

Civilian Trauma in the 1980s

A 1-Year Experience with 456 Vascular and Cardiac Injuries

DAVID V. FELICIANO, M.D., CARMEL G. BITONDO, PA-C, KENNETH L. MATTOX, M.D., JON M. BURCH, M.D.,
GEORGE L. JORDAN, JR., M.D., ARTHUR C. BEALL, JR., M.D., MICHAEL E. DE BAKEY, M.D.

During 1982, 312 patients with 408 vascular injuries and 48 cardiac injuries were seen. Two or more vascular or cardiac injuries were present in 34% of patients. Over 87% of injuries were secondary to gunshot wounds, stab wounds, or shotgun wounds. Vascular injuries were most commonly seen in the extremities (39.9%) or abdomen (31.9%). The most common arterial injuries occurred in the brachial artery (39 patients), while the most common venous injuries occurred in the internal jugular vein (26 patients). Arterial injuries were treated by the insertion of substitute vascular conduits (33.9%), ligation (22.6%), lateral arteriorrhaphy (18.6%), or end-to-end anastomosis (15.4%). Venous injuries were treated by lateral venorrhaphy (63.7%) or ligation (25.1%). In the 272 patients admitted with only vascular injuries, survival was 84.2%. Cardiac injuries in 38 patients most commonly occurred in the right ventricle (50%) and right atrium (25%). In the 34 patients who had only cardiac injuries and less than 4 minutes of prehospital cardiopulmonary arrest prior to arrival in the emergency center, survival was 64.7%.

TRAUMA CONTINUES TO BE the leading cause of death in patients in the first 4 decades of life in the United States. While the total number of deaths has continued to rise, it is clear that appropriate early surgical intervention will save many patients with vascular or cardiac injuries who would otherwise die from hemorrhagic shock or tamponade.¹

In many areas of this country, techniques of transport, resuscitation, and operation that were originally used for military casualties have now been transposed to the care of injured civilians. This is particularly true in "trauma centers" where surgical teams have daily exposure to patients with a wide variety of major injuries. With increased experience, the application of innovative approaches to the care of the critically injured, and careful analysis of techniques and results, salvage rates for patients with ci-

From the Cora and Webb Mading Department of Surgery, Baylor College of Medicine, and the Ben Taub General Hospital, Houston, Texas

vilian vascular or cardiac injuries have now reached extraordinary levels.

This is a report of a 1-year experience (1982) with 456 vascular and cardiac injuries at the Ben Taub General Hospital in Houston, Texas, a major urban trauma center affiliated with the Baylor College of Medicine.

Methods

Patients with vascular or cardiac injuries are resuscitated in the field by trained paramedics and emergency medical technicians in Houston. In patients with suspected vascular or cardiac injuries, care in the field is limited to endotracheal intubation, if necessary, administration of oxygen, the insertion of peripheral intravenous lines for crystalloid infusion, and compression to control hemorrhage from peripheral vascular injuries. For the past year, a prospective study on the efficacy of the medical anti-shock trousers has been taking place, but was not part of routine care in the field in 1982.

In the emergency center, a surgical resuscitation team supervises the care of the injured patients. Once resuscitation is underway, a patient with a suspected vascular injury is triaged directly to the operating room, to a radiologic room for emergency center arteriography (Fig. 1), or to a cardiovascular radiologic suite elsewhere in the hospital for retrograde angiographic studies of the great vessels, etc. Patients with suspected cardiac injuries and exsanguination or life-threatening tamponade at the time of arrival or during resuscitation undergo emergency center thoracotomy with cardiorrhaphy and clamping of the descending thoracic aorta (Fig. 2). These patients are then moved to the operating room for reinforcement of the cardiorrhaphy, ligation of the internal mammary ves-

Presented at the Ninety-Fifth Annual Session of the Southern Surgical Association, Hot Springs, Virginia, December 5-7, 1983.

Reprint requests: David V. Feliciano, M.D., Department of Surgery, Baylor College of Medicine, One Baylor Plaza, Houston, TX 77030.

Submitted for publication: January 1, 1984.

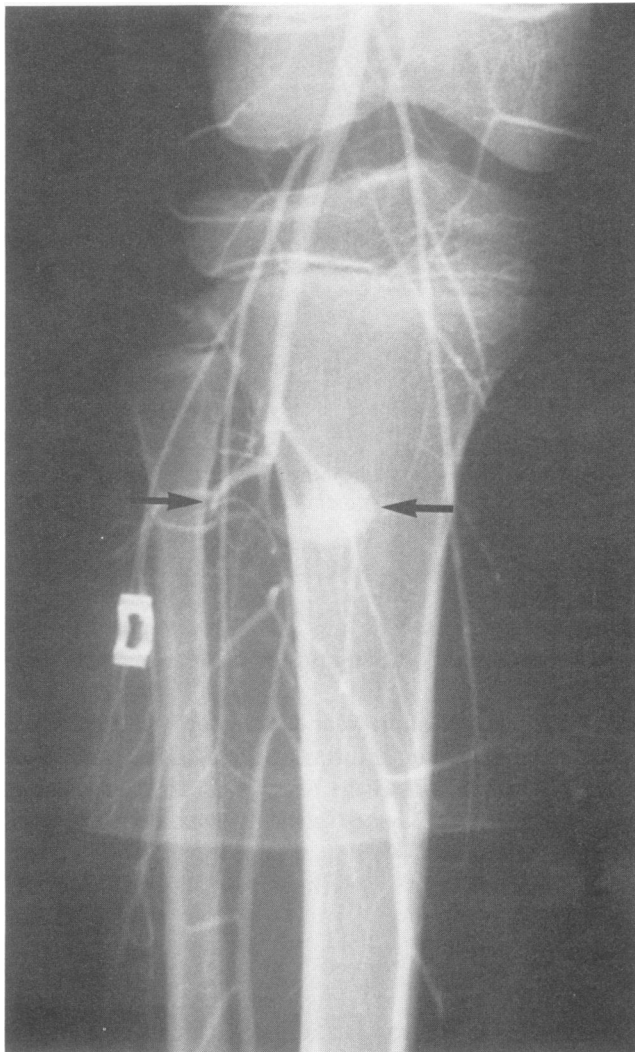


FIG. 1. Emergency center arteriogram showing transection of the anterior tibial artery and a false aneurysm of the tibioperoneal trunk after a stab wound of the right leg.

sels, irrigation of the pericardium and pleural cavities, and possible closure of the pericardium. Pericardiocentesis is not routinely used. More stable patients are moved to the operating room for thoracotomy with cardiorrhaphy. In the emergency center, intravenous antibiotics are given to all patients with suspected vascular or cardiac injuries.

In the operating room, surgery in patients with vascular or cardiac injuries is performed by one of three surgical teams staffed by full-time attending surgeons and senior residents with extensive experience with trauma patients. In patients with vascular injuries, standard principles of vascular control, minimal debridement, repair as indicated utilizing fine monofilament suture material, and antibiotic irrigation of the wound are used. When cardiac injury is present, anterolateral thoracotomies are preferred

to allow for widest possible exposure of both the heart and descending thoracic aorta. Cardiac repairs on the surface of the heart are repaired without cardiopulmonary bypass. Either echocardiography or cardiac catheterization is performed prior to discharge in all patients who have previously suffered a penetrating wound of the heart that required cardiorrhaphy.

The names of all patients with vascular or cardiac injuries are recorded in a running log maintained by the Department of Surgery at the Ben Taub General Hospital. Data reviewed in this study was retrieved from this running log and from individual patient charts, when necessary.

Results

From January 1, 1982 to January 1, 1983, 312 patients with 408 vascular injuries and 48 cardiac injuries were seen. There were 272 patients (87.2%) with only vascular injuries, 38 patients (12.2%) with only cardiac injuries, and two patients (0.6%) with combined cardiovascular injuries. The average age of patients was 29 years and 89% were male. Over 87% of injuries were secondary to penetrating wounds, while the remainder were due to lacerations, iatrogenic mishaps, or blunt trauma (Table 1). Approximately 71% of iatrogenic injuries were related to arterial or central venous catheterization attempts performed by anesthesiologists or cardiac catheterizations performed by cardiologists. Two or more vascular or cardiac injuries were present in 34% of patients seen in this series.

Vascular injuries were most commonly seen in the extremities (39.9%) or abdomen (31.9%), and arterial injuries were somewhat more common than venous injuries during the period of the review (Table 2). The most frequently injured vessels by location included the common carotid artery (eight injuries) and internal jugular vein (26 injuries) in the neck, the internal mammary artery (12 injuries) and subclavian vein (seven injuries) in the chest, and the suprarenal aorta (eight injuries) and inferior vena cava (23 injuries) in the abdomen (Table 3). In the upper extremities the most frequently injured vessels were the brachial artery (39 injuries) and brachial veins (nine injuries), while in the lower extremities the most frequently injured vessels were the superficial femoral artery (23 injuries) and superficial femoral vein (11 injuries) (Table 3). Arterial injuries were repaired by a variety of techniques with the insertion of substitute vascular conduits being the most common (Table 4). Ligation was performed in 50 arterial injuries (22.6%), with 42% of ligations occurring in the internal mammary artery, intercostal arteries, profunda femoris artery, or internal iliac artery. Venous injuries were managed by lateral venor-



FIG. 2. Emergency center thoracotomy performed for gunshot wound of the left ventricle.

rhaphy or ligation in 89% of instances (Table 5); most ligations (66%) were performed on the internal jugular vein, external jugular vein, iliac veins, or profunda femoris vein. In the 272 patients who were admitted with only vascular injuries, survival was 84.2% (229/272). Of the 43 deaths, 37 (86%) were due to hemorrhagic shock and 39 (90.7%) occurred in patients who had suffered penetrating wounds.

In the 38 patients who presented with only cardiac injuries, mechanisms of injury were most commonly gunshot wounds (50%) and stab wounds (39.4%) (Table 6). Two cardiac injuries occurred in eight patients, and the right ventricle was the most frequently injured chamber (50%) (Table 7). Emergency center left anterolateral thoracotomy for cardiac wounds was required in 15 patients, including one who subsequently had a right anterolateral thoracotomy performed in the operating room as well. Operating room left anterolateral thoracotomy

for more stable patients with cardiac wounds was required in 23 patients. Survival was 57.9% in the 38 patients who were admitted with only cardiac injuries. Analysis of the charts of patients dying in the emergency center, however, revealed that four deaths occurred in patients who were resuscitated in the emergency center after a period of prehospital cardiopulmonary arrest exceeding 4 minutes. If these four patients are eliminated as being dead on arrival in the emergency center, survival was 64.7% (22/34). Deaths after resuscitation and surgery for cardiac wounds occurred most commonly in the emergency center (10/16 = 62.5%). Gunshot wounds (nine patients) and shotgun wounds (two patients) to the heart accounted for 87.5% of the deaths. Cardiac catheterization performed during hospitalization in two surviving patients revealed a ventricular septal defect in one and a right atrial-left ventricular fistula in the other. Both patients underwent successful repair utilizing cardiopulmonary bypass.

Associated organ injuries were present in 156 patients

TABLE 1. Mechanisms of Injury—All Vascular and Cardiac Injuries

Mechanism	Number	
GSW	166 (53.2%)	} 87.2%
SW	88 (28.2%)	
SGW	18 (5.8%)	
Laceration	17 (5.4%)	
Iatrogenic	14 (4.5%)	
Blunt	9 (2.9%)	
Total	312 (100%)	

TABLE 2. Distribution of Vascular Injuries

Location	Arteries Injured	Veins Injured	Total
Neck	17 (33.3%)	34 (66.7%)	51 (12.5%)
Chest	40 (62.5%)	24 (37.5%)	64 (15.7%)
Abdomen	41 (31.5%)	89 (68.5%)	130 (31.9%)
Extremity	123 (75.5%)	40 (24.5%)	163 (39.9%)
Total (%)	221 (54.2%)	187 (45.8%)	408 (100%)

TABLE 3. Location of Vascular Injuries

Location	Number of Injuries				Total
	Artery		Vein		
Head and neck	Common carotid	8	Internal jugular	26	51 (12.5%)
	External carotid	3	External jugular	7	
	Thyrocervical trunk	3	Superior thyroid	1	
	Vertebral	1			
	Superior thyroid	1			
	Inferior thyroid	1			
Chest	Thoracic aorta	4	Superior vena cava	4	64 (15.7%)
	Pulmonary	5	Inferior vena cava	7	
	Innominate	5	Pulmonary	1	
	Subclavian	9	Innominate	1	
	Internal mammary	12	Subclavian	7	
	Intercostal	5	Azygos	1	
			Internal mammary	2	
			Intercostal	1	
Abdomen	Suprarenal aorta	8	Suprarenal vena cava	8	130 (31.9%)
	Common hepatic	1	Hepatic	2	
	Superior mesenteric	4	Portal	6	
	Renal artery	2	Superior mesenteric	9	
	Infrarenal aorta	5	Splenic	1	
	Inferior mesenteric	2	Renal	6	
	Common iliac	4	Infrarenal vena cava	23	
	External iliac	6	Inferior mesenteric	2	
	Internal iliac	6	Colic	1	
	Epigastric	2	Common iliac	15	
	Lumbar	1	External iliac	9	
			Internal iliac	6	
			Testicular	1	
Peripheral	Axillary	10	Axillary	2	163 (39.9%)
	Brachial	39	Brachial	9	
	Radial	9	Common femoral	9	
	Ulnar	6	Superficial femoral	11	
	Common femoral	8	Profunda femoris	4	
	Superficial femoral	23	Popliteal	4	
	Profunda femoris	8	Tibioperoneal	1	
	Popliteal	14			
	Tibioperoneal	3			
	Anterior tibial	2			
	Posterior tibial	1			
	Total	221 (54.2%)	187 (45.8%)	408 (100%)	

(50%) who presented with vascular or cardiac injuries. One other organ was injured in 70 (45.5%) patients, while two to six other organs were injured in the remaining 86

(54.5%) patients. The most commonly injured associated organs in this series were in the gastrointestinal tract (48.8%) and respiratory tract (13.8%).

In the 257 patients surviving beyond the first 24 hours

TABLE 4. Treatment of Arterial Injuries

Treatment	Number
Conduit	75 (33.9%)
PTFE	60
Vein	12
Dacron	3
Ligation	50 (22.6%)
Arteriorrhaphy	41 (18.6%)
End-to-end	34 (15.4%)
Other	21 (9.5%)
Total	221 (100%)

TABLE 5. Treatment of Venous Injuries

Treatment	Number
Venorrhaphy	119 (63.7%)
Ligation	47 (25.1%)
Conduit	8 (4.3%)
PTFE	6
Vein	2
Other	13 (6.9%)
Total	187 (100%)

in the hospital, complications occurred in 16.7% (43/257). The most common complications after surgery for vascular or cardiac injuries were intra-abdominal abscesses in eight patients (three deaths), postoperative bleeding in seven patients (one death), thrombosis of vascular repair in six patients (no deaths), and pneumonia in five patients (one death).

Discussion

In comparison with previous large series of civilian vascular or cardiac injuries,²⁻¹⁰ this report reviews only those patients seen in one hospital in one recent year (1982). The tremendous increase in injuries of this type is clearly related to the ready availability of firearms in the United States, as well as to the continuing epidemic of urban violence.¹¹ Gunshot wounds and shotgun wounds accounted for 59% of all vascular and cardiac injuries in this series. When stab wounds are added to this total, 87.2% of injuries were due to penetrating wounds. The large number of iatrogenic injuries is also disturbing, but will likely increase as invasive diagnostic and therapeutic maneuvers performed by nonsurgeons are now routine.

Vascular Injuries

The high incidence of vascular injuries in the extremities, especially to the brachial and superficial femoral arteries, has been found in all civilian and military reviews.^{3-5,12} The incidence of truncal vascular injuries, however, is significantly higher as compared to military reviews.¹² This is most likely due to the diminished wounding power of civilian handguns as compared to the usually fatal truncal wounds secondary to military high velocity bullets, grenades, artillery rounds, and rockets.¹³

Negative explorations for suspected vascular injuries have been reported in many civilian reviews.^{6,14} With a large volume of potential peripheral vascular injuries being evaluated annually in our hospital, it is essential that explorations be performed only in patients who have injuries. The technique of emergency center one-shot percutaneous arteriography was used in 353 patients with potential peripheral vascular injuries during the period of this study and essentially eliminated negative explorations.¹⁵

TABLE 6. Mechanisms of Injury—Cardiac Injuries Only

Mechanism	Number
GSW	19 (50%)
SW	15 (39.4%)
SGW	2 (5.3%)
Blunt	2 (5.3%)
Total	38 (100%)

TABLE 7. Location of Cardiac Injuries

Location	Number
Right ventricle	24 (50%)
Right atrium	12 (25%)
Left ventricle	7 (15%)
Left atrium	5 (10%)
Total	48 (100%)

Arterial repairs were most commonly performed by segmental resection followed by the insertion of substitute vascular conduits or performance of an end-to-end anastomosis in this series. The incidence of end-to-end anastomoses (15.4%) is significantly less than the 28% to 45% reported in other large series,^{3,4,6} while the incidence of insertion of substitute vascular conduits (33.9%) is significantly greater. The large number of gunshot wounds that obviously cause a more extensive arterial wound as compared to stab wounds undoubtedly accounts for some of the increased usage of substitute vascular conduits in this review. Also, an institutional policy of avoiding the ligation of main arterial branches near vascular wounds in order to gain length as well as a recently completed 5-year study on the efficacy of PTFE prostheses in traumatic vascular wounds contributed to the increased number of substitute vascular conduits that were inserted.¹⁶

Venous injuries can usually be repaired by lateral venorrhaphy, as narrowing or even subsequent occlusion are generally well tolerated in young trauma patients except in the popliteal vein.¹⁷ Venous ligation is also well tolerated¹⁸ and was utilized in 25% of the venous injuries in this series.

Survival in patients with vascular injuries depends upon the rate of bleeding, time interval from injury to vascular control, and the magnitude of associated injuries. The 86% incidence of death from hemorrhagic shock in patients with vascular injuries in this series underscores the need for speed in transport from the field to the emergency center, rapid evaluation, and early operation in order to lower the mortality associated with these injuries. Late deaths are uncommon in young trauma patients who have had appropriate repair of vascular and associated injuries.

Cardiac Injuries

The incidence of gunshot wounds as a cause of cardiac injuries in this series (50%) was significantly increased as compared to other civilian series including those from our own institution.⁸⁻¹⁰ Despite this fact, emergency center thoracotomy was required in only 15 of 38 patients (39.5%) with isolated cardiac wounds in 1982. While other centers have suggested that pericardiocentesis may be of temporizing therapeutic value in patients with penetrating

cardiac wounds,¹⁹ an aggressive approach with emergency center thoracotomy has been used in this series based on our extensive previous experience.²⁰⁻²³ Patients requiring emergency center thoracotomy for cardiac wounds are near death and accounted for 62.5% of the deaths.

Survival figures for patients with cardiac injuries have reached extraordinary levels in recent years.^{8,10} As the number of gunshot wounds accounting for cardiac injuries in this series is approximately twice that noted in other large reports,⁸⁻¹⁰ it is remarkable that the survival rate of 65% was attained. This is felt to be due to faster transport from the field to the emergency center in recent years, earlier recognition of tamponade based on previous experience, and the aforementioned aggressive use of emergency center thoracotomy for moribund patients.

The late sequelae of cardiac injuries from either penetrating or blunt trauma are now well recognized.^{24,25} As previously noted, it has been our continuing policy to evaluate all patients who survive cardiorrhaphy with an echocardiogram or cardiac catheterization prior to discharge from the hospital. The two intracardiac defects that were discovered in 1982 were both easily repaired at the time of reoperation.

Associated Injuries; Complications

The high incidence of truncal wounds in this series (47.6%), especially to the abdomen (31.9%), accounted for the large number of associated injuries to the gastrointestinal tract (48.8%). Also, gastrointestinal contamination was present in all eight patients who developed intra-abdominal abscesses, the most common complication in this series.

Conclusions

Analysis of an extensive experience with vascular and cardiac injuries at one urban trauma center in 1982 leads to the following conclusions:

1. Civilian trauma in urban centers is now mainly associated with firearms.
2. Arterial injuries tend to be more extensive than in former years and segmental resection coupled with end-to-end anastomosis or insertion of substitute vascular conduits is now commonly performed.
3. Ninety per cent of venous injuries are now treated by lateral venorrhaphy or ligation.
4. Two-thirds of patients with cardiac wounds who arrive at the hospital with some sign of life will survive.
5. Improved salvage rates for patients with vascular or cardiac wounds will likely result from faster transport and better care in the prehospital phase and newer approaches to patients with "irreversible" hemorrhagic shock.

Acknowledgment

We thank Charlotte Jordan for her technical assistance in the preparation of this article.

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DISCUSSION

DR. NORMAN M. RICH (Bethesda, Maryland): It is frightening to think of the violent society in which we live, as emphasized in this report. Dr. Mattox, Dr. Feliciano, and their co-authors have produced another one of the outstanding reviews that we have learned to expect from Houston.

I would like to reflect a little historically, Ken, if I may. I have been told by our Chief Historian that Hippocrates said that anyone who wanted to be a surgeon should follow an Army. President Cohn outlined for us that Dr. Matas, who was President in 1911, said in an international meeting in 1913 in London that it was only during the time of warfare that young surgeons could benefit from the opportunity to treat a large number of similar injuries in a short period of time. The senior author of this paper, Dr. DeBakey, had one of the classic reports, along with Dr. Simeone, in 1946 from World War II, with 2471 acute arterial injuries.

Now we send our military medical students to the Ben Taub! It is frightening, isn't it? I am overwhelmed by the magnitude of this situation. Although Dr. Feliciano was kind enough to give me a copy of this paper, I have not had time to go back for a detailed review. I can tell you, however, that in Vietnam over an 8-year period surgeons like Dr. Arnold, Dr. Chandler, Dr. Rich, and others in this room contributed to an experience of managing approximately 7500 vascular injuries. There was no one hospital in 1 year that had as many vascular injuries as they have had at the Ben Taub during this 1 year reported.

I wonder whether we should start working on our societal structure more than our medical support of injured patients! I did not want to ask; but I am beginning to wonder, if we go to Houston, if we should get a Kevlar jacket? Will that give us more chance for survival?

Use of polytetrafluoroethylene (PTFE) has been one of the contributions that they have made in Houston in the management of some arterial injuries. We continue to differ in the military experience, and we still follow Lexer's "ideal operation" in 1907, if you will, and use the autogenous greater saphenous vein when possible. But we continue to learn from Dr. Mattox and his group, and we will follow their long-term results for the repair of arterial injuries with prosthetic material.

I am very pleased to see the aggressive effort to repair injured veins, recognizing that most of them are by lateral suture. This has been a change effected, collectively, by the experience of the 600 American-trained surgeons who served in Southeast Asia (1965-1972). If anything good came out of that experience, it was the emphasis to also repair injured veins, as well as injured arteries.

DR. GEORGE JOHNSON, JR. (Chapel Hill, North Carolina): I would like to take a moment to relate some observations on the general surgery training programs in the management of vascular trauma. As past Chairman of the Community Hospital Committee of the Board of Governors, American College of Surgeons, I heard the fears, as Dr. Edwards reported to you on Monday, of my colleagues in nonteaching institutions relative to vascular surgery, and specifically vascular trauma. They were afraid that with the current emphasis on vascular surgery the general surgery trainee might not gain sufficient experience in the management of vascular trauma.

Although I am a general surgeon who performs vascular surgery, I echo the concerns of The American Board of Surgery, as reported by Dr. Sawyers, that all general surgeons need to be able to manage these patients with vascular trauma, as reported by Dr. Mattox. The technical aspects of the operation may not be as difficult as an inflamed gallbladder or an operation on chronic pancreatitis, but the judgment in preoperative management is critical and has to be made rapidly.

From what I have seen, the general surgery trainee throughout the United States does manage vascular trauma in our training programs. We need to be sure that it stays that way.

The group at Houston deserves special credit for reporting to those

of us who do not have this enormous experience, the systematic approach that they have developed in the management of these patients. They have correctly emphasized the necessity of developing a prehospital, as well as an intrahospital, management plan, ones that we should have in each of our communities.

Dr. Mattox reports increasing numbers of patients seen with vascular injuries. We are seeing the same in North Carolina. Whether this represents an increase in the incidence or increasing referral to trauma centers is not clear.

I think we all recognize that this is an epidemiological study and a report of a patient management system, and it is appropriate that they do not dwell on results. These depend on the etiology and associated soft tissue and bone injuries. Thus, the close-range shotgun injury is a difficult management problem; whereas, the simple knife laceration to the same vessel can be straightforward. Likewise, the injury from a high-velocity *versus* a low-velocity missile to the same vessel will give different results.

I, as Dr. Rich and others, am very impressed with their courage and good results in using a plastic vascular conduit in these patients with extensive soft-tissue injury and frequent contamination.

When 400 cases of a disease entity are reported from a 1-year experience, a number most of us will not see in our entire career, it is foolish for a discussant to make any substantive critical comment. We North Carolinians are more peaceful people.

DR. LEWIS M. FLINT, JR. (Louisville, Kentucky): I think Dr. Feliciano and his associates have described to us a marvelous clinical experience and have correctly identified three factors critical to survival: that is, recognition of injury, treatment of shock and hypoxia, and avoidance of delay. I admire their accomplishments, and I think those of you in the audience who have been privileged to hear Dr. Feliciano's work, as well as Dr. Fabian's work yesterday, will join me in being encouraged that the level of clinical inquiry by young trauma surgeons is going in the right direction.

I must admit that I am a little disappointed in the paper, however, in that the authors have chosen to tantalize us with a description of what they have done, and really not told us how they did it. I have some questions about the judgments involved in the peripheral vascular injuries.

Our experience has been somewhat different than the Ben Taub experience, and much smaller, as almost everyone's experience is, since we find that autogenous tissue is available for reconstruction in over 90% of our patients, and have not used polytetrafluoroethylene (PTFE) prostheses except on rare occasions. I would ask, then: How is the decision to use PTFE as a conduit made? Specifically, if the patient has combined intestinal injury and vascular injury, would PTFE be chosen as a conduit?

Second, what is the current long-term result in patients with PTFE grafts? As I recall the presentation made at the trauma meeting this fall, the long-term follow-up was less than 30%. Had this improved over time?

And finally, if one recognizes that the follow-up is not as good as in elective operations, would a patient who developed either an abdominal or a soft-tissue abscess who had a PTFE conduit in place be treated any differently than if such an infectious complication had not surfaced?

DR. HENRY LAWS (Birmingham, Alabama): I too am awed by this vast experience. I can tell you, we in Alabama are very peace-loving. As a consequence, I would like to comment on one aspect of this paper, which is blunt trauma to the heart.

(Slide) Our experience in Birmingham was reported to the American Association for the Surgery of Trauma some time ago. We had seven injuries to the heart from blunt trauma, with five survivors. One survivor