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Advances in the Management of Acute Popliteal Vascular Blunt Injuries

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This report evaluates critical points in the management of 30 consecutive blunt traumatic popliteal vascular injuries. All arterial injuries were diagnosed both clinically and by Doppler and PVR examinations. Twenty-eight of the 30 arterial reconstructions required interposition bypass grafts, nine of which were PTFE and the remainder were autogenous saphenous veins. In 19 patients the distal anastomosis was made to the distal popliteal artery and in nine patients to the tibial-peroneal arteries. In ten patients in whom limb survival was threatened, the ischemic time was shortened by the use of temporary Silastic shunt for rapid restoration of arterial flow. Nine patients had associated venous injuries which were repaired. Nine of the first 14 patients required fasciotomy but the last 16 patients were treated with hypertonic mannitol and only two of them required fasciotomy. There were no amputations, but in four limbs there were functional losses. In spite of the more extensive damage of blunt trauma, prompt and aggressive management aided by vascular laboratory tests, indwelling shunt, and hypertonic mannitol is rewarded with preservation of limbs following acute popliteal vascular injuries.

Distal extremity injuries have assumed almost epidemic proportions in the United States today because of motorcycle and other vehicular injuries. Severe blunt trauma to the region of the knee is notorious for producing limb-threatening vascular injury (7, 8, 10, 12). Despite the awareness of this fact, and improvements in resuscitation and transportation and vascular surgical techniques, perigeniculate vascular injuries continue to be responsible for the highest rate of post-traumatic leg amputations. In recent published series, the limb loss rate following popliteal vascular injury has been as high as 42% (2, 3, 5, 9, 11, 16, 20). But it has been difficult to dissect out the results and the significance of blunt traumatic popliteal vascular injuries since reports of blunt and penetrating trauma are mixed together in the literature. Furthermore, this rate is higher following blunt trauma than penetrating trauma, probably because of the more extensive nature of the injuries (15, 20). It is well recognized that rapid restoration of pulsatile blood flow is essential in the prevention of functional and structural limb loss and the principal cause of therapeutic failure is delayed recognition of the vascular lesion and restoration of pulsatile flow to the distal limb (4, 6, 12, 14). This report evaluates our experience and critical points in the management of 30 consecutive blunt traumatic popliteal vascular injuries which have been treated at the Regional Trauma Center at Albany Medical Center Hospital over the past 5 years.

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MATERIALS AND METHODS

During the 5-year period 1979–1984, 30 consecutive patients with vascular injuries to the region of the knee were treated at the Albany Medical Center Hospital. Twenty patients had condylar fractures, seven had dislocations of the knee, and three had no discernible skeletal injuries. Their vascular injuries were caused by direct crushing injury to the back of the knee. The time interval between injury and management varied from 2 to 18 hours. The patients whose treatment was delayed were usually seen initially in an outlying hospital and transferred to the regional trauma center subsequently. Beyond the 4- to 6-hour period of acute ischemia, clinical signs of severe ischemia of the limb such as loss of voluntary motion and sensation, muscle tenderness, and ankle fixation were most apparent. Ten of the 30 patients showed some or all of these signs.

Upon their arrival in the Emergency Room all patients were handled in the Trauma Room and other systemic injuries were evaluated simultaneously with their limb injuries. Clinical examination included pulse-palpation, capillary filling, temperature, and evaluation of motor and sensory functions. These observations were supplemented by vascular physiologic examinations including Doppler ultrasound examination of the

distal arterial tree as well as segmental Doppler pressures and PVR tracings. Any decrease in Doppler signal or ankle pressure by greater than 20 mm Hg and abnormal PVR wave forms were considered to be diagnostic of arterial injury. The combination of clinical examinations and vascular laboratory testing accomplished the diagnosis of arterial vascular injury in all patients.

In 14 patients, preoperative artriography was performed. These patients did not have profound ischemia and they were seen in the Trauma Room within 4 hours of the accident. On the average the angiographic study required 2 hours and only in four of the 14 patients was new information gained: in one patient it showed normal vessels distal to the occlusion; in a second it showed a distal clot at the trifurcation of the popliteal artery; in a third there were two areas of occlusion, i.e., popliteal and anterior tibial arteries; and in the other patient it showed arterial continuity but the presence of a traumatic false aneurysm. In all other patients angiography showed complete occlusion of the artery without visualization of the distal runoff.

There were nine females and 21 males in this series. Ages ranged from 14 to 56 years (average, 36 years). Half of these patients had multiple injuries. Three patients had near-total amputation of the limb and one of these patients also had injury to the adjoining nerves. In two of the three patients with near-total amputation, orthopedic stabilization was obtained before definitive restoration of circulation. In three other patients, orthopedic immobilization of fracture was done first in outlying hospitals and when the pulse did not return the patients were referred for further evaluation. In all other patients, the vascular injuries were repaired before the fracture fixation.

Twenty-eight of the 30 arterial reconstructions required bypass or grafts because of extensive tissue destruction. More than 3 cm of the artery was lacerated in each patient and in 21 of the 30 vascular injuries there was complete transection of the artery. In nine patients, 6-mm thin-walled PTFE was used as graft material and in the remainder of the patients autogenous saphenous veins were used. In five of 19 patients the saphenous vein was used in situ as a remote bypass around the area of the popliteal vascular injury (Fig. 1). In these five patients, prior Doppler examination of the venous system confirmed the integrity of the popliteal vein in the region of the injury. The remaining 14 had excised reversed saphenous vein bypasses. In five of these patients, in whom there was no popliteal venous injury and saphenous vein was injured, the vein was harvested from the same limb. In the other patients it was harvested from the opposite limb. In 19 patients, distal anastomosis was made with the distal popliteal artery below the knee and in nine patients with the tibial-peroneal artery. In ten patients in whom the ischemic time was more than 6 hours and in whom neuromuscular dysfunction was present, immediate restoration of pulsatile flow was achieved by the use of an indwelling shunt (Fig. 2) and followed by permanent vascular reconstruction at a more deliberate pace. In two of these ten patients this maneuver permitted skeletal stabilization before the definitive arterial reconstruction. Nine patients had associated popliteal venous injuries which were repaired by lateral venorrhaphy with or without patch in five patients and 8-mm thin-walled PTFE grafts in four patients. The first 14 patients were not treated with hypertonic mannitol and nine of these patients required tricompartmental fasciotomy following arterial reconstruction for prevention or treatment of musculofascial compartment swelling. At this time, the compartment pressures were greatly increased and the muscles appeared swollen and nonviable to stimulation. The last 16 patients were treated with hypertonic mannitol just before restoration of circulation to prevent reperfusion and compartment syndrome and only two of them required fasciotomy (1). The clinical indications for fasciotomy were similar in all patients.

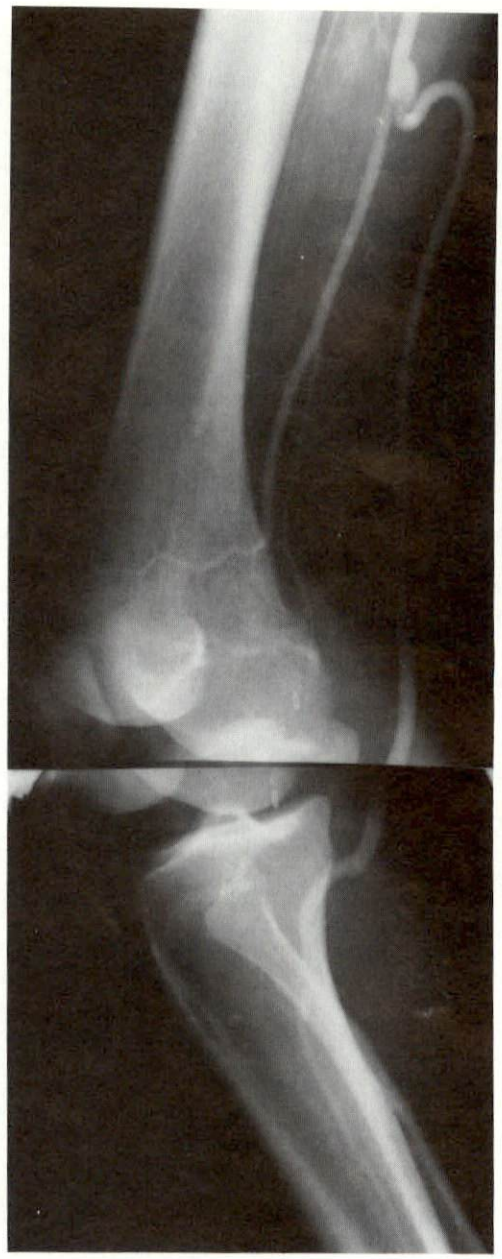

FIG. 1. Postoperative angiogram showing a patent remote in-situ saphenous vein arterial bypass around the area of popliteal arterial injury.

Operative Techniques. The usual vascular surgical techniques were used in the management of all these vascular injuries. Proximal and distal control remote from the area of injury was first achieved when the area of injury had to be explored. All interposition bypasses were constructed by end-to-end anastomosis and in two patients end-to-end direct repair was done using 6/0 or 7/0 prolypropylene suture in a continuous fashion for vascular anastomosis. When the proximal and distal artery was thought to be in extreme spasm then gentle hydrostatic or #3 Fogarty balloon catheter dilatation was used. If any visible propogated thrombi were present after resection of the damaged arterial segment, then clot extraction was done carefully with a Fogarty balloon catheter. Apart from this, the vessels were not instrumented. After completion of arterial anastomosis and restitution of blood flow, the flow characteristics were tested by Doppler and if they were not adequate then an operative angiogram was done. Of 12 such patients, in only one patient were distal thrombi found and extracted. In

FIG. 2. Photograph showing indwelling shunt in the injured popliteal artery for immediate restoration of pulsatile blood flow before definitive arterial reconstruction.

all instances the entire lower limb was prepared in the operative field and pedal pulses were confirmed before release of the patient from the operating room. Patients were not systemically heparinized and dilute heparin solution was used only locally and in the distal arterial tree.

RESULTS

There was no major amputation (i.e., foot) in this series, but in four patients, because of delayed revascularization and severe loss of neuromuscular function noted before revascularization, there was functional loss without tissue loss. One of the three patients with near-total amputation who had the nerve injury has also had functional loss. There were no operative deaths. There were two early failures of arterial reconstructions. In one patient ASV bypass failed in 1 week and was replaced by a PTFE graft, and in the other patient a PTFE graft needed thrombectomy 4 days later with resultant restoration of blood flow. There were no vascular graft infections. Postoperatively vascular laboratory tests in all patients have shown that all reconstructions were open during 5 years of followup. All these patients were treated by a multidisciplinary team including vascular, trauma, orthopedic, and plastic surgeons. Orthopedic management consisted of immediate rigid fixation with excellent results. Five of the 30 patients required delayed plastic surgery reconstruction for both function and soft-tissue coverage.

DISCUSSION

Although popliteal vascular trauma with occlusion has been associated with frequent limb loss, prompt recognition and rapid restoration of both arterial and venous circulation should result in a dramatic decrease in the amputation rate from this injury. In this series of 30 consecutive patients following blunt trauma to the popliteal vessels, there was no limb loss. Using the approach of aggressive revascularization, irrespective of the perceived degree of threatening ischemic damage, the limb loss rate can be reduced drastically even following blunt trauma. However, significant delays in revascularization because of failure of recognition will clearly result in neuromuscular functional loss in the intact limb as was the case in four of our patients.

Compared with low-energy penetrating trauma, blunt trauma generally causes extensive damage to the vessels. In the vast majority, no less than 3 cm of the artery was injured necessitating interposition or remote bypass. In addition to the musculoskeletal injuries and crushing injury to the soft tissues, the vascular injury itself is of a different complexity when blunt and penetrating trauma are compared. Except for high-velocity missile injuries, our experience of penetrating trauma is either a puncture injury or clean severance of the vessel which frequently can be managed by direct repair. In contrast, 28 of our 30 patients required bypass surgery. In untreated popliteal vascular injuries, amputation rate is rarely less than 75% (4). With prompt treatment of such vascular injuries, the rate may be lowered (7, 13, 15, 20). Reported series showed that blunt trauma carries a higher amputation rate compared to penetrating trauma (15, 20). Orcutt et al. reported that in their series of 37 popliteal vascular injuries, overall amputation rate was 16%. In 20 patients with penetrating trauma, only one limb was lost (5%) but in the 17 with blunt trauma, five limbs (30%) were lost (15). This marked difference is presumably due to delayed recognition of the popliteal vascular injury after blunt trauma. In our patients with blunt trauma, there were no amputations although some functional impairment occurred in four (13%). The preservation of these limbs was achieved by aggressive and prompt revascularization of all patients early or late and prevention of postoperative failure by attention to technical details.

Awareness of the possibility of popliteal vascular injuries following trauma should make it possible to correctly diagnose all popliteal vascular injuries by clinical examination aided by Doppler and vascular laboratory tests. In all our patients this diagnosis was made preoperatively. Angiography is not needed for establishing the diagnosis but when time can be spared it may provide a road map for vascular reconstruction when the limb is not jeopardized by the inevitable delay (>2 hours). In addition, angiography only provided further information in four of our 14 patients in whom this was done. Strict guidelines for vascular laboratory tests and acceptance of abnormal tests as a sign of vascular injuries would make a diagnosis of all blunt popliteal vascular injuries with accuracy. When venous injuries occur, they must also be repaired in the popliteal area because there is very little venous collateral capacity in the skin and bone around the knee joint and limb salvage may be jeopardized without venous repair (17, 18, 20). We have also adopted vascular laboratory testing and Doppler examination of the venous flow in the popliteal and femoral

veins for diagnosis of concomitant obstructing venous injury. When the Doppler examination suggests that there is normal venous flow by augmentation and there is no indication to explore the injured area, we have carried out remote in-situ saphenous vein bypass in these patients. In five such patients there was no leg swelling or arterial bypass failure due to venous outflow obstructions.

Most often the diagnosis is missed or delayed when the absent or diminished pulse is thought to be due to spasm or direct pressure from the musculoskeletal deformity. Under these circumstances when the skeletal abnormality is corrected, the normal pulse should return. If the limb is unquestionably viable with adequate circulation, fracture or dislocation may be corrected before specific vascular attention is undertaken. However, as in most instances, orthopedic management must not be allowed to delay vascular reconstruction.

Our experience is that findings of any circulatory compromise were associated with a vascular lesion. When the limb is profoundly ischemic then circulation can be rapidly restored by the use of indwelling shunt. We have used this shunt in ten patients who presented with neuromuscular functional changes. This shunt can be used promptly and without systemic heparinization, which is obviously contraindicated especially in multiply injured patients. Use of the temporary shunt provides immediate relief of ischemia and allows time for further dissection of the vessel and preparation of the vein. Its use should not be prolonged to cover orthopedic fixation. Recently use of the PTFE graft has also reduced the reconstruction time in our patients and it performed very well in both open and closed blunt traumatic vascular injuries (19).

Compartment compression syndrome due to late ischemic muscle swelling is a well-known phenomenon following delayed revascularization of the limb. In nine of our first 14 patients a fasciotomy was done immediately after vascular reconstruction to release compartment pressure. We used the clinical guidelines of tightness of compartment and checking the viability of the muscle at the time of surgery. In the subsequent 16 patients hypertonic mannitol was used before restoration of circulation to prevent a most serious consequence of the reperfusion syndrome, i.e., muscle swelling. Only two of these 16 patients required fasciotomy using the same clinical guidelines. We believe that our criteria of clinical observation of compartment syndrome are adequate since only four patients suffered neuromuscular loss, two of 14 patients who did not receive mannitol and two of 16 patients who received mannitol. Three of these four patients had these changes before arterial reconstructions. This study confirms a previous observation that hypertonic mannitol is helpful in the management of vascular trauma to the limb when there is need for prevention of compartment syndrome (19). However, mannitol may not work adequately in patients with direct crushing injury to the muscle and a tight compartment.

We were aggressive about restoration of arterial circulation in all patients in spite of delay or neuromuscular changes and did not resort to primary amputations on the basis of clinically 'dead' limbs. Ten patients already had neuromuscular changes at the time of their surgical management but prompt restoration of circulation completely reversed the functional impairment in six and provided useful weight-bearing limbs in the other four patients without any structural tissue loss. We would therefore recommend that unless the limb is unquestionably dead, hope of limb salvage by vascular reconstruction should not be given up in this relatively young population.

In summary, our experience in the management of 30 patients with blunt traumatic acute popliteal vascular injuries indicates that despite the more extensive damage of blunt trauma, prompt and aggressive restoration of circulation is rewarded with preservation of the injured limb. Vascular laboratory measurement, indwelling shunt, and hypertonic mannitol were also important adjuncts in the successful management of these patients.

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DISCUSSION

DR. WILLIAM M. STAHL (Lincoln Medical and Mental Health Center, Bronx, NY 10451): I would like to compliment Doctor Shah and his colleagues in Albany for demonstrating to us the results of careful planning and close followup of patients. I think we have heard an excellent series that really should be the gold standard for all of us in the care of popliteal vascular injuries. As we know, these are the highest risk for limb loss. I also thank Doctor Shah for providing me with a copy of his manuscript, and I compliment him on his excellent presentation.

What I can do is to point out again the things he has mentioned, because I envy him his successful series. On our own vascular service, directed by Doctor Pravin Shah, of 26 such patients we have had two limb losses, and they can be ascribed to the points mentioned by Doctor Shah, where in the past we have perhaps fallen down.

I think the most impressive thing is the diagnostic accuracy in this series, and the use of the noninvasive vascular laboratory techniques, PVR and Doppler, and also the statement that is made at least two or three times in the manuscript, that any diminution in peripheral circulation indicates a vascular injury.

I think the second important point is the speed of revascularization, especially in terms of the delayed patients. The use of a shunt, of course, brings up the question of preoperative angiography. I think appropriately the authors have stated that it does take time, an average of 2 hours, and when revascularization is imperative within a short time, the gain from angiography may not justify the delay.

[Slide] Not only is angiography often not impressive, but it can be misleading. Here is a patient with a tibial fracture whose initial angiogram shows a cutoff in the popliteal region.

[Slide] This shows that after revascularization the problem was at the popliteal but was due to pressure in the tibial compartment preventing outflow.

My next question has to do with the exact approach to this. Do you approach the lesion directly, or should one use remote bypass? The concept of leaving the fracture site closed and not opening it up by operative intervention is a good one, and we have used extra-anatomic bypass in these patients.

I have one question, Doctor Shah. When you have a patient with an acute problem, when your time is short and you have signs of distal obstruction and loss of arterial flow, and when there is no time to do an angiogram, how do you decide whether to approach it directly or to do an extra-anatomic bypass?

Another point Doctor Shah mentioned was assuring the venous competence. As we have published in the past, the problem of limb loss and compartment syndrome relates very much to venous insufficiency.

Again Doctor Shah is to be complimented on his results in the use of PTFE grafts, which we all seem to be getting around to using in the arterial system, in the venous system. The demonstration that there is no venous obstruction in these patients on the operating table, either by noninvasive means or angiography, is important.

As to the use of mannitol, I think this is an interesting concept. Whether the osmotic effect really works to reduce swelling is still a question. It will probably take a prospective randomized study of this to settle that question.

I enjoyed the paper very much. It is an excellent series. Thank you.

DR. DHIRAJ M. SHAH (Closing): Doctor Stahl, thank you for your very nice and complimentary remarks and discussion. We are also aware of your excellent results in extremity vascular trauma.

Specifically, to answer your questions, I would like to mention that when there is a limb-threatening ischemia, expanding hematoma, or open wound, we will explore the injured vessels directly and will not do a remote bypass. However, if the extremity is less threatened, and if we can determine that the vein is not occluded, then we might consider remote bypass. In some of these patients the orthopedic surgeons used an external fixator without directly opening up the injured areas.

Second, we recently started using Doppler examination for determination of venous patency. If there is any question, then the injury site will be explored. Furthermore, in those patients in whom we have done remote in-situ arterial bypass, we have kept our eye open for development of signs and symptoms of deep venous outflow obstruction, but in none of these patients this did occur. All patients with venous repair had venogram 7 to 10 days postoperatively.

Third, the use of hypertonic mannitol was based on our experimental data and subsequent clinical observation (Reference 1 in the text) in acute arterial ischemia. I agree that a prospective control study should be done to conclude the effectiveness of mannitol therapy, but we are so biased in favor of its therapeutic benefit and are using it almost routinely, that it will be difficult for us at this point to try to do a prospective randomized study. We will be glad to see other investigators carrying out such a study.

Again, I would like to thank the Association for allowing us to present this paper.