Pelvic Fracture: The Last 50 Years

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Abstract: The past 50 years have been a time of rapid progress in the control of mortality and morbidity of pelvic fracture. Early understanding of the anatomic features of the fracture and the potential for major, life-threatening arterial hemorrhage in a small proportion of patients led to multidisciplinary approaches designed to control hemorrhage and temporarily stabilize the fracture. Progress in the diagnosis and management of lower urinary tract injuries has resulted in maintenance of urinary continence and sexual function in a large proportion of patients with pelvic fracture-associated urinary tract injury. Finally, definitive open reduction and fixation of the fracture has led to permanent pelvic stability and pain-free walking in most patients. With successful combination of these approaches, survival and return to a satisfactory level of function is now the rule rather than the exception for patients with severe pelvic fracture.

Key Words: Pelvic, Fracture, Hemorrhage, Fixation, Genitourinary injuries.

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As the Journal of Trauma celebrates the 50 years of publication, it is appropriate to review the key developments in the management of pelvic fracture. It is safe to say that there is probably no other injury for which the treatment has undergone such an evolution as pelvic fracture, yet the successful treatment of pelvic fracture remains one of the most difficult clinical problems in the management of the injured. Fifty years ago, the importance of retroperitoneal bleeding associated with pelvic fracture and the difficulty of diagnosing and treating it was first being recognized and an active debate ensued regarding the relative merits of explorative death by exsanguination. Direct attempts at bilateral pelvic packing were complicated by the inability to identify discrete bleeding sources and often resulted in operative death by exsanguination. Direct attempts at bilateral hypogastric artery ligation had similar results. The classic postmortem studies of Huitinen and Slätsi demonstrated that pelvic bleeding usually comes from lacerations to several small- and medium-sized vessels within and around cancellous bone that would be almost impossible to find in a large hematoma with active bleeding. In addition, these studies showed that the retroperitoneal bleeding associated with pelvic fracture was most often from venous tributaries that should eventually stop bleeding if the hematoma was left undisturbed and only occasionally from an artery that probably would not. From these observations, the principle developed that pelvic retroperitoneal hematomas associated with pelvic fracture should not be explored and a search for alternative means to control hemorrhage ensued.

During the 1970s and 1980s, a new technology led to the development of three therapeutic modalities to treat pelvic fracture hemorrhage without opening the pelvic hematoma: the pneumatic antishock garment (PASG) has been replaced by various pelvic binders, external pelvic fixation, and angiographic embolization. Because the majority of bleeding in the pelvis is from multiple small veins and cancellous bone, the idea of splinting or compressing the pelvis was an attractive one. The PASG was introduced to accomplish this and was shown to be remarkably effective.5 External pelvic fixation was attractive because it could reduce pelvic volume and also stabilize the pelvic fracture, and this approach gradually replaced the PASG. Subsequently, several cadaver studies showed that the effect of external fixation on reducing pelvic volume was much less than previously thought with the result that today the PASG is virtually obsolete and external fixation has been largely replaced by a variety of temporary pelvic binders used only during the initial resuscitation phase of care. Although these techniques are quite effective for patients with venous bleeding, patients with arterial hemorrhage do not respond to wrapping techniques. Angiographic embolization of pelvic arterial bleeding was shown to be effective for these patients and associated with a low complication rate.6-9 This approach has been adopted as the preferred method for controlling persistent pelvic fracture bleeding by most trauma centers. The key to success of angiographic embolization remains the ability to have available, at all times, the appropriate personnel and equipment to perform the procedure in a patient with ongoing active arterial hemorrhage. The most formidable challenge remaining is the more than occasional need to treat bleeding arising simultaneously in more than one site. A variety of recent protocols have used intraoperative angiography, operative pelvic packing of the extra peritoneal pelvic retroperitoneum through the space of Retzius, and angiographic embolization of multiple sites to address this problem. The degree to which these techniques are used varies between institutions depending on available resources and it remains to be seen which will work the best.
The second major advance in the treatment of patients with pelvic fracture was the development of technology, allowing accurate reduction and fixation of the pelvic fracture. During the 1980s and 1990s, it became clear that open reduction and internal fixation of pelvic fractures had markedly superior functional results than either prolonged traction or external pelvic fixation. The latest developments include the use of percutaneous pin techniques, which limit the morbidity of posterior approaches to the pelvis. As a result, the principal issues currently facing pelvic fracture care are prompt management of other associated life-threatening injuries and limitation of morbidity from pelvic fracture itself. In the review that follows, we will provide additional detail relevant to the management of severe pelvic fracture emphasizing the contributions that have appeared in the Journal of Trauma.

**EPIDEMIOLOGY**

Pelvic fracture is encountered in ~10% of patients admitted to urban trauma centers in North America. Reported overall mortality rates for these patients vary, but there is a broad agreement that death as a direct result of the pelvic fracture occurs in <1% of the patients admitted with this injury. Pelvic fracture-related mortality occurs in <15% of patients who sustain pelvic fracture as a component of a multiple, severe injury pattern. Most patients with pelvic fractures are injured by blunt force impacts caused by motor vehicle crashes. Patients with heavy force transfer causing displaced pelvic fractures (that carry an associated increase in risk for pelvic fracture bleeding) are more likely to be injured because of auto-pedestrian collisions, motorcycle crashes, and falls from heights >15 feet. Important risk factors for increased mortality and morbidity risk because of pelvic fractures are increased patient age (due, at least in part, to osteoporosis); female gender (probably because of decreased resistance of pelvic bones and ligaments to forced disruption); and increased impact forces. Certain vehicle crash characteristics are also associated with pelvic fracture. These include lateral impacts, particularly when the striking vehicle is larger and heavier than the impacted vehicle and lack of restraint use.

**IMPORTANT ANATOMIC CONSIDERATIONS**

The pelvic ring is a major supporting structure in humans that permits bipedal walking in an upright posture. The ring is made up of three bones (right ilium, left ilium, and midline dorsal sacrum), which are held together by strong ligaments. The iliac bones are formed by the fusion of the embryonic iliac, ischium, and pubic bones. The sacrum is an important component of the dorsal axial skeleton. The acetabula, bony complexes where the hip joints articulate bilaterally, are anatomically part of the pelvis, but fractures of these structures will not be discussed in this section. Major neural, vascular, and visceral structures reside within the bony pelvis and within the sacrum. These include the rectum, bladder, vessels of the iliac, obturator, femoral arterial and venous systems, internal reproductive organs in women, and portions of the lower urinary tract in men. The distal branches of the spinal motor, sensory, and autonomic nerves are located within the sacrum and enter the pelvic visceral space via the sacral foramina. Pelvic fracture hemorrhage can occur because the arteries and veins of the internal iliac system and the presacral venous plexus are located just anterior to the ligaments that bind the iliac bones to the sacrum and are, therefore, subject to injury by forces that disrupt these ligaments. Motor and sensory nerves, particularly the sciatic, femoral, and obturator nerves, are vulnerable to injury because of proximity to the pelvic bones and ligaments. Autonomic nerves supplying the reproductive organs are found in these same areas. Therefore, it is not surprising that neurologic injury gives rise to painful walking; paresthesias, muscle weakness, and sexual dysfunction are the most important sources of long-term disability after pelvic fracture. The proximity of the bladder and urethra to the anterior components of the pelvic ring exposes these structures to injury when there are fractures of the pubic bones.

**PELVIC FRACTURE CLASSIFICATION**

The most frequently used pelvic fracture classification system is the one modified and published by Burgess et al. This system grades pelvic injury based on the estimated direction of the major force vector (lateral compression, anterior compression, vertical shear, and combined) and the degree of bony displacement. Displacement of pelvic skeletal elements is a function of fracture of the bones and disruption of the ligaments of the pelvis. In general, vascular injuries that produce pelvic hemorrhage tend to cluster in the groups of fractures associated with the largest degree of bony displacement as determined by plain pelvic radiograph or computerized tomography imaging. However, fracture classification has limited utility in predicting the risk of bleeding for individual patients because, as noted by Sarin et al., a significant proportion of patients with high-grade pelvic fracture do not have pelvic fracture hemorrhage. Conversely, ~50% of patients with significant pelvic arterial hemorrhage have relatively minor appearing nondisplaced fractures at the time of pelvic x-ray. For the surgeon evaluating and setting management priorities for patients with high-impact trauma resulting in pelvic fracture, a composite approach that includes assessment of injury mechanism, physical examination, and physiologic data indicative of significant, ongoing bleeding and imaging will be necessary to identify patients who have ongoing pelvic fracture-associated bleeding.

**INITIAL ASSESSMENT OF PATIENTS WITH PELVIC FRACTURES**

As mentioned earlier, most patients who sustain pelvic fractures have only minor injuries. As understanding of the risk for significant pelvic fracture has become more refined, data have been presented that supports a selective approach to imaging of the patient who is awake, alert, and able to cooperate in a physical examination. Computed tomography (CT) imaging has been shown to be a very sensitive means of detecting pelvic fractures and identifying the wide variety of potential associated injuries that often accompany the pelvic fracture and have
become indispensable in the care of these patients. In recent experience using rapid multislice helical scanners, head to pelvis images can be obtained rapidly in intervals of 5 millimeters to 7 millimeters. Computer-assisted reconstructions of these images can provide high-resolution views that can guide plans for operative interventions needed for pelvic reconstruction and other associated injuries. There are recent data from an analysis of patients in a European trauma registry that suggest incorporation of whole-body CT imaging into the initial resuscitation of severely injured patients is associated with improved survival. This observation is particularly pertinent for patients with evidence of ongoing hemorrhage when the pelvic fracture adds a potential bleeding site that may be treated more effectively in the angiographic suite rather than the operating room. Relying on the ultrasound Focused Abdominal Sonography for Trauma (FAST) examination to make this determination can result in the patient ending up in the wrong place because of its poor specificity. However, careful clinical judgment and a full understanding of the imaging capabilities of each individual institution are necessary to support the decision to transport a potentially unstable patient to the CT scanner.

DETECTION AND MANAGEMENT OF INJURIES TO THE LOWER URINARY TRACT

Fractures of the pubic bones are often associated with injuries to the lower urinary tract. Bjurlin et al. recently found that of 1,400 patients with pelvic fracture in the NTDB, ~4% had a bladder injury and 2% had a urethral injury with males having twice the incidence of each injury than females. Bladder rupture usually occurs because of anterior compression forces transmitted in a ventral to dorsal direction or from lateral compression forces that displace the pubic bone in a lateral to medial direction catching the bladder wall on the bone ends. Straddle injuries and forces that produce thigh abduction are important causes of perineal trauma and urethral injury. Urethral injury is a common complication of pelvic trauma that, if untreated, may lead to significant long-term morbidity. Segments of the urethra that are near the pubic rami and the puboprostatic ligaments are particularly vulnerable, and the injury usually occurs at the junction of the membranous and bulbourethra. Careful physical examination of these patients searching for signs of injury is paramount. The examination should seek out suprapubic pain and tenderness, perineal ecchymosis, laceration, and/or tenderness, blood at the urethral meatus, and blood or periprostatic hematoma discovered on digital rectal examination. Urethral injury is not confined to male patients only! In women with suspected pubic bone fractures, vaginal examination to examine the urethra for blood or laceration is necessary. The physical examination, although valuable, is not foolproof. A significant proportion of patients found to have urethral injury will not have positive physical findings. A cautious attempt to place a bladder catheter is indicated. If resistance is felt, a retrograde urethrogram is performed. Although CT is commonly used for the initial imaging evaluation of patients with multiple injuries, urethral injury is better assessed and classified by using urethrography. Complete urethral imaging is especially important at presentation because the insertion of a transurethral bladder catheter may exacerbate an existing injury (e.g., cause a partial urethral tear to become a complete transection). In the acute setting, when a posterior urethral disruption is suspected, retrograde urethrography should be performed. Posterior urethral disruptions can be managed acutely by realignment of the urethra over a urethral catheter or by placement of a suprapubic catheter for bladder drainage only. If the latter approach is chosen, the distraction defect between the two ends of the urethra often scars and becomes fibrotic, blocking the urethra and bladder emptying. Once fibrosis has stabilized, the patient can undergo posterior urethroplasty. In most cases, this procedure can be performed via a perineal approach in a single-stage surgery. The results of this single-stage perineal urethroplasty are excellent, and a patent urethra can be reestablished in the majority of men who undergo surgery.

Although suprapubic cystostomy and delayed repair of the urethral disruption are time-honored approach, clinicians now understand that it takes many months for the fibrotic stricture to stabilize and the long-term presence of a suprapubic catheter delays or even prevents definitive open reduction and internal fixation (ORIF) of the pelvic fracture. If ORIF of the pelvic fracture is delayed or cannot be done, significant disability because of pain on walking is the result. In a recent study, Hadjizacharia et al. showed that patients undergoing immediate endoscopic repair had an average time to spontaneous voiding of 35 days compared with 229 days for patients undergoing delayed repair and had a significantly decreased rate of stricture formation (14% vs. 100%). Moreover, all patients with delayed therapy required formal surgical urethroplasty, whereas the two patients with strictures after early endoscopic realignment required only outpatient clinic dilatation.

Data are also clear that early realignment of the disrupted urethra in men and early definitive repair of the injured urethra in women are both associated with improved long-term sexual function. For these reasons, early, expeditious diagnosis and realignment of urethral disruptions with avoidance of suprapubic catheterization are preferred. Injury to the bladder neck in association with a disrupted prostatic urethra is a particularly troublesome rare injury that can lead to chronic incontinence if not identified early and has recently been successfully managed with implantation of an artificial sphincter.

Gross hematuria discovered after spontaneous voiding or after insertion of a Foley catheter is the most common sign of bladder injury. CT cystogram with distended bladder and postemptying views has replaced the traditional retrograde cystourethrogram for the diagnosis of bladder injury. Extraperitoneal bladder ruptures can usually be managed with bladder drainage only unless the patient is going to have abdominal exploration for other reasons in which case, accessible bladder tears may be directly sutured. Intraprostatic rupture of the bladder is an indication for abdominal exploration and suture repair of the bladder. Laparoscopic bladder repair has been reported, but there are not enough data available to analyze the real value of this approach.
PERINEAL INJURY AND OPEN PELVIC FRACTURE

Open pelvic fracture is a particularly troublesome problem to deal with because the associated perineal laceration may involve the anus, rectum, vagina, and urethra and direct communication with the pelvic fracture site can lead to early decompression of the pelvic hematoma and exsanguination or contamination of the pelvic hematoma, leading to sepsis and multiple organ failure. Moreover, later contamination of the fracture site or pelvic hematoma is possible because of transmural laceration of the vagina or rectum or fecal soiling of the laceration when bowel activity resumes. Careful digital rectal examination with selective sigmoidoscopy (either rigid or flexible) will often disclose the extent of injury and allow an estimate of the risk for contamination and fecal soilage. Vaginal lacerations should be repaired. When injured, the anal sphincter complex should be reapproximated to the degree possible. Large complex wounds should undergo daily debridement and pulse irrigation in the operating room until bedside dressing changes can be tolerated. Diverting colostomy may be necessary to prevent septic complications and when indicated should be performed within 48 hours of injury. Open pelvic fractures with lacerations in the groin or pubic area carry a much lower risk of fecal soilage and colostomy will usually not be needed in this situation.

DETECTION AND MANAGEMENT OF PELVIC FRACTURE HEMORRHAGE

The most challenging patients with pelvic fracture are those who arrive in hemorrhagic shock. The presence of a pelvic fracture in the hemodynamically unstable patient adds another important source of bleeding to all the other potential sources of hemorrhage associated with high-force blunt injury. Significant blood loss from pelvic fracture is possible because of the rich arterial and venous channels within the pelvis, the plentiful blood supply of the pelvic bones, and the fact that tissue pressure within the pelvic retroperitoneum is low, permitting accumulation of substantial volumes of blood before tissue pressure rises sufficiently to tamponade bleeding. Life-threatening hemorrhage can occur because of disruption of the branches of the internal iliac artery within the pelvis. Branches of the internal pudendal artery are commonly the source of bleeding in these patients. Detection of bleeding sufficient to justify intervention is based on physiologic variables indicative of ongoing bleeding, the fracture pattern disclosed on pelvic imaging, and the presence of associated significant injuries. Pelvic fracture hemorrhage occurs in the setting of major force transfer. This usually means that the surgeon is confronted with several potential bleeding sites necessitating rapid assessment. Unfortunately, there is no definitive way to analyze whether pelvic fracture bleeding is present without either going to CT scan or operative exploration. Major cavitary bleeding in the chest can usually be identified or excluded with plain anterior-posterior chest radiograph. FAST ultrasound examination is the initial rapid test used to assess for intraperitoneal bleeding. If FAST ultrasound discloses intraabdominal fluid, then there is usually intraperitoneal source of hemorrhage. Intraperitoneal bladder rupture can lead to a false-positive test, and occasionally, the blood is actually from a ruptured retroperitoneal hematoma. In addition, there may also be pelvic fracture-associated hemorrhage, which is the primary source of hemorrhage and is best treated in angiography. Nonetheless, in a patient with signs of ongoing blood loss (variable blood pressure, tachycardia alternating with intervals of bradycardia, hematocrit <30%, arterial pH <7.2 that is resistant to blood and fluid therapy) and a positive FAST examination, abdominal exploration is usually chosen as the primary intervention. Pelvic fracture bleeding is approached when abdominal sources have been controlled and/or a large or expanding pelvic hematoma is found at operation. Unfortunately, a negative FAST ultrasound examination does not rule out an intra abdominal source of hemorrhage and has poor specificity as an indirect test for pelvic hemorrhage. Ideally, a CT scan evaluation is performed, which can delineate all sources of hemorrhage and allow an informed plan of care to be developed. Unfortunately, as discussed earlier, not all patients respond sufficiently to resuscitation to allow a safe trip to CT scan in all institutions. If a patient is too unstable to go to CT scan and has a negative FAST examination, pelvic hemorrhage must be assumed and treated expeditiously. Later, repeat FAST ultrasound imaging can be done if no pelvic bleeding site is discovered or signs of ongoing bleeding persist even after pelvic bleeding is controlled.

The approach to pelvic bleeding is chosen based on the type of pelvic fracture, the resources available in the individual institution, and the rapidity of bleeding. The available approaches to pelvic fracture bleeding include measures to decrease pelvic volume and thus increase pelvic retroperitoneal tissue pressure (pelvic C-clamp, external fixator, or compression device), angiography with embolization, and pelvic gauze packing.

Significant pelvic fracture bleeding can occur from veins, bone edges, lacerated arteries, or combinations of these. Injuries to major pelvic arterial or venous trunks are unusual but occur occasionally and can be effectively managed with endovascular approaches. The more typical patient presents with anterior compression, vertical shear, or combined type pelvic fracture with disruption of one or both sacral-iliac ligamentous complexes. Separation of the pubic symphysis by >1 cm to 2 cm is the rule. The recognition that reapproximation of the separated pubic symphysis with a bed sheet placed around the pelvis just caudal to the anterior superior iliac spines reduced pelvic volume and controlled bleeding in a significant proportion of patients stimulated efforts to permanently achieve this with devices such as the pelvic C-clamp and external fixators. The pelvic C-clamp is applied to the dorsal iliac bones, and the external fixator is applied anteriorly. These devices are favored, variably, by trauma Orthopedic Surgeons. They can be applied in the emergency department, but many trauma Orthopedic Surgeons prefer to place these in the operating room. The need to transfer the patient to the operating room without assurance that the device will control bleeding has stimulated trauma surgeons to attempt other means of reducing pelvic volume.
The simplest of these approaches is the bed sheet described earlier. However, recently, a pelvic compression device (T-Pod Ping Medical, Richmond, British Columbia, Canada) has proven valuable for its ease of placement, lack of displacement with patient movement, and effective reduction of pelvic volume. A satisfactory response to pelvic volume reduction is signaled by stabilization of blood pressure and heart rate and improvement of acidosis. If these do not occur within 30 minutes to 1 hour of device placement, alternate approaches are indicated. Complications of pelvic compression include pressure injury to the skin and fracture overcorrection. Pressure injury to the skin can be avoided by removing the device within the first 36 hours after application or by periodically inspecting the skin for injury. Follow-up imaging will disclose overcorrection.

In most North American trauma centers, angiography with embolization is the approach preferred for patients with rapid pelvic fracture bleeding and/or an inadequate response to pelvic volume reduction. Guidance as to the general location of the pelvic bleeding site can be gained by observing contrast extravasation on the pelvic CT images. Pelvic contrast extravasation is associated with an angiographically demonstrated bleeding site in ~75% of patients. The choice of angiography and embolization means that the patient has to be transported to the angiography suite. This choice is not easily made by most trauma surgeons but the alternative, transporting the patient to the operating room for pelvic packing (discussed below) is not attractive either. It is critical that all of the resources available within the trauma operating room be available in the angiographic facility during the procedure. These include anesthesiology support, devices for the rapid infusion of blood and blood products, monitoring devices, and surgeon presence. Fortunately, this challenge is becoming less burdensome in many institutions because of a move to equip angiographic suites for elective and emergency endovascular procedures. If one or more bleeding sites can be demonstrated, embolization will usually control these and patient stability will result. Complications of embolization include gluteal muscle necrosis (infrequent) that may prevent or delay ORIF. Rectal necrosis is a rare complication resulting from bilateral internal iliac embolization.

Gauze packing of the pelvic retroperitoneum is an alternative for patients when angiographic embolization is not readily available. This approach has been used successfully in Europe and there have been reports of successful use of this approach in the United States. The approach that these authors describe uses a lower midline incision into the space of Retzius, the bladder is retracted, and gauze packs are positioned in the dorsal and lateral pelvic retroperitoneum. It is likely that similar exposure and access to the dorsal pelvic retroperitoneum could be achieved by unilateral or bilateral transverse incisions in the infraumbilical lower abdomen. A reduction in pelvic fracture mortality from 40% (historical comparison group) to 25% using retroperitoneal gauze packing complemented by angiography, and embolization has been reported by this group. Additional confirmatory clinical experience has not been forthcoming from other centers, to date, but a flexible, multidisciplinary approach to pelvic fracture bleeding has been shown to improve mortality attri-
posterior fixation involve sacral bars, larger plate configurations, and combinations of posterior and anterior internal fixation.

REFERENCES