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A correlation of the surgical anatomy of the dura to head and neck surgery*

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Summary. Head and neck surgery may be complicated by penetration of the dura resulting in meningitis, cerebrospinal rhinorrhoea, cerebral abscess or other intracranial complications. The strength of the dura mater both protects the brain and spinal cord and makes dura an ideal material for grafting (when needed). This study examines the thickness and histological composition of dura mater at various sites encountered in head and neck surgery. Dura was removed from eight specified locations in 14 adult cadavers. Microscopically, this dura was found to consist predominantly of collagen fibres, although the thickness of the dura varied between sites. Dura was significantly thinner in relation to the ethmoid sinus ($P < 0.01$), tegmen ($P < 0.05$) and sigmoid sinus ($P < 0.001$), indicating its greater susceptibility to possible injury at these sites during surgery. The variety of its thickness also makes dura a more versatile homograft material than hitherto realised.

Key words: Dura-Meninges-Histology-Morphometry

Introduction

Dura mater is a thick, dense, inelastic membrane that is conventionally described as consisting of two layers. The outer layer is the periosteum investing the inner surface of the skull and is closely united with the inner meningeal layer except along certain lines where the two layers separate to enclose the venous sinuses. Dura provides protection of the brain and spinal cord, it forms reflexions or septae which minimise rotatory displacement of the brain, and it is in direct contact with the underlying arachnoid "bag" containing cerebrospinal fluid, which in turn cushions the brain [2].

Dura mater is reputed to be one of the strongest membranous tissues in the human body [4]. Its strength serves not only to protect the central nervous system but also makes dura a useful graft material. Despite the strength of dura, it can still be penetrated during head and neck surgery, resulting in meningitis, cerebrospinal rhinorrhoea, cerebral abscess or other intracranial complications. However, few studies have investigated the variation in the properties of dura at different donor sites and no study has examined its properties at sites encountered in head and neck surgery. Thus, the aim of our present study was to define the thickness and histological structure of the dura at various intracranial sites likely to be encountered in such surgery.

Materials and methods

Representative portions of dura mater from eight different regions of the skull were removed from 14 adult cadavers at necropsy (Table 1). Nine cadavers were women and five were men. Their median age was 71 years (range 55–87 years).

Table 1. Cranial sites encountered in head and neck surgery from which postmortem samples of dura mater were obtained for tissue study

Anterior cranial fossa	Frontal sinus
	Cribriform plate
	Ethmoid sinus
Middle cranial fossa	Tegmen
Posterior cranial foss	Trautmann's triangle
	Sigmoid sinus plate
Tubers	Frontal tuber
	Parietal tuber

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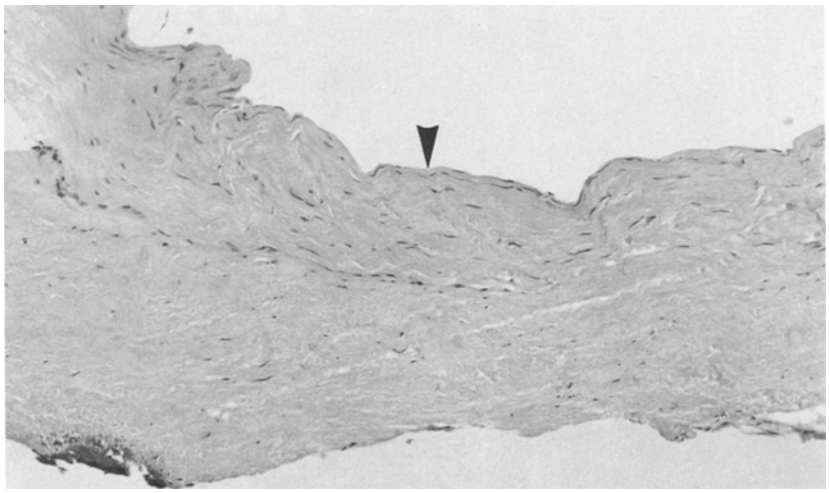

Fig. 1. Cross-section through dura mater from over the frontal tuber, showing inner *(arrow)* and outer layers of collagenous tissue. Haematoxylin and eosin stain, ×150

None of the cadavers had a premortem history of or evidence of local head and neck pathology.

Representative samples of dura measuring 1.0 × 0.5 cm were fixed in 4% neutral buffered formalin or 3% glutaraldehyde in 0.15 *M* sodium cacodylate buffer (pH 7.4). Tissues were then routinely processed and embedded in paraffin wax. Samples from cases 1–7 were preserved in either fixative for at least 24 h and each case processed individually. To eliminate possible variation due to different fixation and processing methods, samples from cases 8–14 were fixed for 24 h in glutaraldehyde and then stored in 0.15 *M* sodium cacodylate buffer (pH 7.4) for up to 4 weeks before being processed as a single batch of tissue. Sections of 0.005 mm thickness were cut perpendicular to the plane of the dura and stained with Miller's elastic stain and a van Giesen counterstain to assess the distribution of collagen and elastic fibres. Alcian blue at pH 4.2 was used to demonstrate acid mucopolysaccharides.

The thickness of each section of dura was measured using a calibrated eyepiece graticule. To estimate the shrinkage of the tissue resulting from fixation and processing, two samples of dura were bisected. One half of each sample was prepared using glutaraldehyde fixation and paraffin-embedded sections as described above, while the other portion was frozen and sectioned in a cryostat. The thicknesses of the two halves were then measured and compared.

Results

At all sites, dura consisted mainly of collagen with a small amount of elastic fibre and acid mucopolysaccharide ground substance. Figure 1 shows a section of dura overlying the frontal tuber. Two layers of collagen fibres can be discerned which are orientated at right angles to each other. Whereas the inner layer is covered with a smooth layer of mesothelial cells, the outer layer is rough where it has been elevated from bone. It was intended to investigate whether or not any variation in the thickness or histological composition between sites was due to a variation within either the inner or outer layers, or a combination of both. However, it was not possible to differentiate the two layers in the majority of samples.

Table 2. Thickness of fixed dura (mm) at eight sites in 14 cadavers

Cadaver	Sites[a]							
	A	B	C	D	E	F	G	H
1	0.66	0.78	0.68	0.44	0.19	0.41	0.78	0.11
2	0.65	0.55	0.46	0.37	0.48	0.38	0.59	0.26
3	0.72	0.58	0.53	0.42	0.52	0.48	0.51	0.26
4	0.55	0.40	0.26	0.28	0.23	0.36	0.63	0.15
5	0.62	0.46	0.53	0.33	0.31	0.41	0.62	0.15
6	0.39	0.36	0.52	0.32	0.32	0.42	0.44	0.15
7	0.49	0.44	0.38	0.33	0.24	0.45	0.37	0.14
8	0.50	0.34	0.30	0.22	0.36	0.44	0.53	0.40
9	0.35	0.31	0.30	0.26	0.29	0.40	0.26	0.22
10	0.40	0.20	0.48	0.23	0.31	0.48	0.59	0.21
11	0.44	0.33	0.55	0.14	0.32	0.49	0.46	0.20
12	0.40	0.34	0.23	0.26	0.26	0.31	0.44	0.29
13	0.36	0.36	0.26	0.24	0.20	0.33	0.40	0.28
14	0.73	0.68	0.31	0.28	0.40	0.59	0.58	0.26
Mean	0.52	0.44	0.41	0.29	0.32	0.43	0.51	0.22

[a] Key to sites: A = frontal tuber, B = frontal sinus, C = Cribriform plate, D = Ethmoid sinus, E = Tegmen, F = parietal tuber, G = Trautmann's triangle, H = sigmoid sinus plate

Fixed samples of dura were on average 12% thinner than portions of the same samples subjected to frozen sectioning. The thicknesses of the fixed dura are shown in Table 2. The mean thickness of the dura in cases 1–7 was greater than in cases 8–14 for all sites except over the parietal tuber and the sigmoid sinus plate. The overall difference in thicknesses between the two groups was not statistically significant. The thickest dura was located over the frontal tuber while the thinnest was found between the sigmoid sinus and the sinus plate. The latter is the endosteal or outer layer and is attached to the sigmoid venous sinus

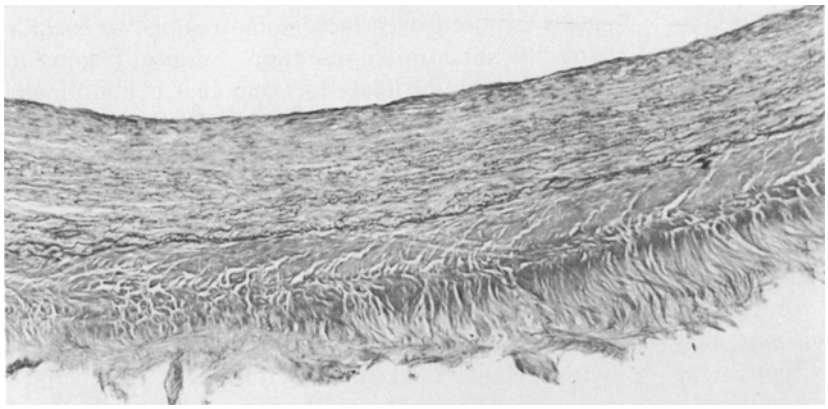

Fig. 2. Cross-section through dura mater from over the sigmoid sinus plate showing the endosteal layer of dura mater and the elastic laminae of the wall of the sigmoid venous sinus. Elastic van Gieson stain, ×150

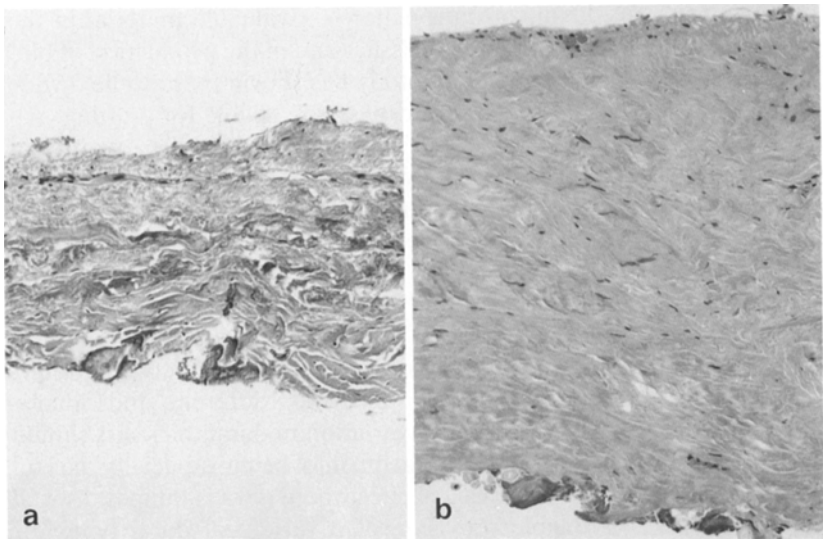

Fig. 3. Cross-section through dura mater from over the tegmen (**a**) and Trautmann's triangle (**b**), showing the differences in tissue thickness. Haematoxylin and eosin stain, ×150

(Fig. 2). Figure 3 shows samples of dura taken from over the tegmen and Trautmann's triangle in the same case, with the difference in thickness readily apparent.

A two-way analysis of variance [1] for sites and for cases shows a significant difference in thickness between sites ($F = 15.36$, $df = 7$ and 91, $P < 0.005$), as well as between cases ($F = 2.65$, $df = 13$ and 91, $P < 0.01$). The least significant difference in thickness between two site means at the 5% level is 0.08 mm. Differences between pairs of mean thickness at different sites which are significant at this level can be readily seen in Table 2. In the anterior cranial fossa, the dura over the ethmoid sinus is significantly thinner than that over the frontal tuber ($P < 0.001$), frontal sinus ($P < 0.001$) and cribriform plate ($P < 0.01$). When comparing the anterior, middle and posterior cranial fossae, dura over the tegmen of the middle cranial fossa is significantly thinner than that over the frontal sinus ($P < 0.01$) and cribriform plate ($P < 0.05$) in the anterior cranial fossa, and that over Trautmann's triangle ($P < 0.001$) in the posterior cranial fossa.

Discussion

There have been few previous studies of the variations in the properties of the dura in different intracranial sites. The thickness of the dura as well as its strength and ability to withstand deformation of the cranial vault has been shown to vary from site to site according to the presence and orientation of the blood vessels present [6]. The strength of the fixation of the dura mater to the bones of the skull has also been shown to vary with site, thus explaining some regular features of extradural haematoma formation [3].

Both the fixation and the processing of specimens for the preparation of paraffin-embedded sections are known to cause tissue shrinkage. In our present

study, the thickness of the samples of dura was 12% less than in portions of the same samples subjected to frozen section. This should be borne in mind when assessing the absolute thickness of dura from the actual measurements made. Due to the number of specimens studied, it was not practical for us to use frozen sections for our entire study. The measured thickness of the dura could also be influenced by the type of fixative used and by day-to-day variations in tissue processing schedules. Our first seven cases were fixed for a variable time in either formalin or glutaraldehyde and each tissue specimen was then processed individually. In order to achieve consistent treatment of all tissues, it was necessary to find a method whereby tissues could be fixed soon after removal from each cadaver and then stored for a variable period of time without shrinkage due to progressive fixation. For this purpose, formalin fixation was rejected since it causes progressive fixation and tissue shrinkage. For cases 8–14, fixation in 3% glutaraldehyde was used as a rapid fixative; after 24 h, further fixation and shrinkage was then prevented by storing the tissue in isotonic sodium cacodylate buffer [5]. These seven cases were processed, sectioned and stained as one batch. The standardised method of preparation used for the second seven cases is recommended for comparisons of morphometry between different cases.

In a previous study of dural thickness over the cranial vault [6] the methods of preparing the tissue studied and estimating its thickness were not described. Nonetheless, the thickness of dura was found to vary from 0.720 to 0.880 mm, depending on the distance from the sagittal sinus and whether the samples were taken from the frontal, temporoparietal or occipital regions. These values are greater than those found in our study and may reflect differences in the methods used or in the region examined. No indication of the degree of inter-case variation in sample thickness was given.

Our results show considerable variation in the dural thickness in different cases. The dura taken from over the frontal tuber was over twice the thickness in one case as compared with another. This inter-case variation occurred in cases 1–7 and cases 8–14. Samples from cases 8–14 were processed identically. Thus, the variation does not appear to be due to differences in handling the tissues, but rather due to individual case variations which must be borne in mind if dura of a particular thickness is required for possible homograft use.

Accidental injury to the dura is more likely to occur when the dura is exposed either by disease or as part of an operative procedure. In the middle ear, disease may expose dura over the tegmen or the sigmoid sinus. During mastoidectomy, dura is often surgically exposed over these some regions to exclude extra- or subdural suppuration. Surgical trauma to the dura is more likely to occur if it is abnormally situated. In mastoid surgery, injury to the dura is particularly prone to occur if it is unusually low-lying or the sigmoid sinus is anteriorly placed. Dura is also thinnest over the tegmen and sigmoid sinus, and therefore is in particular danger to surgical damage at these sites.

The reason why the thickness of dura should vary from site to site is unknown, perhaps, as illustrated by the relative thicknesses of dura over Trautmann's triangle, the tegmen and the ethmoid air cells, dural thickness is related to the thickness of the adjacent bone.

Human dura mater is a valuable material in the surgical repair of tissues and in the production of bioprosthetics. This study has shown there to be a wide range of dural thicknesses available for grafting. Although we would acknowledge that the quantity of dura available may be limited at certain sites, the surgeon's ability to choose an optimum thickness makes it a more versatile homograft material than hitherto realised.

In conclusion, this study has shown a significant variation in dural thicknesses but no differences in the histological composition present between different intracranial sites and different individuals. Knowledge of the variation in dural thickness should also alert the surgeon into being especially careful when operating at sites where dura is thinnest as well as enable provision of a variety of dural types for homograft use.

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