

**Practice Management Guidelines for
Penetrating Trauma to the Lower Extremity**

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PRACTICE MANAGEMENT GUIDELINE FOR EVALUATION AND MANAGEMENT OF LOWER EXTREMITY VENOUS INJURIES FROM PENETRATING TRAUMA

I. Statement of the Problem

Venous injuries occur frequently with penetrating trauma to the lower extremity. Neither the natural history nor the optimal treatment of isolated venous injuries is known. Most frequently, venous injuries are diagnosed in association with a concomitant arterial injury or during exploration for a presumed arterial injury. In this scenario, controversy still exists regarding the proper management of these injuries.

II. Process

A Medline computer search was conducted on all articles in the English literature during the years 1980-1997 pertaining to venous injuries of the lower extremity. The subject words used included "Avascular injury," "Avenous injury," "Aextremity trauma," "Apenetrating trauma," "Avascular trauma," and "Avenous trauma." The references of these articles were also used to locate articles not found in the Medline search. Personal files were also used. All letters to the editor, case reports, book chapters, review articles, series involving less than 20 cases, series involving predominantly blunt trauma, and series in which the percentage and outcome of the penetrating injuries were not clearly specified were excluded. Also articles whose focus was the management of arterial injuries but also included the results of their venous injuries were excluded. This left 14 articles of relevance to this practice parameter.

III. Recommendations

A. Level 1

There is no class I evidence to support a standard of care for this parameter.

B. Level 2

There is no class 2 evidence to support a standard of care for this parameter.

C. Level 3

1. There is insufficient data to recommend treatment for isolated venous injuries. Isolated venous injuries accompanied with active hemorrhage require exploration and cessation of bleeding.
2. Venous injuries found during exploration for associated arterial injury should be repaired if the patient is hemodynamically stable and the repair itself will not significantly delay treatment of associated injuries or destabilize the patient's condition.
3. Lateral venorrhaphy that does not significantly narrow the lumen or paneled grafts appear to be the best options for repair. Interposition vein grafts consistently have poor results, and synthetic grafts are the least desirable option for repair.
4. There is insufficient data to recommend adjunctive measures to improve vein repair patency.

5. Venous ligation in conjunction with leg elevation, compression stockings, and liberal use of fasciotomies offers similar results to repair.
6. Fasciotomy should be considered when there is a combined arterial and venous injury.

IV. Scientific Foundation

Most available studies on venous injuries secondary to penetrating trauma to the lower extremity are retrospective in nature. There is virtually no data available on isolated venous injuries. Except for Borman et al., virtually no one has attempted to diagnose venous injuries preoperatively.¹² Even in this paper, in which 30% of patients had a preoperative venogram, 90% of the patients underwent exploration for the indication of suspected arterial injury. Since most patients with penetrating trauma to the lower extremity get evaluated for the possibility of arterial injury, there is probably an unknown population of patients with normal arterial evaluations and undiagnosed isolated venous injuries. There are no data to show adverse sequelae of missed isolated venous injuries. Thus neither the natural history nor the optimum management of isolated venous injuries is known. It is reasonable to assume that only the isolated injuries that present themselves because of active bleeding need to be pursued. Otherwise, management recommendation cannot be given.

Most of the literature on venous trauma deals with venous injuries that are diagnosed during exploration for suspected arterial injuries. In this scenario, there has been an ongoing debate regarding the optimal management strategy. Again, except for one prospective study, most of the literature is retrospective.⁶ Nonetheless, these studies provide enough evidence to support a number of recommended and suggested management options, as well as directions for future investigation.

The majority of papers on this subject deal with whether to ligate or repair. Venous injuries found during exploration for associated arterial injury should be repaired if the patient is hemodynamically stable and the repair itself will not significantly delay treatment of associated injuries or destabilize the patient's condition.^{7,9,12,14} With respect to the type of repair performed, the highest patency rates are achieved with lateral venorrhaphies that do not significantly narrow the lumen of the repaired vein or vein patching.^{5,6,8,11,12} For complex repairs, end-to-end and paneled repairs are probably the best options. Synthetic or interposition vein grafts have the worst reported patency rates.^{6,8,11} Nevertheless, irrespective of the type of repair chosen, the thrombosis rate and lower extremity edema rate are significant. Even the patent or recanalized repairs have significant physiologic impairment when assessed with photoplethysmography.¹⁰ When ligation is performed, the clinically significant edema rate does not appear to be significantly different if leg elevation, compression stockings, and liberal use of fasciotomies are utilized.^{7,8,9,11,12,14} Fasciotomy rates are not affected by the type of management of the venous injury.^{1,7,9,12} Rather, it is the presence of a combined arterial and venous injury that significantly increases the rate of fasciotomy. Adjunctive measures that improve venous repair patency rates have not been clearly elucidated in the literature. There is some evidence that creation of an arteriovenous fistula may improve patency rates.³ There is no rigid scientific data to support use of anticoagulants.

V. Summary

Very little data exists on the diagnosis and management of isolated venous injuries. The literature suggests that venous injuries encountered during exploration for an arterial injury should be repaired if the patient is stable. Lateral venorrhaphies result in the best patency rates, synthetic and interposition vein grafts have much lower patencies. Complications of thrombosis and distal edema are common regardless of the type of repair chosen.

VI. Future Investigation

While all areas concerning the management of venous injuries require more rigorous scientific evaluation, there are some issues that have not been studied in great detail which lend themselves to prospective study:

The natural history of isolated venous injuries

The proper management of isolated venous injuries

Role for post operative venography or venous duplex

Role of anticoagulation after repair or ligation

VII. References

1. Agarwal N, Shah PM, Clauss RH, et al. Experience with 115 Civilian Venous Injuries. *J Trauma* 22:827-832, 1982.
2. Phifer TJ, Gerlock AJ, Rich NM, et al. Long-term Patency of Venous Repairs Demonstrated by Venography. *J Trauma* 25:342-346, 1985.
3. Richardson JB, Jurkovich GJ, Walker GT, et al. A Temporary Arteriovenous Shunt in the Management of Traumatic Venous Injuries of the Lower Extremity. *J Trauma* 26:503-509, 1986.
4. Sharma PV, Shah PM, Vinzons AT, et al. Meticulously restored lumina of injured veins remain patent. *Surgery* 112:928-932, 1992.
5. Nypaver TJ, Schuler JJ, McDonnell P, et al. Long-term results of venous reconstruction after vascular trauma in civilian practice. *J Vasc Surg* 16:762-768, 1992.
6. Meyer J, Walsh J, Schuler J, et al. The Early Fate of Venous Repair after Civilian Vascular Trauma. *Ann Surg* 206(4):458-464, 1987.
7. Timberlake GA, O'Connell RC, Kerstein MD. Venous injury: To repair or ligate, the dilemma. *J Vasc Surg* 4:553-558, 1986.
8. Khaneja SC, Arrillaga A, Ernst A, et al. Outcome in the Management of Penetrating Venous Injury. *Vasc Surg* 28:39-43, 1994.
9. Yelon JA, Scalea TM. Venous Injuries of the Lower Extremities and Pelvis: Repair Versus Ligation. *J Trauma* 33:532-538, 1992.
10. Aitken RJ, Matley PJ, Immelman EJ. Lower limb vein trauma: a long-term clinical and physiologic assessment. *Br J Surg* 76:558-588, 1989.
11. Hardin WD, Adinolfi MF, O'Connell RC, et al. Management of Traumatic Peripheral Vein Injuries. *Am J Surg* 144:235-238, 1982.
12. Borman KR, Jones GH, Snyder WH. A Decade of Lower Extremity Venous Trauma: Patency and Outcome. *Am J Surg* 154:608-612, 1987.
13. Hobson RW, Yeager RA, Lynch TG, et al. Femoral Venous Trauma: Techniques for Surgical Management and Early Results. *Am J Surg* 146:220-224, 1983.
14. Mullins RJ, Lucas CE, Ledgerwood AM. The Natural History following Venous Ligation for Civilian Injuries. *J Trauma* 20:737-743, 1980.

First Author	Reference	Class	Findings
Meyer J, et al	The early fate of venous repair after civilian vascular trauma. Ann Surg 206(4):458-464, 1987	II	28 LE v.v. injuries. All dx=d in OR. 94% assoc. a.a. injuries. Mostly penetrating trauma. Mostly complex repairs- 17% lat. Venorrhaphy. All pts had US & impedance plethysmography on POD 7 followed by venography. 39% thrombosis by venography. Interposition grafts had significantly higher thrombosis. No difference between sights of repair. 4 pts w/ edema(1 patent repair). Edema resolved in two @ 3 months. Venography was more accurate than PE which was more accurate than non-invasive tests in assessing patency. Limb salvage equal in the patent vs. thrombosed groups.
Mullins RJ, et al	The natural history following venous ligation for civilian injuries. J Trauma 20: 737- 743, 1980	III	129 pts w/ major v.v. injuries identified. 6 died before TX & were excluded. 68 had primary repair most by lat. Venorrhaphy. The results of these patients were not included. 55 pts. had v.v. ligation. 9 of these excluded for various reasons. 32 of the remaining were of the LE. 11 of these underwent fasciotomies. Main reasons for ligation were hemorrhagic shock, extensive injury to v., multiple associated injuries. Most injuries were from penetrating mechanism. Pt. Were kept at bed rest w/ involved leg elevated until edema free. Ambulation trials followed by bed rest & leg elevation cont=d until edema would not recur- this occurred in most pts by second trial. Median LOS 29 d. 40/46 were free of edema on ambulation. Of the 33 pts w/ long-term f/u, 30 remained edema free on long-term f/u. None had severe edema or evidence of venous stasis. 28/46 w/ assoc. a.a. injuries had successful a.a. repairs.
Agarwal N, et al	Experience with 115 Civilian Venous Injuries. J Trauma 22:827-832,1982	III	Retrospective. 115 pt.=s w/ venous injuries. Intraabdominal v.v. included. 92% penetrating. 28 LE venous injuries. 75% assoc. a.a. injuries . 8 ligate ; 20 repaired. Incidence of edema significantly greater in ligation group. Compartment syndrome significantly > in combined injury group. No one who had fasciotomy at time of initial repair developed foot drop. Patency of venous repairs was not established
Hardin WD, et al	Management of traumatic peripheral vein injuries. Am J Surg 144: 235-238, 1982	III	86 v.v. injuries- 69 in the LE=s. 97% penetrating. 66% had repair- 21% by lat suture; 14% had interposition grafts. 2 had primary amputation. Results classified as good (no sequelae), fair (short term sequelae), & poor (long term sequelae). 88% had long-term full recovery. 36% had short-term sequelae (fair), 10% had long-term sequelae (poor). 1 PE and 1 post-op amputation both pts had had repair w/ interposition v. grafts. Vein interposition was associated w/ the highest rate of long-term morbidity. Primary repair & V. ligation had long-term morbidity of 9.3 & 3.5 % respectively.

Hobson RW, et al	Femoral venous trauma: techniques for surgical management and early results. Am J Surg 146: 220-224, 1983	III	24 femoral v.v. injured over 4 yr pd. 22 from a penetrating mechanism. 10 repaired by lat. Venorrhaphy, 5 by venous patch, 4 by end-to-end, 3 by interposition graft & 2 ligated- 1 of them later underwent in situ bypass w/ saphenous v. 3 Illustrative case reports reported. The pt. W/ ligation had no complications. Of the repairs 74% deemed patent on f/u venography and or non-invasive evaluation. No clinically evident PE=s. 3 pts w/ narrowed repairs had clinically significant edema. 5/6 occluded repairs had significant edema. Claim to be first to report in-situ saphenous v. bypass and spiral grafts for repair of femoral v.v. injuries.
Phifer TJ, et al	Long-term patency of Venous Repairs Demonstrated by Venography. J Trauma 25:342-346, 1985	III	Retrospective. Attempt made to locate 31 patients w/ femoral v. injury over 20 yr. Pd. 24 of these repaired. 5 patients w/ 6 reconstruction=s located. 5 gsw, 1 shotgun. All were 5-20 yr. post-injury. 5/6 were patent. The occluded repair had used Teflon interposition graft. This patient had edema and incompetent deep valvular system. All others had nl valvular fxn and no edema.
Richardson JB, et al	A Temporary AV Shunt in the Management of Traumatic Venous Injuries of the Lower Extremity. J Trauma 26:503-509, 1986	III	8 patients over two year period with venous reconstruction who had distal AV shunts (Scribner type) created. All gsw=s. 7 had combined a.a & v.v injuries. All pts w/ shunts that worked greater than 3 days had patent venous repair on post-op venograms @ 1-2 weeks.
Timberlake GA, et al	Venous injury: To repair or ligate, the dilemma. J Vasc Surg 4:553-558, 1986	III	Gp I 31 LE isolated v.v. injuries all dx=d during operations for suspected a.a. injuries. All penetrating. Gp II 38 pts. w/ LE v.v. injuries also had assoc. a.a. injuries. Venous injuries were either ligated or repaired by end-to-end or lat. Venorrhaphy. No permanent sequelae of ligation identified. No limb loss in this series. 31/43 w/ isolated injuries were ligated. Transient post-op edema was not significantly different between ligation & repair. Fasciotomies were higher in popliteal v. group again no difference w/ respect to Tx. Repaired popliteal v.v thrombosed. Results in the combined injury gp-similar.

Borman KR, et al	A Decade of Lower Extremity Venous Trauma: patency and outcome. Am J Surg 154: 608-612, 1987	III	Retrospectively identified pts w/ v.v. injuries who had been explored. 71 v.v. injuries. 87% penetrating. 46% were in shock on admission. 25 (30%) had preoperative venograms- 22 of these were abnl. 90% of patients were operated on for suspicion of a.a. injury. 76% had concomitant a.a. injuries. 46% had lat. venorrhaphies the rest were complex repairs of which 44% were interposition grafts. 1 v. was repaired w/ synthetic material. 8% of v. were ligated. V.v. repairs usually preceded a.a. repairs. 40% of repairs and 43% of ligations had fasciotomies. 11% pts w/ repair had major post-op morbidity (sepsis), 46% had early LE complications mostly edema but 24% these had gangrene and 8% had PE=s. These complications were more often following repair 49% vs. 14% in ligation group. 67% repaired limbs were intact w/o sx=s on long-term f/u and 40% of ligations. 9 repairs and two ligations had edema. In the long-term venography group 41(56%)- 4 initially patent occluded, 1 initially thrombosed was partially recanalized. 63% in repair grp remained patent. Simple repairs were more likely patent vs. Complex repairs. 19% of patent repairs had DVT=s at distant site and 33% of occluded repairs. 4% of patent repairs and 13% of occluded repairs had PE=s. 74% of patent repairs had intact limbs vs. 38% of occluded repairs. Edema was higher in the failed repairs.
Aitken RJ, et al	Lower limb vein trauma: a long-term clinical and physiologic assessment. Br J Surg 76: 558-588, 1989	III	f/u study. Pts w/ v.v. injuries were identified & asked to come back for assessment. Venography used to assess patency & photoplethysmography used to assess fxn. 26/48 pts contacted. Median elapsed time from injury was 19.5 months. Mostly penetrating trauma. 6 ligation. 11 repairs were either lat. or patch venorrhaphy, the remaining were complex repairs of which 5 were interposition v.v. grafts. 11/12 pts w/ fasciotomies had assoc a.a. injuries. 5/6 pts w/ ligation had clinical dependent pedal edema. 9/20 repairs had edema. 12 pt. W/o edema had abnl v.v. fxn. 4/6 ligations were assessed as poor outcome; 7/20 of repairs were poor, 6/20 fair & 7/20 were good. 58% of the repairs thrombosed. The patent repaired v.v. had serious physiologic impairment when assessed w/ photoplethysmography.
Nypaver TJ, et al	Long-term results of venous	III	Follow-up study. Retrospectively were able to locate 32 pt.=s w/ previous venous

	reconstruction after vascular trauma in civilian practice. J Vasc Surg 16:762-768, 1992		reconstruction. 94% penetrating. 26 LE injuries. 84% assoc. a.a. injuries. Most v.v. injuries discovered during exploration for a.a. repair-3 seen on preop a-gram. 56% lat. venorrhaphy, 13% patch, 9% end- to- end, 22% interposition grafts. 41% had fasciotomies. 17/32 pt.=s had early venography-53% thrombosed. 4/32 had edema @ dc. 1 PE. 2 thrombosed repairs required rehospitalization for IV anti-coagulation. 7 had venous stasis @ long term f/u. Long-term duplex studies revealed 90% venous repairs patent. 94% of lat venorrhaphies and 86% of complex repairs were patent- not significant. Of the 17 pts who had had venography all patent repairs remained patent and 8/9 repairs, which were occluded, were now patent.
Sharma PV, et al	Meticulously restored lumina of injured veins remain patent. Surgery 112:928-932, 1992	III	38 v.v. injuries mostly penetrating; 81% assoc. a.a. injuries. Retrospectively divided into two groups. Those that underwent intra-op venogram and those who did not. 2/17 in group 1 had repair revised secondary to venogram. Group 1 had significantly better patency rates and lower post repair fasciotomy rates
Yelon JA, et al	Venous injuries of the lower extremities and pelvis: Repair versus ligation. J Trauma 33:532-538, 1992	III	55 LE v.v. injuries. Almost all penetrating. 24/55 repaired. Most of the repaired v.v. (74%) had an associated a.a. injury. 48 pts. 60% of total group (pelvic and LE v.v. injuries) had associated a.a. injuries. Popliteal v.v. were more frequently repaired than ligated. 57% presented in shock/71% of these had venous ligation which represents 60% of the venous ligation group.39/45 w/ grade III/IV v.v. injuries had ligation. 15 had lat. venorrhaphies & 15 had complex repairs. 2 had interposition grafts. No difference in fasciotomy rates. All pts. W/ fasciotomies had concomitant a.a. injuries. No difference in clinically significant post-op edema rates. No difference in LOS.
Khaneja SC, et al	Outcome in the management of penetrating venous injury. Vasc Surg 28:39-43, 1994	III	19 LE v.v. injuries due to penetrating trauma. 13/17 femoral v.v. were repaired for by lat. venorrhaphy the rest by complex repair. Both popliteal v.v repaired/thrombosed. 6/8 interposition v. grafts thrombosed. The only isolated v. injury (femoral) was Tx=d w/ PTFE and distal AV fistula & was patent on f/u after ligation of fistula. None of the pts. w/ ligation had post-op sequelae. 4/6 thrombosed repairs had post-op sequelae.

PRACTICE PARAMETER FOR DIAGNOSIS AND MANAGEMENT OF LOWER EXTREMITY ISOLATED ARTERIAL INJURIES FROM PENETRATING TRAUMA

I. Statement of the Problem

Evaluation and management of arterial injuries to the lower extremity due to penetrating trauma continues to challenge trauma surgeons. Questions remain concerning the method of evaluation and management of the arterial injury. The vast majority of the literature on this subject is retrospective in nature. There is sufficient data to support the recommendations made.

II. Process

A Medline computer search was conducted on all articles in the English Literature during the years 1980-1997 pertaining to arterial injuries of the lower extremity. The subject words used included Avascular injury@, Aartery injury@, Aextremity trauma@, Apenetrating trauma@, Avascular trauma@, and Aartery trauma@, . The references of these articles were also used to locate articles not found in the Medline search. Personal files were also used. All letters to the editor, case reports, book chapters, review articles, series involving less than 20 cases, and series in which the percentage and outcome of the penetrating injuries were not clearly specified were excluded. This left 36 articles of relevance to this practice parameter. In addition there were 2 abstracts that were relevant to this practice parameter.

III. Recommendations

A. Level 1

There is no class I evidence to support a standard of care for this parameter.

B. Level 2

Patients with hard signs of arterial injury (pulse deficit, pulsatile bleeding, bruit, thrill, expanding hematoma) should be surgically explored. There is no need for arteriogram in this setting unless the patient has an associated skeletal injury or a shotgun injury. Restoration of perfusion to an extremity with an arterial injury should be performed in less than six hours in order to maximize limb salvage.

C. Level 3

1. There is no defined role for the use of noninvasive Doppler pressure monitoring or duplex ultrasonography to confirm or exclude arterial injury. There may be a role for these studies in patients with soft signs of vascular injury or with proximity injuries.
2. Absence of hard or soft signs of vascular injury reliably excludes surgically significant arterial injury and does not require arteriography.

3. Nonoperative observation of asymptomatic nonocclusive arterial injuries is acceptable.
4. Repair of occult and asymptomatic nonocclusive arterial injuries managed nonoperatively that subsequently require repair can be done without significant increase in morbidity.
5. Simple arterial repairs fare better than grafts. If complex repair is required, vein grafts appear to be the best choice. PTFE, however, is also an acceptable conduit.
6. PTFE may be used in a contaminated field. Effort should be made to obtain soft tissue coverage.
7. Tibial vessels may be ligated if there is documented flow distally.
8. Early four-compartment lower leg fasciotomy should be applied liberally when there is an associated injury or there has been prolonged ischemia. If not performed, compartment pressures should be closely monitored.
9. Arteriography for proximity is indicated only in patients with shotgun injuries.
10. Completion arteriogram should be performed after arterial repair.

IV. Scientific Foundation

The limb salvage rate following uncomplicated penetrating arterial injury is over 95%. Faster transport times, improved resuscitation, early operative intervention, and advances in critical care have all contributed to these impressive results. The approach to these injuries continues to evolve. Based on the physical exam, patients with hard signs of arterial injury (pulse deficit, arterial bleeding, bruit, thrill, expanding hematoma) without associated skeletal injury can proceed to operative exploration without an arteriogram(1,8,9,15,21,24,25,27,30,35). There may be some exceptions to this statement. Patients with shotgun wounds or with preexisting peripheral vascular disease may still benefit from a preoperative arteriogram. Soft signs of arterial injury (nerve deficit, nonexpanding hematoma, associated fracture, significant soft tissue injury, history of bleeding or hypotension), while being a widely recommended indication for arteriography, do not appear to be clinically useful predictors of arterial injuries with the exception of shotgun wounds (8,15,20,24,35). In those patients without hard or soft signs of arterial injury there is no role for proximity angiogram (9,15,20,21,23,24,35,36). Patients with clinically occult arterial injuries may be treated nonoperatively in most instances (8,19,26,27,28,29). There still remains questions on selection criteria for nonoperative management of patients with pseudoaneurysms or arteriovenous fistulae. Patients with clinically occult arterial injuries which later manifest themselves as needing repair can be repaired without additional morbidity (19,21,25,26,27). Patients with hard signs that are surgically explored are best managed with simple repair, either by end-to-end anastomosis or arteriorrhaphy (1,7,8,9,11,12,16). If complex repair is required, vein grafts appear to have the highest patency rates. PTFE however seems to be an acceptable alternative even in contaminated fields (2,3,5,9,11,12,14,15,38). Ligation of tibial vessels is

acceptable when there is evidence of good perfusion distally (7,8,13,14,24).

The role of noninvasive evaluation of the lower extremity has not been elucidated. There is data to suggest that duplex studies are accurate in diagnosing arterial injuries (17,18,23,31,32,33,34). However, it is unclear when to initiate these studies. Should they be performed for proximity or in the presence of soft signs of arterial injury? If there is no role for proximity arteriography, why then do noninvasive testing for proximity? Should they be used to follow up patients with normal vascular exams? These questions require further investigation.

V. Summary

Most patients with hard signs of arterial injury should be operated upon without a preoperative arteriogram. A preoperative arteriogram may be helpful in patients with shotgun wounds or preexisting peripheral vascular disease. There appears to be no role for proximity angiography in patients with soft signs of arterial injury, as most patients with occult injury may be treated nonoperatively.

Patients who have an arterial injury that requires exploration (ie. those with hard signs) are best repaired with simple repair or vein grafts. PTFE grafts are an acceptable alternative even in a contaminated field.

VI. Future Investigation

Several issues in diagnosis and management of arterial extremity injuries remain unresolved. Future studies should focus on prospective evaluation of the following:

Role of noninvasive tests to diagnose vascular injury in extremity penetrating trauma

1. Use of PTFE versus autogenous vein in the repair of arterial injuries
2. Role of intraoperative completion arteriogram
3. Nonoperative observation of asymptomatic nonocclusive arterial injuries
4. Proper follow up of patients treated nonoperatively for asymptomatic nonocclusive arterial injuries
5. Role of heparin/thrombolytics in the repair of arterial injuries
6. Evaluation of patients with soft signs of vascular injury
7. Role of antioxidants in prevention of reperfusion injury and need for fasciotomy

VII. References

1. Reichle FA, Golsorkhi M. Diagnosis and Management of Penetrating Arterial and Venous Injuries in the Extremities. *Am J Surg* 140: 365-367, 1980.
2. Shah DM, Leather RP, Corson JD, et al. Polytetrafluoroethylene Grafts in the Rapid Reconstruction of Acute Contaminated Peripheral Vascular Injuries. *Am J Surg* 148: 229-233, 1984.
3. Feliciano DV, Mattox KL, Graham JM, et al. Five-year Experience with PTFE Grafts in Vascular wounds. *J Trauma* 25:71-82, 1985.
4. Meyer JP, Lim LT, Schuler JJ, et al. Peripheral Vascular Trauma From Close Range Shotgun injuries. *Arch Surg* 120: 1126-1131, 1985.
5. Menzoian JO, Doyle JE, Cantelmo NL, et al. A Comprehensive Approach to Extremity Vascular Trauma. *Arch Surg* 120: 801-805, 1985.
6. Whitman GR, McCroskey BL, Moore EE, et al. Traumatic Popliteal and Trifurcation Vascular Injuries: Determinants of Functional Limb Salvage. *Am J Surg* 154: 681-684, 1987.
7. Armstrong K, Sfeir R, Rice J, et al. Popliteal Vascular Injuries and War: Are Beirut and New Orleans similar? *J Trauma* 28: 836-839, 1988.
8. Ashworth EM, Dalsing MC, Glover JL, et al. Lower Extremity Vascular Trauma: A Comprehensive, Aggressive Approach. *J Trauma* 28: 329-336, 1988.
9. Feliciano DV, Herskowitz K, O=Gorman RB, et al. Management of Vascular Injuries in the Lower Extremities. *J Trauma* 28: 319-328, 1988.
10. Feliciano DV, et al. Extraanatomic Bypass for Peripheral Arterial Injuries. *Am J Surg* 158: 506-9, 1989.
11. Peck JJ, Eastman AB, Bergan JJ, et al. Popliteal Vascular Trauma: A Community Experience. *Arch Surg* 125: 1339-1344, 1990.
12. Cargile JS III, Hunt GF. Acute Trauma of the Femoral Artery and Vein. *J Trauma* 32: 364, 1992.
13. Padberg FT, Rubelowsky JJ, Hernandez-Maldonado JJ, et al. Infrapopliteal arterial injury: Prompt revascularization affords optimal limb salvage. *J Vasc Surg* 16: 877-885, 1992.
14. Trooskin SZ, Sclafani S, Winfield J, et al. The Management of Vascular Injuries of the Extremity Associated with Civilian Firearms. *SG & O* 176: 350-354, 1993.

15. Degiannis E, Levy RD, Sofianos C, et al. Arterial Gunshot Injuries of the Extremities: A South African Experience. *J Trauma* 39: 570-575, 1995.
16. Melton SM, Croce MA, Patton JH Jr, et al. Popliteal Artery Trauma: Systemic Anticoagulation and Intraoperative Thrombolysis Improves Limb Salvage. *Ann Surg* 225: 518-527, 1997.
17. Fry WR, Smith RS, Sayers DV, et al. The Success of Duplex Ultrasonographic Scanning in Diagnosis of Extremity Vascular Proximity Trauma. *Arch Surg* 128: 1368-1372, 1993.
18. Knudson MM, Lewis FR, Atkinson K, et al. The Role of Duplex Ultrasound Arterial Imaging in Patients with Penetrating Extremity Trauma. *Arch Surg* 128: 1033-1038, 1993.
19. Frykberg ER, Vines FS, Alexander RH. The Natural History of Clinically Occult Arterial Injuries: A Prospective Evaluation. *J Trauma* 29: 577-583, 1989.
20. Francis H, Thal ER, Weigelt JA, et al. Vascular Proximity: Is it a Valid Indication for Arteriography in Asymptomatic Patients? *J Trauma* 31: 512-514, 1991.
21. Frykberg ER, Dennis JW, Bishop K, et al. The Reliability of Physical Examination in the Evaluation of Penetrating Extremity Trauma for Vascular Injury: Results at One Year. *J Trauma* 31: 502-511, 1991.
22. Johansen K, Lynch K, Paun M, et al. Non-invasive Vascular Tests Reliably Exclude Occult Arterial Trauma in Injured Extremities. *J Trauma* 31: 515-522, 1991.
23. Anderson RJ, Hobson RW, Lee BC, et al. Reduced Dependency on Arteriography for Penetrating Extremity Trauma: Influence of Wound Location and Noninvasive Vascular Studies. *J Trauma* 30: 1059-1065, 1990.
24. Martin LC, McKinney MG, Sosa JL, et al. Management of Lower Extremity Arterial Trauma. *J Trauma* 37: 591-599, 1994.
25. Richardson JD, Vitale GC, Flint LM. Penetrating Arterial Trauma: Analysis of Missed Vascular Injuries. *Arch Surg* 122: 678-683, 1987.
26. Stain SC, Yellin AE, Weaver FA, et al. Selective Management of NonOcclusive Arterial Injuries. *Arch Surg* 124: 1136-1141, 1989.
27. Feliciano DV, Cruse PA, Burch JM, et al. Delayed Diagnosis of Arterial Injuries. *Am J Surg* 154: 579-584, 1987.
28. Frykberg ER, Crump JM, Vines FS, et al. A Reassessment of the Role of Arteriography in Penetrating Proximity Trauma: A Prospective Study. *J Trauma* 29: 1041-1052, 1989.
29. Rose SC and Moore EE. Angiography in patients with arterial trauma: correlation between

angiographic abnormalities, operative findings, and clinical outcome. *AJR Am J Roentgenol* 149:613-619, 1987.

30. Sirinek KR, Gaskill HV, Dittman WI, et al. Exclusion Angiography for Patients with Possible Vascular Injuries of the Extremities a Better Use for Trauma Center Resources. *Surgery* 94: 598-603, 1983.
31. Meissner M, Paun M, Johansen K. Duplex Scanning for Arterial Trauma. *Am J Surg* 161: 552-555, 1991.
32. Schwartz M, Weaver F, Yellin A, et al. The Utility of Color Flow Doppler Examination in Penetrating Extremity Arterial Trauma. *Am Surg* 59: 375-378, 1993.
33. Bergstein JM, Blair JF, Edwards J, et al. Pitfalls in the Use of Color- Flow Duplex Ultrasound for Screening of Suspected Arterial Injuries in Penetrated Extremities. *J Trauma* 33: 395-402, 1992.
34. Bynoe RP, Miles WS, Bell RM, et al. Noninvasive Diagnosis of Vascular Trauma by Duplex Ultrasonography. *J Vasc Surg* 14: 346- 352, 1991.
35. Menzoian JO, Doyle JE, LoGerfo FW, et al. Evaluation and Management of Vascular Injuries of the Extremities. *Arch Surg* 118: 93-95, 1983.
36. Gomez GA, Kreis DJ, Ratner L, et al. Suspected vascular trauma of the extremities: the role of arteriography in proximity injuries. *J Trauma* 26: 1005-1008, 1986.
37. Dennis JW, Veldenz HC, Menawat MD, et al. Validation of Nonoperative Management of Occult Vascular Injuries and Accuracy of Physical Examination Alone in Penetrating Proximity Trauma: Five to Ten Year Follow-up. *J Trauma* 43: 196, 1997.
38. Carillo EH, Spain DA, Wilson MA, et al. Alternatives in the Management of Penetrating Injuries to the Iliac vessels. *J Trauma* 43: 196, 1997.

First Author	Reference	Class	Findings
Feliciano DV, et al.	Five-year Experience with PTFE Grafts in Vascular wounds. J Trauma 25: 71-82, 1985	II	Prospective study. 206 pt(85% penetrating) all w/ resex/PTFE. 46% lower extremity. Completion arteriogram performed routinely in the LE=s. Fasciotomies performed on clinical criteria alone. 5% early occlusion due to technical error, delay in Tx, or low flow-1/2 successfully revised. Only exposed grafts became infected. Concluded PTFE an acceptable conduit unless no soft tissue coverage.
Frykberg ER, et al	The Natural History of Clinically Occult Arterial Injuries: A Prospective Evaluation. J Trauma 29: 577-583, 1989	II	20 arterial injuries managed nonoperatively (65% pen). 9 LE injuries. Proximity was the indication for a-gram. Intimal flap the most common finding(13),segmental narrowing in 6 cases, 1 pseudoaneurysm. Of those who had follow-up a-gram (15 lesions) 10 had resolution of the lesion, 3 showed improvement. The 4 who refused f/u angio remained asymptomatic. The false aneurysm of brachial a. required surgery due to enlargement-w/o morbidity.
Frykberg ER, et al	A Reassessment of the Role of Arteriography in Penetrating Proximity Trauma: A Prospective Study. J Trauma 29: 1041-1052, 1989	II	Pts w/o hard or soft signs of vascular inj. were a-gramed. 135 pts w/ 107 LE wounds. 27 abnormalities detected on a-gram. 11 were on noncritical vessels-all did well w/o surgery. 16 abnormalities in LE in major a.a. included 7 narrowing, 6 intimal flaps, 2 sm. pseudoaneurysms, 1 AVF. The AVF was repaired immediately. The other 15 were observed. 1 of these enlarged at 10 wks & even though the pt remained asymptomatic he underwent repair w/o morbidity. 3 pts refused f/u a-gram but remained clinically asymptomatic. 9 showed complete resolution, 2 showed improvement. Both pts that required surgery were from SGW. 50% of pts w/ soft signs had injury.
Bynoe RP, et al	Noninvasive Diagnosis of Vascular Trauma by Duplex Ultrasonography. J Vasc Surg 14: 346- 352, 1991	II	pts w/ proximity injuries were studied. After pts were studied further evaluation & TX depended on Trauma surgeon not protocol. 319 studies performed-23 had a.a. inj. dx=d by duplex-13 lacs, 4 intimal flaps,3 pseudoaneurysms 2 AVF, 1 shotgun inj. All confirmed either by a-gram or operation. 13 vasospasms & 6 ext. compression=s also identified giving 42 true positive studies. 13 operations based on Duplex alone. 6 venous injuries also identified. 2 FN duplex studies. 153 TN studies based on continued nl. Vasc. Exam. Only 20 of these had a-grams as well. 1 study called false pos.
Frykberg ER, et al	The Reliability of Physical	II	pts w/ proximity inj. were observed for 24 hrs. All SGW had a-grams performed.

	Examination in the Evaluation of Penetrating Extremity Trauma for Vascular Injury: Results at One Year. J Trauma 31: 502-511, 1991		260 wounds of the LE. 2 pts w/ missed inj. 1 SGW & 1 gsw. Both pt were operated on w/o morbidity. The rest of pt w/ vascular injury had hard signs. Therefore 92% of injuries that required surgery were detectable by physical exam.
Johansen K, et al	Non-invasive Vascular Tests Reliably Exclude Occult Arterial Trauma in Injured Extremities. J Trauma 31: 515-522, 1991	II	All pts w/ hard signs were explored. The rest underwent Doppler arterial pressure measurement. Pts w/ API < 0.9 underwent a-gram. 100 limbs studied(84 pen) - 17 w/ API < 0.9. 16 of these (94%) had pos. a-gram. 7 of these underwent surgery. Of the 79 limbs w/ API > 0.9 f/u duplex studies revealed 5 minor a.a. lesions- 1 required operation.
Trooskin SZ, et al	The Management of Vascular Injuries of the Extremity Associated with Civilian Firearms. Surg Gynecol & Obstet 176: 350-4, 1993	II	Prospective. 50 UE/LE pen (only GSW=s) A. inj. 42 LE injuries. 32 req=d repair. 22 w/ hard signs went to OR w/o a-gram. 19/41 a-grams on pts w/ soft signs were pos.- 2 intimal flaps(observed),3 nonessential a.a. embolized. Only 9/41 taken to OR. Of the repairs-62% vein graft, 22% PTFE, 12% ligation. No rec=s given on type of repair. 153 a-grams performed for proximity- 7 injured a.a. noted(3 intimal flaps (observed),1 AV fistula,1 thrombosis and 2 pseudoaneurysms)- 2 of these injuries required operation. Despite this authors still recommended a-gram for proximity.
Reichle FA, et al.	Diagnosis and Management of Penetrating Arterial and Venous Injuries in the Extremities. Am J Surg 140: 365-367, 1980	III	Descriptive review of 44 pts w/ penetrating injuries to UE/LE. 32 to LE. 21 SW, 18 gsw, 3 shotgun,2 blunt. Avg interval bet injury & repair- 2 hr 50min.Explored if had pulse deficit, active bleeding, expanding hematoma, shock, bruit, thrill, proximity, ischemic signs, nerve deficit. A-gram obtained for shotgun injuries felt to be helpful. Arteriorrhaphy in 24,end-to-end in 10, patch repair in 4, interposition v. graft in 6. Limb salvage of all penetrating injuries achieved. Tension free anastomosis felt to be important.Fasciotomy of ischemic legs recommended.
Menzoian JO, et al	Evaluation and Management of Vascular Injuries of the Extremities. Arch Surg 118: 93-95, 1983	III	records of 306 pts w/ 315 extremity injuries were reviewed. The majority of pts w/ hard signs who were explored had a.a. inj. repaired. 42 pts w/ a-grams performed for proximity -5 (12%) w/ pos. results.
Sirinek KR, et al	Exclusion Angiography for Patients with Possible Vascular Injuries of the Extremities a Better Use for	III	63/124 pts explored for proximity had neg. explorations. 9 of these pts developed complications. 1 arterial injury was missed @ exploration. 50/124 pts who had a-gram underwent surgery. This gp included 11 pseudoaneurysms, 7 AVF, 2

	Trauma Center Resources. Surgery 94: 598-603, 1983		intimal tears.. There were 2 false pos. a-grams, 1 false neg.
Shah DM, et al.	Polytetrafluoroethylene Grafts in the Rapid Reconstruction of Acute Contaminated Peripheral Vascular Injuries. Am J Surg 148: 229-233, 1984	III	Review of 20 patients tx w/ PTFE. Mostly blunt trauma. 20% penetrating. Arterial repair before skeletal. Acceptable choice in contaminated wounds where rapid repair is necessary.
Menzoian JO, et al	A Comprehensive Approach to Extremity Vascular Trauma. Arch Surg 120: 801-805, 1985	III	Rev. 368 pt w/ UE/LE A/V inj. (89% pen). 70 pts w/ LE injuries. Recommend : repair artery before bone. Simple repair when feasible over grafting. Completion arteriography recommended. PTFE only if no vein available.
Meyer JP, et al	Peripheral Vascular Trauma From Close Range Shotgun injuries. Arch Surg 120: 1126-1131, 1985	III	Review of 49 pt w/ UE/LE/neck injuries due to SGW. LE 56%. Assoc. injuries present > 80%. All stable pts had A-gram. Ortho fixation & fasciotomy performed before arterial repair. All fx=s of LE stabilized w/ ext. fixation. 88% resex/vein graft(16% extra-anat), 10% repair or patch, 2% PTFE(extra-anat.). Most had systemic heparin. Conclusion: If stable preop angio helpful, most require vein graft, soft tissue coverage is important
Gomez GA, et al	Suspected vascular trauma of the extremities: the role of arteriography in proximity injuries. J Trauma 26: 1005-1008, 1986	III	72 pts had a-gram for proximity. 55/72 (76%) were nl. 17 had angio abnormalities but exploration was not warranted. 1 pt was explored & found to have spasm of a. & repair not needed.
Feliciano DV, et al	Delayed Diagnosis of Arterial Injuries. Am J Surg 154: 579-584,1987	III	Pt w/ hard signs were explored. Pt w/ soft signs including diminished pulse or proximity inj. were a-gramed. All clinically detected inj. were repaired. Pts w/ delayed dx of a.a. injury(28) were studied. 27 from pen mech. Delay ranged from 12 hr. to 26 yr. 64% delayed dx involved LE- tibioperoneals being the most common. These injuries were either repaired or embolized. Perioperative morbidity was considered significant.
Richardson JD, et al	Penetrating Arterial Trauma: Analysis of Missed Vascular Injuries. Arch Surg 122: 678-683, 1987	III	137 a.a. identified on surgical exploration. Some of these pt were explored for proximity, for hard signs, some had a-grams before exploration. 65% of the explored LE had a.a. injuries. The majority of inj. Were repaired w/ interposition v. graft followed by primary repair. 8 grafts thrombosed. There were 17 initially unrecognized injuries found on f/u. 8 missed by a-gram, 6 by exploration, 3 by

Rose SC and Moore EE	Angiography in patients with arterial trauma: correlation between angiographic abnormalities, operative findings, and clinical outcome. AJR Am J Roentgenol 149:613-619, 1987	III	sm gp of pts who had proximity a-grams & nl vasc. Exams w/ angiographic abnormalities who were TX=d nonoperatively. Concluded that nonoperative Tx of these lesions can be successful as long as there is no clinical evidence of vascular insufficiency.	observation. No lives or limbs were lost as a result of missed injuries.
Whitman GR, et al	Traumatic Popliteal and Trifurcation Vascular Injuries: Determinants of Functional Limb Salvage. Am J Surg 154: 681-684, 1987	III	Review of 47 pts(38% pen) w/ pop/trif a. injury. The majority repaired w/ v. graft. All had assoc. injuries. 79% had fasciotomy. The greater the number of associated injuries the worse the outcome.	Review of 47 pts(38% pen) w/ pop/trif a. injury. The majority repaired w/ v. graft. All had assoc. injuries. 79% had fasciotomy. The greater the number of associated injuries the worse the outcome.
Armstrong K, et al	Popliteal Vascular Injuries and War: Are Beirut and New Orleans similar? J Trauma 28: 836-839, 1988	III	Review of 76 pt w/ popliteal a. injury. Vein graft had 36% amputation rate vs. 11% for repair & 8% for end-to-end anastomosis. Vein graft group had more assoc. injuries.	Review of 76 pt w/ popliteal a. injury. Vein graft had 36% amputation rate vs. 11% for repair & 8% for end-to-end anastomosis. Vein graft group had more assoc. injuries.
Ashworth EM, et al	Lower Extremity Vascular Trauma: A Comprehensive, Aggressive Approach. J Trauma 28: 329-336, 1988	III	Review 25 pt w/ LE A/V injuries(84% pen). Anast or repair in 88%, 12% ligated-all tibial vessels. 96% limb salvage & 88% patency. Rec: completion angio, arterial repair before ortho, liberal fasciotomy.	Review 25 pt w/ LE A/V injuries(84% pen). Anast or repair in 88%, 12% ligated-all tibial vessels. 96% limb salvage & 88% patency. Rec: completion angio, arterial repair before ortho, liberal fasciotomy.
Feliciano DV, et al	Management of Vascular Injuries in the Lower Extremities. J Trauma 28: 319-328, 1988	III	Review of 220 pt w/ LE A/V inj (82% pen). 39% resex/graft, 28% anast., 17% ligated, 7% repaired. PTFE had higher occlusion rates but was more commonly used. No amputations in the delayed Tx group. Rec. contralateral vein graft if graft required.	Review of 220 pt w/ LE A/V inj (82% pen). 39% resex/graft, 28% anast., 17% ligated, 7% repaired. PTFE had higher occlusion rates but was more commonly used. No amputations in the delayed Tx group. Rec. contralateral vein graft if graft required.
Feliciano DV, et al	Extraanatomic Bypass for Peripheral Arterial Injuries. Am J Surg 158: 506-9; 1989	III	Reviewed 12 pt w/ a and soft tissue injuries(67% pen). Extra-anat. RSV used. 92% w/ pulses at D/C. 1 pt w/ anastomotic blowout. Presented as another option for repair.	Reviewed 12 pt w/ a and soft tissue injuries(67% pen). Extra-anat. RSV used. 92% w/ pulses at D/C. 1 pt w/ anastomotic blowout. Presented as another option for repair.
Stain SC, et al	Selective Management of NonOcclusive Arterial Injuries. Arch Surg 124: 1136-1141, 1989	III	All pts a-gramed for proximity & even w/ hard signs. All nonocclusive a.a. injuries detected were Tx=d nonoperatively if they were not hemorrhaging or had evidence of distal ischemia. Repeat a-grams obtained 1-3 wks after inj. 61 nonocclusive a.a. inj. were managed in this fashion. 44 of these were of major	All pts a-gramed for proximity & even w/ hard signs. All nonocclusive a.a. injuries detected were Tx=d nonoperatively if they were not hemorrhaging or had evidence of distal ischemia. Repeat a-grams obtained 1-3 wks after inj. 61 nonocclusive a.a. inj. were managed in this fashion. 44 of these were of major

			<p>a.a.- 20 in the LE. 17 minor. 5 pseudoaneurysms & 5 AVF were embolized on f/u a-gram. 21 a.a. inj. were observed w/o f/u a-gram-all w/ nl vascular exams . 30 inj=d a.a had serial a-grams-all pt were clinically asymptomatic. Of the 6 minor a.a. inj. in this group 2 resolved,1 improved,1 stabilized, 2 progressed. 24 major a.a. were serially studied. 10 intimal defects-7 of which resolved or markedly improved on f/u study, 1 progressed but pt. Refused Tx., there were 4 intimal flaps-3 resolved,1 stabilized. 7 pseudoaneurysms-4 resolved,1 stabilized. Only one pt w/ major a. injury required operation.</p>
Anderson RJ, et al	<p>Reduced Dependency on Arteriography for Penetrating Extremity Trauma: Influence of Wound Location and Noninvasive Vascular Studies. J Trauma 30: 1059-1065, 1990</p>	III	<p>All pts w/ hard signs explored. Performed a-grams on 22 pts w/ SW for proximity all were neg. Performed a-gram on 412 gsw for proximity 368 (89.3%) were neg. Of the 44 pos. results 30 were explored. However of the surgical group there were 7 intimal flaps, 1 pseudo aneurysm & 4 thrombosed nonessential a.a. that could have potentially been Tx nonoperatively w/ observation and embolization.</p>
Peck JJ, et al	<p>Popliteal Vascular Trauma: A Community Experience. Arch Surg 125: 1339-1344, 1990</p>	III	<p>Reviewed 108 pt w/ pop a inj. 63% had end-to-end anast., 37% had vein graft/patch. 6% amputation rate(both SGW). All SW?GSW w/ good results. Recommend operative exploration w/ hard signs. Vascular repair before skeletal repair.</p>
Francis H, et al	<p>Vascular Proximity: Is it a Valid Indication for Arteriography in Asymptomatic Patients? J Trauma 31: 512-514, 1991</p>	III	<p>160 a-grams performed on 146 pts w/ proximity injury (98% pen). 89% true neg. a-grams. 10.6% (17 pts)suggestive of inj. 6 were found to be false pos. on exploration, 4 pts w/ pos. study were not operated on. Of the 7 true pos. 6 were intimal injuries. 3.8% a-gram complications (hematomas). SGW were more likely to have asymptomatic injuries.</p>
Meissner M, et al	<p>Duplex Scanning for Arterial Trauma. Am J Surg 161: 552-555, 1991</p>	III	<p>69 LE studied out of 93 total study group. 65% done for proximity. API also measured. Duplex studies done for a variety of reasons. There were 25 abnl duplex. In the proximity group 4/60 scans were abnl.- mostly tibial vessels. & a lg hematoma. Pts w/ signs of vascular injury 13/19 were pos.- 4 pseudoaneurysms, 4 occlusions, 1 laceration, 1 intimal flap, 1 AVF, 1 combined AVF/pseudoaneurysm. Some pts received post-op scans. 7/23 pts underwent surgery on basis of duplex alone. 4 pts had abnl a-gram & nl duplex.</p>
Bergstein JM, et al	<p>Pitfalls in the Use of Color- Flow</p>	III	<p>Pt w/ hard signs were explored & not included in study. Pts w/ soft signs or</p>

	Duplex Ultrasound for Screening of Suspected Arterial Injuries in Penetrated Extremities. J Trauma 33: 395-402, 1992		proximity were studied .CFD =s done first if not those performing/interpreting CFD were blinded to a-gram results. 72 neg. & 3 pos. CFD. A-gram revealed 4 pos. results. CFD 50% sensitivity, 99% specificity.
Cargile JS III, et al	Acute Trauma of the Femoral Artery and Vein. J Trauma 32: 364, 1992	III	Review 233 pt w/ femoral A/V inj (88% pen). 18% repair, 43% anast, 37% vein graft, 1% PTFE, 1% ligation. Rec: simple repairs, vein graft when graft necessary.
Padberg FT, et al	Infrapopliteal arterial injury: Prompt revascularization affords optimal limb salvage. J Vasc Surg 16: 877-885, 1992	III	Review 68 pt w/ infrapop a. inj. 50% pen. 21% of single a. injuries were ischemic & required repair. Others treated w/ ligation or observation. Rec: preop angio, most single vessel inj do not req. repair.
Fry WR, et al	The Success of Duplex Ultrasonographic Scanning in Diagnosis of Extremity Vascular Proximity Trauma. Arch Surg 128: 1368-1372, 1993	II	175 extremities were evaluated for proximity. Duplex detected 18 injuries, 17 confirmed by a-gram & 1 by surgical exploration. 1 false positive-a CFA spasm seen on a-gram. 7 unsuspected venous injuries detected. ABI only demonstrated 4 injuries.
Knudson MM, et al	The Role of Duplex Ultrasound Arterial Imaging in Patients with Penetrating Extremity Trauma. Arch Surg 128: 1033-1038, 1993	II	77 patients w/ proximity injury were studied. All pts had nl vascular exams including ABI. 4 pts w/ abnl color imaging underwent a-gram which confirmed injury. 3 of these patients did not require surgery. The remaining 73 pts w/ nl studies none developed signs or sx of vascular injury on f/u exams.
Schwartz M, et al	The Utility of Color Flow Doppler Examination in Penetrating Extremity Arterial Trauma. Am Surg 59: 375-378, 1993	III	12 pts w/ angiographically documented nonocclusive a.a. inj. from penetrating trauma that were managed nonoperatively had color flow Doppler exams to see if the injuries could be detected. 7/12 injuries detected.
Martin LC, et al	Management of Lower Extremity Arterial Trauma. J Trauma 37: 591-599, 1994	III	Pts w/ hard signs were explored w/o a-gram. Pts. W/ soft signs had a-gram. Pts w/ proximity injuries were observed. Arterial flow for the most part was restored prior to skeletal repair. Local heparin infusion was used. Systemic heparinization was used sparsely. Simple repairs (lateral or end-to-end) were attempted as much as possible. PTFE or vein interposition grafts were used when necessary depending on the location, size of injured vessel and hemodynamic status of pt.

			<p>PTFE was used more than vein. No sig. Diff. in patency bet vein & PTFE grafts. Vein grafts were used more frequently for popliteal repairs. None of the primary repairs of popliteal a. failed but 6/24 pts w/ interposition grafts failed at this site (2 vein & 4 PTFE). All of these were from blunt trauma. 31/45 tibial a. injuries were not repaired. Int iliac, profunda, and single tibial a.a. injuries were uniformly ligated. Completion a-gram performed for popliteal & distal a.a. but not for a.a. proximal to popliteal. Fasciotomy performed if clinically indicated, for prolonged ischemia time & for combined A/V injuries.</p>
<p>DeGiannis E, et al</p>	<p>Arterial Gunshot Injuries of the Extremities: A South African Experience. J Trauma 39: 570-575, 1995</p>	<p>III</p>	<p>Reviewed 173 pt w/ UE/LE pen a. inj. 76% req=d graft (vein>PTFE). PTFE used when vein not available, vein diameter < 6 mm, or when speed was of essence. Pt w/ hard signs taken to OR w/o angio, all w/ pos. exploration. 13 pt w/ soft signs had angio- 9 were pos. Completion angio only performed when distal pulse nonpalpable. Early revascularization is important. W/ femoral a. no difference in patency rates vs. PTFE</p>
<p>Melton SM, et al</p>	<p>Popliteal Artery Trauma: Systemic Anticoagulation and Intraoperative Thrombolysis Improves Limb Salvage. Ann Surg 225: 518-527, 1997</p>	<p>III</p>	<p>Reviewed 102 pt (61% pen) w/ pop a. inj. 56% primarily repaired. 2 pt w/ PTFE failed & req=d amputation. 52% had systemic heparin. Recommend use of heparin and simple repairs when possible</p>

PRACTICE PARAMETER FOR EVALUATION AND MANAGEMENT OF COMBINED ARTERIAL AND SKELETAL EXTREMITY INJURY FROM PENETRATING TRAUMA

I. Statement of the Problem

Combined arterial and skeletal extremity injury remains a difficult management problem even for the most experienced trauma surgeons. While over 95% of extremities are now successfully salvaged following uncomplicated penetrating arterial injury, an associated skeletal injury may still result in amputation rates as high as 70% in major trauma centers. These results are most pronounced in the lower extremity, which has more tenuous vascular collaterals and more adverse consequences from nerve injury than the upper extremity.

In the past, virtually all of the combined extremity injuries have been due to blunt trauma in the civilian sector and high velocity missile trauma in the military sector. Over the last two decades there has been an increase of these injuries from a penetrating mechanism. Improved limb salvage rates have been reported recently in these difficult injuries as those factors most closely correlating with limb loss have been identified and addressed. However individual trauma centers and trauma surgeons see relatively few of these injuries, and there are virtually no scientifically sound studies of the proper approach to their management. Several issues remain unclear relating to the appropriate diagnosis, prioritization and treatment of combined arterial and skeletal injuries from penetrating trauma.

II. Process

A Medline computer search was conducted on all articles in the English Literature during the years 1980-1997 pertaining to arterial injuries of the lower extremity in combination with skeletal injuries. The subject words used included Avascular injury@, Artery injury@, Aextremity trauma@, Apenetrating trauma@, Avascular trauma@, Aextremity fracture@, Aextremity dislocation@ and Artery trauma@, . The references of these articles were also used to locate articles not found in the Medline search. Personal files were also used. All letters to the editor, case reports, book chapters, review articles, series involving less than 20 cases, series involving predominantly blunt trauma, and series in which the percentage and outcome of the penetrating injuries were not clearly specified were excluded. This left 25 articles of relevance to this practice parameter.

III. Recommendations

A. Level 1

There is no class I evidence to support a standard of care for this parameter.

B. Level 2

The interval between injury and reperfusion should be minimized to less than six hours in order to maximize limb salvage. Restoration of blood flow should always take priority over skeletal injury management, either by temporary shunting to allow

stabilization of unstable fractures and/or dislocations prior to definitive arterial repair, or by immediate definitive arterial repair when the skeletal injury is stable and not significantly displaced.

C. Level 3

Orthopedic surgeons should be involved immediately in assessment and management decisions.

1. Arteriography should be done promptly when hard signs of vascular injury are manifest.
2. There is no defined role for the use of noninvasive Doppler pressure monitoring or duplex ultrasonography to confirm or exclude arterial injury in this setting.
3. Evidence suggests that an absence of hard signs of vascular injury in this setting reliably excludes surgically significant arterial injury, and does not require arteriography.
4. Nonoperative observation of asymptomatic nonocclusive arterial injuries may be considered.
5. Four-compartment fasciotomy should be liberally applied at the time of arterial and skeletal repair. If not done compartment pressures should be monitored closely.
6. Completion arteriography should be performed.
7. External fixation is preferable for the immediate management of unstable, displaced, comminuted and open fractures or dislocations. This is especially important in those with severe contamination, extensive soft tissue injury, or in an unstable patient.
8. Primary amputation should be considered in those with tibial or sciatic nerve transection, prolonged ischemia, massive soft tissue injury, severe contamination, open comminuted tib-fib fractures (Gustilo-III), or life-threatening associated injuries.
9. Mangled extremity scoring systems are not sufficiently reliable to serve as the sole determinant of extremity amputation.

IV. Scientific Foundation

All available studies of the epidemiology, diagnosis and management of combined penetrating arterial and skeletal extremity injuries are retrospective. Most civilian series report both blunt and penetrating etiologies, and in some the outcome cannot be related to the mechanism. These considerations prevent firm practice standards from being derived. Nonetheless, these studies provide enough evidence to support a number of recommended management options, as well as directions for future investigation.

Combined extremity injuries are relatively uncommon, making up only 0.2% of all civilian trauma (1). Only 1.5% to 6.5% of all extremity skeletal injuries are associated with an arterial injury (2-5), while 20% to 73% of all extremity arterial injuries may be associated with skeletal fractures or dislocations (2,6-8). Blunt trauma is the predominant mechanism for these injuries in most civilian series. However, over the last decade penetrating trauma has increased in its incidence in this setting, causing from 24% to 71% of cases (1,6-8,9,10). One recent series reported 30 combined injuries from gunshots only (11).

It is clear that combined extremity injuries pose a substantially increased risk of limb loss and limb morbidity than do isolated or skeletal extremity injuries (1,3,4,8,9,10). This is most likely due to greater disruption of collaterals, soft tissues and nerves. Combined injuries from penetrating trauma have a substantially lower amputation rate than those from blunt trauma in the civilian sector. Five civilian series over the past decade have reported the highest proportions of penetrating trauma as a cause of these complex injuries in the literature, being 50% (8), 57% (2), 67% (9), 71% (5), and 100% (11). Their combined results show a total of 39 amputations among 228 patients (17%), but only 9 amputations among the 147 patients (6%) with penetrating trauma. In three of these series reporting 88 patients with penetrating combined injuries there were remarkably no amputations (2,5,11). The apparent increasing trend in penetration as the etiology of these injuries in recent years may have made in of itself a substantial contribution to reducing limb loss. It should be noted that three recent series of combined extremity trauma showed either no difference in amputations between blunt and penetrating trauma or a higher amputation rate among the penetrating injuries (1,4,10). However, these series involved small numbers (40 total) of especially severe injuries. Nonetheless, they demonstrate that there are still other variables which affect outcome besides mechanism.

Prompt diagnosis of vascular injury in any injured extremity is essential because of the well established direct relationship between the time interval from injury to treatment and the chance of limb loss. This principle is confirmed by several series which cite prolonged ischemia, delay in restoration of blood flow, or failure of vascular repair as the most common reasons for limb loss in combined arterial and skeletal extremity injuries (3,4,6-8,10). Arteriography is the modality of choice to confirm or exclude arterial injury, although the indications for its use are debated. Unlike isolated arterial injuries, an associated skeletal injury significantly decreases the predictive value of physical exam findings, since hard signs of vascular injury may be due solely to the bone injury or associated soft tissue injury, without any damage to major vessels, in as many as 60% to 70% of cases (2,3,17). Therefore, immediate arteriography is warranted in combined extremity trauma manifesting hard signs, in order to avoid up to a 70% rate of unnecessary limb exploration (10).

Several recent series suggest that a negative physical examination following combined injury (i.e. no hard signs present) reliably excludes vascular injury which requires repair. Nonocclusive

vascular injuries with benign natural history, however, may occur. Three series report a total of 98 asymptomatic combined extremity injuries from both blunt and penetrating trauma, of which only one underwent surgical repair: an intimal flap of a distal radial artery which may have not required surgery (5,11,17). One series followed 15 asymptomatic nonocclusive arterial injuries from combined extremity trauma for a mean of 6.5 months, none requiring intervention (5). Authors now recommend that arteriography is not necessary for combined extremity trauma with no hard signs of vascular injury.

Although noninvasive vascular studies, Doppler pressure measurements and duplex ultrasonography, have been used in this setting, there is no evidence of any benefit or role for these studies in this setting (2,17,18). In fact, the significant swelling, soft tissue and bone disruption, bulky splints and dressings that characterize these injuries cast doubt on the utility and validity of these tests. Arteriography is clearly the modality of choice for evaluation of high risk extremity skeletal trauma for vascular injury.

Studies have shown that restoration of blood flow within six hours, both with and without skeletal injury significantly improves limb salvage (3,10). There are studies which fail to show a clear correlation between time delay and outcome and some with average treatment delays in excess of eight hours which report amputation rates equivalent to those with prompt treatment within six hours (1,2,4,5,8,9,10). This again stresses that multiple variables affect outcome, and they cannot be controlled in retrospective reports. However, the weight of evidence indicates that rapid diagnosis must be followed as expeditiously as possible by restoration of blood flow.

Studies in the past have recommended that skeletal repair should be done routinely prior to vascular repair (19). More recent studies have advocated selective initial vascular repair only when limb ischemia is clinically evident (1,2,4,7). The rationale for orthopedic priority was the potential disruption of a fresh vascular anastomosis by subsequent manipulation of bone fragments, or length discrepancies in the vascular repair caused by subsequent stabilization of comminuted, unstable skeletal injuries. However, evidence has refuted these conjectures. Snyder et al, noted vascular repair disruption in only 2/29 (7%) cases, neither of which affected outcome as they were repaired immediately (6). Howe et al, found no cases of vascular disruption in 21 combined injuries with subsequent orthopedic repair (3). This data is further supported by studies showing significantly lower amputation rates in those undergoing restoration of blood flow prior to skeletal repair than in those undergoing skeletal repair first (19,22). Although some studies showed either a higher amputation rate, or no difference in amputations, when revascularization was done first, their validity is suspect because vascular priority was only applied to the most ischemic limbs (1,4,8). Howe et al, emphasize that the known importance of a short time interval to revascularization, as discussed above, as well as the absence of any demonstrable disadvantage, should be enough justification to always revascularize first, which is the current consensus (3,5,6,9,14,23).

Restoration of blood flow does not have to be through immediate definitive vascular repair. Temporary vascular shunts effectively solve the dilemma of severely comminuted and unstable fractures/dislocations, in which setting definitive vascular repair cannot be accomplished until the skeleton is stabilized. Shunting still allows immediate restoration of blood flow, without worry of anastomotic disruption. It should also be considered in unstable patients who will not tolerate

further surgery. The definitive vascular and skeletal repair may then follow whenever appropriate (3,6,7,18,23).

It is reasonable to recommend that orthopedic surgeons be consulted and actively participate in the management decisions immediately after combined extremity injury is diagnosed, although there is no firm evidence to prove benefit. Smooth interdisciplinary teamwork is essential to achieving the primary goal of rapid diagnosis and treatment.

In order to document anastomotic patency and distal flow, performance of intra-operative completion arteriography is considered critical following arterial repair in combined extremity trauma (6,23). This is especially important when palpable pulses and signs of distal perfusion are uncertain. Bishara et al, reported that routine completion arteriograms led to detection of unsuspected problems which required revision of repairs in 16% of cases (2). Certainly any loss of pulses postoperatively mandates immediate investigation by either arteriography or surgery, as further ischemia will threaten limb salvage.

The proper method of fracture management has been debated, although it is probably not affected by the concomitant arterial injury to any great extent. Military series have demonstrated a clear advantage of external fixation over internal fixation in the immediate management of these complex, open and highly contaminated combat fractures. Civilian series, which involve lower risk and less complex wounds, have shown good results with internal fixation, although some exclusively applied external fixation (2,9,10). This evidence suggests that combined injuries with a substantial risk of infection (i.e. open, comminuted, severe soft tissue damage), with very comminuted or unstable skeletal injuries, or those in unstable patients who require rapid treatment, are best managed with external fixation, either as a definitive or temporizing measure.

Combined arterial and skeletal trauma poses a high risk for compartment syndrome. Its presence must be considered in every case. Several series of lower extremity vascular trauma have partially attributed excellent limb salvage rates to aggressive use of early fasciotomy (14,19).

In combined injuries, fasciotomy has been applied in 30% to 71% of combined cases (2,5,9,10). In virtually all reported cases its application has been recommended either at the time of, or before, the vascular repair is undertaken (2,5,6,8,9,23). It is widely agreed that prophylactic rather than therapeutic fasciotomy, offers the best opportunity for limb salvage and limb function. The nonspecific clinical manifestations of compartment syndrome are late manifestations which are not reliable in helping to avoid limb morbidity (18). When fasciotomy is not performed, compartment pressures should be closely monitored.

Current evidence suggests that nonoperative observation of asymptomatic nonocclusive extremity arterial injuries found on arteriography is safe (21). This appears true in the specific setting of combined arterial and skeletal trauma, where some arterial injuries have been observed (2,5,10,11). In two studies, only one of 45 nonocclusive arterial injuries in this setting underwent surgery, without a single amputation or complication related to arterial injury. Fifteen

of these occult vascular injuries were followed for an average of 6.5 months, and the avoidance of vascular exploration in these severely injured limbs was felt to contribute to the low (7.3%) overall amputation rate (5).

Early amputation may sometimes provide better long term outcome, in terms of cost and function, than overly extensive attempts at limb salvage (1). Gustilo III-C injuries (open comminuted tib-fib fractures with arterial injury), sciatic or tibial nerve transection, severe prolonged ischemia, older age with comorbidity, multiple long bone fractures, crush or extensive soft tissue trauma and severe contamination are factors predicting a high rate of amputation (3,8,24). Although several scoring systems for predicting the need for early amputation have been proposed, none have yet shown sufficient prospective reliability to permit a firm decision for amputation (3,4,25). Initial revascularization and skeletal stabilization should be done in most cases before a decision is made.

V. Summary

There is an increased risk of limb loss with combined skeletal/arterial extremity injuries. The associated skeletal injury will significantly decrease the value of physical examination, thus warranting immediate angiography in patients with hard signs of vascular injury. Patients with a negative physical examination or soft signs of arterial injury do not need angiography.

It is extremely important that blood flow to the distal extremity be restored within six hours. This may be accomplished through use of a temporary vascular shunt while the orthopedic stabilization is accomplished, followed by definitive vascular repair.

Combined injuries are at a high risk for compartment syndrome. Prophylactic fasciotomies should be performed early to reduce the incidence of limb loss.

VI. Future Investigation

Several issues in diagnosis and management of combined arterial and skeletal extremity injuries remain unresolved. Future studies should focus on prospective evaluation of the following:

1. Proper sequence of vascular and skeletal repair in stable, nonischemic extremities
2. Indications for internal fixation of extremity skeletal trauma in this setting
3. Prophylactic vs. Therapeutic fasciotomy
4. Role of arteriography in extremity skeletal trauma with no signs of vascular injury
5. Nonoperative observation of asymptomatic nonocclusive arterial injuries
6. Role of noninvasive tests to evaluate extremities with skeletal injuries for vascular trauma
7. Prognosis and implications of penetrating vs. Blunt mechanisms
8. Indications for immediate or early amputation

9. Role of intraoperative arteriography

VII. References

1. Drost TF, Rosemurgy AS, Proctor D, et al. Outcome of Treatment of Combined Orthopedic and Arterial Trauma to the Lower Extremity. *J Trauma* 29: 1331-1334, 1989.
2. Bishara RA, Paasch AR, Lim LT, et al. Improved Results in the Treatment of Civilian Vascular Injuries Associated with Fractures and Dislocations. *J Vasc Surg* 3: 707-711, 1986.
3. Howe HR, Poole GV, Hansen KJ, et al. Salvage of Lower Extremities Following Combined Orthopedic and Vascular Trauma: A Predictive Salvage Index. *Am Surg* 53: 205-208, 1987.
4. Poole GV, Agnew SG, Griswold JA, et al. The Mangled Lower Extremity: Can Salvage be Predicted? *Am Surg* 60: 50-55, 1994.
5. Attebery LR, Dennis JM, Russo-Alesi F, et al. Changing Patterns of Arterial Injuries Associated with Fractures and Dislocations. *J Am Coll Surg* 183: 377-383, 1996.
6. Snyder WH. Vascular Injuries Near the Knee: An Updated Series and Overview of the Problem. *Surgery* 91: 502-506, 1982.
7. Keeley SB, Snyder WH, Weigelt JA. Arterial Injuries Below the Knee: Fifty-one Patients with 82 Injuries. *J Trauma* 23: 285-292, 1983.
8. Russell WL, Sailors DM, Whittle TB, et al. Limb Salvage Versus Traumatic Amputation: A Decision Based on a Seven-Part Predictive Index. *Ann Surg* 213: 473-481, 1991.
9. Swetnam JA, Hardin WD, Kerstein MD. Successful Management of Trifurcation Injuries. *Am Surg* 52: 585-587, 1986.
10. Bongard FS, White GH, Klein SR. Management Strategy of Complex Extremity Injuries. *Am J Surg* 158: 151-155, 1989.
11. Norman J, Gahtan V, Franz M, et al. Occult Vascular Injuries Following Gunshot Wounds Resulting in Long Bone Fractures of the Extremities. *Am Surg* 61: 146-150, 1995.
12. Graham JM, Mattox KL, Feliciano DV, et al. Vascular Injuries of the Axilla. *Ann Surg* 195: 232-238, 1982.
13. Borman KR, Snyder WH, Weigelt JA. Civilian Arterial Trauma of the Upper Extremity: An 11 Year Experience in 267 Patients. *Am J Surg* 148: 796-799, 1984.
14. Ashworth EM, Dalsing MC, Glover JL, et al. Lower Extremity Vascular Trauma: A Comprehensive Aggressive Approach. *J Trauma* 28: 329- 336, 1988.
15. McCroskey BL, Moore EE, Pearce WH, et al. Traumatic Injuries of the Brachial Artery. *Am J Surg* 156: 553-555, 1988.

16. Frykberg ER, Dennis JW, Bishop K, et al. The Reliability of Physical Examination in the Evaluation of Penetrating Extremity Trauma for Vascular Injury: Results at One Year. *J Trauma* 31: 502-522, 1991.
17. Applebaum R, Yellin AE, Weaver FA, et al. Role of Routine Arteriography in Blunt Lower Extremity Trauma. *Am J Surg* 160: 221-225, 1990.
18. Gates JD. The Management of combined Skeletal and Arterial Injuries of the Lower Extremity. *Am J Orthoped* 24: 674-680, 1995.
19. Lim LT, Michuda MS, Flanigan DP, et al. Popliteal Artery Trauma. *Arch Surg* 115: 1307-1313, 1980.
20. Itani KMF, Burch JM, Spjut-Patrinely V, et al. Emergency Center Arteriography. *J Trauma* 32: 302-307, 1992.
21. Frykberg ER, Crump JM, Dennis JW, et al. Nonoperative Observation of Clinically Occult Arterial Injuries: A Prospective Evaluation. *Surgery* 109: 85-96, 1991.
22. McCabe CJ, Ferguson CM, Ottinger LW. Improved Limb Salvage in Popliteal Artery Injuries. *J Trauma* 23: 982-985, 1983.
23. Allen MJ, Nash JR, Ioannidies TT, et al. Major Vascular Injuries Associated with Orthopedic Injuries to the Lower Limb. *Ann Royal Coll Surg* 66: 101-104, 1984.
24. Moniz MP, Ombrellaro MP, Stevens SL, et al. Concomitant Orthopedic and Vascular Injuries as predictors for Limb Loss in Blunt Lower Extremity Trauma. *Am Surg* 63: 24-28, 1997.
25. Bonanni F, Rhodes M, Lucke JF. The Futility of Predictive Scoring of Mangled Lower Extremities. *J Trauma* 34: 99-104, 1993.

First Author	Reference	Class	Findings
Snyder WH	Vascular Injuries Near the Knee: An Updated Series and Overview of the Problem. Surgery 91: 502-506, 1982	III	Review of 110 popliteal artery injuries over 14 yr., 75% from penetrating trauma, 57 (52%) w/ combined injuries though not clear how many combined injuries were from pen. Mech. Revascularization was always done first -only 2/29 (7%) were disrupted during subsequent skeletal repair, but rapidly corrected w/o morbidity. Use shunt first for unstable fx=s, then ex-fix, then definitive vascular repair. Only two amputations (9%) in pen gp. Fasciotomy should be done liberally before vascular repair. All amputations were in limbs presenting w/ severe ischemia, delayed dx & Tx. Completion angio essential.
Keeley SB, et al	Arterial Injuries Below the Knee: Fifty-one Patients with 82 Injuries. J Trauma 23: 285-292, 1983	III	Review of 82 tibial & peroneal a.a. injuries in 51 pts, 67% from penetrating trauma over 13 yrs. 30 (60%) assoc. w/ skeletal injuries, though not clear how many of combined injuries were from penetrating mech. Late dx and blunt mechanism were greatest contributors to 16% amputation rate. Vascular repair first is most important in ischemic limb.
Bishara RA, et al	Improved Results in the Treatment of Civilian Vascular Injuries Associated with Fractures and Dislocations. J Vasc Surg 3: 707-711, 1986	III	Review of 51 combined skeletal and vascular extremity injuries over six years, 57% from penetrating trauma. Combined injuries occurred in 29% of all extremity vascular injuries and 6.5% of all skeletal trauma. Fasciotomy only performed in 19% of isolated vascular injuries. Overall 2.6% amputation rate, none in pen. Gp. Skeletal repair done first in 79%, by ex-fix in 12/23 cases, 11 by int. fixation. Completion angio. Essential-in 16% led to revision of repair. Vascular repair first only w/ ischemia. No difference in outcome related to ex-fix or int. fixation. Early recognition and Tx essential.
Swetnam JA, et al	Successful Management of Trifurcation Injuries. Am Surg 52: 585-587, 1986	III	Review of 36 combined skeletal and popliteal vascular injuries over 15 yrs., w/ 16 amputations (44%). 24 (67%) were penetrating, in whom only 8 (33%) underwent amputation. Primary immediate amputation was done in 8 (only 2 w/ penetrating injury), and fasciotomy in 20 of the remaining 28 (71%) undergoing revascularization. Prompt arterial repair & early fasciotomy emphasized. All orthopedic repairs used ex-fix. Avg. 95 mins. From injury to OR.

<p>Howe HR, et al</p>	<p>Salvage of Lower Extremities Following Combined Orthopedic and Vascular Trauma: A Predictive Salvage Index. Am Surg 53: 205-208, 1987</p>	<p>III</p>	<p>Review of 21 combined skeletal and vascular extremity trauma over six years, making up to 2.2% of all extremity skeletal injuries, resulting in amputation in 9 (43%). Penetrating trauma in 5 (24%), in which gp three had amputations (60%). All had vascular repair first, w/ no subsequent disruptions from skeletal repair. Scoring system derived showed 78% sensitivity and 100% specificity for predicting the need for primary amputation. Uses shunt to revascularize unstable fractures. Interval to revascularization over 6 hours has significantly greater chance of poor outcome, thus vascular repair should always come first.</p>
<p>Bongard FS, et al</p>	<p>Management Strategy of Complex Extremity Injuries. Am J Surg 158: 151-155, 1989</p>	<p>III</p>	<p>Review of 37 combined skeletal/vascular extremity injuries over 6 yrs., 11 (30%) penetrating. 32/37 had vascular repair done prior to skeletal fixation, and 11/37 had prophylactic fasciotomy. No early amputations, 5/31 late amputations (16%), 2 (40%) amps in penetrating injuries, 6 lost to f/u, no deaths. Emphasized importance of early recognition & Tx of a.a. inj, aggressive fasciotomy. Avg. 2.9 hr interval injury to presentation. A-gram only necessary in bone fx when clinical signs of a.a. inj. present.</p>
<p>Drost TF, et al</p>	<p>Outcome of Treatment of Combined Orthopedic and Arterial Trauma to the Lower Extremity. J Trauma 29: 1331-1334, 1989</p>	<p>III</p>	<p>Review of 22 pts w/ combined LE skeletal/vascular injuries over 6 yrs. Out of total 10,000 total trauma pts (0.2%). 8 (36%) were from penetrating trauma. Avg. ischemic time 9.6 hr. , 15 had revascularization before ortho repair (4 shunts, 11 definitive repairs) due to concerns of prolonged ischemia. 8 amputations, 4 in pts w/ penetrating trauma, and 6/8 (75%0 were in those revascularized first. Thus ortho first 2/9 (22%) amputation, revascularization first 6/13 (46%) amputations the latter having significant ischemia. Sequence of repair, type of reconstruction and ischemic interval had no impact on outcome, though location of inj. did- popliteal injuries had the best salvage rate, though high incidence of subsequent permanent disability. Those w/ amputation all w/o problems. Concludes liberal use of amputation may better serve this population- more cost effective and better quality of life.</p>

<p>Poole GV, et al</p>	<p>The Mangled Lower Extremity: Can Salvage be Predicted? Am Surg 60: 50-55, 1994</p>	<p>III</p>	<p>Review of 48 mangled lower extremities w/ combined arterial/skeletal injuries, 21 (43.7%) penetrating making up only 1.5% of all LE fractures, w/ overall 50% amputation rate (8 primary). Amputation rate did not differ between blunt or penetrating mechanism, age, shock, level of inj., or ischemic time. Vascular-ortho repair sequence had twice the amputation rate as the converse (52% vs. 26%) although not statistically significant. Vascular went first in the most ischemic cases. Failure of arterial repair was leading cause of limb loss. Scoring systems do not correlate close enough w/ risk of amputation to be used solely in decision for primary amputation-degree of bone, vascular, nerve, and soft tissue injury determines salvage.</p>
<p>Norman J, et al</p>	<p>Occult Vascular Injuries Following Gunshot Wounds Resulting in Long Bone Fractures of the Extremities. Am Surg 61: 146-150, 1995</p>	<p>III</p>	<p>Review of 75 extremity fx=s from gsw over a 6 yr pd among 331 gsw=s in proximity to major limb a.a. (23%), to examine the incidence of occult vascular injury. 41% had abnormal a-grams. 14 pts (19%) had absent or decreased pulses, w/ 13 993% abnl agram. 17/61 pts w/ nl vasc exam had abnl agram (28%). 83% of agram abnormalities were minor and never underwent surgery. Only 1 major abnormality had surgery (1.6% of asymptomatic limbs). No limb loss or morbidity in any of the observed occult injuries over mean f/u of 5.4 months. Physical exam is accurate in confirming and excluding those vascular injuries requiring surgery even in presence of bone fx.</p>
<p>Russell WL, et al</p>	<p>Limb Salvage Versus Traumatic Amputation: A Decision Based on a Seven-Part Predictive Index. Ann Surg 213: 473-481, 1991 Am Surg 61: 146-150, 1995</p>	<p>III</p>	<p>Review of 70 LE a.a. injuries, 50% (35) from penetrating trauma 51 of which had concomitant bone injuries (73% over 5 years. There were 19 (27%) amputations, all among those w/ bone injuries (37%). Only 1 amputation was in the gp w/ pen trauma (3%). Of 22 Gustillo III-C injuries, 13 (59%) required amputation. Avg. injury-Tx interval was 4.6 hrs. Combined vascular/skeletal repair in 29 limbs, 23 w/ revascularization first (4 amps-17%), 6 w/ ortho repair first (17%). A limb salvage index accurately predicted amputation. Index > 6, Gustillo III-C injuries, tibial or sciatic nerve transection should mandate amputation. 22 fasciotomies. Early dx essential to limb salvage.</p>
<p>Attebery LR, et al</p>	<p>Changing Patterns of Arterial Injuries Associated with Fractures and Dislocations. J Am Coll Surg 183: 377-383, 1996</p>	<p>III</p>	<p>Review of 41 combined skeletal/vascular injuries out of 1091 pts over 4.5 yrs w/ skeletal extremity trauma (3.8%). 29 (71%) were due to penetrating trauma. Mean interval from injury to vascular repair was 1.1 hrs. Three amputations (7.3%) all among blunt injuries. 15/41 (37%) had occult nonocclusive vascular injuries, which were nonoperatively followed for mean of 6.5 months w/o complications. New trend toward predominance of penetrating trauma and non-op management of occult injuries may account for low amputation rate. Physical exam can reliably exclude surgically significant vascular injury.</p>