

VINYON "N" AS DURAL SUBSTITUTE AND ITS USE IN OTHER NEUROSURGICAL CONDITIONS

BY

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The search for a material to be utilized as dural substitute has been a continuous one for the last six decades. Many materials have been tried, including the different metals, various biological tissues, and plant derivatives. Recently, synthetic products have been utilized as dural substitute. Among these, Vinyon "N" (Teng and Feigin, 1955), Teflon (Teng, unpublished data), and Orlon* (Huertas, 1955) have shown the most promising results, producing only minimal tissue reaction when buried intracranially in experimental animals.

Since publication of the results obtained in experimental monkeys, Vinyon "N" has been used in 40 clinical cases with various neurosurgical conditions, which included its use as (1) dural substitute in repairs of dural defects produced by surgery, trauma, or tumour; (2) bone lining, in the prevention of bone reunion in craniostenosis; and (3) nerve wrap after neurolysis in cicatrization (Table I).

144 wrap threads and 90 filling yarns per square inch. The pattern weave, consistency, and colour are those of China silk. It can readily and repeatedly be sterilized in boiling water without any appreciable damage. Autoclaving stiffens it.

Clinical Observations

From February, 1956, to July, 1960, Vinyon "N" cloth has been used in 40 neurosurgical cases. In 32 instances it was used as dural substitute. These included 26 cerebral dural defects, two cerebellar dural defects, and four spinal dural defects. In 2 infants it has been utilized as bone lining after "grooving" craniectomy for craniostenosis. It also been used in two patients as nerve wrap, in sciatic trunk and a radial nerve, after neurolysis in severe cicatrization. The duration of observation in these 40 cases varied from four to 52½ months (Table II).

As Cerebral Dura Substitute.—Vinyon "N" cloth has been used to cover cerebral dural defects in 26 clinical cases, which included 13 malignant gliomas, four meningiomas, four subtemporal decompressions, and one case each of astrocytoma, cerebrospinal fluid rhinorrhoea, cortical laceration, vascular anomaly, and haemangioma (Table I). In each instance, the Vinyon "N" cloth was tucked under the edge of the dura (Fig. 1B). The technique used in applying Vinyon "N" cloth as a dural substitute has been described in detail in a previous paper on animal experiments (Teng and Feigin, 1955). Meningocerebral adhesions frequently developed along the suture line in edge-to-edge anastomosis (dura to Vinyon "N"), but no such adhesions occurred in eversion suturing or when tucking the edge of dural substitute under the edge of dura mater. This technique has been followed in all cases of this series.

In 15 cases, it was possible to recover the Vinyon "N" cloth from the site of surgery. These included 13 cases of malignant glioma at necropsy, and

TABLE I

VINYON "N" USED IN VARIOUS NEUROSURGICAL CONDITIONS

<i>Cerebral Dural Defects</i>	
Glioma.....	13
Meningioma.....	4
Astrocytoma.....	1
Haemangioma.....	1
Vascular anomaly.....	1
Cortical laceration, open wound.....	1
Cerebrospinal fluid rhinorrhoea.....	1
Subtemporal decompression.....	4
<i>Cerebellar Dural Defects</i>	
Astrocytoma.....	2
<i>Spinal Dural Defects</i>	
Tumour.....	2
Trauma.....	2
<i>Peripheral Nerve Wrap after Neurolysis</i>	2
<i>Craniostenosis</i>	6
Total	40

Vinyon "N" Cloth

The Vinyon "N" used in these experiments, is a synthetic fabric woven into cloth, constructed of

*The Vinyon "N" cloth used in this study was supplied by the Carbido and Carbon Chemical Company, New York.

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TABLE II
VINYON "N" CLOTH RESIDENT IN TISSUE

Case No.	Manner of Utilization	Diagnosis and Site of Vinyon "N" Used	Date of Operation	Approximate Duration to July 1, 1960 (mth.)
1	Substitute for cerebral dura	Left parieto-occipital astrocytoma	6/3/58	25
2	" " " "	Left temporal lobe haemangioma	1/23/57	41
3	" " " "	Left frontal meningioma	8/6/56	47
4	" " " "	Left frontal parasagittal meningioma	5/26/56	49
5	" " " "	" " " "	11/14/57	31½
6	" " " "	Right frontal parasagittal meningioma	8/14/57	34½
7	" " " "	Left parietal vascular anomaly	5/14/16	49½
8	" " " "	Right temporoparietal laceration	10/5/56	45
9	" " " "	Right subtemporal decompression	8/15/56	46½
10	" " " "	" " " "	8/21/56	46½
11	" " " "	Left subtemporal decompression	11/17/56	43½
12	" " " "	" " " "	12/29/57	30
13	" " " "	Frontal base, cerebrospinal fluid rhinorrhoea	5/3/57	38
14	Substitute for cerebellar dura	Right cerebellar astrocytoma	2/29/56	52
15	" " " "	" " " "	6/5/59	13
16	Substitute for spinal dura	D ₂ to D ₃ meningioma	11/19/58	19½
17	" " " "	C ₂ to C ₄ intramedullary hemangioma	4/19/57	38½
18	" " " "	Cauda equina, compression fracture	11/20/57	31½
19	" " " "	" " " "	6/10/57	36½
20	Bone lining, in craniostenosis	Premature closure, sagittal and frontal sutures	2/15/56	52½
21	" " " "	Premature closure, sagittal suture	3/4/56	52
22	" " " "	" " " "	5/6/57	38
23	" " " "	" " " "	9/1/59	10
24	" " " "	" " " "	9/12/59	9½
25	" " " "	" " " "	9/17/59	9½
26	Peripheral nerve wrap	Cicatrization, left radial nerve, upper arm	4/9/57	38½
27	" " " "	Cicatrization, right sciatic nerve	4/29/59	14

two instances it was recovered from patients undergoing subsequent surgery. In the 13 necropsied cases, the length of time that the Vinyon "N" cloth had been buried in tissue ranged from four to 22 months. In the others, one a case of frontal meningioma and the other a subtemporal decompression, the cloth was removed, in part, for microscopic examination, after being examined *in situ*. In these two, the dural substitute had been used to cover the dural defect for periods of 34 and 30 months, respectively. None of the 27 patients currently alive reveal any clinical evidence of irritative effect from the synthetic fabric up to the time of writing.

In all of the 15 cases mentioned above, the dural substitute was easily reflected or removed, with or without gentle blunt dissection, as necessary, there being no adhesions at the site of the cerebral wound. Here and there were scattered fine strands of fibrous tissue adherent to cortical vessels, where dissection was needed to lift the dural substitute from the cortex without tearing the pia mater. As a rule, dense scar tissue was found on the outer surface of the dural substitute, but on its under surface there was a thin layer of transparent, glistening membrane, the thickness of an opaque arachnoidea. No connective tissue capsule was found to enclose the dural substitute in any of the 15 cases. Microscopic examination showed the dural substitute to be infiltrated by a few lymphocytes and foreign body giant cells. Minimal proliferation of the arachnoid cells was noted. The underlying cortex appeared

normal. There was no adhesion between the dural substitute and the surgical wound in the cerebrum.

The following case is illustrative:—

This 30-year-old man was operated on on August 6, 1956 (Table II, Case 3). A large meningioma, *en plaque*, was removed through a left frontal craniotomy. Both the bone flap and the dura were discarded because of tumour infiltration. The frontal bone measured 1.5 in. in thickness. Hyperostosis extended to the left supra-orbital plate and the ocular globe was displaced downward. A piece of Vinyon "N" cloth, 3 × 3 in. in diameter, was used to cover the dural defect.

Two years and 10 months later he was again operated upon for removal of the remaining portion of left frontal bone, supra-orbital rim and plate, and the nasal bone. The frontal wall of the cranium and the orbital rim were reconstructed with grafted ilium. At surgery, the Vinyon "N" cloth was examined. Dense fibrous tissue was found on the outer surface of the dural substitute, but its under surface was covered only by a thin layer of fibrous strands which were not adherent to the underlying cortex. In places, the dural substitute was loosely anchored to the cortical vessels by thin strands of connective tissue which were easily separated by dissection, without tearing the pia membrane and cortex. In one small area, where the cortex was not covered with dural substitute, dense scar tissue was found, extending from the epidural region to the cerebral cortex, with abundant traversing vessels.

A small piece of Vinyon "N" cloth, excised for microscopic examination, showed scattered lymphocytes and foreign body giant cells lodged among the meshes of the

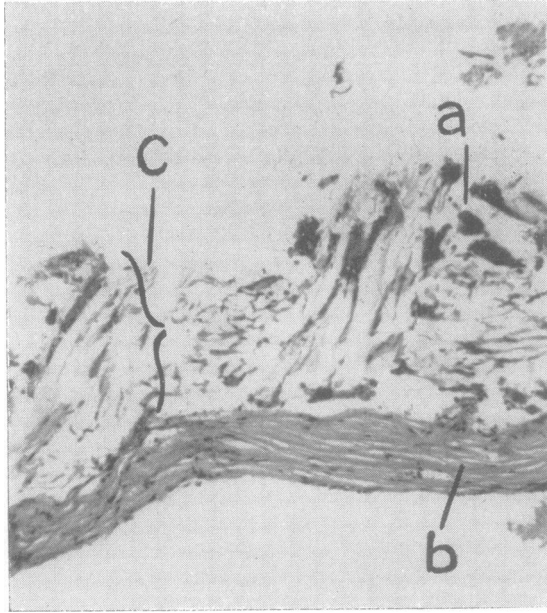


FIG. 2.—Section of dural substitute, Vinyon "N", removed 34 months later. $\times 80$. (a) large foreign body giant cells; (b) thin layer of fibrous tissue lining under surface; (c) total thickness of silk-like Vinyon "N" cloth.

dural substitute, and a thin layer of connective tissue on its under surface (Fig. 2).

Despite the fine pores of the Vinyon "N" cloth, it has been used to repair rhinorrhoea of the cerebrospinal fluid. The following is an illustration of an extreme case of cranionasal fistula.

A 27-year-old man (Table II, Case 13) was admitted to the hospital on May 1, 1957, because of cerebrospinal fluid leaking through the nose for two years, after a motorcycle accident. He had survived five episodes of septic meningitis in the past two years. Surgical repair of the fistula had been recommended at another hospital, but this was refused. On May 3, 1957, a right frontal craniotomy was performed, and a large bone and dural defect, 1.5 cm. in diameter, was found in the cribriform plate. Granulations in the fistula were curetted, then packed with gelfoam soaked with bacitracin and polymyxin solution. A small piece of Vinyon "N" cloth was laid on the inner surface of the dural defect. The post-operative course was uneventful, and no cerebrospinal fluid has leaked since surgery.

As Cerebellar Dural Substitute.—In two cases of cerebellar astrocytoma, after removal of the tumour, the dura was not resutured but the cerebellum was covered with a piece of Vinyon "N" cloth, placed in a position similar to that used to cover the cerebrum. Neither of the patients, after 13 and 52 months

respectively, show any ill effects since its placement in the posterior fossa.

As Spinal Dural Substitute.—Vinyon "N" has been used to cover spinal dural defects in four cases. In three instances it was placed after decompression of the spinal cord or cauda equina. Compression was caused by trauma in two of the cases, and tumour in the other. In the two patients with compression of the cauda equina caused by a compression fracture of the upper lumbar spine, the roots of the cauda equina were markedly congested and swollen. The dura was left open for the purpose of decompression and a strip of Vinyon "N" cloth was placed to cover the dural defect. The dural defect in the third patient was produced by excision of a meningioma. In all three cases the dural substitute has been in place for periods ranging from 19½ to 36½ months, and none have demonstrated any irritative effect.

One case of spinal dural substitute is illustrated below:

This 36-year-old male school teacher (Table II, Case 17) went to surgery on April 19, 1957, where a C₂ to C₆ laminectomy was performed, and a large intramedullary haemangioma was found. Excision of the tumour was deemed infeasible. The cervical cord was hugely distended by tumour, its width measuring approximately 1.5 cm. The tumour extended from C₂ to C₆. Multiple posterior incisions were made in the distended cord, and the dura left open for the purpose of decompression. A piece of dural substitute, 1 × 4 in., was sutured to the dura to cover the exposed section.

Before exploration, the patient was quadriplegic. After surgery, he regained the limited use of both upper limbs. Up to the time of writing, he is able to feed himself and can roll his own wheelchair. The Vinyon "N" material, buried in the spinal canal for 38½ months, had not produced any untoward effect.

As Nerve Wrap in Cicatrization.—One of the aims of neurolysis is to prevent recurrence of compression by regrowth of scar tissue along the course of the dissected nerve. It has often been a problem to find a healthy soft tissue bed for transplantation of the nerve after neurolysis, in cases of severe and extensive cicatrization. In this series, two cases of cicatrization of a major nerve trunk, one a sciatic nerve and the other a radial nerve, were treated with neurolysis and wrapping with Vinyon "N" cloth. The purpose of using a nerve wrap in these cases was to prevent scar tissue infiltration of the nerve.

The case of cicatrization of the sciatic nerve is illustrated in the following:

A 36-year-old man (Table II, Case 27) was injured in World War II (1944) by a shell wound in the right posterior

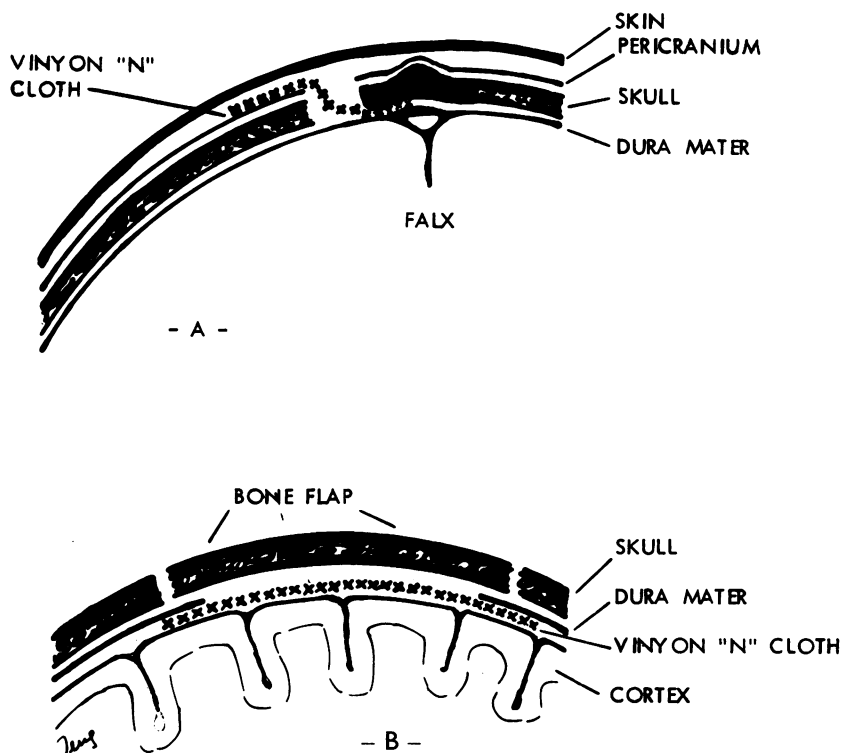


FIG. 1.—Diagram of intracranial use of Vinyon "N" cloth. (A) As bone lining in craniostenosis. Line of cross indicates position of Vinyon "N" cloth lining bone incision. (B) As dural substitute. Note dural cloth tucked under edges of dural defect.

thigh, with subsequent prolonged infection. The right sciatic nerve was partially injured, and pain developed in the right lower leg and foot from this injury. He was operated upon three times at other hospitals, both in the United States and Europe, in an attempt to relieve the pain. After each operation, the pain was partially relieved for a few weeks up to two months, then recurred with increasing severity. For the past one and a half years he has been disabled because of the pain.

On April 29, 1959, the right sciatic nerve in the upper and middle thirds of the thigh was delivered by sharp dissection from an area of extensive cicatrization, which extended through almost the whole thickness of the posterior compartment of the upper thigh, and measured 8×4 in. in size. The sciatic nerve was wrapped in a tube made of Vinyon "N" cloth, with the upper and lower ends of the tube placed above and below the field of cicatrization.

Since his last operation 14 months ago, the patient has been free of pain, and there is no evidence of irritation to the sciatic nerve caused by the synthetic cloth.

As Bone Lining in Craniostenosis after Craniectomy.—In six infants with craniostenosis, ranging in age from 1 to 7 months, Vinyon "N" cloth was

used as bone lining after craniectomy, to prevent reunion of the bone edges. In all six cases only the sagittal suture was prematurely closed. The surgical treatment consisted of a simple unilateral parasagittal bone incision made 1.5 cm. lateral to the midline. The anterior end of the bone incision (or the artificial groove) extended 1.0 cm. beyond the coronal suture, and its posterior end extended 1.0 cm. beyond the lambdoid suture. A thin strip of Vinyon "N" cloth was used to line the bone edges of the craniectomy. The outer half of the Vinyon "N" cloth was tucked under the outer bone edge between the bone and the periosteum-dura, and the inner half of the cloth was buried under the skin medial to the incision between the galea aponeurotica and the pericranium (Fig. 1A). This procedure is simple, and less traumatic than the multiple bone incisions usual in craniostenosis. The shape and contour of the skull appeared normal one to three months after surgery. The cases were followed for a period of nine and a half, nine and a half, 10, 38, 52, and $52\frac{1}{2}$ months respectively. Radiological study showed no evidence of bone union or bony bridges across the incision. Repeated

clinical examinations revealed no indication of untoward reaction in any of the six cases. Furthermore, Vinyon "N" cloth is soft, silk-like, and it is easy to use in lining the bone edges.

Discussion

The purpose in using a dural substitute is not specifically for the covering of a dural defect but rather for (1) prevention of meningocerebral cicatrization in cerebral lesions caused by either injury or surgery, (2) repair of cerebrospinal fluid fistulas, and (3) preventing adhesions to the spinal cord or cauda equina in instances where the dura cannot be approximated without tension.

The normal dura has no cellular lining, but a fibrous wall with naked fibroblasts. It is analogous to any connective tissue structures when exposed or damaged, being capable of proliferation or regeneration (Leary and Edwards, 1933). Through this so-called ability of regeneration, the dura can bridge over a wide defect. The regenerated dura is formed mainly by the proliferation of fibroblastic cells in the adjacent soft tissues rather than from the edges of the dural defect. Keener (1959) demonstrated that dural regeneration adjacent to bone, *i.e.*, in the upper calvarium, is inadequate, whereas regeneration is adequate when the dural wound is adjacent to soft tissues such as the temporal or suboccipital muscles. The same cells that can repair a dural defect are also capable of forming scar tissue. The use of a dural substitute, therefore, is not meant to replace normal dura but to prevent extension of scars onto cerebral tissue. Vinyon "N" cloth as a dural substitute satisfactorily serves this purpose. It prevents the formation of meningocerebral adhesions and cross-circulations. Its irritative effect is minimal. This has been adequately demonstrated, both in animal experimental studies and in the clinical applications as described above. The amount of the connective tissue formed between the Vinyon "N" cloth and cerebral cortex, after being buried intracranially three to four years, was minimal. In none of the patients treated in this series has any untoward effect been noted in repeated clinical examinations.

Several authors have stated that one of the qualities of Vinyon "N" cloth which makes it un-

suitable as dural substitute, is in its fine pores which render it permeable. However, we have found the opposite to be true. In 1953, in animal experiments with Vinyon "N" cloth, it was originally used as an aortic graft, the material being crudely sutured in tube form and anastomosed to the aorta of dogs. For a few minutes, perspiratory drops of blood were seen to penetrate its pores, but shortly afterwards they stopped completely, the pores having been sealed by blood protein. In like manner, when it is used as dural substitute, the exudate of the wound renders the Vinyon "N" material waterproof. Furthermore, the dural substitute does not necessarily have to be waterproof, except when it is used to cover a cerebrospinal fluid fistula in rhinorrhoea, and in the latter condition, Vinyon "N" cloth can be used successfully to seal the fistula.

Its use in craniostenosis, for the prevention of bone reunion after craniectomy, has also shown gratifying results in this series. It is easy to use for lining the bone incision. For as long as 52½ months there has been no indication of bone reunion or bridge formation across the bone incision.

In severe cicatrization of peripheral nerves Vinyon "N" cloth has been used satisfactorily as a nerve wrap after neurolysis.

Summary

Vinyon "N" cloth, a synthetic fabric, has satisfactorily been used as a dural substitute, peripheral nerve wrap in cicatrization, and bone lining in craniostenosis after craniectomy in 40 clinical cases. The period of observation ranged from four to 52½ months.

The material is relatively inert and not toxic. It is not absorbed, and has a tensile strength like that of China silk. It can be sterilized by boiling in water. The fine pores in the cloth do not hinder its use in repairing cerebrospinal fluid fistulae, for the serum protein in the wound itself rapidly seals the pores, thus rendering it waterproof.

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