## **Combat-Related Hemipelvectomy**

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Traumatic and trauma-related hemipelvectomies are rare and severe life-threatening injuries. Rapid hemostasis, early aggressive resuscitation, amputation completion, and wound debridement are the mainstays of initial treatment. Second-look debridements and delayed wound closure are mandatory. A multidisciplinary team is necessary in order to treat associated injuries as well assist with eventual rehabilitation. Adherence to specific treatment tenants outlined herein may minimize mortality and secondary morbidity, improving patient outcomes following these devastating injuries. (Journal of Surgical Orthopaedic Advances 21(1):38–43, 2012)

Key words: hemipelvectomy, trauma, combat trauma, war wounds, amputation

#### Introduction

Traumatic hemipelvectomies are rare, highly destructive open pelvic ring disruptions associated with extremely high-energy mechanisms of injury. Despite its rarity, there has been a slow but steady increase in the number of reported cases of this injury since its first described occurrence in 1945 (1). In 1989, there were 39 published survivors of this injury. By 2005, that number was believed to be 65 (2), suggesting an evolution in medical evacuation and resuscitative techniques over the years, making this a nonetheless devastating, but potentially more survivable, injury pattern. In the military, the severe

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nature of high-energy, explosive blast injuries has led to a number of combat-related hemipelvectomies over the last several years. Treating these injuries has advanced the level of understanding of these injuries at the authors' institution and fostered the evolution of treatment principles that may benefit the orthopaedic surgeon faced with a similar injury pattern in the civilian sector.

#### Presentation

While all of the combat-related hemipelvectomies performed at our institution were a result of blast injuries, the typical civilian mode of injury involves motor vehicles (2). Beal and Blaisdell (3) observed three main mechanisms of injury upon their review of the literature. The most common is responsible for over 40% of the reported cases (2), and occurs when an abducted lower extremity is forced into sudden hyperabduction and external rotation, as in the case of a cyclist getting struck in the knee by an oncoming vehicle. In this scenario, first described by Wade and Macksood (4), the hip is rapidly loaded axially, into further abduction and into external rotation, thus disrupting the symphysis and sacroiliac joints and avulsing the femoral and gluteal vessels. The next most common mechanism is a tractiontype avulsion of the extremity from a fixed residual pelvis. This occurs when the affected limb is entangled within the mechanisms of heavy machinery (3,5,6). Finally, a direct crush mechanism has been described as well (3). Together, these mechanisms account for virtually all of the trauma-related hemipelvectomies in the civilian medical literature.

The average age on presentation is 21 (range, 3 to 34) years (2), which not only underscores the vocational and recreational risk factors associated with the aforementioned injury mechanisms, but also suggests that patients must be physiologically robust in order to survive

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until presentation to the emergency department. The left hemipelvis is more commonly involved than the right (3), which may be due to the fact that most reported cases involve a hyperabduction mechanism of injury on American roads. In their review of the literature, Beal and Blaisdell observed that 21 of 38 traumatic hemipelvectomies reported at that time were incomplete (3). Complete avulsions of the hemipelvis cause an initial massive amount of bleeding, but the bleeding frequently stops spontaneously due to vessel spasm and retraction or can be managed with direct pressure (7). The presence of an incomplete injury, with the hemipelvis still connected to the axial skeleton with a soft tissue bridge, may predispose the patient to persistent hemorrhage, as torn blood vessels are prevented from fully retracting, and the presence of the avulsed extremity may be an impediment to obtaining adequate hemostasis (3.5,7). Crush injuries can cause hemorrhage that can be even more difficult to control (3). Associated injuries are common with this injury pattern. Urogenital and colorectal injuries are present 85% and 60%, respectively (2), the former typically involving the prostatic and membranous urethra.

The combat-related hemipelvectomies treated at our institution are universally the result of severe blast injuries and have been performed in delayed fashion (Fig. 1). Patients typically present 5 to 10 days after initial wounding, usually with existing very proximal amputation(s), frequently a hip disarticulation level, with concomitant open pelvic fracture. As the zone of injury continues to declare itself and wound necrosis continues to evolve, resection of some portion of the pelvic ring eventually becomes necessary. At times, this conversion has been made during the first debridement, as there are few options for treating a degloved innominate bone in the setting of profound wound necrosis or infection. In other instances, severe wound necrosis with advancing infection into the true pelvis or a paucity of soft tissue coverage subsequently requires a complete or partial resection of the hemipelvis. A pelvic ring-disrupting injury has uniformly been present, most commonly a disruption through the sacroiliac joint, but occasionally the point of failure has been a fracture through the acetabulum that involves both columns. In nearly all cases to date, the contralateral lower extremity has already sustained traumatic or undergone early proximal amputation. Extensive damage to the nondominant upper extremity is common as a result of the way weapons are typically carried on dismounted patrols (i.e., at the time of injury) with the non-dominant hand forward and lower. Collectively, this severe injury pattern involving both lower extremities and at least one upper extremity has proven typical of dismounted complex battle injuries, which have become common with the transition from mounted to dismounted patrols in the theater of operations.



**FIGURE 1** Intraoperative clinical photograph of a blast injury victim with a right open hip disarticulation with associated acetabular fracture. Residual soft tissue coverage is inadequate and the bone is grossly devitalized, necessitating hemipelvectomy.

#### Treatment

As with all open fractures and dislocations, prompt administration of broad-spectrum antibiotics and tetanus prophylaxis is of paramount importance (8), as sepsis is the most common source of mortality during hospitalization of patients that survive the initial injury and hemorrhage (3,7). Casual exploration of the wounds outside of the operating room should be avoided, as doing so may dislodge hematoma and early clot, thus exacerbating hemorrhage. Rather, direct pressure should be applied (3), in addition to aggressive resuscitation with blood products (6). Complete injuries may stop bleeding spontaneously from spasm and retraction of the vessels with subsequent thrombosis (9). These injuries also lend themselves to hemostasis under direct visualization or may require intra-abdominal control of the vasculature. Some bleeding may persist from the bone and soft tissues, prompting Siemens and Flint (10) to recommend the potential ligation of the contralateral hypogastric artery in that scenario. With incomplete or closed injuries, hemorrhage control may require the aid of angiography.

Early multidisciplinary consultation and care, as well as rapid resuscitation with whole blood or component therapy, is critical. A urologic surgeon should be consulted to evaluate for genitourinary injuries as well as for the potential need for a suprapubic catheter. The general surgery service should be present as well, not only to assess for colorectal injuries but also to be available for retroperitoneal access to the vasculature. A diverting colostomy with a distal colonic washout or flushing should be performed as a matter of course, as fecal contamination of the wound is otherwise inevitable (2).

In general, one should proceed with early completion of hemipelvectomies when practicable, as doing so may lower the complication rate associated with these injuries (2,3,11). The involved lower extremity is typically both non-viable and neurologically impaired, if not absent. Completion of the amputation permits better access to bleeding, contamination and necrotic tissue. Since sepsis, often secondary to multi-drug resistant organisms (MDRO) and fungus or mold, is the most common early cause of mortality in this patient population (3,7), the first priority after controlling hemorrhage should be the aggressive debridement of the wound. The amount of tissue necrosis is easily underestimated, and attention should be paid to the iliopsoas, quadratus lumborum, and retroperitoneal and paraspinous muscles (2,3). Maintenance of an unsalvageable but partially perfused distal extremity also places the patient at risk for a deadly triad of coagulopathy, acidosis, and hypothermia. For these reasons, it is recommended to complete the amputation as early as possible in the treatment course (2-4,6,7,11,12). Eventual coverage options are typically sparse, so it is important during this step to perform an open, lengthpreserving amputation, preserving any viable tissue that might be incorporated into atypical local fasciocutaneous or myocutaneous fillet flaps. If the patient is well enough to tolerate a free tissue transfer at the time of amputation completion, distal tissue in the lower extremity may be used for the donor site. However, thoughts of this process should only be entertained if the wound is ready for closure and no further visits to operating room are foreseen. Additional procedures, such as debridements immediately after or shortly following free tissue transfer, may jeopardize microvascular anastomoses and is generally best avoided following free tissue transfer.

In our patient population, the injuries have been uniformly blast-related, leading to a broader, more proximal, and more severe level of soft tissue injury. Moreover, nearly all of the combat-related hemipelvectomies at our institution have had contralateral amputations, almost all of which were at a transfermoral level or higher. Between the contralateral amputation and the patients' overall injury severity, the period of bed rest and relative immobility is protracted. As a result, we have observed a high rate of partial or full-thickness pressure ulcers over the sacrum. Accordingly, while we are very aggressive about completion of amputation, we generally attempt to preserve most or a portion of the ilium, rather than performing a sacroiliac disarticulation, as the wound will allows. This modification serves to increase the weightbearing surface area of the posterior pelvis, thus reducing the sacral prominence; maintenance of a portion of the iliac wing is also helpful for later prosthetic suspension and support. Our preferred technique, when practicable, involves making an osteotomy from the roof of the greater sciatic notch extended to the posterosuperior iliac crest. Once the soft tissues are ready for closure, the residual iliac wing is fixed to the axial skeleton with iliosacral screws. This can often be achieved with short ilosacral screws since the pelvis no longer needs to support an entire lower extremity. Likewise, for patients with sufficient residual anterior soft tissues, a subtotal hemipelvectomy preserving the distal posterior acetabular column, specifically the ischial tuberosity and inferior pubic ramus, may improve sitting balance (Fig. 2).

Schoderbek et al. reported that they did not find the use of external fixation to be worthwhile in the treatment of their blunt trauma patient because they were unable to



FIGURE 2 (A) Anteroposterior pelvic radiograph of a blast injury patient with bilateral hip disarticulations and right-sided acetabular fractures. (B) Repeat anteroposterior radiograph after partial right hemipelvectomy necessitated by ongoing infection, fractures and inadequate soft tissue coverage. The ischial tuberosity has been retained to improve eventual sitting balance despite an adjacent inferior pubic ramus fracture as the bone was grossly viable and local soft tissue coverage was sufficient. This fracture was stabilized with two screws at the time of definitive closure and healed uneventfully.

maintain a reduction of the pelvis (2), but external fixation of the pelvic ring may help with soft tissue rest, may protect the plethora of intrapelvic vessels from secondary injury and likely improves patient comfort during transfers and positioning, depending on how much of the ipsilateral hemipelvis remains following subtotal hemipelvectomy injuries.

Second-look debridements are de rigueur for these highenergy, contaminated wounds. Despite some published reports (4,13), we strongly believe that these injuries should not be closed during the initial period following injury. Rather, patients should, and typically do, undergo multiple debridements in an attempt to identify an often slowly evolving zone of injury and decrease the potential for sepsis. The tissues typically continue to evolve for days to weeks and premature closure may lead to a substantial amount of necrotic material being left in the wound, predisposing to infection (Fig. 3). The iliopsoas has been described as undergoing delayed necrosis, possibly due to a traction injury to its blood supply (5,6). It is important to keep the urologic and general surgical services engaged throughout this phase of treatment, as the zone of required debridement can extend into the walls of the bladder and rectum. We have found the use of hydrosurgical debridement devices (e.g., VersaJet, Smith & Nephew, St. Petersburg, FL) to be very helpful by facilitating the rapid debridement of large surface area wounds while limiting the depth of debridement to the minimum necessary and thus avoiding trauma to the underlying tissues. Depth of debridement can also be adjusted to allow partialthickness debridement of intra-pelvic structures. Maintaining hemostasis during debridement can be difficult, due to the large vessels and robust venous plexuses in the pelvis, and postoperative bleeding requiring a return to the operating room is a potential concern. The large wound beds of friable, inflamed tissue can bleed for some time, especially after having performed a proper sharp debridement. While we routinely utilize negative pressure wound therapy, we advocate local application of thrombin and/or other topical hemostatic agents and packing the wounds for several minutes before dressing application. Only when hemostasis has been achieved and the wound appears dry are the negative pressure sponges applied.

The lateral femoral cutaneous and femoral nerves should be transected as proximally as possible, at least at the level of the inguinal ligament. The sciatic nerve can be divided at the confluence of nerve roots or more proximally, as the roots emerge from the sacral foramina. The latter should be performed with caution as the subdural space may still persist at this level, making it possible to contaminate the cerebral spinal fluid and produce potentially fatal meningitis (4,6). Accordingly, the nerve roots should either be tied off prior to transection, or the division should be made through the sciatic nerve proper. At



**FIGURE 3** Intraoperative clinical photograph of a blast injury patient with a right open hemipelvectomy and proximal left transfemoral amputation, demonstrating continued wound evolution and tissue necrosis 10 days post-injury, despite serial operative debridements. The patient is in the left lateral decubitus position and the perineum is centrally located in this photograph.

this level, the nerve is quite vascular; use of electrocautery for transection may be beneficial or the entire nerve can be ligated. In general, we delay the dissection and proximal division of the nerves until the wound bed is clean enough to minimize the risk of tracking contaminants or infection up into the abdomen or up the nerve roots into the subdural space and cerebrospinal fluid. This also ensures that the final neurectomy places the ultimate resulting neuroma in a location adequately protected from painful stimuli and pressure by the available soft tissues.

#### Reconstruction

Traumatic hemipelvectomy wounds are rarely amenable to primary closure. Every effort should be made to place intact skin and subcutaneous tissue over the weightbearing areas of the pelvic girdle, as these can tolerate shearing forces and direct pressure more reliably than granulation tissue and skin graft. After maximizing primary coverage over these areas, rotational fasciocutaneous pedicle flaps (9) or free tissue transfer can be employed. The latter must be employed with caution. The rectus abdominus should not be used, as the hemipelvectomy patient usually lacks adequate peritoneal support from the injury and the impact on core muscle strength with harvest may have catastrophic effects on the ability to rehabilitate or transfer; furthermore, the requisite inferior epigastric vessels are often involved within the zone of injury and overtly thrombosed or transected. The latissimus should also optimally be preserved, as patients' ability to power a non-motorized wheelchair would be negatively impacted after harvest. Free fasciocutaneous flaps can be employed with little to no impact on function as can free fillet flaps of the avulsed extremity or even contralateral extremity (14,15). Naturally, the extensive local trauma and paucity of residual smaller caliber vessels, as well as any history of wound infection, increases the potential for microsurgical anastomosis failure. When all full-thickness tissue options have been exhausted, negative pressure wound therapy and regenerative medicine techniques such as acellular extracellular matrix and dermal substitutes can be used to ready the wound for eventual split-thickness skin graft. Use of banked skin graft from the avulsed extremity has been described, but with only moderate efficacy approximately 60% graft loss with this technique - due to the lengthy delay before wound maturation (16).

It is uncommon to regain rectal control after these injuries, due to the typical amount of damage to the pelvic floor and rectal sphincters. Rieger et al found a 36% return to fecal continence rate in their review of the literature (7). Urinary function is believed to be restored more frequently, although this outcome measure is inconsistently reported, so the actual percentage of patients with return of urinary continence is unknown. Resulting urinary continence is impacted by both local damage to the urethra and sphincter and injuries to the contralateral sacral nerve roots, as injury to the ipsilateral nerve roots is common.

#### **Prosthesis and Rehabilitation**

About 90% of patients in the literature have been noted to return to ambulation with either crutches or prosthesis, but only about 55% of patients ambulate with the prosthesis, usually still requiring the aid of crutches (7). This is likely due to the high level of energy expenditure associated with prosthetic gait in these individuals. Hemipelvectomy patients exert up to 125% more energy while ambulating with a prosthesis compared to able-bodied controls and also take up 50% more oxygen during fast walking. In comparison, single-leg crutch ambulation alone in these patients requires only 45% more energy expenditure (17). The prostheses themselves require a substantial amount of skill in fabrication and fitting. A Canadian-type hip disarticulation prosthesis is often utilized, using pressure on the soft tissues to immobilize the residual skeleton. Gel spacers are typically used to restore sitting balance and posture in patients who have lost their ischial tuberosity. These are used in conjunction with a body sleeve of lowfriction material to limit the shear forces on the skin. Initial gait training and rehabilitation requires participation and dedication of both prosthetists and physical therapists.

The psychosocial toll on traumatic hemipelvectomy patients is understandably high. Patients surviving these devastating injuries are typically quite young and used to a fairly high level of function. Psychiatric maladjustment, opioid dependence, and a refusal to rehabilitate have been described (3,9,10,18). Accordingly, early engagement of the psychiatric and social services should be a standard part component of the treatment of these patients.

### Conclusion

Treatment of a patient with a traumatic hemipelvectomy requires an aggressive approach to early resuscitation, debridement, and the early involvement of multiple surgical services. The management of hemipelvectomy patients is resource intensive. Hospital and intensive care unit length of stay are predictably prolonged. Close coordination with the blood bank should be undertaken to ensure an adequate supply of all components are available throughout the early treatment course. Wounds should be meticulously and serially debrided until the tissues within the wide zone of injury have ceased evolving and all devitalized tissue has been removed. Complex, and often creative, soft tissue coverage methods are then required to restore the soft tissue envelope and to maximize the chance of functional recovery. Nonetheless, with thorough and assertive treatment involving the orthopaedic, general, urological, and plastic surgery services as well as psychiatry, prosthetics and rehabilitation, patients with these injuries may resume a remarkably high level of function and independence.

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