Definitive Control of Bleeding from Severe Pelvic Fractures

LEWIS M. FLINT, JR., M.D., ANGELETTA BROWN, M.D., J. DAVID RICHARDSON, M.D., HIRAM C. POLK, M.D.

Forty patients with severe pelvic fracture and extraperitoneal hemorrhage were reviewed. Eighteen patients seen prior to 1975 (group I) were clinically similar to 22 patients seen subsequently (group II). Major pelvic fracture hemorrhage was defined as bleeding in excess of 2,000 ml over and above initial resuscitation volumes. Ten of 22 group II patients met the criteria for continued extraperitoneal bleeding and were immobilized in an inflatable G-suit after surgically remediable lesions had been excluded. Ventilator support and hemodynamic monitoring were instituted and clinical response recorded. Prompt cessation of bleeding was observed in nine of ten patients. One patient required selective catheterization of a bleeding artery with subsequent embolic occlusion. Significant reductions in overall mortality and the frequency of shock related death were observed in group II patients. Sepsis was the leading cause of late death in survivors. Immobilization of pelvic fracture patients in the G-suit is recommended as a means of controlling continuing retroperitoneal hemorrhage when surgically correctable bleeding points have been dealt with. Failure of patients to respond promptly to the G-suit strongly suggests arterial bleeding amenable to selective catheterization and embolic occlusion.

From the Department of Surgery, University of Louisville School of Medicine Health Sciences Center, Louisville, Kentucky

U NRELENTING EXTRAPERITONEAL HEMORRHAGE remains the major source of mortality in patients who sustain serious pelvic fractures. Pelvic fracture is frequently a result of vehicular, auto–pedestrian, motorcycle and industrial accidents and is second only to skull fracture as the most common injury to bone documented in patients who die following automobile accidents.[2] Although the disability following this injury is significant due to the pelvic fracture itself and associated multisystem injuries, the immediate threat to life is hemorrhage. Rothenberger and associates[12] reported that of 26 patients who died primarily of pelvic fracture, 18 exsanguinated within the first nine hours after hospital admission. Exsanguination is a particular danger when there are multiple fractures of the pelvic ring.[4] Not unexpectedly, the morbidity and mortality from pelvic fractures increases greatly with the need for multiple transfusions.[9,13]

Postmortem dissection and injection studies of hypogastric arteries following fatal pelvic fractures demonstrate that multiple lacerations of small and medium sized arteries and veins occur, giving rise to persistent hemorrhage.[3] Single vessel injuries are infrequent. Because the pelvic retroperitoneum has abundant collateral vessels, occlusion of a single inflow-trunk such as the hypogastric artery has little effect on the total blood flow into the pelvis.[8] These dual factors, multiple injured vessels and rich arterial collateralization, account for the failure of standard operative approaches to lessen early mortality due to hemorrhage.

Several reports of successful identification of bleeding sites using angiography with subsequent control following balloon occlusion or embolization are encouraging, but this approach has not been widely applied.[5,7] The usefulness of such techniques may be limited by availability of qualified personnel and facilities. Because of an increasing frequency of pelvic fracture as a major cause of morbidity and mortality on our trauma service, we began in 1975 to evaluate the use of the external compression device (G-suit) as a means of immobilizing the fracture and controlling pelvic retroperitoneal hemorrhage.

Materials and Methods

Since September 1, 1975, we have rapidly evaluated each patient with pelvic fracture by clinical and roentgenographic means in an attempt to grade the severity of the fracture and the likelihood of severe retroperitoneal hemorrhage. A group of patients at high risk because of pelvic fracture have been identified as those incurring: 1) at least two major fractures of the pelvic ring; 2) unstable pelvic fractures disclosed by physical examination; 3) crushing injuries, defined as multiple comminuted fractures of the pelvic ring involving both hemipelves; and 4) large posterior fractures. The treatment protocol outlined in Table 1 is employed in such patients.

TABLE 1. *Treatment Protocol Employed in High Risk Pelvic Fracture Patients*

Identify high risk pelvic fracture	
Multiple ring	
Unstable	
Crushing injury	
Resuscitation	
Multisystem evaluation	Cystogram
Genitourinary injury	→ Urethrogram
Intra-abdominal injury	→ Upper midline peritoneal lavage
Blood replacement <2,000 ml/8 hr	→ Standard Therapy
Blood replacement >2,000 ml/8 hr	→ G-Suit
Continued bleeding post-G-Suit application	→ Angiography and selective embolization

Patients are admitted to the operating room and resuscitated from hypovolemic shock using multiple large bore catheters placed in upper extremity veins. Long bone fractures are splinted and vigorous efforts are made to exclude major intrathoracic and intra-abdominal injuries. A modification of the standard infraumbilical peritoneal lavage technique is generally employed, utilizing instead an *upper* midline approach in order to avoid false positive results which often occur if the retroperitoneal hematoma is entered. Because of the frequent association of concomitant urinary tract injuries, intravenous pyelography and cystography are performed routinely to detect genitourinary injuries. Urethrography is also utilized when urethral bleeding or obstruction to passage of a bladder catheter is encountered. Once the pelvic fracture has been identified as the primary source of hemorrhage and other injuries have been appropriately treated, the patient is transferred to the intensive care unit for monitoring and further therapy. Symptoms of continued bleeding and the necessity for transfusion of more than 2,000 ml of blood in the eight hour period after initial resuscitation dictate the use of an external compression–immobilization device (G-suit). These guidelines were selected because most patients with less severe pelvic fractures will spontaneously cease bleeding and become hemodynamically stable with a blood loss less than 2 l. However, in patients who require more than 2000 ml in eight hours, bleeding usually continues with a resulting high mortality if the hemorrhage is not controlled.

In patients with continued bleeding, the Jobst® antishock trouser is applied to both lower extremities and the lower torso. The extremity compartments are inflated to 50 mmHg and the abdominal compartment to 40 mmHg. The skin is observed frequently for signs of pressure necrosis. Arterial pressure, central venous pressure, arterial gas tensions, urine output and continuing transfusion requirements are monitored hourly. An endotracheal tube is inserted, and the patient is

maintained on a mechanical ventilator. If the patient is hemodynamically stable without the need for continuing blood replacement after eight hours, the G-suit is decompressed but left in place. If no further evidence of bleeding occurs in the ensuing 12 hours, the suit is removed. Coagulation factors are carefully monitored throughout this crucial period with appropriate correction of factor deficiencies with fresh frozen plasma and/or platelets.

Failure to achieve hemodynamic stability within two hours after application of the G-suit suggests a major arterial injury, and selective pelvic angiography to identify the bleeding site is then performed. Once identified, embolization is employed in an attempt to occlude such bleeding points.

We recently reviewed the records of 22 patients treated since 1975 according to the protocol described. The results obtained with this group of high risk patients were compared to similarly injured patients treated from August 1968 through August 1975. For the purposes of data analysis, all patients were divided into: group I, those severely injured patients treated prior to the introduction of the protocol outlined above; and group II, those patients treated since the protocol was begun. The groups were compared in terms of severity of fracture and frequency of hemorrhagic shock (defined as an admitting arterial systolic pressure less than 80 mmHg with clinical signs of hypovolemia). The mode of injury and frequency of associated injuries were examined. Comparative differences in shock-related mortality and overall mortality were determined, utilizing chi square analysis.

Results

Since January 1, 1968, 540 patients have been treated for pelvic fracture. There were 18 patients in the pre-1975 group (group I) who met the criteria for severity of injury. Twenty-two similarly injured patients have been treated since 1975 (group II).

The demographic characteristics of the two treatment groups studied are similar. Half of the group I patients were men while 40 per cent of the group II patients were men. The age range in both groups was 16–84 years and was similarly distributed in each group. Vehicular accidents and auto–pedestrian collisions were frequent modes of injury in both groups (Fig. 1).

All three patients in this series older than 65 years sustained pelvic fracture as a result of auto–pedestrian mishaps, a previously described significant risk factor for this age group.[2] In group II patients, motorcycle accidents assumed a major role as a mode of injury. All of the 40 patients had clinically unstable fractures
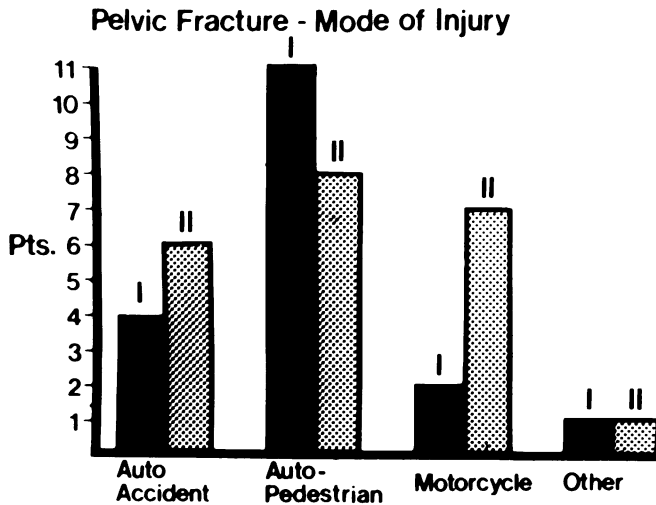
Pelvic Fracture - Mode of Injury

FIG. 1. Depicts incidence of mode of injury in groups I and II.

TABLE 2. *Injuries Associated with Pelvic Fracture*

Injury	Group I	Group II
Pleuropulmonary	7	9
Musculoskeletal	7	7
Major anorectal	5	6
Genitourinary	4	4
Central nervous system	3	3
Intra-abdominal	4	2
Cardiovascular	3	2
Miscellaneous	3	2
Peripheral nerve	2	1

on physical examination. Twenty-three patients, 11 in group I and 12 in group II, had lacerations which communicated with fracture sites representing open pelvic fractures. Thirteen patients in the entire series, six in group I and seven in group II, had crushing injuries of the pelvis with multiple comminuted fractures involving both hemipelves. Hemorrhagic shock was present on admission in 30 of 40 patients. Fourteen were in group I and 16 in group II.

Associated injuries were frequent and are listed in Table 2. Major intra-abdominal injuries requiring operative repair were encountered commonly, but the diagnosis of intra-abdominal injury was occasionally difficult to confirm. Peritoneal lavage using an infraumbilical approach was initially employed on our service as a means of diagnosing intra-abdominal hemorrhage and was the main diagnostic modality in six patients. In three of these six patients, no intra-abdominal injury was encountered, rendering a false positive rate of 50%. Laceration of the anteriorly dissecting extraperitoneal hematoma with the dialysis catheter was responsible for the bleeding in all three false positive lavages.

Records were reviewed in an attempt to identify the major hemostatic modality utilized in each case. The relationship between the treatment modality employed and subsequent mortality is illustrated in Table 3. In group I, transfusion alone was frequently relied upon to manage severe extraperitoneal hemorrhage. Eleven patients were so treated; six died. In the patients treated since initiation of the protocol, seven of 22 stopped bleeding spontaneously and did not require the G-suit. One patient who died is included in this group because no other treatment modality save transfusion was employed. He was admitted in full cardiac arrest from massive hemorrhage combined with

a severe neurologic injury and died before the G-suit could be applied. Hypogastric artery ligation was rarely successful. Four patients from group I had this procedure performed and three died. In group II, two patients underwent hypogastric artery ligation with one death. This procedure was performed in both patients because of external bleeding from an open pelvic fracture.

Attempts to open retroperitoneal hematomas operatively were unsuccessful because of torrential hemorrhage in all six cases. Packing of the pelvis was necessary in three patients in group I and one patient in group II.

The G-suit was utilized in ten patients in group II with no deaths. Hemorrhage persisted in one patient after initial placement of the G-suit. Subsequently, he underwent angiography and selective embolization of a single bleeding vessel. A second patient, admitted at a time when the G-suit was unavailable, had primary angiographic control of a branch of the internal pudendal artery.

Mortality rates for the two groups are illustrated in Table 4. The reductions in overall mortality and in shock related deaths are statistically significant.

TABLE 3. *Hemostatic Measures After Pelvic Fracture*

	Group I		Group II	
	Number of Patients	Deaths	Number of Patients	Deaths
Transfusion alone*	11	6	8	1
Hypogastric artery ligation	4	3	2†	1
G-Suit	0	0	10	0
Angiography-embolization	0	0	2	0
Packing	3	2	1	0

* The therapy for these groups differs in that patients in group I had only operative intervention available as an alternative. If patients in group II failed to stabilize with transfusion alone they were treated with the G-Suit and/or angiography.

† Both operations necessitated by external bleeding that communicated with the pelvic fracture.

TABLE 4. *Pelvic Fracture—Mortality*

Group	Number of Patients	Deaths	Patients Admitted in Shock	Death from Hemorrhage
I	18	12 (67%)	14	9
II	22	6 (27%)*	17	2†

*p < 0.05. † p < 0.01.

TABLE 6. *Morbidity After Pelvic Fracture*

	Group I	Group II
Respiratory failure	2	5
Infected hematoma	3	5
Pulmonary embolus	1	2
Renal failure	1	1
Urinary fistula	0	1

Causes of death in the 17 patients who died are listed in Table 5.

Complications were frequent in surviving patients and these are tabulated in Table 6. Respiratory failure and infected hematomas frequently coexisted, representing the unique relationship betwen infection and respiratory dysfunction. Significantly pulmonary embolus was encountered in three patients and led to the death of one. Acute tubular necrosis and persistent urinary fistula were each encountered in one patient.

Meaningful comparisons in transfusion volumes between groups I and II were not possible because nine group I patients died within 14 hours after admission. The majority of group II patients survived and required multiple transfusions in their continuing care and for further reconstructive procedures. However, in the first 18 hours after admission those patients treated with a G-suit required an average of 4,000 ml transfusion while group I patients required 6,200 ml of blood.

No complications occurred from the use of the external compression suit and, using the precautions outlined, we did not observe skin blistering or declamping hypotension. There were no complications related to the angiographic procedures.

Discussion

The frequency of severe pelvic fractures is increasing in our institution and seems to be related to an increased number of motorcycle accidents. We have been extremely frustrated by our previous attempts to control bleeding operatively, either by bilateral hypogastric artery ligation or by isolation and ligation of a single bleeding vessel. We therefore sought different methods to manage bleeding in these patients. Our experience with severe pelvic fractures is not unlike that reported by Rothenberger and associates.[12] They re-

TABLE 5. *Cause of Death in 17 Patients*

	Group I	Group II
Exsanguination	9	2
Infection	1	1
Respiratory failure	1	1
Head injury	0	1
Pulmonary embolus	1	0

ported that 84% of 26 patients who died as a result of the pelvic fracture itself died of hemorrhage initially or of late pelvic sepsis. They also observed that, of fatalities in their series, only six of 72 were the result of a single bleeding pelvic vessel that was potentially controllable by operative or angiographic measures.

Limitation of hemorrhage around fracture sites depends upon immobilization of the injured area and apposition of bone edges. The G-suit has two potential advantages in the treatment of such fractures: 1) it allows for compression of the pelvic area which may tamponade venous and small arterial bleeding, and 2) it provides for immobilization of the fracture. Batalden and associates[1] evaluated the use of the G-suit for severe pelvic fracture in 1974 and reported that the device was effective in controlling hemorrhage, but patient mobility and access were limited by the full body suit. The lower extremity torso suit utilized in our patients provides effective immobilization of the fracture site while allowing unlimited access to the patient. In addition, the G-suit improves hemodynamics and leads to early control of hemorrhage. Our experience indicates that improvement in arterial pressure, cardiac output and urine production are noticeable within 30 minutes after application. Patients who are bleeding from major arterial lacerations are easily identified because the G-suit does not provide hemodynamic stability within the first two to three hours after application in these cases. Such patients are taken to the angiographic suite with the G-suit in place and selective angiography is performed to identify the bleeding point. Embolization of the bleeding vessel has been useful in two of our patients. Our data indicate that mortality related to bleeding and shock has been significantly reduced.

The use of historical controls to compare survival data must always be carefully evaluated to avoid bias and inaccurate conclusions. However, the patient data (*i.e.*, severity of fracture, number of patients in shock, etc.) presented indicate that both groups were equivalently injured, and the improved survival is likely due to our use of the treatment modalities described. Using this approach, we have been able to effectively obviate the need for opening pelvic hematomas to control bleeding. The only two patients in group II who required hypogastric artery ligation had external hemor-

rhage through soft tissue lacerations that communicated with the pelvic fracture.

After early survival is assured, patients with severe pelvic fracture are subject to numerous complications. Atelectasis and pneumonia are frequent. Trunkey and associates[14] reported that respiratory failure was the most common cause of late death in their patients. They emphasized that vigorous efforts to prevent atelectasis and pneumonia were necessary to assure favorable outcome. Patient access and mobility are unhindered with the G-suit in place, and patients may have respiratory care conducted easily. The application of the G-suit and inflation of the abdominal portion of the device does reduce ventilatory exchange, however, and adjuvant ventilator support was necessary in all ten patients in whom the G-suit was used. Sequential monitoring of arterial gas tensions, tidal volumes and vital capacities is necessary to identify patients who will require ventilator support. Change of patient position utilizing the Stryker frame or other such devices is possible while the G-suit is in place.

Ravitch[10] has emphasized that a potential disadvantage of the external compression device is the development of spurious hemodynamic improvement leading to a false sense of security and the overlooking of a surgically approachable lesion. For this reason, we strongly encourage precise efforts to rule out major bleeding from correctable causes within the abdomen prior to application of the G-suit. Peritoneal lavage has been useful in detecting hemorrhage following blunt abdominal trauma. Three of six patients in whom peritoneal lavage was conducted to detect intra-abdominal hemorrhage had false positive studies. For this reason, we have modified our technique and presently insert the catheter through a small incision in the upper midline of the abdomen. Direct visualization of the peritoneal cavity is absolutely necessary in patients with pelvic fractures so that dissection of the hematoma anteriorly may be detected, and thus false positive results which arise from passage of the peritoneal dialysis catheter through an undetected anterior extraperitoneal hematoma may be avoided. By using such techniques, the false positive rate should be reduced. Exploratory laparotomy to correct any intra-abdominal pathologic state is undertaken as soon as such injury is detected, but opening of the retroperitoneum is avoided if possible. Following laparotomy, the G-suit may be applied without danger to the previous intra-abdominal operation.

The G-suit produces a relative ischemia of the lower extremities and the skin, but we have left the G-suit in place for as long as 48 hours without ill effect. Furthermore, in normovolemic patients we have not observed any evidence of hypotension secondary to declamping. Recurrent hypotension following deflation indicates recurrent bleeding. During our early experience, we removed the G-suit every four to six hours to examine the skin of the lower extremities and the lower abdomen to insure that blistering had not occurred. We have not been able to document any damage to the underlying skin as a result of the use of the G-suit at the pressures recommended. Thus, at the present time, we do not remove the G-suit until the patient has been hemodynamically stable without transfusion for eight consecutive hours, and until normovolemia is achieved according to clinical indices and other factors such as urine output, hematocrit and cardiac output. We frequently utilize the Swan-Ganz catheter and the thermal dilution cardiac output computer in such patients.

Coagulopathy has been frequently observed in patients receiving more than 5,000 ml of bank blood. The G-suit allows valuable time for preparation of specific blood components and subsequent correction of clotting defects.

Our experience with the G-suit indicates that it is easy to apply and provides adequate immobilization of the fracture without impeding access to the patient. The device is relatively inexpensive and durable. Permanent control of hemorrhage was achieved in nine of the ten patients who had the G-suit applied.

The G-suit is contraindicated in patients bleeding from intraperitoneal injuries because it may cause spurious improvement in hemodynamic variables leading to delayed treatment. Once applied, the G-suit is not removed unless preparations for dealing with recurrent hemorrhage have been made.

The presence of a laceration in proximity to a pelvic fracture indicates that the fracture is compound despite the fact that such lacerations may not always provide direct access to the fracture site. Lacerations in the perineum and perianal area are also indicative of compound fracture and indicate that fecal contamination of the hematoma has occurred.[6] In such patients, early diverting colostomy with washout of the defunctionalized segment is indicated. Frequent explorations of such lacerations with debridement and irrigation of the infected area are necessary to insure patient survival. Infection in the retroperitoneal hematoma is the most common cause of late death following pelvic fracture. Prevention of such infection through vigorous surgical debridement and fecal diversion is recommended.

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DISCUSSION

DR. G. RAINEY WILLIAMS (Oklahoma City, Oklahoma): I think both of these papers add valuable suggestions regarding treatment of this very difficult problem. Although my comments are primarily directed to Dr. Weems' paper, I'll be the first to say that I know very little about technical management of the urologic complications, and our urologists tell me that they agree with Dr. Weems.

Dr. Weems mentions that oftentimes the management of these difficult injuries is in the hands of orthopedic surgeons and, in the case of urologic problems, with urologic surgeons. In our own institution, any patient who has injury to more than one major organ system is managed by general surgery. Since we make absolutely no effort to perform the therapeutic maneuvers of surgical specialists, only to coordinate timing, they do not argue with this position. It causes a few more night calls, but I think it ensures improved care for the patient, particularly while the hemodynamic situation is unstable.

The second point is, I think everyone should take home from this meeting the concept that there are generally available improved methods for managing these injuries. The G-suit or MAST pants are now widely distributed. If you are not studying these patients, as Dr. Polk is doing, early application of the G-suit should limit blood loss, and we try to do this as early as possible, including applying the apparatus before admission to the hospital.

The early use of arteriography and embolizing technics when bleeding can be localized has proven valuable.

The last point I'd like to make is that when patients come in with the MAST pants in place, don't take them off.

DR. ELGIN W. WARE, JR. (Dallas, Texas): I would like to refer my remarks to Dr. Weems' paper. I would also like to congratulate him on this discussion of a practical problem of on-going significance.

Just two minor points regarding the diagnosis of urinary tract injury associated with pelvic fracture. First, in regard to the physical examination, rectal examination is usually done, if for no other reason than to ascertain the presence or absence of blood in the rectum; and in those cases of complete transection of the membranous urethra, the prostate may, obviously, be found to be riding high, and can be pushed higher still into the pelvis, unless already fixed by hematoma and edema.

Second, we often do the intravenous pyelogram first. Lamar didn't comment so much on this, but this study should always be done if the general condition of the patient permits to determine the status of the upper urinary tract, and oftentimes will provide sufficient information regarding the integrity of the urinary bladder itself to obviate carrying out an opaque cystogram subsequent to this.

We agree with Dr. Weems that attempted catheterization in the emergency room in those cases suspected of having urethral injury should be avoided, not only because of danger of introducing infection, but because such efforts can convert partial tear or transection into complete disruption of the urethra.

To speak to the title of Dr. Weems' paper, the only controversy, aside from the minor one of handling bladder injuries themselves, as I saw it, had to do with the management of complete transection of the membranous urethra. Specifically, as he has indicated, should attempts be made primarily to re-establish continuity of the urethra, or should simple cystostomy only be done with definitive urethral repair left to a later date?

Dr. Weems has outlined the pros and cons of these two concepts well, and although the number of cases he reports is somewhat small, the negligible occurrence of long-term complications, including stricture, impotence, and incontinence in those cases handled in two stages, would certainly tend to favor this method. Zero incidence of stricture and zero incidence of incontinence is pretty convincing.

It may be that the significantly higher figures for such complications in those cases treated with primary closure are somewhat skewed, owing to the fact that Dr. Weems' series were apparently taken from a regional referral hospital, where the more complicated cases tend to be seen.

I think it would be fair to say, however, that increasing numbers of series throughout the country tend to agree with Dr. Weems' implied results. We in Texas were first made aware of this method through the work of Dr. Kenneth McKinnon, of Canada, and although his early results in a somewhat larger series were not quite so impressive as Dr. Weems', they were sufficiently so to make the two-stage repair the standard method of handling these cases currently at our own University of Texas Southwestern Medical School in Dallas.

I would like to ask Dr. Weems three questions. First, were there any females in his series with bladder injuries? We have on occasion encountered tears of the urinary bladder into the vagina, with, in one case, at least, subsequent development of vesicovaginal fistula.

Second, does he always perform secondary repair of the membranous urethra perineally, or does he utilize an anterior approach, with or without symphysiotomy, on occasion?

Thirdly, does he offer the patient some type of penile prosthesis, such as the Small-Carrion, when impotence does, in fact, ensue as a long-term complication?

DR. KIMBALL MAULL (Richmond, Virginia): I know there are others who probably wish to discuss Dr. Polk's paper, but I do have several points to make, and one closing question and comment for the authors.

First let me say that this report is a major contribution in the management of a problem that up to this time has been largely insolvable.

(slide) Drawing upon a review of the University of Kentucky experience with 357 patients with pelvic fractures, reported originally