Penetrating craniocerebral injuries in the Israeli involvement in the Lebanese conflict, 1982–1985

Analysis of a less aggressive surgical approach

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From June, 1982, through June, 1985, 113 patients were evacuated to Rambam Maimonides Medical Center with penetrating craniocerebral injuries sustained in ongoing military hostilities in Lebanon. Two factors distinguished this group of patients from those presenting in earlier conflicts: 1) this was the first large series in which computerized tomography (CT) was routinely used to initially evaluate combat head injuries; and 2) in an effort to preserve maximum cerebral tissue, intracranial debridement was significantly less vigorous than that advocated during the Korean or Vietnam conflicts. No efforts were made to locate or remove in-driven bone or metal fragments visualized on CT unless they readily presented themselves on gentle irrigation. In fact, it was elected to treat a number of patients without intracranial hematomas nonoperatively. The acute outcome was quite similar to that reported in Vietnam series in respect to both complications and mortality.

Of the 83 survivors, 46 were Israeli citizens and thus were available for follow-up review. These 46 patients were reevaluated in late 1988, a mean follow-up period of 5.9 years. None had died in the interim; 10 had developed chronic seizure disorders, and there was one case of delayed meningitis in a patient with no retained fragments. Repeat CT scans were performed on 43 patients; 22 (51%) were found to have retained intracranial bone fragments. No relationship existed between the presence of retained fragments and the development of either a seizure disorder or an infection of the central nervous system. These findings suggest that not only is it unnecessary to reoperate for retained bone fragments, but it may also be possible to temper the initial debridement in an effort to preserve additional cerebral tissue.

KEY WORDS • head injury • penetrating wound • craniocerebral injury • bone fragment • war wound

Penetrating head injuries are an unavoidable consequence of military conflict. The literature has chronicled the efforts of neurosurgeons to care for such injuries in each major military conflict of this century beginning with Harvey Cushing's experience during World War I.7,8 He advocated early and definitive debridement of necrotic tissue, removal of all in-driven debris, and meticulous dura and scalp closure. Utilizing these measures, he was able to markedly decrease the incidence of brain abscesses and thereby lower the operative mortality rate from 55% to 29%.

Less aggressive surgical approaches in the early phases of both World War II and Korea resulted in higher infection rates and increased mortality.2,15,21,22 These infections were noted by a number of surgeons to occur more frequently when in-driven bone fragments remained after the initial debridement.1,4,5,14,22,23 On reexplanation, residual necrotic tissue or loculated pus was discovered in close approximation to the retained fragments in a large number of cases and culture of this debris was frequently positive.9,23

Because of this experience, aggressive initial debridement was advocated. In fact, a policy strongly urging early routine reoperation to remove retained bone fragments visualized on postoperative radiographs was instituted by the United Nations forces in Korea and was continued by the United States Army Medical Corps throughout the Vietnam conflict. On introduction of this dictum and other measures, the infection rate declined from 53% to 15%, with a concurrent drop in the surgical mortality rate from 25% to 4%.15,21
Despite an improved clinical outcome following the adoption of this policy, there remained questions as to the causal role of bone fragments alone in the development of cerebral abscesses. As early as World War II, Maltby\(^\text{13}\) had presented evidence suggesting no correlation between abscess formation and the presence of retained bone fragments. He described 17 cases complicated by abscess formation, but only three had retained bone fragments. Experimental support was added by Pitlyk, et al.,\(^\text{17}\) in their studies of implanted bone and debris in canine cortex. The incidence of abscess development when sterile or contaminated bone alone was implanted was 8% and 4%, respectively, but when either was combined with scalp or hair the rate increased dramatically to nearly 70%.

Additional evidence has since been added by reports of the Vietnam experience. In Phase I of the Vietnam Head Injury Study, 1221 patients were reviewed 5 years after their wounding.\(^\text{18}\) A total of 37 brain abscesses were discovered but, of these, only 11 had retained bone fragments and none occurred without at least one other major risk factor, including: facio-orbital entry, cerebrospinal fluid (CSF) fistula, wound complication, prolonged coma, or multiple surgical procedures.\(^\text{18}\) In Phase II of the study, 481 of these patients were re-evaluated with computerized tomography (CT) and retained bone fragments were found in 23%, all of whom were free of infection.\(^\text{18}\) Given these data, it has now been recommended by some authors that reoperation for retained bone fragments in the asymptomatic patient may be unwarranted in light of its potential to increase neurological deficits or to convert a transient deficit to a permanent one.\(^\text{10,16}\)

With the availability of CT scanning within rapid evacuation distance of the combat zone, it became possible during the Israeli involvement in the Lebanese conflict to ascertain the extent of the cerebral injury, to determine the exact location of in-driven bone and metal fragments, and to detect intracranial hematomas requiring evacuation by noninvasive means. This, coupled with the evidence downplaying the role of retained bone in abscess formation, led to the adoption of a policy at Rambam Maimonides Medical Center (RMC) calling for a less aggressive approach to intracranial debridement with emphasis on the preservation of cerebral tissue. The surgical plan stressed minimum manipulation of the neural tissue to include a conscious effort not to search for in-driven fragments not presenting themselves during gentle irrigation or hematic maneuvers. In fact, in those cases with no evidence of an intracranial space-occupying lesion and either a punctate convexity entrance wound or penetration through the skull base, no intracranial procedure was advocated and only local wound care was undertaken.

In the following article we review the initial management and acute outcome of the 113 patients with penetrating craniocerebral injuries sustained during military hostilities in Lebanon from 1982 to 1985. In addition, we will present data on 46 of these patients obtained at follow-up examination nearly 6 years after their wounding.

Clinical Method and Materials

From June, 1982, through June, 1985, Israel was involved in ongoing hostilities in Lebanon. During that period RMC acted as the primary evacuation center for those wounded in Israeli-occupied territory. Throughout the course of this conflict, a total of 180 patients were admitted to RMC with head injuries directly attributed to military hostilities. This study includes only those patients who sustained penetrating craniocerebral injuries, as defined by Cushing.\(^\text{7,8}\) Initially, 116 patients were placed into this category but three were subsequently removed when review of their charts and radiographs failed to document sufficient evidence of dural penetration. Of the remaining 113 patients, 67 were Israeli soldiers, 42 were Lebanese militiamen or civilians, and four were United Nations soldiers.

All wounded, regardless of their nationality, were initially evaluated by paramedical personnel in the field and resuscitation was initiated. In general, a physician became involved in the patient's care within 30 minutes of wounding. Crystalloid or blood infusions were begun and antibiotics (cloxacillin or chloramphenicol) were administered. If the patient was comatose or in hemodynamic compromise, endotracheal intubation was performed and mechanical ventilation initiated. In fact, 45 (40%) of the 113 patients were intubated prior to their arrival at RMC.

Following initial stabilization, patients were usually evacuated directly to RMC by ventilator-equipped helicopters, an in-flight distance of approximately 40 minutes. Four patients were initially admitted to other hospitals and subsequently transferred; two had undergone emergency laparotomies at these institutions. The median time from injury to arrival at RMC Emergency Department was 2.0 hours.

Examination. On arrival at the Emergency Department, patients were evaluated by senior general surgery and neurosurgery staff, and multidisciplinary resuscitative measures were continued. Each patient received a loading dose of phenytoin. Comatose patients were hyperventilated and mannitol was given if their hemodynamic status permitted. Routine radiographic studies were obtained; if the patient was hemodynamically stable after resuscitation, a noncontrast CT scan of the head was obtained. Three patients could not be stabilized and were taken directly to the operating theater, two for laparotomies and one for thoracotomy. Three other patients were not subjected to CT scanning because, following resuscitation, they remained flaccid with obvious brain-stem dysfunction. A 340 × 340 matrix Elscint 2002 CT scanner was used for all studies, with a protocol utilizing 6-mm cuts for the posterior fossa and 10-mm cuts for the supratentorial region.
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Hospital Course

The CT results and the patients' clinical condition were both considered in the treatment decision. In patients with either a punctate convexity entrance wound or penetration through the skull base and no evidence of an intracranial space-occupying lesion on CT, only local wound care was undertaken unless their Glasgow Coma Scale (GCS) score was below 8. In these cases a burr hole was placed for continuous intracranial pressure (ICP) monitoring via a subdural catheter.

Patients with extensive entrance wounds or protruding brain tissue were taken to the operating room for craniectomy of the entrance wound, debridement of necrotic tissue and debris, and watertight dural closure unless CT scanning demonstrated a hematoma remote from the entrance wound. In such cases, in addition to entrance wound care, a large craniotomy flap centered over the hematoma was elevated to allow optimal evacuation of the hematoma.

The goal of the intracranial portion of the operation was the removal of gross contamination with minimum manipulation of cerebral tissue. No effort was made to locate or remove in-driven bone or metal fragments visualized on the preoperative CT scan; only those fragments presented during gentle irrigation and hemostatic maneuvers were removed. Retractors were not placed into the missile tract and suction was applied to brain tissue only sparingly. Subdural catheters were inserted for continuous ICP monitoring in patients with a GCS score between 4 and 8 and/or with a clinical picture (based on the operative findings or CT) suggesting the potential for postoperative ICP elevation. Forty-one of the patients in this study received ICP monitoring. In general, the ICP catheters were removed at 48 hours unless the ICP remained elevated.

Postoperative care included the liberal use of CT to evaluate changes in neurological status or elevations in ICP. Delayed hematomas requiring evacuation were discovered in two patients, and a third was found to have massive preherniation temporal lobe edema necessitating lobectomy. Patients routinely received antibiotic therapy for 7 days and were discharged on a course of phenytoin.

Ten patients in this study had a neurological or hemodynamic status precluding operative intervention. Eight of these sustained penetrating wounds to the posterior fossa and manifested pronounced brain-stem dysfunction or clinical brain death either at presentation or abruptly thereafter. The remaining two suffered high-velocity through-and-through gunshot wounds and were not considered to be salvageable even with surgical intervention.

Follow-Up Review

Data concerning each patient's admission status, radiographic findings, hospital course, and discharge condition were entered at the time of their discharge onto a computer grid designed to accommodate over 180 demographic and clinical parameters. Neurological outcome at hospital discharge was determined based on the Glasgow Outcome Scale. All of the data were subsequently verified by review of the inpatient charts, operative reports, and radiographic studies. This review was conducted in late 1988 by an independent team of neurosurgeons from Walter Reed Army Medical Center. During this time, each of the 46 Israeli soldiers surviving his acute injury and hospitalization was invited back to RMC for a follow-up evaluation. This included an in-depth interview with emphasis on their interim course, seizure activity, and present social, educational, and employment status. Each underwent a detailed neurological examination and was assigned a numerical function score based on the modified Kurtzke scale. In addition, a CT scan was performed on each to assess the extent of cerebral injury, presence of retained bone or metal fragments, and potential abscesses. A 100% follow-up rate was obtained for the Israeli patients.

The 37 remaining patients were not presently available for follow-up review. Thirty-five reside within the borders of Lebanon, a country still plagued by ongoing military hostilities; hence, follow-up examination of these patients has been deferred at present, but a future attempt to contact them has been planned. The other two survivors were United Nations troops whose complete identification was not available, thus precluding follow-up contact.

Results

Acute Treatment

As stated previously, from June, 1982, through June, 1985, a total of 113 patients were admitted to RMC with penetrating craniocerebral injuries sustained in military hostilities in Lebanon. The patients ranged in age from 2 to 52 years with a mean of 21.6 years. In the majority of cases the wounds were caused by blast debris (84 cases); in 81 patients (72%) the wounds were the result of direct shrapnel penetration, and in the other three injury was secondary to in-driven stones. Eighteen patients (16%) suffered penetrating gunshot wounds, 13 of which were from high-velocity weapons.

Ten patients (9%) incurred tangential injuries in which the angle of impact was inadequate to allow missile penetration but the energy imparted on impact was sufficient to drive bone fragments deep into the brain parenchyma. The remaining patient was injured when a blast forced a radio antenna through his superior orbital fissure and into his temporal and parietal lobes.

The site of penetration was through the convexity in 95 cases (84%) and through the skull base in 18 (16%). The pathway of penetration in the majority of the transbasilar injuries was through one or both orbits (10 cases). The remaining eight were wounded via three alternative routes: maxillo-orbital (five cases), cervico-mastoid (two cases), and nasoethmoid (one case).

On arrival at RMC, 54 patients (48%) were comatose.
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Fla. 1. The outcome at hospital discharge for each patient based on their admission Glasgow Coma Scale score. Those treated surgically are shown at left whereas those initially managed nonoperatively are shown at right. Included in the nonoperative group are the 10 patients whose hemodynamic or neurological status precluded operative intervention and one who required evacuation of a delayed hematoma resulting in elevation of intracranial pressure (see text). Outcome is based on the Glasgow Outcome Scale: I = minimal or no deficit; II = mild deficit; III = moderate deficit; IV = chronic vegetative state; and V = death.

(defined as a GCS score of ≤ 10). Twenty-nine (26%) were either flaccid or decerebrate in their best response to noxious stimuli. Complete admission GCS score data is given in Fig. 1. Despite vigorous resuscitation in the field, 16 patients were admitted in hemodynamic shock. Multisystem injuries were common; 45 patients (40%) had injuries to other organ systems requiring surgical intervention: orthopedic (25 cases), thoracic (18 cases), abdominal (14 cases), ocular (13 cases), maxillofacial (four cases), and cervical (three cases).

The CT scans were excellent in depicting damage to the skull and the location and nature of in-driven fragments. In 77 (68%) of the 113 cases, CT demonstrated only small focal hemorrhages or contusions at the site of impact or along the tract of in-driven debris, but in another 23 (20%) a significant hematoma exerting mass effect was identified. Fifteen of these hematomas were intraparenchymal and the remainder were extra-axial; four that were of therapeutic concern were remote from the site of penetration. Another important function of CT in triage and treatment-planning was to exclude intracranial penetration in those patients with extensive scalp wounds and multiple subcutaneous metallic fragments, the location of which was equivocal on plain radiographic studies. Computerized tomography also allowed for the classification of injuries based on the extent of cerebral involvement: 61 unilobar, 55 multilobar, and 42 transventricular.

Eighty-five patients (75%) were taken acutely to the operating theater for definitive intracranial procedures. The majority (75 patients) underwent craniectomy of the entrance wound, intracranial debridement, and dural closure as described above. In two patients penetration was through the orbital roof so the operation was performed transorbitally. Craniotomies were performed in 10 patients to allow better access to underlying hematomas. One patient presented with a large subdural hematoma contralateral to the entrance wound and therefore required both a craniectomy of the entrance wound and a contralateral craniotomy to evacuate the hematoma.

Eighteen patients were electively treated nonoperatively. These harbored no intracranial space-occupying lesions on CT; 10 had punctate entrance wounds and eight had transbasilar penetration. Burr holes were placed for ICP monitoring in six of these patients, one of whom developed ICP elevation on the 2nd hospital day and was found to have a delayed intraparenchymal hematoma requiring evacuation. The moribund neurological or hemodynamic status of 10 other patients precluded surgical intervention and all of these quickly died.

In 29 patients CSF leaks developed at some point in the hospital course. Eighteen presented with either otorrhea or rhinorrhea which resolved spontaneously within 2 days. Otorrhea persisted in one patient and required continuous lumbar drainage. Another patient had rhinorrhea which was refractory to both lumbar drainage and lumboperitoneal shunting and eventually required a bifrontal craniotomy to repair the dural rent. Nine patients developed CSF fistulas through their scalp wounds: six resolved spontaneously and the others resolved with continuous lumbar drainage.

Thirteen patients (11%) developed central nervous system (CNS) complications during their initial hospitalizations. Meningitis occurred in nine patients (8%), of whom seven had preceding CSF leaks. One such patient subsequently developed an intracranial abscess ultimately contributing to his death. Three patients required a repeat intracranial operation: one for persistent CSF rhinorrhea, another for a postoperative epidural hematoma, and a third for lobectomy of a pulped temporal lobe threatening herniation. Sagittal sinus thrombosis with resultant neurological deterioration occurred in three patients who had undergone repair of sinus lacerations at the time of their initial surgery.
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Seizures occurred in eight patients during their initial hospitalization, all within the 1st week.

In addition to CNS complications, a number of our patients developed serious systemic complications which often impacted greatly on their outcome. There were nine cases of sepsis and eight of severe pneumonia. Four patients developed respiratory failure clinically consistent with adult respiratory distress syndrome. Renal failure occurred in four patients, usually as the result of multisystem organ failure.

Based on the Glasgow Outcome Scale, the outcome at initial hospital discharge was good in 46 patients (41%). Thirty-one patients (27%) were discharged with moderate or severe disabilities, and six (5%) required ongoing assistance with their activities of daily living or supervision because of poor judgment and/or impulsive behavior. The modified Kurtzke disability scores for patients in this study group ranged from 0.0 to 6.0 with a mean at 2.5.

A direct correlation existed between admission GCS scores and death. In patients with GCS scores of 3 or 4 the mortality rate was 80%; while in those with scores of 5 to 12 and 13 to 15 it was 12% and 6%, respectively. Prior fossa penetration was associated with a high mortality rate (89%) as were gunshot wounds (81%). The mode of injury was an important factor in outcome, with shrapnel and tangential wounds faring much better than gunshot wounds (Table 1). The extent of the cerebral injury was also a predictor of outcome with multilobar and transventricular wounds being associated with mortality rates of 53% and 57%, while unilobar injuries carried a mortality rate of less than 2%. Table 2 reviews factors associated with elevated mortality.

Three patients with CNS infections ultimately died. Each had a CSF leak which became complicated with meningitis and one subsequently developed an intracranial abscess. In addition to their CNS infections, all developed clinical pictures characteristic of multisystem organ failure. Each developed septicemia and renal and respiratory failure; in fact, the patient with the abscess died as a result of ventilator-induced pneumothoraces sustained in treatment of adult respiratory distress syndrome. In total, eight patients died of multiorgan systemic failure while three others succumbed to sequelae of other organ system trauma.

Delayed Follow-Up Findings

Eighty-three patients survived their acute hospitalizations, 36 were discharged home, 31 were transferred to a rehabilitation center, and 16 went to another hospital closer to their home. Of the survivors, 46 were Israeli citizens and the remainder comprised 35 Lebanese citizens or militiamen and two United Nations troops. The Israeli survivors differed from the other survivors in a number of ways. They were a demographically more homogeneous group, comprised entirely of males predominantly between 18 and 25 years of age. The other survivors consisted of both sexes and had a bimodal age distribution with a range of 2 to 52 years, a median age of 11 years and a mean age of 19 years.

Each of the 46 Israeli citizens surviving their acute hospitalization was notified by mail to return to RMC for a follow-up evaluation. Forty-one patients returned to the clinic for an interview, neurological examination, and CT scan. The remaining five patients were contacted and interviewed by telephone. Two of these had undergone CT scanning at other institutions within the last year and these studies were reviewed. The mean time from injury to reevaluation was 70.7 months or 5.9 years, with a median follow-up interval of 6.4 years.

No patient had suffered neurological deterioration in the interim and 42 were completely independent at the time of follow-up consultation. Eleven had received bachelor's degrees since their injury and four had received subsequent postgraduate training. Only four patients required ongoing assistance with their activities of daily living or supervision because of poor judgment and/or impulsive behavior. The modified Kurtzke disability scores for patients in this study group ranged from 0.0 to 6.0 with a mean at 2.5.

The CT scans from 43 patients were reviewed (Fig. 2). Twenty-six had evidence of retained intracranial...
fragments: four had metal fragments alone, nine had bone fragments alone, and 13 had both metal and bone fragments (Table 3). Of the 22 with retained bone fragments, 18 (86%) had either a fragment larger than 5 mm or more than three fragments larger than 2 mm clustered within a 1-cm area.

At the follow-up consultation, no patient gave a history or had an examination or CT scan that suggested a delayed abscess. One patient was admitted 1 year following his injury for new-onset generalized seizures and was found to have pneumococcal meningitis. Evaluation at that time revealed no evidence of a CSF leak, and CT demonstrated no retained intracranial fragments. His infection was treated without complication and he has had no further seizures or febrile illnesses.

Ten (22%) of the 46 surviving Israelis had developed delayed seizure disorders during this 6-year follow-up period. Half of these had retained intracranial fragments: two had bone fragments only and three had both bone and metal fragments (Table 3). Seven patients suffered generalized tonic-clonic seizures, two had partial complex seizures, and one had focal motor seizures. Nine of these patients were under good clinical control and one continued to have frequent seizures despite multidrug therapy.

Eight of the surviving Israelis had been treated nonoperatively. Each had evidence of intracranial metallic foreign bodies, which were intraventricular in one patient. Only one (12%) of these patients developed a seizure disorder and none suffered a delayed infection.

Discussion

Until recently, the trend in the surgical management of penetrating head injuries has been one of increasingly aggressive intracranial debridement with an effort to locate and remove all in-driven bone fragments and any metallic fragments which were reasonably accessible. In fact, during both the Korean and Vietnam conflicts, the presence of residual bone fragments on postoperative radiographs was considered evidence that the initial debridement had been inadequate and reoperation was strongly recommended.

Review of the Phase I and Phase II follow-up results in the Vietnam Head Injury Study suggests that following vigorous debridement by a neurosurgeon, the presence of residual bone fragments alone does not warrant reoperation in an asymptomatic patient.\(^{16,15}\) With the development and availability of modern neuroradiological imaging, a less aggressive surgical approach in the care of penetrating head injuries in civilians has been advocated by a number of authors.\(^ {3,6}\) A similar less aggressive operative strategy was prospectively instituted at RMC in 1982 and applied to all penetrating head injuries sustained during the Israeli-Lebanese conflict. The availability of CT was essential to this approach because it alleviated the need for extensive exploration along the missile tract to rule out a hematoma and thus allowed the surgeon to limit the procedure to decontamination and hemostasis.

Evidence that these procedures were less aggressive is provided by the fact that retained bone fragments were found in 51% of our patients at follow-up examination, compared to only 23% of patients in the Vietnam Head Injury Study. Even more striking is the fact that 43% of the patients in our study harbored fragments either larger than 5 mm or in clusters of more than three within a 1-cm area versus only 3% in the Vietnam group.\(^ {16}\)

Given the uncontrolled nature of this study, inferences can be made only by comparison to prior studies using the traditional surgical approach. Despite the operative mortality at RMC (21%) appearing twice that reported by Hammon\(^ {12}\) in Vietnam (11%), the overall mortality rates for patients admitted with penetrating head injuries were quite similar between these two groups, 26% in our group and 32% in the Vietnam
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series. This disparity may be related to a number of differences between these groups. Nearly 21% of the patients in Hammon's series did not receive surgical intervention because of their "moribund" status. At RMC nearly 20% of the patients treated surgically presented with a GCS score of 4 or less and only three of the operative deaths had admissions scores of greater than 5. Hammon stated that 63% of his patients "dying of their cerebral injuries" were comatose preoperatively. At RMC 94% of the operative deaths occurred in comatose patients.

One of the primary historical concerns with a less aggressive surgical approach has been the fear of intracerebral abscess formation and its associated morbidity and mortality rates. In the two studies from Vietnam with follow-up review after initial hospital discharge, the abscess rate ranged from 3% to 8.4%. At RMC only one patient (0.9%) developed an abscess in our entire treatment group. For fair comparison, if we exclude the 35 patients lost to follow-up review and the 18 dying acutely (< 1 week survival) who likewise would not have been included in the Vietnam Head Injury Study, this results in an adjusted abscess rate of approximately 1.8%. This still compares quite favorably with these earlier studies.

Chronic seizure disorders had developed in 22% of our patients during the 6-year follow-up period. In the Vietnam Head Injury Study, the seizure incidence increased with time from 29% at 2 years to 53% at 15 years. At 6 years the estimated frequency was almost 44%, nearly double that reported for our patients. The lower incidence in our study group may be due to differences in cultural attitudes concerning seizure disorders or to less extensive canvassing of the patients and their families. Another possible explanation supported by Salazar, et al., is that a less aggressive debridement technique may result in less cortical volume loss and therefore a diminished seizure frequency.

This study seems to indicate that not only is reoperation for retained bone fragments unnecessary, but it may be possible with the availability of modern neuroradiographic imaging for the surgeon to tailor his surgical approach to conserve cerebral tissue without exposing his patients to undue risk of seizures, infection, or death by leaving intracranial bone fragments.

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