower extremities, with cervical injuries being less common. In Latin America (7), extremity injuries are twice as common as thoracic and abdominal, although these later result in a higher mortality. As far as extremities are concerned upper and lower injuries occur with similar frequency and the brachial, femoral and popliteal arteries are the most commonly injured vessels. With special relevance to conditions in Africa, in the Latin American survey (7), 68% of cases could be managed on a clinical basis alone, that is without arteriography, and 78% were managed within 6 hours of injury.

Pathology:

Basically, injury to an artery can result in rupture, occlusion or both. Rupture leads to bleeding, either internal or external, depending on the circumstances, or in cases of contained bleeding the more chronic condition of a traumatic or false aneurysm. The other less common consequence of rupture occurs when artery and parallel vein are each breached with a resulting arterio-venous fistula, whose classical physical finding is the machine bruit. This condition, if sufficiently large, can result in high output heart failure (12). Partial rupture may or may not be associated with distal ischemia. Occlusion, whether intrinsic, as in a contusion with intimal flap and dissection or after complete transection, or extrinsic as a result of fracture and compression, results in ischemia of the tissues reliant on the vascular supply. The degree of ischemia is dependent on the associated collateral vessels and can be expressed in the amputation rate when the specific vascular injury is treated by ligation: axillary and brachial artery - 45-60%; common femoral artery – 80%; superficial femoral – 45%; popliteal – 85% (13). Clearly successful revascularization in these cases will reduce morbidity significantly. Thrombosis and embolism are additional associated occlusive mechanisms.
The compartment syndrome (14) is an important complication which may occur after reperfusion of previously ischemic extremities. It is also associated with fractures, soft tissue injuries, burns and crush injuries or, uncommonly, even after prolonged positioning (15). It evolves as increasing pressure in an enclosed fascial compartment in either the leg or forearm, which may surpass arterial pressure and result in further ischemia, muscle necrosis and neurologic injury. Excessive pain and paresthesia are the hallmarks of the complication and a high index of suspicion is required to detect the problem. Intra-compartment pressures can be measured but in general the rule is that fasciotomy should be carried out if the syndrome is suspected or anticipated.

Trauma Mechanisms - Blunt and penetrating trauma each has its associated pathological correlates. Diagnosis of blunt injury is more often delayed. High impact frontal motor vehicle collisions are associated with thoracic aortic injury, which will be discussed below. Injury to abdominal aorta, iliac and femoral vessels may all occur with blunt injury of sufficient force (16). Injury to the femoral artery secondary to bicycle handlebars (17) is a condition of which African surgeons should be aware. Vascular injury as a result of blunt trauma to the extremities (18) is usually associated with fractures although posterior dislocation of the knee is a well recognized cause. Again even in the west 2/3 of these cases can be diagnosed on clinical basis alone. Pediatric vascular injury has its own characteristics (19;20).
The morbidity and mortality of penetrating vascular injury is dependent on the velocity and energy content of the trauma (21;22). External bleeding is more common and the vascular injury usually diagnosed earlier. All cases of penetrating trauma and significant bleeding near major arteries should be explored with the suspicion of arterial injury and with preparation for its repair as part of wound debridement (see below) even in the absence of signs of distal ischemia. This will lower the risk of subsequent false aneurysm or fistula.
Many scoring systems have been developed in order to standardize the assessment of the severity of injury. (23;24)

Clinical Consequences – Diagnosis of arterial injury starts with a suspicion based on the recognized anatomy and mechanism of injury. The five “p”s are the classic clinical signs of ischemia: pain, pallor (in white skinned individuals), paresthesia, paralysis and pulselessness. Anyone having these signs has limb threatening ischemia which mandates re-establishment of blood supply within 6 hours to prevent irreversible tissue death. However lesser degrees of ischemia associated with absence of the distal pulse can be tolerated if collateral flow is good. Trauma surgeons have divided the clinical presentation of vascular trauma into hard and soft signs. Hard signs include arterial bleeding, expanding or pulsatile hematoma, bruit, pulse deficit or distal ischemia. Any one of these is a fairly reliable sign of vascular trauma (25). Soft signs include unexplained shock, history of significant bleeding, small hematoma, adjacent nerve injury and proximity to major vessel and are less indicative of vascular injury.
If you are lucky enough to have a hand held Doppler you can measure the blood pressure at the ankle. An ankle/brachial pressure ratio (ABI) of <1 is abnormal and denotes arterial injury in the absence of pre-existing occlusive disease.

Techniques:

The in hospital care of the trauma victim begins with initial assessment and resuscitation according to the ABC Principles. These do not vary for those with vascular injury except for an increased risk of requiring urgent operative intervention to control bleeding.
Exposure - Standard exposures for major arteries are well defined and should be adapted in cases of wounds to maintain good soft tissue coverage (26). Specific descriptions of these can be found in the relevant articles in the sections below (27-29).
Surgical Techniques – Specific surgical techniques (30) must be mastered if successful vascular repair is to be achieved. These include: proximal and distal exposure for control with vascular clamps and

loops; dissection and isolation of injured vessels including veins; heparinization: local and/or systemic; use of vascular sutures; magnification loops; assessment of injury: debridement, contusion, intimal flap and distal dissection and thombosis; selective use of shunting; anatomic repairs:with vein patch, end/end anastomosis without tension and reversed autologous vein graft for larger defects; technical details of spatulated ends, running versus interrupted sutures; distal thrombectomy (31); completion arteriography (32); fasciotomy and soft tissue coverage. Proper handling of the autogenous vein graft is important (33).

Fracture Management – The timing of the vascular repair in relation to fracture management has long been a source of controversy. The standard recommendation is for vascular repair to precede orthopaedic management. Prevention of prolonged tissue ischemia is the objective. While no prospective studies exist, McHenry (34), in a retrospective study, suggested an increased need for fasciotomy when fractures are stabilized before revascularization. No cases of disruption of vascular repair occurred in 22 cases of subsequent fracture stabilization. Most fractures can be adequately stabilized with traction or posterior plaster splinting but external fixation may be necessary in some cases. Volgas (35) gives a good review of management of ballistic injury.

Ancillary Measures – While the standard techniques have been discussed above, certain other approaches can be mentioned. Heroic extra-anatomic bypasses (36) can be carried out either primarily in conditions of major tissue loss or presence of infection or secondarily after initial failure. Endovascular techniques are being used increasingly in hospitals with advanced vascular capability (37-39). These are unlikely to be at the disposal of most African surgeons. Cardio-pulmonary bypass may be of value in selected patients in settings where it is available (40).

Imaging:

Imaging, in particular contrast arteriography, has played an important role in the development of vascular surgery. While it is clear that advanced imaging techniques are important in the management of zones 1 and 3 neck injuries (41) and thoracic aortic disruption (42), for most extremity vascular injuries pre-operative arteriography is not necessary. However on table operative angiograms are easily carried out with a minimum of equipment and give important information about the extent of injury and the adequacy of repair (32). In suspected vascular injury exclusion arteriography has been shown to be cost-effective (43).

Clinical and anatomic problems:

Cervical Vascular Injuries – Penetrating injuries to the neck have been divided into three zones (28). Suspected vascular injury in zones 1 & 3 in the presence of hard signs of intra-cranial dysfunction mandates arteriography prior to exploration (41;44). The operative approach is more difficult and the mortality higher with these problems. Zone 2 injuries are recommended to undergo prompt exploration. Study of the neurologic outcomes in neck injuries (45) shows that the risk of cerebral infarction is unpredictable but that repair of injured vessels gives a more favourable outcome than ligation.

Thoracic Vessels – Blunt thoracic aortic injury is a specific clinical syndrome related to high impact deceleration injuries and, although treatable, causes significant mortality related partially to delayed diagnosis (27). Although 50% of victims die on impact, in the rest the bleeding is temporarily contained by the aortic adventitia and pleura and these patients are potentially salvageable. The injury typically occurs at the site of the ligamentum arteriosum, just distal to the take off of the left subclavian artery. The classic sign of widened mediastinum is unreliable and investigation should be carried out in cases where there is a high index of suspicion (42;46). Controversy remains whether arch arteriography or CT scanning is more efficient in the diagnosis. It appears that the use of heparin-bonded shunts allows improved results with a lower incidence of paraplegia. Endovascular techniques are playing an expanding role in the treatment of this problem (47).

Massive hemothorax requiring thoracotomy is defined as >1-1.5L at the time of insertion of chest drains or 200-300ml/hr for the subsequent 4 hours. Some of these cases will involve injury to the pulmonary vessels (48).

Abdominal Aorta and Visceral Vessels- Injuries to major abdominal vessels are usually penetrating and cause significant mortality often exceeding 50% (27;49;50). Rapid decision-making is important in preventing exsanguination. Excessive attempts at stabilization prior to laparotomy are unrewarding and fluid should actually be restricted before surgical intervention (51). Severe refractory hypotension or cardiac arrest prior to control of the abdominal aorta suggests the need for initial thoracotomy and aortic clamping with cardiopulmonary massage to stabilize the patient before exploration of the abdomen. A significant percentage of cases have injuries to more that one major vessel. Visceral artery injuries are particularly deadly (52). Survival rates are improved with isolated venous and iliac injuries (51).

Upper Extremity - Injuries to the upper extremity vessels are common, usually penetrating and may be associated with significant nerve and orthopaedic injury (53). Blunt injury is usually a result of supracondylar fracture of the humerus or dislocation of the elbow. The amputation rate for ligation of the common brachial vessel is 55%; below the take-off of the profunda brachial it is 25%. With isolated injury to the infra-brachial vessels the amputation rate is even lower and ligation of either the radial or ulnar arteries alone is usually well tolerated. A higher level of technical skill is required in dealing with smaller vessels and use of magnification loops has much to recommend it. Spasm of the vessels is more frequent and may require topical lidocaine or intra-arterial papaverine. Prosthetic material is not recommended. Passing of Fogarty catheters distally is important to remove distal thrombus. Completion angiograms are important to detect abnormalities, which might result in post-operative thrombosis of the repair. Soft tissue coverage of the repair uses adjacent muscle. Fasciotomy needs to be done if ischemic time is prolonged and orthopaedic stabilization should occur after vascular repair. I would agree with Shanmugan (54) that pre-operative angiography is seldom necessary, but cannot advocate all aspects of their management.

Lower Extremity: Hafez (55) describes a large series of patients from South Africa with lower extremity vascular injury. Only 19% of cases were a result of blunt trauma, the rest penetrating. Only patients with "soft" signs of arterial injury had pre-operative angiography, the rest were taken to the operating room for exploration. Surgically the use of shunts was not routine, local heparinization only was used, fogarty catheters were routinely passed and completion angiograms obtained, simple venous injuries were repaired, complex ligated. If grafting was required contralateral reversed saphenous vein was used. Revascularization was carried out before fracture stabilization. In 46% of cases fasciotomies were performed; when there were tense compartments, combined arterial and venous lesions, in the presence of motor or sensory defect or in limbs of questionable viability. In the latter case, if the superficial posterior and one other compartment showed non-viability, a primary amputation was carried out. The amputation rate was 16%. I consider this series to include all the important surgical features and recommend it for further reading.

Femoral – Carillo (25) provides an excellent review of femoral vascular injuries and describes the Mangled Extremity Severity Scale (MESS) and its correlation with need for eventual amputation. He also discusses the treatment of false aneurysm and arterio-venous fistula in this area.

Popliteal/Infra-popliteal – Frykberg (56) gives an excellent in-depth review of popliteal artery injuries and their management. Blunt injuries carry almost 3 times the risk of amputation in comparison to penetrating injuries. He points out that, in blunt trauma or major complex injury of the lower leg, hard signs of vascular injury may be present as a result of soft tissue or bony injury themselves. He recommends peri-operative hand injection femoral arteriography for diagnosis. This does not mean delaying surgical management by formal arteriography. In the presence of soft signs, non-operative management on a clinical basis appears to yield as good results as arteriography and aggressive vascular repair for minimal lesions. Posterior knee dislocations in the absence of hard signs also can be managed without vascular exploration or arteriography. Frykberg reviews the details of surgical management. Prepping the contralateral leg for possible harvesting of the long saphenous vein should be remembered. Injuries requiring resection of more than 2 cm are not amenable to primary anastomosis. Popliteal vein injuries, which usually occur together with arterial ones, should be repaired if possible. In the case of combined injuries intra-arterial shunts may play a particular role. Prophylactic 4 quadrant fasciotomy done often as the initial procedure is recommended in delayed injuries or those with complex soft tissue damage. Woolgar (57) presents an experience with the delayed presentation of popliteal artery pseudo-aneurysms.

Rowe (58) presents a review of infra-popliteal artery injuries. The presence of 3 arteries in the leg, 2 of which the anterior and posterior tibial arteries continue into the foot, provides a margin of safety when one or even two is occluded. I should point out that the revascularization of infra-popliteal vessels requires advanced vascular techniques. In the usual case of major soft tissue trauma the decision is often one of primary amputation versus repair. The absolute indications for primary amputation in these cases are: more than 6 hours of ischemic time and disruption of the posterior tibial nerve. The relative indications are: severe foot wounds, poly-trauma, injuries requiring extensive soft tissue coverage and tibial reconstruction. The details of repair are provided.

Complications:

Rich (10) reviews the complications, which may occur after vascular repair. These are considerable and may occur in up to 30% of cases. The major acute complications are thrombosis, infection and stenosis. Completion angiography, the use of only autologous material for repair and adequate soft tissue coverage are the means to decrease these risks. Delayed complications are discussed as well.

Summary

Despite the specialized skills required, I believe repair of vascular injuries primarily extremity injuries is not beyond the capacity of the district African surgeon. This is also the position of COSECSA, which lists arterial repairs in the FCS syllabus. The articles presented here provide the theoretical basis for acquiring these skills. The traumatized population will provide the clinical basis.

A vascular surgery box

A box containing these instruments and products should be available in every hospital, providing emergency surgical care. (* materials are considered extremely important)

1. A standard set of surgical instruments* including: non-crushing vascular clamps* of various sizes, self-retaining retractors*, fine non-toothed vascular forceps*, fine scissors* or angled Potts scissors.
2. Rummel tourniquets, surgical rubber loops *or other means of atraumatically controlling small vessels.
3. Prolene sutures* with non-cutting needles – 2-0, 3-0, 4-0, 5-0
3. Fogarty catheters* – sizes 3-5
4. Heparin* to make a solution of 1000units/20 ml NS for local irrigation. For systemic heparinization the dose is 100units/kg, but this might require reversal with protamine sulfate.
5. Papaverine for intra-arterial injection or xylocaine* for topical adventitial administration to counteract spasm in smaller vessels.
6. Equipment for hand-held intra-operative angiography including soluble intravenous contrast*, syringes, intra-venous cannulae.

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Clinical cases

- Brachial artery injury
- False Aneurysm of Popliteal Artery
- False Aneurysm of Femoral Artery
- Arterio-Venous Fistula of Femoral Vessels

Reference List

1. Asfar S, Al Ali J, Safar H, Al Bader M, Farid E, Ali A et al. 155 vascular injuries: a retrospective study in Kuwait, 1992-2000. European Journal of Surgery 2002; 168(11):626-630.
2. Razmadze A. Vascular injuries of the limbs: a fifteen-year Georgian experience. European Journal of Vascular & Endovascular Surgery 1999; 18(3):235-239.
3. Menakuru SR, Behera A, Jindal R, Kaman L, Doley R, Venkatesan R. Extremity vascular trauma in civilian population: a seven-year review from North India. Injury 2005; 36(3):400-406.
4. Lakhwani MN, Gooi BH, Barras CD. Vascular trauma in Penang and Kuala Lumpur Hospitals. Medical Journal of Malaysia 2002; 57(4):426-432.
5. Sugrue M, Caldwell EM, Damours SK, Crozier JA, Deane SA. Vascular injury in Australia. Surgical Clinics of North America 2002; 82(1):211-219.

6. Morales-Uribe CH, Sanabria-Quiroga AE, Sierra-Jones JM. Vascular trauma in Colombia: experience of a level I trauma center in Medellin. Surgical Clinics of North America 2002; 82(1):195-210.
7. Sonneborn R, Andrade R, Bello F, Morales-Uribe CH, Razuk A, Soria A et al. Vascular trauma in Latin America: a regional survey. Surgical Clinics of North America 2002; 82(1):189-194.
8. Fingerhut A, Leppaniemi AK, Androulakis GA, Archodovassilis F, Bouillon B, Cavina E et al. The European experience with vascular injuries. Surgical Clinics of North America 2002; 82(1):175-188.
9. Gupta R, Rao S, Sieunarine K. An epidemiological view of vascular trauma in Western Australia: a 5-year study. ANZ Journal of Surgery 2001; 71(8):461-466.
10. Rich NM. Complications of Vascular Injury Management. Surgical Clinics of North America 2002; 82(1):143-174.
11. Fox CJ, Gillespie DL, O'Donnell SD, Rasmussen TE, Goff JM, Johnson CA et al. Contemporary management of wartime vascular trauma. Journal of Vascular Surgery 2005; 41(4):638-644.
12. Durakoglugil ME, Kaya MG, Boyaci B, Cengel A. High output heart failure 8 months after an acquired arteriovenous fistula. Japanese Heart Journal 2003; 44(5):805-809.
13. Chapter 10: Wounds of Limbs. In: Dufour D, Kromann Jensen S, Owen-Smith M, Salmela J, Stening GF, Zetterstrom B, editors. Surgery for victims of war. Geneva: International Committee of the Red Cross, 1998: 83-87.
14. Velmahos GC, Toutouzas KG. Vascular trauma and compartment syndromes. Surgical Clinics of North America 2002; 82(1):125-141.
15. Mallik K, Diduch DR. Acute noncontact compartment syndrome. Journal of Orthopaedic Trauma 2000; 14(7):509-510.
16. Baker WE, Wassermann J. Unsuspected vascular trauma: blunt arterial injuries. Emergency Medicine Clinics of North America 2004; 22(4):1081-1098.
17. Sarfati MR, Galt SW, Treiman GS, Kraiss LW. Common femoral artery injury secondary to bicycle handlebar trauma. Journal of Vascular Surgery 2002; 35(3):589-591.
18. Rozycki GS, Tremblay LN, Feliciano DV, McClelland WB. Blunt vascular trauma in the extremity: diagnosis, management, and outcome. Journal of Trauma-Injury Infection & Critical Care 2003; 55 (5):814-824.
19. Milas ZL, Dodson TF, Ricketts RR. Pediatric blunt trauma resulting in major arterial injuries. American Surgeon 2004; 70(5):443-447.
20. Soares G, Ibarra R, Ferral H. Abdominal aortic injury in a child: intravenous digital subtraction angiogram (IVDSA) for the diagnosis of pediatric vascular trauma. Pediatric Radiology 2003; 33 (8):563-566.
21. Wolf YG, Rivkind A. Vascular trauma in high-velocity gunshot wounds and shrapnel-blast injuries in Israel. Surgical Clinics of North America 2002; 82(1):237-244.
22. Bowley DM, Degiannis E, Goosen J, Boffard KD. Penetrating vascular trauma in Johannesburg, South Africa. Surgical Clinics of North America 2002; 82(1):221-235.
23. Injury Severity Scoring. www.surgicalcriticalcare.net . 5-29-2001. Ref Type: Electronic Citation
24. Trauma Scoring Systems. www.surgical-tutor.org.uk . 2005. Ref Type: Electronic Citation
25. Carillo EHea. Femoral Vessel Injuries. Surgical Clinics of North America 2002; 82(1):49-65.
26. Hoyt DBea. Anatomic Exposure for Vascular Injuries. Surgical Clinics of North America 2001; 81(6).
27. Bongard F. Thoracic and Abdominal Vascular Trauma. In: Rutherford RB, editor. Vascular Surgery. Philadelphia: W.B. Saunders Company, 1995: 686-704.
28. Perry MO. Injuries of the Brachiocephalic Vessels. In: Rutherford RB, editor. Vascular Surgery. Philadelphia: W.B. Saunders Company, 1995: 705-712.
29. Thal EReal. Vascular Injuries of the Extremities. In: Rutherford RB, editor. Vascular Surgery. Philadelphia: W.B. Saunders Company, 1995: 713-736.
30. Rutherford RB. Basic Vascular Surgical Techniques. In: Rutherford RB, editor. Vascular Surgery. Philadelphia: W.B. Saunders Company, 1995: 395-404.
31. Fogarty TJ. Fogarty Catheter Thrombectomy. In: Rutherford RB, editor. Vascular Surgery. Philadelphia: W.B. Saundes Company, 1995: 410-414.
32. Subber SWeal. Contrast Arteriography (excerpt). In: Rutherford RB, editor. Vascular Surgery. Philadelphia: W.B. Saunders Company, 1995: 195-202.
33. Towne JG. The Autogenous Vein. In: Rutherford RB, editor. Vascular Surgery. Philadelphia: W.B. Saunders Company, 1995: 482-491.
34. McHenry TP, Holcomb JB, Aoki N, Lindsey RW. Fractures with major vascular injuries from gunshot wounds: implications of surgical sequence. Journal of Trauma-Injury Infection & Critical Care 2002; 53(4):717-721.
35. Volgas DA, Stannard JP, Alonso JE. Current orthopaedic treatment of ballistic injuries. Injury 2005; 36(3):380-386.
36. Feliciano DV. Heroic procedures in vascular injury management: the role of extra-anatomic bypasses. Surgical Clinics of North America 2002; 82(1):115-124.
37. Nicholson AA. Vascular radiology in trauma. Cardiovascular & Interventional Radiology 2004; 27(2):105-120.
38. Scalea TM, Sclafani S. Interventional techniques in vascular trauma. Surgical Clinics of North America 2001; 81(6):1281-1297.
39. Risberg B, Lonn L. Management of vascular injuries using endovascular techniques. European Journal of Surgery 2000; 166(3):196-201.
40. Chughtai TS, Gilardino MS, Fleiszer DM, Evans DC, Brown RA, Mulder DS. An expanding role for cardiopulmonary bypass in trauma.[erratum appears in Can J Surg 2002 Jun;45(3):223]. Canadian Journal of Surgery 2002; 45(2):95-103.
41. Ferguson E, Dennis JW, Vu JH, Frykberg ER. Redefining the role of arterial imaging in the management of penetrating zone 3 neck injuries. Vascular 2005; 13(3):158-163.
42. Blackmore CC, Zweibel A, Mann FA. Determining risk of traumatic aortic injury: how to optimize imaging strategy. AJR 2000; American Journal of Roentgenology. 174(2):343-347.
43. Keen JD, Keen RR. The cost-effectiveness of exclusion arteriography in extremity trauma. Cardiovascular Surgery 2001; 9(5):441-447.
44. Cox CS, Jr., Allen GS, Fischer RP, Conklin LD, Duke JH, Cocanour CS et al. Blunt versus penetrating subclavian artery injury: presentation, injury pattern, and outcome. Journal of Trauma-Injury Infection & Critical Care 1999; 46(3):445-449.
45. du Toit DF, van Schalkwyk GD, Wadee SA, Warren BL. Neurologic outcome after penetrating extracranial arterial trauma. Journal of Vascular Surgery 2003; 38(2):257-262.
46. Degiannis E, Boffard K. Critical decisions in trauma of the thoracic aorta. Injury 2002; 33(4):317-322.

47. Iannelli G, Piscione F, Di Tommaso L, Monaco M, Chiariello M, Spampinato N. Thoracic aortic emergencies: impact of endovascular surgery. Annals of Thoracic Surgery 2004; 77(2):591-596.
48. Deneuville M. Injury of the pulmonary artery and its branches due to penetrating chest trauma. Annals of Vascular Surgery 2000; 14(5):463-467.
49. Davis TP, Feliciano DV, Rozycki GS, Bush JB, Ingram WL, Salomone JP et al. Results with abdominal vascular trauma in the modern era. American Surgeon 2001; 67(6):565-570.
50. Asensio JA, Chahwan S, Hanpeter D, Demetriades D, Forno W, Gambaro E et al. Operative management and outcome of 302 abdominal vascular injuries. American Journal of Surgery 2000; 180 (6):528-533.
51. Haan J, Rodriguez A, Chiu W, Boswell S, Scott J, Scalea T. Operative management and outcome of iliac vessel injury: a ten-year experience. American Surgeon 2003; 69(7):581-586.
52. Asensio JA, et al. Visceral Vascular Injuries. Surgical Clinics of North America 2002; 82(1):1-20.
53. Fields CE, Latifi R, Ivatury RR. Brachial and forearm vessel injuries. Surgical Clinics of North America 2002; 82(1):105-114.
54. Shanmugam V, Velu RB, Subramaniyan SR, Hussain SA, Sekar N. Management of upper limb arterial injury without angiography--Chennai experience. Injury 2004; 35(1):61-64.
55. Hafez HM, Woolgar J, Robbs JV. Lower extremity arterial injury: results of 550 cases and review of risk factors associated with limb loss. Journal of Vascular Surgery 2001; 33(6):1212-1219.
56. Frykberg ER. Popliteal vascular injuries. [Review] [101 refs]. Surgical Clinics of North America 2002; 82(1):67-89.
57. Woolgar JD, Reddy DS, Robbs JV. Delayed presentation of traumatic popliteal artery pseudoaneurysms: a review of seven cases. European Journal of Vascular & Endovascular Surgery 2002; 23 (3):255-259.
58. Rowe V, Salim A, Lipman J, Asensio JA.. Shank Vessel Injuries. Surgical Clinics of North America 2002; 82(1):91-104.

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