Pediatric neurosurgery during Operation Enduring Freedom

Clinical article

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Object. Operation Enduring Freedom (OEF) is the current US military conflict against terrorist elements in Afghanistan. Deepening US involvement in this conflict and increasing coalition casualties prompted the establishment of continuous neurosurgical assets at Craig Joint Theater Hospital (CJTH) at Bagram Airfield, Afghanistan, in September 2007. As part of the military’s medical mission, children with battlefield-related injuries and, on a selective case-by-case basis, non–war-related pathological conditions are treated at CJTH.

Methods. A prospectively maintained record was created in which all rotating neurosurgeons at CJTH recorded their personal procedures. From this record, the authors were able to extract all cases involving patients 18 years of age or younger. Variables recorded included: age, sex, and category of patient (for example, local national, enemy combatant), date, indication and description of the neurosurgical procedure, mechanism of injury, and in-hospital morbidity and mortality data.

Results. From September 2007 to October 2009, 296 neurosurgical procedures were performed at CJTH. Fifty-seven (19%) were performed in 43 pediatric patients (16 girls and 27 boys) with an average age of 7.5 years (range 11 days–18 years). Thirty-one of the 57 procedures (54%) were for battlefield-related trauma and 26 for humanitarian reasons (46%). The vast majority of cases were cranial (49/57, 86%) compared with spinal (7/54, 13%), with one peripheral nerve case. Craniotomies or cranielectomies for penetrating brain injuries were the most common procedures. There were 5 complications (11.6%) and 4 in-hospital deaths (9.3%).

Conclusions. As in previous military conflicts, children are the unfortunate victims of the current Afghanistan campaign. Extremely limited pediatric neurosurgical service and care is rendered under challenging conditions and Air Force neurosurgeons provide valuable, life-saving pediatric treatment for both war-related injuries and humanitarian needs. As the conflict in Afghanistan continues, military neurosurgeons will continue to care for injured children to the best of their abilities. (DOI: 10.3171/2010.3.PEDS109)

Key Words • pediatric neurosurgery • Operation Enduring Freedom • Afghanistan • penetrating brain injury • humanitarian service

Abbreviations used in this paper: CJTH = Heathel N. Craig Joint Theater Hospital; CN = cranial nerve; EVD = external ventricular drain; ICP = intracranial pressure; IED = improvised explosive device; GSW = gunshot wound; OEF = Operation Enduring Freedom; OIF = Operation Iraqi Freedom.

In-theater, continuous neurosurgical assets at Bagram Airfield were not in place until late September 2007. Prior to 2007, there were limited coalition casualties that required emergent neurosurgical intervention. At that time, deploying trauma surgeons and otolaryngologists had received basic training in neurotrauma diagnosis, stabilization, and craniotomy. Fortunately, this skill set was infrequently required, and injured US and coalition forces were safely transferred to Germany, where neurosurgical capabilities were present. However, as US involvement in OEF deepened with more and more troops being deployed, an escalation in combat activity, and without any foresee-
able end in sight to the conflict, there was a commensurate increase in coalition casualties. Thus, there was a clear need for a continuous neurosurgical presence in the area of operation.

Currently, the US Air Force deploys one neurosurgeon to Afghanistan (Bagram Airfield) for a 4–6 month period. Delivery of neurosurgical care is clearly defined by medical rules of engagement. The obvious top priority is to care for all US and coalition troops with battlefield injuries. Care is also rendered to Afghan National Security Forces, contractors, and local nationals, including children and enemy combatants who are injured as a result of combat operations. As hospital census and resources permit, “humanitarian” cases are also treated at CJTH. This paper discusses our experience with pediatric neurosurgical cases over a 2-year period at CJTH. We detail cases observed, treatment provided, and the environment under which military neurosurgeons work.

**Methods**

From September 2007 to October 2009 (at the onset of the neurosurgical mission in Bagram), neurosurgeons kept track of their personal surgical case war records. Data recorded included: age, sex, category of patient (for example, US service member, coalition force member, enemy combatant, local national, member of the Afghan National Security Forces), date of procedure, description of the procedure, mechanism of injury, and in-hospital morbidity and mortality.

**Results**

Over a 2-year period, 296 neurosurgical procedures were performed in adult and pediatric patients at CJTH, 215 (73%) for war injuries and 81 (27%) for humanitarian needs. Of these procedures, 138 (47%) were cranial, 52 (18%) spinal, 86 (29%) ICP monitors (EVDs and fiberoptic bolts), and 20 (7%) were categorized as miscellaneous. Fifty-seven (19%) of these 296 procedures were performed in 43 pediatric patients (16 girls and 27 boys, average age 7.5 years, range 11 days–18 years, Fig. 2). Thirty-one (54%) of the 57 procedures were for battlefield-related trauma; 26 (46%) were for humanitarian reasons. The vast majority of cases were cranial (49/57, 86%). A small percentage were spinal (7/54, 13%), and one was a peripheral nerve case.

**Battlefield Cases**

War or battlefield cases were defined as those in which the child was injured as a direct result of a military weapon (Table 1). Craniotomies or craniectomies for penetrating brain injuries were the most common procedures (15/31, 48%), with IEDs being the most frequent source of the projectile(s). In the majority of these patients, an ICP monitor was also placed at the time of the craniotomy/craniectomy. Placement of an ICP monitor was performed as the sole procedure in 4 patients with closed head injuries from explosions. Two patients with transspinal high-velocity GSWs required instrumentation and fusion. One patient with a GSW to the posterior thigh suffered a femur fracture and a near-complete severing of the sciatic nerve that required debridement and primary reanastomosis. Two patients underwent 3 surgeries for repair of nonhealing scalp wounds from a penetrating head injury; in 1 of these 2 cases, cranioplasty was performed with a rotation scalp flap to cover a large defect. There were no in-hospital deaths.

**Humanitarian Cases**

Humanitarian cases were defined as those in which the indications for surgery were not directly due to the damaging effects of military weapons (Table 2). Craniotomies or craniectomies were performed in 9 patients for closed head injuries, most commonly resulting from a fall. Nine procedures were performed in 6 patients for congenital anomalies. Two of the 6 patients were treated for posterior fossa arachnoid cysts with associated obstructive hydrocephalus; 2 were neonates undergoing myelomeningocele repair; and 2 were children undergoing delayed repair of spinal dysraphism. Shunts were placed in 4 children (Table 2). One
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**Illustrative Cases**

**Case 1: Penetrating Brain Injury From IED Fragment**

This 15-year-old boy was injured during a vehicle-borne IED attack. The patient presented to CJTH awake, combative, and following commands but with left hemiparesis (arm worse than leg). Computed tomography revealed a metal fragment in the anterior left frontal lobe with an entry point in the right posterior frontoparietal region (Fig. 3). Upon opening the dura mater, the hemisphere was found to be markedly swollen and brain tissue herniated through the bony and dural opening (Fig. 4). The entry site of the fragment was debrided and residual bleeding stopped. The bone flap was not replaced and a duraplasty was performed. A right frontal EVD was also placed. Postoperatively, the patient did not have elevated ICP, and the EVD was removed after several days. Hemiparesis improved and the boy was discharged to his village 10 days postoperatively. He returned 5 months later for replacement of his bone flap, which he tolerated well.

**Case 2: Penetrating Brain Injury From Rocket Fragment**

This 5-year-old girl was injured when her village came under a rocket attack (Fig. 5). She was intubated and flown to CJTH. She had been struck in the left posterior frontoparietal region, and the fragment had traveled superiorly ending just under the calvaria to the right of midline (Fig. 6). Intraoperatively, she had near-catastrophic blood loss from a large tear in the superior sagittal sinus that could never be precisely visualized. Bleeding was eventually controlled with large quantities of hemostatic...
agents. An EVD was placed and postoperatively the patient kept sedated and paralyzed for 48 hours and then gradually awakened. She had a dense right hemiparesis and an expressive aphasia. Her postoperative course was otherwise unremarkable. Eight months later, she returned for a cranioplasty. Hemiparesis had recovered well, however, significant expressive dysphasia remained.

**Case 3: Delayed Closure of Terminal Myelocystoceles**

This 11-month-old female infant presented with a very large lumbosacral mass just above the glutal cleft (Fig. 7). Her neurological development was normal and she was almost walking independently. According to the parents, the mass was getting bigger and prevented the girl from sitting in a chair or lying on her back. On examination, the patient had good motor and sensory function in her legs and feet, including strong dorsiflexion and good but weaker plantar flexion. She had decreased rectal tone. The mass had areas of pressure necrosis, granulation tissue, and was weeping serous and clear fluid. Computed tomography demonstrated a focal bony defect in the sacrum through which a cystically dilated spinal cord opened into the fluid-filled mass. These features were felt to be most consistent with a terminal myelocystocele. The CT study also demonstrated moderate hydroureter. CT study also demonstrated moderate hydronephrosis and hydroureter.

Intraoperatively, the skin was incised at the superior and inferior poles of the mass and the dissection carried down to and through the fascia to identify normal anatomy. There was clearly dura coming through a defect in the bone and fascia (Fig. 8 left). We then incised the skin circumferentially around the base of the mass. The dura was incised revealing numerous nerve roots and what appeared to be the conus with a large terminal syrinx (Fig. 8 right). These nerve roots came from the conus medullaris, entered the cystic cavity, then presumably made a loop at the dome of the mass, reentered the spine and were visualized to exit through the anterior sacral foramina. To resect the mass and achieve a watertight dural and wound closure, these neurological structures were transected. Extensive suprafascial dissection of the subcutaneous tissue was required to mobilize and reapproximate it without excessive tension.

Postoperatively, the child retained the same neurological function in her legs. However, 1 month post surgery, a renal ultrasound showed worsening hydronephrosis, which was confirmed by CT. After careful consideration, it was felt that an urostomy would be the best treatment for her neurogenic bladder and this was performed by general surgery.

**Case 4: Posterior Fossa Arachnoid Cyst With Obstructive Hydrocephalus**

American soldiers found this 5-month-old male infant in a remote mountainous village with a large head and bulging fontanel. The parents stated that he was becoming increasingly irritable and that his eye movements were abnormal. On examination, his head circumference was 50 cm, his fontanel was bulging and firm, and he had esotropia of his left eye due to a sixth nerve palsy. Computed tomography revealed severe obstructive hydrocephalus due to a large left posterior fossa arachnoid cyst (Fig. 9 left).

After an EVD was placed, a midline suboccipital craniotomy was performed with aggressive fenestration of the arachnoid cyst into the subarachnoid cisterns. Cranial nerves VII–XII were visualized exiting through their respective foramina (Fig. 9 right). Postoperatively, he developed a new right sixth nerve palsy. The EVD was left open for several days and then gradually weaned and clamped. Computed tomography with the EVD clamped demonstrated decreased size of the ventricles and the drain was removed. The patient was seen approximately 1 month later. His fontanel was soft and flat, a head ultrasound showed decreased ventricle size, and his sixth nerve palsy had improved.

**Discussion**

The conflicts in Afghanistan (OEF) and Iraq (OIF) have presented many challenges to military medicine. Medical assets in the form of personnel and equipment are delivered and established in distant, hostile environments to provide timely in-theater treatment and evacuation of injured troops. Military providers must rapidly learn how to treat the injuries of war weapons, with IEDs being the hallmark of current conflicts. Over the past several years, there have been numerous publications discussing the lessons learned from these conflicts, primarily in the trauma and general surgery literature. There have also been publications specific to the pathophysiology and treatment of neurological injuries, such as traumatic brain injury, vascular injury, and spinal injuries.

As in every preceding military conflict, civilians,
including children, often suffer injuries similar to combatants. There have been numerous publications detailing the treatment of children who have suffered injuries during OEF and OIF. During a 6-month period at a combat support hospital in Afghanistan, in 2006, children accounted for 19% of all admissions. Other authors analyzing data from both OEF and OIF found that pediatric admissions ranged from 4.2 to 10% of all admissions and that the in-hospital overall mortality rate for these patients ranged between 5.4 and 6.9%, with younger children (less than 6–8 years of age) having mortality rates that were significantly higher (10–18%). Creamer et al. found that the most common causes of death in children were head injuries and burns, with the case fatality rate for pediatric head injuries being 20%. Although there have been recent reports detailing the challenges of providing pediatric neurosurgical care in austere, noncombat conditions, this manuscript represents the first publication that details pediatric neurosurgical care in a wartime environment.

**Battlefield Injuries**

Children are often the innocent bystanders of military conflicts. In Afghanistan, they are injured from the weapons of the current conflict, in particular rockets, mortars, and IEDs, but also from weapons of prior conflicts, such as mines left by the Russians more than 20 years ago. Although just under half of all children who were treated at CJTH by neurosurgeons were injured as result of these weapons, over half (56%) of all neurosurgical procedures were for battlefield injuries. Penetrating injuries due to projectiles of various sources were the most common injuries. The principles that dictated our treatment of penetrating head injuries were to wash out extra- and intracranial wounds, debride any necrotic tissue, and retrieve any foreign objects that were easily accessible (such as, metallic fragments, debris, or bone), evacuate any intracranial hematoma, and control any bleeding. In patients in whom there was little wound contamination and minimal intracranial injury, local scalp debridement and repair were performed. One could argue that this should have been the strategy in Case 2 to avoid having a near fatal hemorrhage from the torn superior sagittal sinus.

One observation made was that the degree of swelling and hyperemia of the hemisphere was often greater intraoperatively than expected on the basis of the initial CT examination (Case 1). Therefore, we quickly learned, as our Army and Air Force neurosurgical colleagues did in Iraq, to make a larger than necessary bony and dural opening and be prepared to leave the bone flap off. The institution of early and aggressive decompressive craniectomy decreased the risk of problems with intracranial hypertension in the postoperative period and, in our collective opinion, led to good outcomes. Bone flaps were stored in a freezer at CJTH and replaced at the earliest opportunity. These children were typically treated with seizure prophylaxis for 1 week and with a third-generation cephalosporin (administered intravenously) for 5 days.

Four patients suffered closed head injuries from an IED and underwent ICP monitor placement. Fortunately, there were no deaths due to battlefield head injury, but a small number of children had scalp wounds that broke down after their initial surgery. The reasons for this are likely several-fold. Scalp injuries from penetrating brain...
Humanitarian Cases

All potential humanitarian cases, adult and pediatric, at CJTH are carefully evaluated to determine need and feasibility. There are a number of issues at hand. 1) The first consideration is bed status at CJTH. The pace of warfare and, therefore, war-related casualties are typically at their highest rates during the late spring and summer months. Rules of engagement prohibit taking on humanitarian cases if the hospital is on “amber” or “red” status, as determined by bed-space availability. 2) Another factor that is of equal importance is that of the limits in available equipment (for example imaging and surgical equipment) and depth of experience among personnel who would be involved in patient care through all phases of their hospital stay (for example, surgeon, anesthesiologists, and intensive care unit staff). The experience of

trauma are often irregular, with the tissue being devitalized and contaminated. Moreover, most children in Afghanistan are malnourished—as evidenced by their much smaller size-for-age appearance—and virtually every child has intestinal roundworms that further contribute to malnourishment. These factors all place the children at higher risk of wound complications.

Two children had transabdominal/transspinal GSWs that created extensive bone destruction. Coalition soldiers shot one child, who in fact was an enemy combatant, with the bullet traversing L-2 and severely fracturing it. The other child had the bullet pass through the sacroiliac joint with severe comminution resulting in pelvic instability. Although the literature on penetrating spinal injury from an urban, noncombat environment suggests that the majority of these patients do not suffer spinal instability, we feel that there is a greater chance of instability with the higher-velocity, higher-energy projectiles being used in a combat environment. For example, the typical muzzle velocity of a 9 × 19–mm round (used in handguns) is about 350–400 m/second compared with 930–975 m/second for the 5.56 × 45–mm rounds used in the M-4 and M-16, the most common weapons used by US troops.

Fig. 7. Case 3. A and B: Photographs showing the very large lumbosacral mass in this 11-month-old girl with good motor and sensory function in her legs. The mass was fluid-filled, weeping serous fluid, and had dystrophic skin in some areas with other areas showing necrotic, thickened skin interspersed with granulation tissue. C: Sagittal CT reconstruction demonstrating the defect in the sacrum through which the spinal cord with a terminal syrinx communicates with the fluid-filled mass.

Fig. 8. Case 3. Intraoperative photographs. A focal defect in the dorsal lumbar fascia through which a dural-covered stalk exited and entered the mass (left). Upon opening the dura, multiple nerve roots and the conus medullaris with a terminal syrinx were seen (right).

Fig. 9. Case 4. Left: Axial CT obtained in a 5-month-old male infant with macrocephaly, left CN VI palsy, and obstructive hydrocephalus due to a large left posterior fossa arachnoid cyst. Right: Intraoperative photograph showing the space that was occupied by the arachnoid cyst. The left cerebellar hemisphere is being gently retracted medially. The superior petrosal sinus is just barely visible under the cottonoid. Caudal to this is the CN VII–VIII complex entering the internal auditory canal (white arrow) and caudal to that is the CN IX–XI complex entering the jugular foramen (black arrow).
incoming personnel naturally varies from rotation to rotation. Finally, it is readily apparent that children in Afghanistan have extremely limited resources and services, beyond what can be provided by military personnel, and therefore, cases or their potential complications, that required prolonged postoperative follow-up and care were generally avoided. In summary, humanitarian cases were performed if it was felt we could provide a high degree of benefit for the children and their families with a low risk of complications and relatively low (and finite) utilization of our resources. Thus, non–field-related neurotrauma best fit these criteria and was the type of humanitarian work that was most commonly undertaken (accounting for 14 [54%] of 26 cases).

Nonetheless, we were able to undertake a number of nontrauma humanitarian cases as described in Table 2. We closed myelomeningoceles in 2 newborns and resected large CSF-filled lumbosacral masses in 2 other infants. The latter 2 cases were particularly challenging to the primary author (P.K.) as it was difficult to identify and impossible to preserve neurological structures within the mass. One child suffered a superficial wound dehiscence due to a combination of malnutrition (see previous section) and excessive tension on the skin edges. The other patient developed a worsening of her neurogenic bladder and had to undergo a urostomy. These 2 cases were the most severe of a number of similar cases that were evaluated by several of the rotating neurosurgeons. The decision to treat these 2 children surgically was made after considerable deliberation and the operations were ultimately performed because of the extreme size and disfiguring nature of the masses.

Shunt placement was avoided in the children we treated as a rule, but we felt that it was necessary and beneficial in 4 cases. As stated previously, children have extremely little to virtually no means of receiving neurosurgical care and follow-up in Afghanistan, although personnel certainly tried to establish follow-up at the few places in Kabul that apparently had neurosurgical services. It would be difficult for a patient and his or her family to return to Bagram Airfield on an urgent basis for a shunt revision because of the numerous layers of security. Fortunately, to our knowledge none of the patients that had shunts required any revisions as of this writing.

Study Limitations

This study obviously suffers from several limitations. The goal of this 2-year “snapshot” is to provide the reader with an understanding of the types of cases that are undertaken and the conditions under which pediatric neurosurgical care is being rendered at a military hospital in a combat environment. Although we have relatively good periorperative data, follow-up data are limited. This is for a number of reasons. Many patients never returned for their follow-up or had limited follow-up, with one reason being the long and often dangerous travel that would be required to return to Bagram Airfield. Many patients were flown to CJTH and then returned to their respective villages when ready to leave the hospital. Another reason is that there is limited clinic time available to military providers. Each provider or service has some dedicated clinic time but this is strictly limited both in terms of time so that the providers can be available to respond to incoming trauma and also in terms of the number of local nationals that can be seen on any given week. Improved in-theater studies can only be accomplished if there are personnel on staff whose function is to help providers plan studies and then gather the necessary data in a prospective manner. At this time, no such position exists.

Conclusions

As the US involvement in Afghanistan deepens, there will undoubtedly be further combat and with this, more children will be harmed. Over a 2-year period, 19% of all neurosurgical procedures performed at CJTH by Air Force neurosurgeons were in children, with just over half (54%) of these procedures being undertaken for war-related injuries. The vast majority of pediatric cases, both battlefield and humanitarian, were cranial. The most common battlefield injury treated was penetrating head injury from any of the various IEDs. The most common type of humanitarian case was closed head injury from a fall or motor vehicle accident. There were several manageable complications that did not result in any long-term sequelae; there were 4 in-hospital deaths (9%). Air Force neurosurgeons at CJTH are providing valuable, life-saving services to the children of Afghanistan injured as a direct result of the war under challenging conditions. When feasible, Air Force neurosurgeons are also selectively taking on humanitarian cases. It is the authors’ hope that this manuscript provides the reader with a glimpse of what is being accomplished in Afghanistan and the outcomes, albeit limited, that are being achieved. Although deployment was trying for the authors, the experience of caring for these children was highly satisfying both personally and professionally.

Disclosure

The opinions and assertions contained herein are the private views of the authors and are not to be construed as official or reflecting the views of the US Air Force or the Department of Defense. The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper. Author contributions to the study and manuscript preparation include the following. Conception and design: all authors. Acquisition of data: all authors. Analysis and interpretation of data: all authors. Drafting the article: all authors. Critically revising the article: all authors. Reviewed final version of the manuscript and approved it for submission: all authors.

Acknowledgments

The authors thank Shirley McCartney, Ph.D., for editorial assistance and Andy Rekito, M.S., for graphic assistance.

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