The Repair of Dural Defects by Graft *

An Analysis of 540 Penetrating Wounds of the Brain Incurred in the Korean War

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TREATMENT of the dural defect produced by a penetrating wound of the brain has been a matter of controversy for a long period of time. Opinions range from unequivocal opposition to the repair of a dural defect by graft, to the school of strict adherence to the principle of watertight closure of the meninges in every instance.

Our purpose here is to present a critical analysis of 540 consecutive penetrating wounds of the brain in which the dural defect was closed with a graft. The penetrating wounds reported in this series were incurred in the Korean War during the period September 1950 to September, 1952. The total experience and over-all statistics have been reported elsewhere.[12, 14, 15, 22] Many of these grafts were inserted, by mobile neurosurgical teams in forward areas, at the time of primary closure of the penetrating wound. The established principle of radical debridement, removal of devitalized tissue and retained bone fragments, primary closure of dura and scalp, combined with adequate dosages of antibiotics, were followed in all cases, except those treated in the early phase of the Korean War.[12-14] In that phase, inadequate dural closure frequently necessitated reoperation. Primary closure of the dura was considered essential and was made a policy, in the management of penetrating craniocerebral trauma of Korean War casualties.[8, 14] Even during those phases of the Korean War in which time was at a premium, as, for instance, during the spring offensive in 1951, when the first mobile neurosurgical team performed 126 craniotomies in 26 days, this policy was adhered to strictly.

A total of 590 grafts were used in 540 cases. Of these grafts, 489 were inserted at time of primary craniectomy; 64 were inserted at secondary craniectomy. In 37 instances grafts had to be reinserted or replaced in secondary operations (Table 1).

TABLE 1

Number of consecutive cases of penetrating wounds of the brain with dural graft		540
Number of grafts		590
Insertion at primary craniectomy	489	
Insertion at secondary craniotomy	64	
Reinsertion at secondary craniotomy	37	

Cerebrospinal fluid fistula, retained bone fragments subdural hematoma, or seizures, necessitated secondary operation.

Mode of Injury

In these 540 penetrating wounds of the brain, in which a dural graft was used, metallic fragments were responsible for the brain wound in 259 cases and high velocity missiles in 160 cases.** Vehicular accidents and injuries with various penetrating ob-

* Submitted for publication April 2, 1959.

** "Metallic fragments" refers to fragments from grenades, mortars and high explosive shells. "High velocity missiles" refers to bullets from rifles, carbines, machine guns and other automatic weapons.[24]

TABLE 2

Mode of injury:	
Shell fragment	259
Missile	160
Other	35
Unknown	86

jects accounted for 35 cases. The mode of injury was not listed in 86 cases (Table 2).

Topography of Wound

In this series, there were 524 cerebral wounds and 25 cerebellar wounds. The cerebrum and cerebellum were involved nine times. There were 167 transventricular wounds,[22] 67 dural sinus wounds [15] and 75 air sinus wounds [2] (Table 3).

Types of Grafts

Kirschner, in 1910, concluded from experiences with fascia lata as a dural substitute in the dog, that "living" and autoplastic materials offer better conditions for healing without reaction than artificial and inert materials.[7] He further pointed out that fascia is always ready for use and is easy to work with, as well as being aseptic. We are in agreement with these concepts and especially so since all of the cases in this series were grossly contaminated and potentially infected. Homografts were used exclusively as tissue grafts. Fascia lata was used 198 times, temporal or occipital fascia 186 times, and pericranium 155 times (Table 4). Gelfilm was employed as a dural substitute in 19 cases and in conjunction with a tissue graft in eight cases. The use of Gelfilm in conjunction with a tissue graft presents inviting possibilities. It seems to offer all the advantages of plastic and of tissue grafts while it minimizes the disadvantages of each substance. Gelfilm used in this manner helps to prevent adhesions between cortex and natural graft. It does not lend itself readily to adequate fixation with sutures for purpose of water tight closure. The latter can be effected only by a tissue graft which is secured with closely-spaced interrupted sutures.

In several instances Gelfilm was employed as a temporary measure in cases necessitating two-stage operation.[15] In the second stage a tissue graft was inserted in lieu of the plastic material.

TABLE 3

Type of wound:	
Cerebral	524
Cerebellar	25
Dural sinus wound	67
Air sinus wound	75
Transventricular	161

TABLE 4

Type of graft:	
Fascia lata	198
Temporal or occipital fascia	186
Periosteum	155
Gelfilm or fibrin film	27

Surgical Technic

An existing dural tear requires debridement of its edges, inasmuch as they have been contaminated by the penetrating foreign body and by the comminuted pieces of bone which have been forced through the tear in the dura. Not infrequently minute, but contaminated, pieces of bone become adherent to the dura. Necrotic and grossly-contaminated portions of the dura should be excised. Debridement of the dura is then completed by resection of a narrow edge of dura. Closure of the defect must be accomplished by graft whenever primary closure cannot be effected without tension.

1. **Fascia Lata.** An adequate piece of fascia lata can be obtained best by preparation of a horseshoe-type flap over the lateral aspect of the thigh and excision of the fascia lata with a scalpel. The skin flap should be closed in two layers. The fascia lata is then sutured to the edges of the dural defect with closely-spaced interrupted sutures of No. 4-0 nonabsorbable suture material (Fig.

1). It is inconsequential which side of the graft faces the cortex. However, it is of the utmost importance to space the sutures closely together in order to effect a watertight closure (Fig. 2). The silk sutures are cut short in the usual manner.

The story of K-28, a 23-year-old infantryman, who was wounded when stepping on a trip flare in North Korea, February 9, 1952, illustrates fascia-lata closure of a dural defect. When first seen, he appeared drowsy, but could be aroused and responded coherently. Examination revealed avulsion of a large triangular scalp flap in the left frontoparietal region. The apex of this flap was formed by the upper lid of the left eye, while its base was situated about the helix of the left ear. The distance from apex to base of this avulsed flap measured 24 cm. The left supraorbital region and the left frontal bone were comminuted and depressed. Macerated frontal lobe was exposed in an area measuring 8 cm. by 8 cm. The left frontal air sinus was widely exposed.

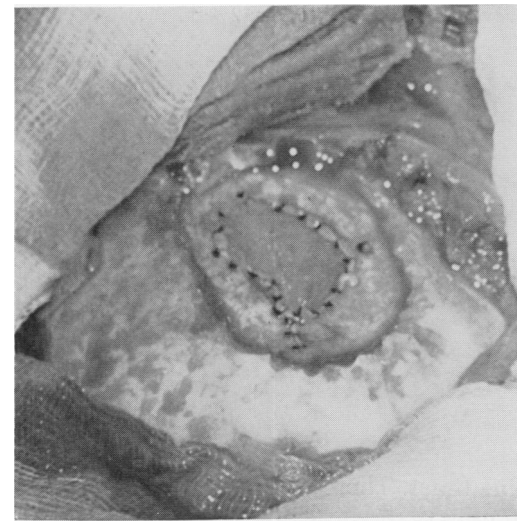

FIG. 2. Fascia lata graft. (K-413)

At operation, the left eye was enucleated. A tear in the anterior portion of the sagittal sinus was repaired with silk sutures tied over Gelfoam. The membranous lining of the exposed frontal air sinus was resected; its remaining edges were coagulated. The devitalized portions of the left frontal lobe

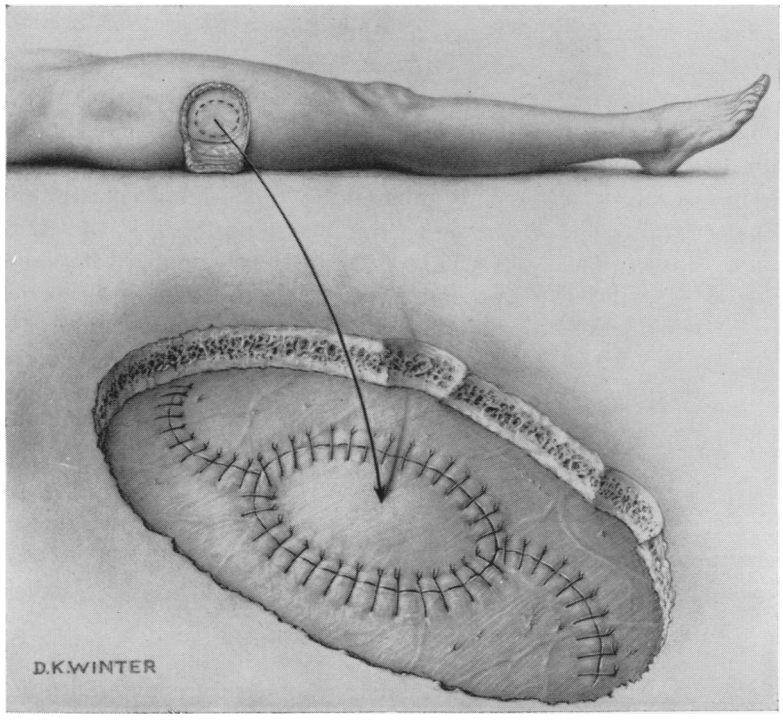

FIG. 1. Fascia lata graft. Insert demonstrates horseshoe flap.

were resected and all debris and retained bone fragments removed. Closure of the gaping dural defect was accomplished by using a large piece of fascia lata which was inserted with closely-spaced interrupted No. 4-0 nonabsorbable sutures. The scalp flap was closed, in individual layers, with interrupted nonabsorbable sutures. Postoperatively, the patient fared well. Healing took place by primary intention.

2. **Temporal or Occipital Fascia.** For medium or small defects, temporal or occiptal fascia is ideally suited, provided that it can be obtained from exposed areas which are not contaminated. A graft prepared from temporal or occipital fascia is inserted in the same fashion as the fascia lata graft. The story of K-332, a 32-year-old rifleman who sustained a penetrating brain wound of the left parietal region, November 7, 1950, illustrates the uncomplicated closure of a dural defect with this type of graft. When first seen he appeared semicomatose but he responded with movements of all extremities to painful stimuli. The site of missile entrance was in the left parietal region of the scalp which appeared swollen and contused. Necrotic brain tissue, blood clots and debris, exuded from the entrance wound under pressure. Blood and necrotic brain tissue also exuded from the external canal of the left ear. It appeared that the bullet had made its entrance through the left parietal lobe and its exit through the left ear.

A liberal left parieto-occipital flap was turned down and an *en bloc* resection of the site of fracture was performed. The existing dural tear measured 2 cm. by 2 cm. This tear was debrided and enlarged, permitting resection of necrotic brain tissue as well as blood clots. A sizeable number of comminuted bone fragments was encountered within the missile canal which could be traced without difficulty to the left ear.

All bone fragments were removed. A piece of occipital fascia was then obtained from an uncontaminated area posteriorly and used as dural graft. It was inserted and secured with closely-spaced interrupted sutures of No. 4-0 silk. The flap was then turned back into its place and primary closure performed in two layers with interrupted sutures of silk. After a few stormy postoperative days, the patient made an uneventful recovery. The flap healed without complications. The patient was evacuated to the Zone of Interior, December 5, 1950.

TABLE 5

Complications:		
Cerebrospinal fluid fistula secondary to graft		49
Spontaneous closure	8	
Surgical closure	41	

3. **Pericranium.** Small defects can readily be closed with available pericranium, provided that it can be obtained from noncontaminated areas. The pericranium is inserted in the same manner as fascia.

4. **Gelfilm.** Inasmuch as Gelfilm cannot be sutured in place in such a fashion as to produce watertight closure, its use for the purpose of permanent closure of a dural defect was abandoned, in the Korean War, after an initial trial period. The great value of Gelfilm, for the purpose of closure of dural defects, lies in its use in conjunction with a tissue graft. This applies particularly to small and medium defects. The Gelfilm can be inserted subdurally and secured to the edges of the dural defect with a couple of sutures. Watertight closure is then performed by a superimposed tissue graft. The advantages of using Gelfilm temporarily whenever a second-stage craniotomy is planned have already been mentioned.

TABLE 6

Infection:	
Infected at time of graft	37
Persistence of initial infection	11
First manifestation of infection after graft	30

Surgical Evaluation

Because of the necessity of secondary neurosurgical intervention, it was possible to inspect surgically the condition of the graft in 144 instances. The graft was found to be viable 90 times. In addition there were 25 viable grafts in which a defect was found; either a pin-point opening or an opening along the suture line. The latter usually resulted from placing sutures too far apart or from sutures' pulling loose. In 20 cases the graft was not viable, as witnessed by necrosis and discoloration. The type of tissue used for the graft did not seem to influence the ultimate viability. Gelfilm was noted to be displaced in five, and in place in four instances (Table 7).

Complications

Cerebrospinal fluid fistula, with the fluid accumulating beneath the closed scalp, occurred in 49 cases; 41 required secondary surgical closure, while spontaneous arrest occurred in eight (Table 5). Of the 41 cases requiring surgical closure, occurrence of the fistula could be traced directly to displacement of Gelfilm in nine cases. The remaining fistulae resulted from mechanically defective grafts. In a few instances, cortical herniation occurred as the result of defective grafts. The story of K-438 illustrates this complication.

This 23-year-old rifleman sustained a penetrating left parietal shell fragment wound, March 9, 1951. He appeared unresponsive on admission. The neurologic deficit included a right hemiparesis. Vital signs were stable.

On March 10, 1951, a left parietal craniectomy, with an *en bloc* excision of the depressed fracture, was carried out. The dural penetration was debrided and enlarged. Blunt resection of the dural attachments to the cortex yieled a moderate-sized subdural hydroma. Devitalized, partly liquefied brain tissue and comminuted bone fragments were resected from the missile canal. The linear extensions of the dural opening were sutured after a large piece of Gelfilm had been inserted subdurally to cover the central dural defect. Routine closure of the scalp was performed. The wound healed well except for an accumulation of fluid under the flap which did not subside despite frequent combined flap and spinal taps.

TABLE 7

Secondary inspection of graft		144
Viable	90	
Viable with mechanical defect	25	
Nonviable	20	
Film in place	4	
Film displaced	5	

On March 21, 1951, a secondary craniotomy was performed. A small extradural cerebral herniation, which was viable, was found. The herniation was surrounded by an accumulation of cerebrospinal fluid under the galea. Retraction of the dura surrounding the herniated material resulted in spontaneous evacuation of a subdural hydroma which in turn permitted the herniation to retract within the dural confines. The dural edges were debrided and the defect repaired with fasci lata. Routine closure of the scalp was performed. The incision healed well. There was no further fluid accumulation under the flap. The patient remained afebrile. His neurologic deficit subsided.

The postoperative occurrence of focal seizures may indicate cortical herniation through a small dural defect produced by an incompletely closed graft. The story of K-212 illustrates this complication.

This 23-year-old private sustained a through-and-through bullet wound, May 20, 1951. The entrance wound was in the left naso-orbital angle. The exit wound was cephalad and posteriorly to the right ear. The patient was drowsy on admission but could be aroused. The neurologic deficit was limited to a seventh-nerve paralysis of lower motor neuron type. His blood pressure was 104/58; pulse was 64. X-rays re-

vealed eleven comminuted bone fragments within the right temporal lobe.

Right temporal craniotomy permitted evacuation of an extensive subdural hematoma from the middle fossa. The temporal lobe was lacerated. There was a tear in the dura underlying a defect in the temporal bone. Fourteen comminuted bone fragments were removed from the lacerated temporal lobe. Necrotic brain tissue was resected. A piece of fibrin film was inserted subdurally to cover the dural defect. It was weighted down with strips of Gelfoam. Primary closure of the scalp was performed in individual layers.

On the third postoperative day, the patient developed focal seizures without syncope, involving the left side of the face only. Vital signs remained stable. The patient appeared rational and well oriented. The flap did not bulge. These seizures recurred frequently during the next five days. On the fifth day the patient had a focal seizure with syncope. Because of the possibility of a subdural hematoma, secondary craniotomy was decided upon. The dural suture line was found to be intact. It was partially opened. There was no subdural hematoma. The pathology was found at the site of the dural tear, corresponding to the exit wound. The Gelfilm, which had been used to cover the dural defect, was found extradurally. Through the dural defect a small area of soft and discolored temporal lobe cortex had herniated. A piece of pericranium was used as a graft to cover the area of herniation after this portion of temporal lobe was allowed to fall back in place. Routine closure was performed. Because of the proximity of this very small hernia (1 cm.) to the face area, it was considered a possible etiologic factor for the postoperative seizures. Recovery was uneventful. Seizures did not recur.

Discussion

It was the British practice, during World War II, to leave the dura open, primary stress being laid on accurate scalp closure without tension.[8] Ashcroft [1] pointed toward an increased risk of sepsis. He believed that it is essential to establish external drainage in order to prevent infected material from draining toward the ventricular system. Martin and Campbell's experiences,[10] however, indicated that satisfactory drainage of deeply infected brain wounds seldom occurred. The importance of protecting the brain against external contamination became obvious with the appearance of cerebral fungi resulting from localized cerebritis associated with superficial wound infection in the presence of an open dura.[10, 18] Gillingham reported 17 cases with initial superficial infection, of which, ten developed cerebral fungus.[5] He believed that two of the remaining seven did not develop cerebral fungus because the dural defect had been repaired by fascia lata, preventing infection from spreading into depth. With the advent of chemotherapy and careful attention to scalp debridement and closure,[3] watertight dural closure without drainage, using a graft whenever needed, became the method of choice of most American neurosurgeons.[4, 6, 11, 19, 21, 23] It must be pointed out, however, that Small and Turner's extensive study of brain wounds [20] did not lead them to conclude that dural closure was a primary factor in the prevention of infection.

A comparison between the penetrating wounds of the early phase of the Korean War, when infection occurred in 41 per cent of all cases, and those that occurred after a neurosurgical management had been organized in all echelons of the Far East Command, leaves no doubt in our minds that primary watertight closure of the dura is of the utmost importance if centripetal infection is to be prevented.

Other advantages afforded by careful dural closure, such as prevention of cerebrospinal fluid fistula, which may lead to breakdown of wounds and secondary men-

ingitis, are well recognized. Watertight dural closure also facilitates cranioplasty, allowing for a satisfactory plane of cleavage.[8, 17] Although there is, as yet, no statistical evidence to support the theory that dural closure lowers the incidence of posttraumatic epilepsy, many authors believe that it is the corticodural scar which is epileptogenic rather than the foreign body or the foreign body reaction. Dural closure by primary suture or by insertion of graft certainly serves to minimize the occurrence of corticodural scars and re-establish as nearly a normal anatomic relationship as possible.[9, 16]

Summary and Conclusions

1. Five-hundred and forty consecutive cases of penetrating craniocerebral trauma, with repair of the dural defect by graft, are reported.

2. The advantages of watertight closure of the dural defect are discussed. These are prevention of centripetal infection, prevention of cerebrospinal fluid fistula, facilitation of cranioplasty and avoidance of corticomeningeal scar formation.

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