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The subarachnoid space develops early in the human embryonic period

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The anlage of the subarachnoid space is seen in embryos at stage 14 (33 days) in the innermost zone of the primary meninx as irregular spaces on the ventral surface of the spinal cord. At first this space is only on the ventral surface of the spinal cord.

From stage 18 (44 days) on, when the dura mater proper is formed, the reticular tissue of the primary meninx and spaces are around the circumference of the spinal cord. These spaces gradually coalesce and contain many blood vessels.

Key words: human neuroembryology, primary meninx, subarachnoid space

INTRODUCTION

The subarachnoid space consists of 3 major components: the cerebrospinal fluid, the leptomeninges and attached free macrophages [14], collagen fibres and granular material [5, 6].

The arachnoid meninx in an adult human is formed of 2 parts [5, 6]. The outer part is formed by several layers of dark cells. Beneath this outer part is an inner part which is composed of groups of clear cells, trabeculae of interweaving processes and collagen fibres as well as fibrillar material. Sometimes the arachnoid and pia mater are in contiguity and the subarachnoid space is not observed [5, 6]. The pia mater is generally considered to constitute a complete cellular layer, forming a barrier between the central nervous system and the subarachnoid space [5, 6, 9, 10].

The major unresolved question regarding the leptomeningeal tissues is their embryonic germ cell layer of origin [10]. This controversy is due to the fact that the neural crest and mesenchymal cell populations are initially cytologically indistinguishable.

Detailed study on the development of the cranial meninges made by O'Rahilly and Müller [11] pointed out several sources of their origin, such as the prechordal plate, parachordal mesoderm, paraxial mesoderm, neural crest cells, and neural tube.

Many papers have been devoted to the development of the subarachnoid space [3, 4, 7, 8, 12, 13, 15–18]. In the embryonic period this space is referred to as the "primitive subarachnoid space".

The aim of the present study is to trace the development of the subarachnoid space in staged human embryos.

MATERIAL AND METHODS

The study was performed on 58 human embryos (Table 1), aged between 32 and 56 days (developmental stages 13 to 23). The embryos were staged according to the international staging system and the age of the embryos was expressed in postovulatory days. All the embryos were embedded in paraffin or paraplast and serial sections were made in the frontal, sagittal, and horizontal planes. The sections were stained according to routine histological methods and impregnated with silver salts.

RESULTS

In embryos at stage 14 (33 days) there are important developmental events in the structure of the

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Table 1. C-R length, developmental stage, and age of investigated embryos

Catalogue no.	C-R length [mm]	Developmental stage	Age [days]	Plane of section
B-194	4.0	13	32	Horizontal
B-218	4.0	13	32	Horizontal
B-174	6.0	13	32	Horizontal
I	6.0	13	32	Sagittal
P-41	5.0	14	33	Horizontal
B-207	6.5	14	33	Horizontal
A-19	7.0	14	33	Frontal
II WW	7.0	14	33	Sagittal
PJK-21	8.5	15	36	Horizontal
PJK-5	8.5	15	36	Sagittal
B-175	9.0	15	36	Horizontal
PJK-20	9.0	15	36	Horizontal
PJK-18	9.0	15	36	Sagittal
IV	10.0	16	39	Sagittal
PJK-8	10.0	16	39	Horizontal
B-216	11.0	16	39	Horizontal
B-70	12.0	17	41	Horizontal
B-180	13.0	17	41	Sagittal
B-64	13,5	17	41	Frontal
PJK-2	13.5	17	41	Horizontal
PJK-14	13.5	17	41	Sagittal
B-68	14.0	17	41	Horizontal
A-1	14.0	17	41	Horizontal
B122	14.5	18	44	Frontal
Bł-4	15.0	18	44	Horizontal
B128	15.0	18	44	Sagittal
B-65	16.0	18	44	Horizontal
B-66	16.5	19	46	Horizontal
Bł-5	17.0	19	46	Horizontal
Z-13b	17.0	19	46	Frontal
Bł-10	17.5	19	46	Horizontal
B-123	17.5	19	46	Sagittal
KA-2	18.0	19	46	Horizontal
B-112	18.0	19	46	Ssagittal
A-10	18.0	19	46	Horizontal
PJK-1	19.0	19	46	Sagittal
KA-3	19.0	19	46	Sagittal
PJK-28	19.0	19	46	Horizontal
PJK-13	19.0	19	46	Horizontal
B-99	19.5	20	49	Horizontal
Bł-2	20.0	20	49	Sagittal
Bł-1	20.5	20	49	Horizontal
PJK-27	21.0	20	49	Horizontal
B-126	22.0	21	51	Horizontal
B-170	22.5	21	51	Horizontal
B-127	23.5	21	51	Sagittal
A-4	23.5	21	51	Frontal
PK-61	24.0	21	51	Sagittal
WR-II	25.0	22	53	Horizontal
ZJ-2	26,0	22	53	Sagittal
Z-3	26.5	22	53	Horizontal
B-114	27.0	23	56	Sagittal
WW	28.5	23	56	Frontal
B-177	28.5	23	56	Horizontal
A-4	29.0	23	56	Horizontal
A-2	29.0	23	56	Frontal
A-71	29.0	23	56	Horizontal
B-184	30.0	23	56	Horizontal

sclerotomes, spinal cord, and primary meninx. At this stage each sclerotome splits into the cranial zone and the caudal zone. The cranial zone consists of loosely arranged cells and the caudal zone is composed of densely packed cells (Fig. 1). Both zones contribute to the cellular sheath of the notochord.

Within the spinal cord the deep sulcus limitans separates the basal and alar plates and the mantle layer increases markedly in thickness, particularly in the future anterior horns (Fig. 2).

The primary meninx has more loose structure than sclerotomes. In its innermost zone, adjacent to the pia mater, are small, irregular spaces, which may be considered as the primordia of the subarachnoid space (Fig. 3).

At stage 15 (36 days) the primary meninx is clearly demarcated from the vertebral bodies and intervertebral discs and it surrounds the spinal ganglia (Fig. 4). The cavities forming the subarachnoid space are the same as at the previous stage.

In embryos at stage 16 (39 days) the primary meninx is clearly visible around the whole circumference of the spinal cord and is a more fibrous, loose mesenchymal tissue, particularly on the ventral surface of the spinal cord (Fig. 5). Between the pia mater and the primary meninx a well developed subarachnoid space is observed. This space contains many blood vessels (Fig. 6), branches of which penetrate the surface of the spinal cord.

During stages 17 (41 days) and 18 (44 days) the scanty cellular and more fibrous primary meninx sur-

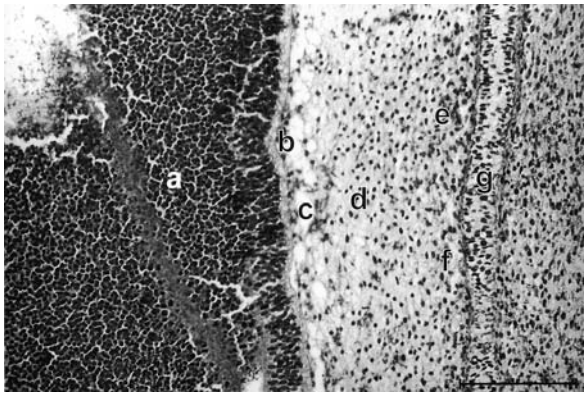

Figure 1. Sagittal section of embryo at stage 14. Staining with Bodian's protargol. Scale bar 100 μm; a — spinal cord, b — pia mater, c — primordium of subarachnoid space, d — primary meninx, e — primordium of intervertebral disc, f — primordium of body of vertebra, g — notochord.

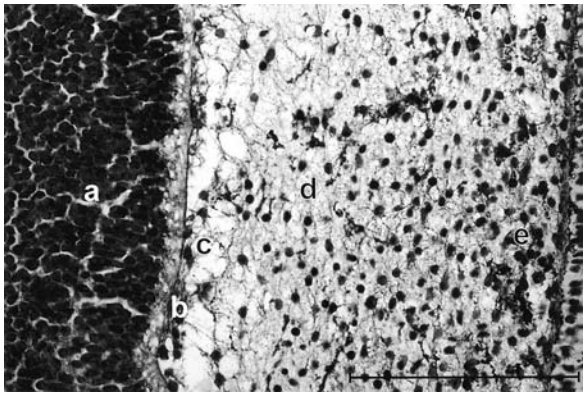

Figure 3. Sagittal section of embryo at stage 14. Staining with Bodian's protargol. Scale bar 100 μm; a — spinal cord, b — pia mater, c — primordium of subarachnoid space, d — primary meninx, e — primordium of intervertebral disc.

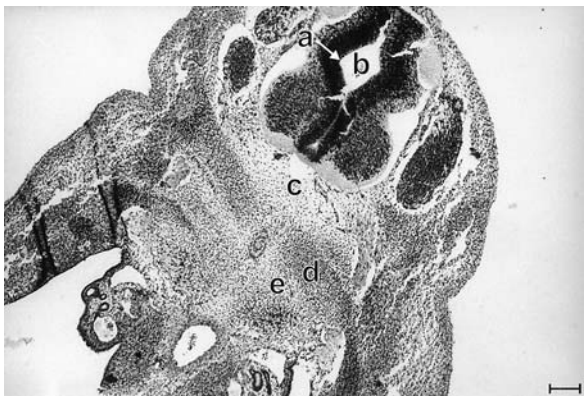

Figure 2. Cross section of embryo at stage 14. Nissl's staining. Scale bar 100 μm; a — sulcus limitans, b — central canal of spinal cord, c — primary meninx, d — primordium of intervertebral disc, e — primordium of body of vertebra.

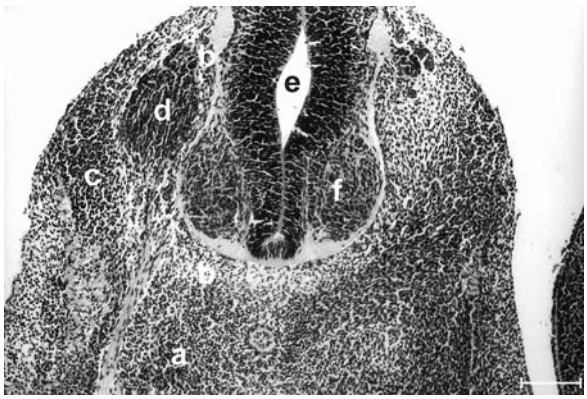

Figure 4. Cross section of embryo at stage 15. Nissl's staining. Scale bar 100 μm; a — body of vertebra, b — primary meninx, c — vertebral arch, d — spinal ganglion, e — central canal of spinal cord, f — mantle layer of the spinal cord.

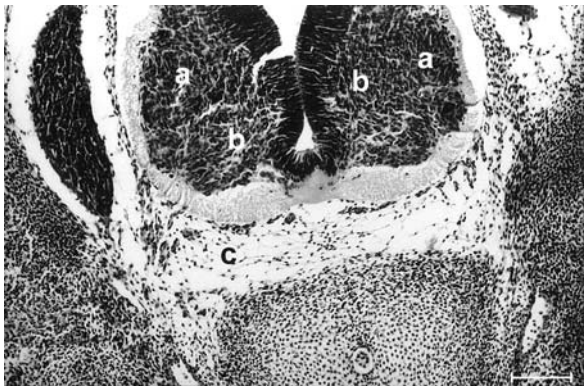

Figure 5. Cross section of embryo at stage 16. Nissl's staining. Scale bar 100 μm; a — cells of lateral group of spinal cord, b — cells of medial group of spinal cord, c — primary meninx.

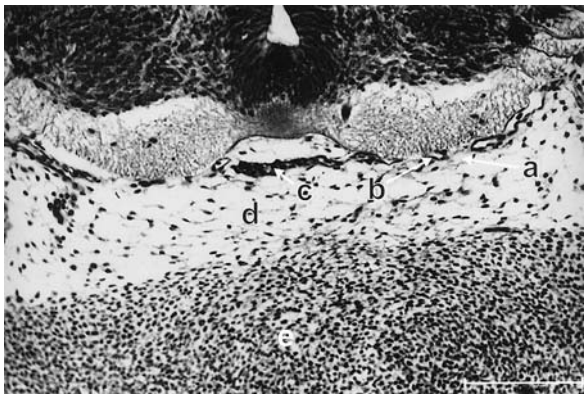

Figure 6. Cross section of embryo at stage 16. Staining with Bodian's protargol. Scale bar 100 μm; a — subarachnoid space, b — pia mater, c — blood vessels, d — primary meninx, e — body of vertebra.

rounds the whole surface of the spinal cord. The meninx is much broader on the ventral surface of the spinal cord (Fig. 7). There are many blood vessels in the subarachnoid space (Fig. 7, 8).

During the last 2 weeks of the embryonic period (stages 19–23, 46–56 days) the subarachnoid space, containing numerous blood vessels, develops around the whole surface of the spinal cord (Fig. 9, 10). At these stages the dura mater proper and the epidural space also develop. The primary meninx has a loose reticular structure.

DISCUSSION

According to Weed [16–18], the differentiation of the arachnoidal components of the leptomeninx is dependent on the presence and circulation of cerebrospinal fluid and first appears in the basilar portion of the brain. His investigation did not include a thorough examination of staged embryos aged approximately 5 to 7 weeks. McLone [8] mentioned that the subarachnoid space develops at stage 19.

Osaka et al. [12] observed a primitive subarachnoid space around the brain stem in embryos of stage 14. By stage 20 this space surrounds the spinal cord. The median aperture between the 4th ventricle and the subarachnoid space opens at the end of the

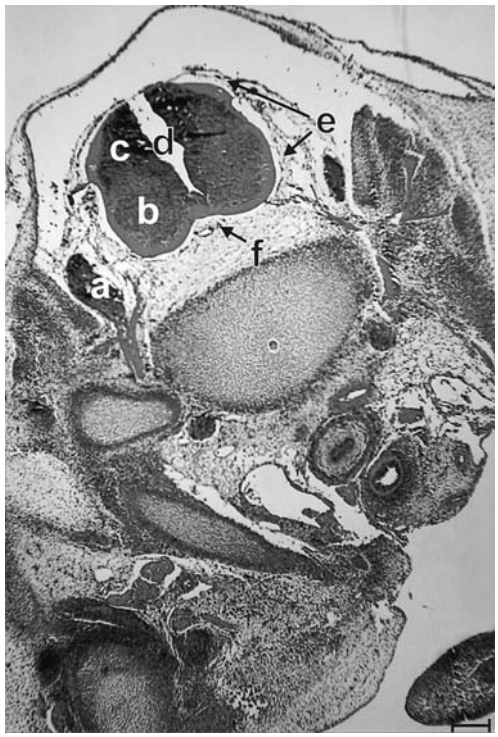

Figure 7. Cross section of embryo at stage 17. H+E; Scale bar 100 μm; a — spinal ganglion, b — anterior horn of spinal cord, c — posterior horn of the spinal cord, d — central canal of spinal cord, e — primary meninx, f — blood vessels in subarachnoid space.

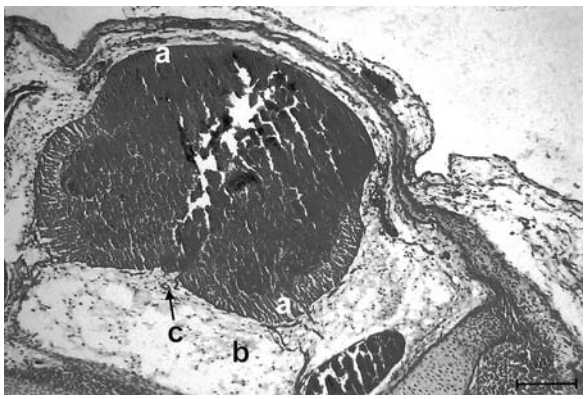

Figure 8. Cross section of embryo at stage 18. H+E; Scale bar 100 μm; a — marginal layer of spinal cord, b — primary meninx, c — blood vessels in subarachnoid space.

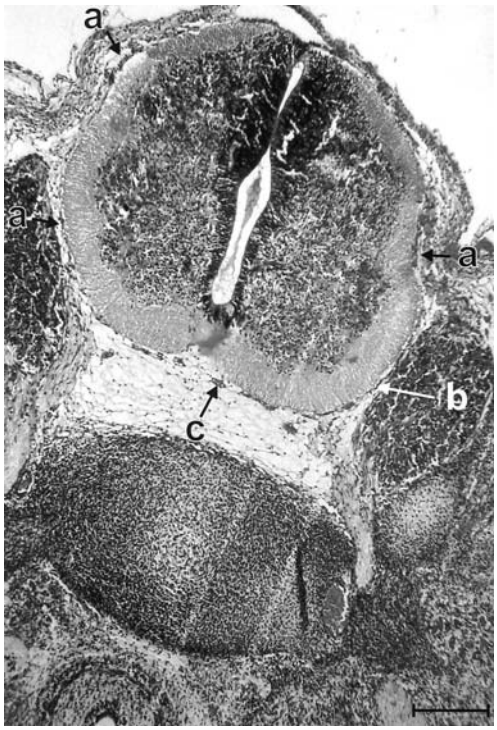

Figure 9. Cross section of embryo at stage 19. H+E; Scale bar 100 μm; a — subarachnoid space, b — pia mater, c — blood vessels in subarachnoid space.

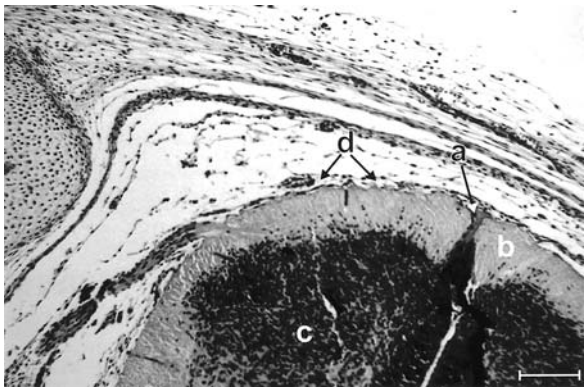

Figure 10. Cross section of embryo at stage 23. Nissl's staining. Scale bar 100 μm; a — primordium of the posterior median septum, b — white substance, c — posterior horn of the spinal cord, d — subarachnoid space with blood vessels.

embryonic period [2]. At this time the future cisterna cerebellomedullaris is defined [11].

Sensenig [15] observed the primordium of the subarachnoid space in embryos at stage 15. These spaces appeared first on the ventral surface of the spinal cord. Braaker [1] described the subarachnoid space and cisterns of the adult type in a human foetus of 34 mm C-R length.

In the present study the primordia of the subarachnoid space were found in embryos at stage 14 (36 days). This space presents irregular cavities within the innermost part of the primary meninx. It contains blood vessels, branches of which penetrate the ventral surface of the spinal cord. It should be noted that during the further stages of the embryonic period the subarachnoid space is formed around the whole surface of the spinal cord and possesses many blood vessels.

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