Practice Management Guidelines for
Penetrating Trauma to the Lower Extremity

The EAST Practice Management Guidelines Work Group:

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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


29. Rose SC and Moore EE. Angiography in patients with arterial trauma: correlation between


<table>
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<tr>
<th>First Author</th>
<th>Reference</th>
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<th>Findings</th>
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<tbody>
<tr>
<td>Feliciano DV, et al</td>
<td>Five-year Experience with PTFE Grafts in Vascular wounds. J Trauma 25: 71-82, 1985</td>
<td>II</td>
<td>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.</td>
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<tr>
<td>Frykberg ER, et al</td>
<td>The Natural History of Clinically Occult Arterial Injuries: A Prospective Evaluation. J Trauma 29: 577-583, 1989</td>
<td>II</td>
<td>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.</td>
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<tr>
<td>Frykberg ER, et al</td>
<td>A Reassessment of the Role of Arteriography in Penetrating Proximity Trauma: A Prospective Study. J Trauma 29: 1041-1052, 1989</td>
<td>II</td>
<td>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 &amp; 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.</td>
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<tr>
<td>Bynoe RP, et al</td>
<td>Noninvasive Diagnosis of Vascular Trauma by Duplex Ultrasonography. J Vasc Surg 14: 346- 352, 1991</td>
<td>II</td>
<td>pts w/proximity injuries were studied. After pts were studied further evaluation &amp; 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 &amp; 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.</td>
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<tr>
<td>Frykberg ER, et al</td>
<td>The Reliability of Physical</td>
<td>II</td>
<td>pts w/proximity inj. were observed for 24 hrs. All SGW had a-grams performed.</td>
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<td>Study</td>
<td>Title</td>
<td>Study Design</td>
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<td>Johansen K, et al.</td>
<td>Non-invasive Vascular Tests Reliably Exclude Occult Arterial Trauma in Injured Extremities.</td>
<td>II</td>
<td>All pts w/ hard signs were explored. The rest underwent Doppler arterial pressure measurement. Pts w/ API &lt; 0.9 underwent a-gram. 100 limbs studied (84 pen) - 17 w/ API &lt; 0.9. 16 of these (94%) had pos. a-gram. 7 of these underwent surgery. Of the 79 limbs w/ API &gt; 0.9 f/u duplex studies revealed 5 minor a.a. lesions - 1 required operation.</td>
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<td>Trooskin SZ, et al.</td>
<td>The Management of Vascular Injuries of the Extremity Associated with Civilian Firearms.</td>
<td>II</td>
<td>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.</td>
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<tr>
<td>Reichle FA, et al.</td>
<td>Diagnosis and Management of Penetrating Arterial and Venous Injuries in the Extremities.</td>
<td>III</td>
<td>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 &amp; 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.</td>
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<td>Menzoian JO, et al.</td>
<td>Evaluation and Management of Vascular Injuries of the Extremities.</td>
<td>III</td>
<td>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.</td>
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<td>Sirinek KR, et al.</td>
<td>Exclusion Angiography for Patients with Possible Vascular Injuries of the Extremities a Better Use for</td>
<td>III</td>
<td>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</td>
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- intimal tears. There were 2 false pos. a-grams, 1 false neg.
- 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.
- 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.
- 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.
- 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.
- 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.
- 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
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<tr>
<td>Rose SC and Moore EE</td>
<td>Angiography in patients with arterial trauma: correlation between angiographic abnormalities, operative findings, and clinical outcome.</td>
<td>AJR Am J Roentgenol 149:613-619, 1987</td>
<td>III</td>
<td>sm gp of pts who had proximity a-grams &amp; 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.</td>
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<td>Stain SC, et al</td>
<td>Selective Management of NonOcclusive Arterial Injuries.</td>
<td>Arch Surg 124: 1136-1141, 1989</td>
<td>III</td>
<td>All pts a-gramed for proximity &amp; 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</td>
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<td>Bergstein JM, et al</td>
<td>Pitfalls in the Use of Color-Flow</td>
<td>III</td>
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**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.

**Anderson RJ, et al**

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.

**Peck JJ, et al**

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.

**Francis H, et al**

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.

**Meissner M, et al**

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.

**Bergstein JM, et al**

Pt w/ hard signs were explored & not included in study. Pts w/ soft signs or

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

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

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

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

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

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.
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.

### Degiannis E, et al

**Arterial Gunshot Injuries of the Extremities: A South African Experience.**

*J Trauma 39: 570-575, 1995*

- 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

### Melton SM, et al

**Popliteal Artery Trauma: Systemic Anticoagulation and Intraoperative Thrombolysis Improves Limb Salvage.**

*Ann Surg 225: 518-527, 1997*

- 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