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Shotgun injuries are often erroneously grouped together with other civilian firearm injuries in the English literature, when in fact the shotgun discharge differs significantly in ballistics and other firing characteristics from rifles and pistols [*1*]. Wounds inflicted by shotguns are clinically different from those inflicted by rifles and pistols (hereafter referred to as gunshot wounds). Since these differences are of particular concern to the vascular surgeon interested in trauma, we will review 39 shotgun injuries and 72 gunshot wounds of the arteries of the extremities treated at the University of Mississippi Medical Center during a 13 year period (1960 to 1973). Arterial injuries of the extremities were selected for this comparison primarily because shotgun injuries of visceral arteries were relatively scarce; only a handful of cases were treated at this institution during the study period. There are fortuitous advantages in comparing limb vessel injuries: first, these injuries are easily assessed for the end results in terms of distal pulses, restoration of limb function, and other variables; and second, vascular injuries in other regions of the body are associated with other serious organ injuries, thus introducing additional variables and reducing the effectiveness of comparison.

Material and Methods

Thirty-nine vascular injuries of the extremities caused by shotgun blasts were treated at the University of Mississippi Medical Center from 1960 to 1973. During the same period, 72 gunshot vascular wounds of the extremities were also treated. The anatomic distribution of these vascular injuries is shown in Table I. While the shotgun injuries were somewhat evenly divided between upper and lower limbs, gunshot wounds were twice as common in the lower limb. Of the 39 shotgun injuries, 29 patients presented with massive tissue loss indicating discharge of the weapon at very close range. The wadding was frequently recovered from such wounds. In the other patients, the shotgun appeared to have been fired from a distance as indicated by a diffuse pattern of pellet enlodgment, and tissue necrosis was relatively minimal.

Associated Injuries. Patients with shotgun injuries invariably had associated injury of accompanying major veins and nerves (Table II). Associated nerve injury was ubiquitous in the upper limb, present in 18 of the 21 cases reviewed. Invariably two or more of the major nerves were affected. Combined median and ulnar nerve injury was the most common form of neurologic injury encountered. Nerve injury was relatively uncommon in the lower limb, being present in only 4 of the 18 patients with shotgun injuries in this area. Bone and joint involvement were frequent. In contrast, only one third of the patients with gunshot arterial wounds had venous injury, and there were only 6 instances of associated nerve injury in the 72 patients with gunshot injuries.

Type of Arterial Injury Inflicted. While gunshot injury of the arteries resulted in a wide range of arterial injuries from contusion to loss of arterial substance, the length of vessel involved was often limited. Shotgun vascular injuries, on the other hand, invariably resulted in multiple lesions of extensive lengths of the artery associated with thrombosis. As long stretches of the artery were involved by shotgun blasts, a considerable number of collateral vessels were absent; a palpable distal pulse was present in only four patients (10 per cent) with shotgun injuries. In contrast, collateral vessels were better preserved in gunshot wounds, and sometimes the main vascular channel itself remained patent as the injury was tangential. As a result, distal ischemia was less frequent and good distal pulses were palpated in 26 per cent of the patients.

Treatment. Since long stretches of the artery had to be replaced after shotgun blasts, saphenous vein graft or another form of prosthetic replacement was the most common type of surgery performed for shotgun injuries (Table III). Such procedures were less commonly required for treating gunshot vascular wounds. End-to-end primary repair without a graft was the most common method of repair used for gunshot wounds.

Infection. Infection was the most common complication in both groups but was considerably more frequent and more serious after shotgun injuries. Fourteen of the 39 shotgun wounds (36 per cent) developed infection. In six patients the infection was deep and serious, resulting in either septicemia, high arterial ligation, or amputation. Infection occurred in only 9 of 72 patients (13 per cent)

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TABLE I Anatomic Distribution of 39 Shotgun and 72 Gunshot Arterial Injuries

Limb	Type of Injury	
	Shotgun	Gunshot
Upper		
Subclavian	1	5
Axillary	4	9
Brachial	13	7
Radial, ulnar	3	2
Total	21 (54%)	23 (32%)
Lower		
Common femoral	3	10
Profunda femoral	0	7
Superficial femoral	13	19
Popliteal	2	9
Posterior tibial	0	4
Anterior tibial	0	0
Total	18 (46%)	49 (68%)

TABLE II Associated Injuries With 39 Shotgun and 72 Gunshot Arterial Wounds

Associated Injury	Shotgun Wound		Gunshot Wound	
	No.	%	No.	%
Vein	32	82	22	31
Nerve or nerves	24	62	6	8
Bone	17	44	7	6
Other organs	9	23	9	13

with gunshot injuries; 2 of these patients had deep infections.

Results

One patient died as a result of septicemia after a shotgun blast to the upper extremity. No patient in the gunshot group died (Table IV). The end result of arterial surgery for gunshot wounds was highly gratifying as measured by patency of the distal artery, amputation rate, and usefulness of the repaired extremity in terms of function. Only two amputations were performed in the 72 patients with gunshot wounds, a rate of less than 3 per cent; 1 patient presented 6 days after the injury with frank gangrene and the second patient was transferred from another hospital several weeks after the injury with infection of the saphenous vein graft. There were no primary amputations. Six of these 72 patients had associated nerve injuries that resulted in compromised limb function postoperatively. One patient had residual ischemia of the lower limb after surgery, but the limb was viable. The remaining 63 patients had an excellent end result with a patent arterial tree and fully restored function of the extremity after surgery (Table V).

TABLE III Methods of Vascular Repair of Shotgun and Gunshot Arterial Injuries

Type of Vascular Repair	Shotgun Injury		Gunshot Injury	
	No.	%	No.	%
Lateral suture	6	15	7	10
End to end anastomosis	11	28	37	51
Autogenous vein graft	16 } 18		11 } 16	22
Prosthetic graft	2 }	46	5† }	
Ligation	2	5	8	11
Other*	2	5	4	6

* Includes embolectomy, vein angioplasty, and primary amputation.

† Includes one instance of homograft.

TABLE IV Mortality and Complications in 39 Shotgun and 72 Gunshot Wounds

Complication	Shotgun Wounds		Gunshot Wounds	
	No.	%	No.	%
Infection				
Superficial	8 } 14	36	7 } 9	13
Deep	6 }		2 }	
Amputation				
Primary	2 } 8	21	0 } 2	3
Secondary	6 }		2 }	
Mortality	1	3	0	0

TABLE V Functional Recovery of the Limb After 39 Shotgun and 72 Gunshot Injuries

Status	Shotgun		Gunshot	
	No.	%	No.	%
Full recovery of function	12	31	63	88
Partial recovery of function	5	13	7	10
Severe limitation of function	22*	56	2†	3

*Includes one death and eight amputations.

† Both secondary amputations.

In contrast to these gratifying results, patients with shotgun vascular injuries presented a bleak picture. Two patients underwent primary amputation due to mutilation of the extremity beyond primary vascular repair. In six other patients a secondary amputation was necessary after an initial vascular repair because of either extensive myonecrosis or infection. The amputation rate in this group was thus extremely high (21 per cent). In the remaining 31 patients who survived with a vascularized limb, functional integrity of the extremity was unsatisfactory in 18 patients; in 13 patients the functional deficit was extreme and the limb was essentially useless. The functional capacity was unrelated to the vascular repair, as the arterial repair itself remained patent in every instance. Without exception, the loss of

Figure 1. Arteriograms showing the extraanatomic bypass performed in a patient with shotgun injury of the femoral artery.

useful function in the limb was related to permanent nerve damage caused by the shotgun blasts. These patients often underwent several secondary procedures to improve the function of the limb, such as tendon transfers, bone and joint stabilization, and neurolysis. In retrospect, normal limb function was restored in only 12 of the 39 patients injured by shotgun blasts. The high morbidity of patients with shotgun arterial wounds is reflected in their longer hospital stay. Patients with shotgun injuries had a mean hospital stay of 15.6 days, roughly twice that of patients with gunshot wounds (8.8 days).

Comments

Civilian arterial injuries caused by firearms are often grouped together in the literature without regard to the variety of weapons in current use. While most of these are low velocity weapons, the ballistics and the wounding mechanism of shotgun blasts are distinctly different from those of other weapons in common nonmilitary use today [*1*]. Injuries caused by shotgun blasts vary in severity, those fired at close range being vastly more serious in nature than those fired from a distance. Unfortunately, the majority of human injuries from shotguns are received at close range [*1*]. Arterial wounds of the extremities caused by a shotgun carry a poor prognosis for the ultimate function and rehabilitation of the injured limb. In a typical close range shotgun injury of the extremity, the injury encompasses extensive skin and soft tissue areas including arteries, veins, nerves and muscles, and the adjoining bone and joints. Extensive shotgun injuries to the extremities sometimes merit primary amputation. Factors that would favor such a course include massive soft tissue and bone injury combined with involvement of two or more important nerves supplying the extremity (for example, median and ulnar nerves if at a high level).

A preoperative or intraoperative arteriogram is obligatory due to the multiplicity and wide dispersion of arterial injuries encountered in shotgun blasts. It is not uncommon for arteriography to reveal that an injury is at a higher or lower level than was expected on the basis of clinical examination. Unsuspected injury of important branches such as the profunda or the subscapular branch of the axillary artery may also be discovered. In emergency situations tourniquet application may be necessary to maintain hemostasis until direct vascular control can be

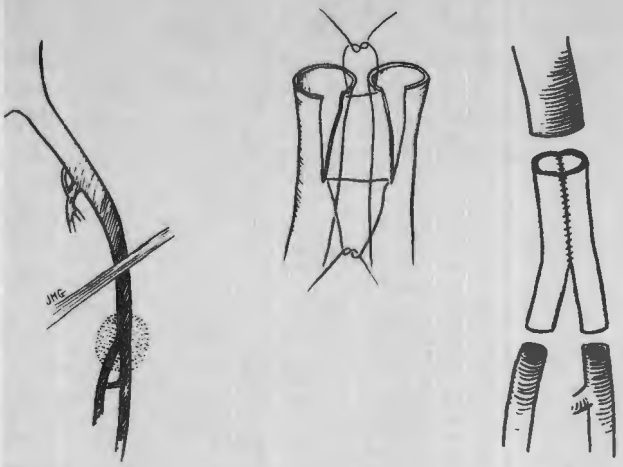

Figure 2. Compound autogenous saphenous vein graft for construction of the profunda femoris artery.

achieved. The soft tissue defect may vary in size from a few centimeters to a few inches, depending on the distance from which the weapon was fired. Extensive debridement to bleeding muscle and soft tissue is done, but judgment is exercised so that enough soft tissue will be retained to provide a cover for the vascular repair. It is common practice to give primacy to achieving bony stabilization before the vascular repair is done, since it is feared that the vascular repair may be disrupted during manipulation of the fracture [2]. However, in our experience the vascular repair is seldom jeopardized if care is exercised during the manipulation; we prefer to attend to the vascular repair first to minimize the chances of irreversible ischemic changes. Complete muscle relaxation is maintained until orthopedic repair is subsequently completed.

Due to involvement of extensive lengths of the artery including considerable portions of the collateral vessels, distal thrombosis of the arterial tree is not uncommon and Fogarty catheterization at the time of surgery is essential. A completion arteriogram is complementary and frequently useful. Where possible an attempt should be made to reconstruct the arterial wound without a graft, since even a vein graft is susceptible to infection. However, if the use of a graft appears inevitable, as is frequently the case, fabric graft should be avoided in favor of autogenous vein grafts. Even though we have used the cephalic vein in a few instances, especially for repair of the brachial artery, the autogenous saphenous vein is technically more satisfactory and less prone to complications such as aneurysmal dilatation. When infection is well established and arterial ligation is necessary because of bleeding, alternative methods of bypass through uninfected tissues can be used (Figure 1). In some selected instances of severe shotgun injury with extreme soft tissue loss, even a primary extraanatomic bypass may be the preferred initial procedure.

In injuries involving large blood vessels it is sometimes impossible to use the saphenous vein due to the limitation of size. Even though construction of a compound graft of a large lumen (Figure 2) is time-consuming, it is worthwhile in some instances for reconstruction of the common, profunda, and superficial femoral trijunction. With increasing facility with vascular reconstruction techniques, repair rather than ligation of all large primary branches of major vessels is becoming the norm. Although redundant from the viewpoint of immediate limb viability, repair of large branches preserves perfusion reserve and may avoid future claudication. A primary fasciotomy is usually necessary in shotgun wounds because postoperative limb swelling generally occurs. Other indications for fasciotomy include extensive soft tissue injury or swelling, vein injuries compromising venous drainage of the limb, or injuries associated with prolonged shock or a long period of ischemia. Fasciotomy is also useful in advancing the level of amputation distally where, despite aggressive arterial reconstructive surgery, limb circulation remains marginal. To be effective fasciotomy must be performed early. We generally prefer subcutaneous fasciotomies done through small skin incisions over both the anterior and posterior compartments of the leg or forearm. In the leg the peroneal compartment as well as the deep posterior compartment is frequently added. When skin constriction is perceived to be a factor in vascular compromise, we have not hesitated to perform extensive transcutaneous fasciotomies. More recently, we have preferred the fibulectomy method [3] of leg compartment decompression as it has been found to be simpler and relieves pressure in all four leg compartments. The wound is profusely irrigated with a suitable solution containing antibiotic additives and the bone fractures, which are often comminuted, are handled in cooperation with orthopedic surgeons. Recently it has become clear that external stabilization of these fractures is far superior to internal fixation [4]. Skin grafts are invariably required to provide wound coverage but we generally do this as a secondary procedure on the third or fourth postoperative day. However, it is important to provide soft tissue cover for the vascular repair. Unessential muscles may be detached from their origin or insertion and swung over to cover the vascular repair. Provided other

factors are favorable, rotation of pedicle skin flaps may be required occasionally to achieve this purpose. Most shotgun wounds require drainage for a few days despite vascular repair. A closed system of drainage is preferable, but where complete skin coverage is absent open drainage may be inevitable. When nerve injury is detected at the time of surgery, primary anastomosis of the neural structures is seldom indicated [5]. This is especially true for shotgun injuries where extensive involvement of other tissue and nerves for a considerable length may be present. The ends of the nerves are marked with silver clips and secondary repair is resorted to after a few weeks, when the wound itself has healed well. Recently, neural repairs at the fascicular level have significantly improved the end result [6]. Brachial plexus injuries are frequently hopeless [7]. If nerve regeneration has not occurred within the projected time, aggressive tendon transfer procedures should be resorted to before extensive atrophy of the limb sets in because of disuse. In the interim, physiotherapy to maintain the integrity of the musculature and joints is essential. In some patients other secondary reconstructive procedures, such as joint fusion or reduction or adjustment of limb length, may be required later for complete rehabilitation of the limb. Despite these various helpful measures, the overall record of salvage of limbs sustaining shotgun injury has been poor indeed. In our own experience, only 12 of the 39 patients reviewed in this report ultimately had useful limbs. One patient died and eight others lost their limbs due to amputation. Of the remaining 30 patients, the limb was completely nonfunctional in 13, and limb function was partially compromised in 5 others, who required orthopedic appliances such as braces. In no instance did the vascular injury itself contribute to the functional impairment. In the immediate postoperative period infection, often resulting in secondary amputation, continues to be the most important and significant complication in patients with shotgun injuries of the extremities. While infection—especially deep infection involving the arteries—was rare in patients with gunshot wounds (2 of 72 patients), the incidence was several times higher in those with shotgun wounds (6 of 39 patients). There were six instances of secondary amputation after attempted primary vascular repair. Besides infection, other factors may lead to extensive muscle necrosis and secondary amputation despite primary vascular repair. The time delay before effecting a vascular repair [8,9], failure to repair a venous injury [9], absence of an adequate fasciotomy, improper stabilization of the bony frame, lack of soft tissue coverage for the vascular repair, failure to clear the distal artery of thrombi, and the presence of thrombus formation in the venous tree have been shown to be contributory factors. Myoglobinuria and extremely high levels of creatinine phosphokinase denote serious muscle necrosis. When combined with toxic systemic manifestations, immediate amputation is called for despite the absence of a clear line of demarcation.

Summary

Even though shotgun injuries are often grouped with gunshot wounds, the former are ballistically and clinically far different from gunshot wounds. Two groups of patients with shotgun and gunshot wounds of the extremities, respectively, were compared with regard to clinical features. Although the vascular wound was the most dramatic aspect in both groups of patients, associated injuries, especially to the nerves and bones, played a significant role in the ultimate rehabilitation of the patients with shotgun wounds. Shotgun injuries more frequently required the use of saphenous vein grafts than did gunshot wounds. The infection and amputation rates were much higher in patients with shotgun wounds than in those with gunshot wounds. Patients with shotgun injuries of the extremities often required secondary reconstructive procedures such as tendon transfer or bone and joint fusion. Despite these measures the outlook for the ultimate rehabilitation of the extremity after shotgun injury was dismal, whereas after gunshot wounds complete rehabilitation was the rule.

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