Efficacy of dural tenting sutures

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Object. The goal of this study was to assess the necessity for the prophylactic use of dural tenting sutures.

Methods. Data that had been prospectively collected from 369 consecutive cranial operations in adults were analyzed. In this series of patients, dural tenting sutures were used on a judicious "as needed" basis. They were never used to satisfy a procedural routine or for use as a prophylaxis against epidural hemorrhage that was not apparent. The sutures were used for the control of epidural bleeding in 33 patients (8.9%); no tenting was required in 336 patients (91.1%). Reoperation for postoperative epidural hematoma was not required in this series.

Conclusions. Dural tenting sutures continue to have an important role in neurosurgery; however, there is no compelling evidence to support their traditional prophylactic use in every intracranial operation.

Key Words * complication of craniotomy * dural tenting suture * cranial suture * epidural hematoma * epidural hemostasis

Hemostasis was the dominant technical problem during the early years of neurosurgical development. Horsley's wax,[8] Cushing's silver clips,[4] and electrocautery[5] were major contributions to neurosurgery. Metal clips, although still used, have fallen out of favor because of the artifacts they introduce on both computerized tomography and magnetic resonance imaging. However these innovations had limited value against postoperative epidural hemorrhage which, according to Dandy,[6] complicated almost 25% of all intracranial operations; death or major neurological impairment were common sequelae. The reason why epidural hemostasis posed such difficulty for neurosurgeons during the early portion of this century no longer resides within the memory of living neurosurgeons nor is the reason intuitively apparent on the basis of neurosurgical experience of the late 20th century. Low blood pressure caused by hypovolemia from intraoperative loss of blood was extremely common in the early days of neurological surgery and apparent hemostasis at the time of closure of the wound was predictably unreliable.[6] Delayed epidural hemorrhage occurred because open or poorly secured dural blood vessels--particularly those arteries not identifiable at the time of closure because they were not bleeding--began to bleed several hours after surgery as a result of improved perfusion after reestablishment of normal systemic blood pressure. Some surgeons completely excised the exposed dura and either left it out or sutured it back in place; the circumferential incision ensured that all dural vessels...
in the line of incision were dealt with at the time of opening.[6] Some early surgeons left the dependent portion of the scalp wound open (Horsley) or placed horse hair in scalp wounds (Keen), to facilitate drainage of accumulated blood; other surgeons routinely reexplored wounds after a few days to remove the predictable epidural hematoma.[9,10]

Walter Dandy reported in 1932 that "a number of permanent silk sutures tightly drawn between the dura and the galea or subaponeurotic tissue . . . will hold the dura firmly against the bone and make postoperative extradural hemorrhage from this source impossible."[6] Although not often cited among Dandy's great achievements, this technical innovation was arguably his greatest and certainly compares favorably in magnitude and duration of impact with Horsley's wax and Cushing's use of electrocautery.

After Dandy introduced dural suspension sutures in the early 1930s, their use became and remained a ubiquitous and unquestioned neurosurgical subroutine and the subject of postoperative epidural hemorrhage almost totally disappeared from the neurosurgical literature. Various names have been applied to the sutures used to attach the dura tightly to cranial bone: tenting sutures, dural-periosteal sutures, tacking sutures,[12] tack-up sutures,[1] stay sutures,[7,13] suspension sutures, and sleeper sutures. The last term, which is common in verbal neurosurgical communication but uncommon in print, apparently derives from the neurosurgical mantra, "Sleeper sutures help the neurosurgeon sleep at night," simultaneously reflecting and perpetuating the notion that this prophylactic subroutine reliably prevents postoperative epidural hematomas and, therefore, must be included in every craniotomy.

The prophylactic use of multiple dural tenting sutures today is a perpetuation of a tradition introduced 67 years ago to deal with an intraoperative pathophysiological state that almost totally disappeared long ago. Then and now, in patients who are severely hypotensive at the time of closure, dural tenting greatly minimizes but does not "make impossible," as Dandy hoped, the risk of delayed extradural hemorrhage. In the early portion of this century, surgical blood loss was not routinely replaced and, indeed, transfusion had considerable risk. Patients received little, if any, intraoperative fluid and were often positioned with the head elevated. Anesthesia was usually induced using ether or chloroform and there was, by current standards, minimal monitoring of cardiovascular and hemodynamic status. It is not surprising that patients were commonly hypotensive at the close of a craniotomy.

A reconsideration of the efficacy of prophylactic dural tenting seems reasonable two thirds of a century after its introduction. For this reason, I have examined the results of the practice of using dural tenting sutures only when needed to control active bleeding, and not on a routine or prophylactic basis.

**CLINICAL MATERIAL AND METHODS**

**Patient Population**

This report is based on prospectively recorded data obtained from 369 consecutive operations performed on patients 16 years of age or older, in which the use of dural tenting sutures might reasonably be considered. All intracranial operations were included, except for the following categories: ventriculostomy of all types, burr or twist drill hole placement regardless of indication, cerebrospinal fluid shunt placement procedures of all types, small procedures on the skull (such as skull biopsy), insertion of intracranial pressure monitors, and stereotactic biopsy or aspiration. Patients who underwent transclival or transsphenoidal procedures and those who received craniofacial reconstructions were excluded. Also excluded were patients who died shortly after surgery without postoperative neuroimaging and in whom no autopsy was performed.
Operative Technique

Bleeding sites on the dural surface were controlled using bipolar (occasionally unipolar) coagulation as soon as they were identified. The source of all arterial bleeding was identified and controlled, usually with electrocoagulation; this occasionally required removal of additional bone. In two cases, arterial hemostasis was accomplished or assisted by ligation of a branch of the middle meningeal artery and, using the same suture, tenting this portion of the dura. Small sites of nonarterial oozing were ignored. After opening the dura, its edges in almost all cases were retracted temporarily with No. 4-0 Neurolon or silk sutures to control venous bleeding from the surrounding epidural space and to improve the surgical exposure. Bleeding from the edge of freshly cut dura was controlled using bipolar coagulation or, much less commonly, by briefly crushing the bleeding site with a needle holder. The temporary traction sutures were removed just before or during closure of the dura.

The dura was tented as needed to establish hemostasis from persistent, low-pressure bleeding into the visualized epidural space from sources beneath the edges of a craniotomy. Occasionally Gelfoam, Surgicel, or, in rare instances, a very small piece of the temporal muscle was tucked beneath the edge of the cranial defect before tying a tenting suture. In a few cases in which vigorous bleeding from the epidural space was apparent from the time the bone flap was removed, the dura was tacked securely with permanent sutures before it was opened. More commonly, however, the decision regarding the use of tenting sutures was made on a "suture-by-suture" basis as the dura was being closed. Most often, permanent tenting was accomplished using No. 4-0 Vicryl (occasionally Neurolon or silk) sutures. All tenting sutures were placed as close to the surrounding cranial bone as reasonably possible, but not so tightly as to further strip dura from bone or compromise dural approximation. Bleeding from a dural venous sinus or a Pacchionian granulation was controlled by using Gelfoam, which was held manually for a few seconds or occasionally secured there with a suture. Dural tenting sutures were never used on a prophylactic basis or as part of an established routine.

A flat, 7-mm noncollapsible drain with multiple perforations (Jackson-Pratt drain; Baxter Health Care Corp., Dearfield, IL) was inserted, via a small separate stab wound, into the subgaleal space before closure of the scalp in all but three patients who underwent supratentorial operations. Continuous suction was applied to the drain via a standard bulb apparatus. In patients in whom the drainage fluid seemed to be partially composed of cerebrospinal fluid, suction was applied for only 5 minutes of each 60-minute period. A snug turban dressing was applied to all patients. Drains were removed in 18 to 36 hours (usually < 24 hours).

Statistical Analysis

Calculations of confidence intervals were made with the assumption of a binomial distribution.[11]

RESULTS

All 369 operations were performed by the author. These operations were conducted with the aid of a neurosurgical resident in 304 instances, with another type of surgical resident in four, an attending neurosurgeon in eight, an attending surgeon with a specialty other than neurosurgery in seven, a medical student in two, a surgical assistant in six, and no assistant in 38 instances. There were 211 males and 158 females in the study. Patients younger than 30 years of age accounted for 34% of operations and 55% of the cases requiring dural tenting; this reflected the higher incidence of trauma in younger patients (Table 1).
The distribution of patients according to diagnostic category (Table 2) may reflect a relatively high proportion of surgery for epilepsy, trauma, and neoplasia, compared to many neurosurgical practices. Dural tenting sutures were used in 33 operations, 16 of which were for trauma (Tables 2 and 3); cranioplasty, which in this population was often required as a consequence of trauma, is tabulated separately. The 43 operations for vascular problems consisted of 19 performed for saccular aneurysms, two for arteriovenous malformations, and 22 performed for a heterogeneous group consisting of intracranial hematomas not known to be related to trauma, most of which were spontaneous and treated on an emergency basis; six of the 43 were in the posterior fossa. When tenting sutures were required, one to three were usually sufficient; however, one patient (acute trauma) required 11 dural tenting sutures and another (cranioplasty) required nine. None of the patients was significantly hypotensive during closure or at completion of surgery. None of the 33 patients who received dural tenting sutures required reoperation for epidural or subdural hemorrhage anywhere near the original operative site; one patient with acute trauma required reoperation for a delayed epidural hemorrhage in the contralateral middle fossa. Dural tenting was considered to be necessary for hemostasis in only 17 (5.8%) of 291 of nontrauma (almost all elective) cases but in 16 (20.3%) of 79 trauma cases. Trauma accounted for 48% (16 patients) of the operations in which dural tenting sutures were used and, in six of these, the injury was a gunshot wound (Tables 2 and 3).
In the 23 operations for cranioplasty (22 of which used autologous cranial bone or ribs) 22% required dural tenting; the major blood loss in these cases occurred as the edge of the cranial defect was cleared from adherent scar and dura. If the five operations for cranioplasty that were required as a result of trauma are combined with the operations performed for recent trauma, then 64% of cases requiring tenting sutures were trauma related. Coagulopathy thought to be related to severe parenchymal brain injury existed in five patients, four of whom had gunshot wounds of the head; all five required dural tenting sutures to establish hemostasis. In only three of the 16 operations for acute epidural hematoma did the dura mater require tenting; in these three cases the dura matter had been extensively stripped preoperatively from overlying bone. Six of the 98 operations for tumor required dural tenting (four procedures for supratentorial meningiomas, one for a meningioma of the posterior fossa, and one transcallosal operation for a colloid cyst). Only five operations related to epilepsy required dural tenting and two of these were operations for the insertion of an interhemispheric recording grid.

Postoperative neuroimaging was performed in almost all patients within the 1st week and most often
within 24 hours after surgery. It was not unusual to observe a thin (1-3 mm maximum thickness) layer of epidural blood beneath the bone flap. None of these thin collections of blood had apparent clinical significance and none were surgically removed. One patient who underwent anterior temporal lobectomy for epilepsy had an extracerebral collection, 1 cm thick, in the anterior pole of the ipsilateral middle fossa and this did not require surgical removal.

**DISCUSSION**

The use of dural tenting sutures only when needed to control active extradural bleeding is associated with no higher incidence of postoperative epidural hematoma than the prophylactic placement of multiple tenting sutures during every craniotomy. In 100% of 369 consecutive cranial operations in adults, the postoperative accumulation of epidural blood not deemed clinically or radiographically sufficient to require reoperation; 91.1% of these cases were judged by the surgeon not to require placement of dural tenting sutures and, therefore, did not receive them. The postoperative extradural hematoma rate of zero in this series compares most favorably with rates published by other centers (Table 4).

<table>
<thead>
<tr>
<th>Author(s) &amp; Yr</th>
<th>No. of Operations</th>
<th>No. of Extradural Hematomas (%)</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zhao, 1984</td>
<td>21,400†</td>
<td>55 (0.26)</td>
<td>0.18–0.33</td>
</tr>
<tr>
<td>Fukamachi, et al., 1986‡</td>
<td>655</td>
<td>15 (2.3)§</td>
<td>1.44–3.44</td>
</tr>
<tr>
<td>Cabantog &amp; Bernstein, 1994\</td>
<td>207</td>
<td>1 (0.48)</td>
<td>0.00–1.67</td>
</tr>
<tr>
<td>Winston, 1996, 1999**</td>
<td>698</td>
<td>1 (1.14)</td>
<td>0.00–0.05</td>
</tr>
</tbody>
</table>

* The confidence with which it is reasonable to accept the percent of operations complicated by postoperative extracranial hematoma is reflected in the 95% confidence interval.
† Approximate numbers in a report with few details.
‡ Categories of operations excluded from the present series have been subtracted from this series.
§ Hematomas that were too small to require treatment are excluded.
\ Series of adults with brain tumors.
** Current series of adults combined with published series of children by the same author.

Except for sporadic case reports, little has been published on the topic of postoperative extradural hematomas. If the types of operations that were excluded from the present series are subtracted from the series published by Fukamachi, et al.,[7] those authors encountered postoperative extradural hematomas in 2.3% of their craniotomies, although they tented the dura tightly in all cases. (Also excluded from the series of Fukamachi, et al., were 152 cases in which hematomas were less than 1 cm in maximum thickness, none of which affected the patient's clinical course or required treatment.) Cabantog and Bernstein[2] reported significant postoperative epidural hemorrhage in 0.48% of adults who underwent surgery for brain tumors. In another report in which relatively little detail or description was given for more than 21,000 operations performed in China, the incidence of postoperative extradural hemorrhage was 0.26% (0.1% of these cases also had subdural hematomas).[15] Surprisingly there is one report of extradural hematomas requiring evacuation during surgery in 0.14% of craniotomies (five intraoperative extradural hematomas in approximately 400 craniotomies per year over a period of 9 years).[12] One published series that is identical to the current one with respect to decision making on the use of dural tenting sutures, but differs totally with respect to the age of the patients, is the pediatric series that I reported previously in which the incidence of postoperative epidural hematoma was 0.3%.[13] All series
discussed here are significantly different from the current series and from one another. Therefore any comparison must be made with caution.

There exists in every craniotomy a risk of postoperative epidural hemorrhage, even though this was not demonstrated in the current series. If the data obtained from the adult patient population in the current series is combined with my experience in pediatric patients,[13] the combined group better resembles most published series because all ages are included.[7,15] In this combined group, one postoperative extradural hematoma (found in a child with hemophilia) occurred in 698 consecutive operations performed by the same neurosurgeon (95% confidence interval 0.00-0.5%; Table 4).[11]

The distribution of diagnostic category is weighted heavily by elective operations (epilepsy 31.7% and neoplasia 26.6%) and by operations for trauma (21.4%), almost all of which were performed on an emergency basis; therefore this series may not represent the case mix of a typical neurosurgical practice treating adults. The high incidence of operations for trauma may actually skew the sample toward an higher-than-average risk of postoperative extradural hemorrhage.

The 33 operations in which dural tenting sutures were used were unevenly distributed among the diagnostic categories (Table 2). Twenty percent of patients who underwent surgery for trauma (almost all on an emergency basis) required tenting sutures, whereas those undergoing elective operations required tenting sutures less often (epilepsy 4.3% and tumors 6.1%). Interestingly, patients who underwent elective surgery to repair cranial defects (cranioplasty) more often required tenting sutures (21.7%). If operations for cranioplasty are excluded, only 4.5% of elective cranial operations required tenting sutures.

Extradural hematomas can occur in the presence of dural tenting sutures, as evidenced by several such cases in the report published by Fukamachi, et al.[7] Tenting effects hemostasis by binding the dura sufficiently tightly against the edge of the overlying bone to occlude the dural vessels immediately underlying the surrounding edge of bone. Sites of bleeding from dura exposed by craniotomy are readily apparent (if systemic blood pressure is near normal or higher) and are usually controlled without difficulty by electrocoagulation.

No hematomas occurred in the supratentorial or infratentorial groups, yet almost all of the former and none of the latter had suction drainage. The possibility cannot be excluded that an equivalent outcome could have followed the less frequent use of suction drainage in the supratentorial group. It is my opinion, however, that the liberal use of suction drainage contributed to, but was not a sufficient explanation for, the zero incidence of postoperative epidural hemorrhage observed in this series.[6,7,9,10]

Suggestions that neurosurgeons of today are better able to recognize the hemostatic state, that they are technically superior in ability to establish epidural hemostasis than were their professional forefathers, or that extradural hemorrhage is more often missed today than it was two thirds of a century ago are untenable. However, the notion that patients today face a much lower risk of postoperative epidural hemorrhage than patients in the era in which Dandy introduced dural tenting is compelling. Since prophylactic dural tenting was introduced, the intraoperative monitoring and manipulation of cardiovascular and other physiological parameters has evolved into a sophisticated specialty--anesthesiology. Significant systemic hypotension at the close of a craniotomy, whether due to hypovolemia or another cause, almost never occurs today.
No complications were recognized from the placement of dural tenting sutures in the 33 operations in which they were used in this series of adults. Nevertheless, placement of each dural tenting suture, particularly if done before the dura is opened or after its closure, is not free of risk because of the possibility of causing bleeding from dural or cerebral vessels. Postoperative acute subdural hematoma resulting from the use of tack-up sutures has been reported[1,15] and most, if not all, experienced neurosurgeons have encountered this complication. A surgical technique for avoiding this complication (place tacking sutures only through the outer layer of the dura) has been published.[3] Also tenting sutures, if closely placed, can obscure marginally controlled or even active epidural bleeding by preventing the flow of blood into the exposed surgical field at the time when the surgeon is trying to establish and confirm hemostasis in preparation for closing the wound. Interestingly, Dandy was aware of the risk associated with dural tenting, as evidenced by his warning that excessively tight dural tenting can increase hemorrhage into the epidural space by further stripping the dura from bone around the periphery of the craniotomy.[6] Also there is a cost associated with dural tenting in terms of consumption of medical resources and a somewhat longer operative time. Therefore, it is compelling to believe that tenting exposes patients to the risks, albeit small, of causing extradural, subdural, and subpial bleeding, and the concealment of epidural bleeding at the time of closure. It is indisputable that the fewer tenting sutures used, the less likely there can be any complication related to their use. However low the risk associated with tenting of the dura, no valid argument can be made in support of unnecessary risk.

The judicious use of dural tenting sutures in this series should not be interpreted to mean that the author considers them to be without value or dangerous. The importance of extradural hemostasis is important and must not be minimized. During the closing phase of an intracranial operative procedure, a dural tenting suture may be the best or only way of accomplishing hemostasis. In 8.9% of the operations reported here, dural tenting sutures were not only helpful but probably essential for establishing hemostasis; if they had not been used in these 33 operations, the incidence of postoperative epidural hematoma probably would have been unacceptably high. It is possible that a few patients in whom dural tenting was used would have achieved as good a result--that is, no epidural hematoma--if the tenting had been omitted. It is not possible that any better result would have followed a more liberal use of dural tenting sutures.

When Dandy introduced dural tenting over 67 years ago, the benefits far outweighed the risks. Tenting of the dura obviated a life-threatening technical problem. The chief cause of that problem, significant systemic hypotension at the time of surgical closure, is now almost nonexistent, except for patients on the operating table. Nowadays patients are almost always normotensive and, occasionally, even hypertensive at the time of closure. Hemostasis established under the typical normovolemic, normotensive intraoperative conditions of the late 20th century is very much more reliable than it was in the early portion of the century when dural tenting was introduced. If dural tenting sutures are to be used routinely today, their use should have currently demonstrable value.

CONCLUSIONS

Dura should be tented when dural tenting is needed, but only when needed. The traditional neurosurgical teaching that the placement of many dural sleeper sutures in every patient is necessary to prevent postoperative extradural hemorrhage is not supported by the data in this report nor is it upheld by any current literature.

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