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Jan Pařízek
Pavel Měřička
Stanislav Němeček
Jana Němečková
Josef Špaček
Petr Šuba
Miroslav Šercl

Posterior cranial fossa surgery in 454 children

Comparison of results obtained in pre-CT and CT era and after various types of management of dura mater

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Presented at the Congress of the Czech and Slovak Neurosurgical Societies, Seč 1997: the Congress was dedicated to Professor Rudolf Petr, founder of the Department of Neurosurgery in Hradec Králové on the occasion of his 85th birthday

J. Pařízek (✉) · S. Němeček
J. Němečková · P. Šuba
Department of Neurosurgery,
Medical Faculty, Charles University,
CZ-50005 Hradec Králové,
Czech Republic
e-mail: suba@LFHK.CUNI.CZ
Fax: +420-49-55 11 116

P. Měřička
Tissue Bank, Medical Faculty,
Charles University,
CZ-50005 Hradec Králové,
Czech Republic

S. Němeček
Department of Histology and Embryology,
Medical Faculty, Charles University,
CZ-50001 Hradec Králové,
Czech Republic

J. Špaček
Department of Pathology,
Medical Faculty, Charles University,
CZ-50005 Hradec Králové,
Czech Republic

M. Šercl
Department of Radiology,
Medical Faculty, Charles University,
CZ-50005 Hradec Králové,
Czech Republic

Abstract At the Department of Neurosurgery, Hradec Králové, 454 children (aged under 18 years) were operated on for posterior cranial fossa lesions in a period of 49 years (1948–1996). The majority (402) had tumours: cerebellar astrocytomas 149 (37.1%), medulloblastomas 139 (34.6%), brain stem gliomas 46 (11.4%), ependymomas 28 (7.0%), and others 40 (9.9%). Postoperative mortality was compared for the pre-CT era (1948–1977) and the CT era (1978–1996): astrocytomas (8.6%:4.7%), medulloblastomas (14.9%:2.9%), brain stem gliomas (21.7%:19.0%), ependymomas (18.2%:6.3%), and others (40.0%:7.4%). The initially high mortality was due to insufficient intracranial decompression, brain oedema and disturbances of cerebrospinal fluid circulation. Obstructive hydrocephalus was treated in 53 children with tumours and 25 with aqueduct stenoses, by Torkildsen's drainage in 5.5%, and/or by catheterisation of aqueduct in 12.3%. The main postoperative complications of medial posterior fossa surgery in 429 children operated on were: pseudomeningocele (12.3%), active hydrocephalus (6.2%) and CSF leakage (4.6%). Only 8.2% had shunts placed for these complications. We presume that this low percentage of shunts used results from a frequent use of duraplasties and drains installed at the primary operation. The dura mater was initially (1948–1954) left open (50 cases), and later (1955–1958) also sutured (37 cases), and from 1958, onward, and especially from 1961, reconstructed by a medial approach by means of various grafts (377 cases). In all, duraplasty was performed in 81.6% of cases. The grafts used for dura mater reconstruction were prepared from autogeneic (1.6%), allogeneic (72.3%), xenogeneic (24.8%), or synthetic (1.3%) material. They were successful in 99.2% of cases (all materials). Our own suture technique for posterior fossa duraplasty is presented.

Key words Posterior cranial fossa surgery · Tumours · Childhood · Computed tomography · Duraplasty · Paediatric neurosurgery

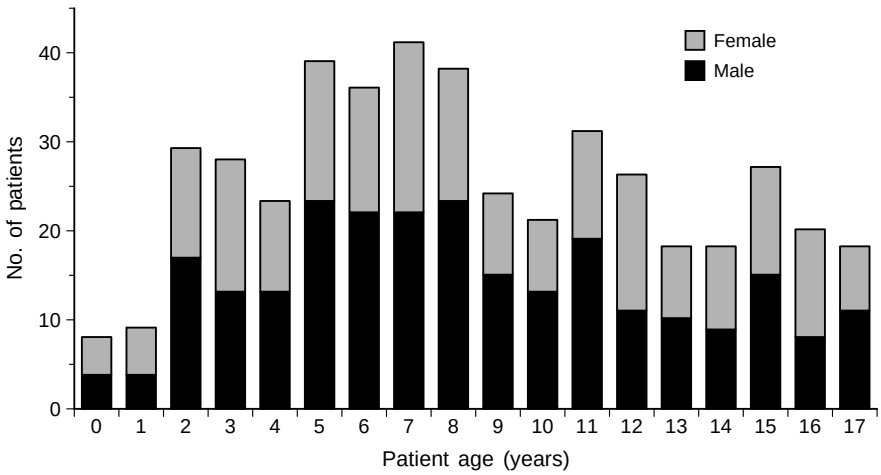

Fig. 1 Bar graph demonstrating age and sex distribution at first operation in 454 children (male : female = 252 : 202)

Introduction

Paediatric infratentorial brain tumours have been evaluated repeatedly and from various points of view in the literature. We decided to evaluate 454 posterior fossa lesions operated on in children (aged under 18 years) from three aspects: (1) results of surgery in the pre-CT and CT eras; (2) results of surgery in cases with the dura mater sutured, left open or reconstructed; and (3) materials used for posterior fossa duraplasty.

Patients, materials, and methods

Patients

From 1948 to 1996, 454 children ranging in age from newborn up to 17 years were operated on for posterior cranial fossa lesions. The age and sex distribution of the children (male-to-female ratio 1.25 : 1) is presented in Fig. 1. The most frequent lesions were posterior fossa tumours (Table 1). The majority of children presented with morning headaches and vomiting. Diplopia, papilloedema, abducent palsy, facial palsy, torticollis due to accessorius compression, dysmetria, and truncal ataxia with abnormal gait were often observed.

Materials

Materials used for duraplasty were tissue grafts in the majority of cases, mostly prepared by the Tissue Bank of the Faculty Hospital, Hradec Králové. Allogeneic fascia lata was a pliable tissue with good healing and restructuring after implantation [16, 30, 31]. Allogeneic dura mater or pericardium and/or xenogeneic pericardium (bovine or ovine) proved to be good materials because of their workability, flexibility and, especially, the reduced thickness and transparency of ovine pericardium [2, 23, 24, 26, 27, 29, 30]. Duraplasty was performed in 81.6% of all cases.

Methods

Skull X-ray, ventriculography, pneumoencephalography and vertebral angiography were gradually used for the diagnosis of posterior fossa lesions of childhood. The introduction of computed tomography, established at our Department in 1978, was used as a milestone between two eras in evaluating the results of posterior fossa surgery in children. For the pre-CT era (between 1948 and 1977) 198 children, were evaluated, and for the CT era (between 1978 and 1996), 256 children.

Table 1 Diagnoses of the posterior fossa tumours in children operated in the years 1948–1996

Diagnoses of tumours	No. of cases	Percentage	Sex (M/F)	Histology
Cerebellar astrocytomas	149	37.1	1.0	143[a]
Medulloblastomas	139	34.6	2.0	128[b]
Brain stem gliomas	46	11.4	0.7	16[c]
Ependymomas	28	7.0	1.3	28[d]
Other tumours	40	9.9	1.3	40[e]
Total tumours	402	100.0	1.3	355

[a] Pilocytic astrocytomas 116, astrocytomas 27 (including variants: fibrillary 1, protoplasmatic 2)
[b] Medulloblastomas 128 (including variants: desmoplastic 1, melanotic 1, myoblastic 1)
[c] Pilocytic astrocytomas 12, astrocytomas 3, anaplastic astrocytoma 1. Surgery without bioptic verification 30
[d] Ependymomas 28 (including variants: anaplastic 2, subependymomas 5)
[e] Neurinoma VIII (8 cases), haemangioblastoma (6), ganglioglioma (5), pineoblastoma (3), plexus papilloma (2), ganglioneuroblastoma (2), neuroblastoma (2), germinoma (1), embryonic carcinoma and a yolk-sac tumour (1), gliohamartoma (1), glioblastoma (1), gliosarcoma (1), epidermoid cyst (1), craniopharyngeoma (1), lipoma (1), meningeoma (1), neurinoma IX (1), mature teratoma of the vermis (1), and polar spongioblastoma (1)

Observations and results

At first, for exploration of the posterior fossa we used a cross-bow incision [31]. The majority of patients were operated on while under endotracheal anaesthesia, in a sit-

Table 2 Posterior fossa lesions in 429 children treated by medial suboccipital craniectomy or craniotomy; comparison of postoperative mortality in pre-CT and CT eras (*M* mortality)

Death/total Operations (*D/O*)	1948–1977 Pre-CT era		1978–1996 CT era		1948–1996 Both eras	
Diagnosis	D/O	M	D/O	M	D/O	M
Astrocytomas	5/58[a]	8.6%	4/85	4.7%	9/143	6.3%
Medulloblastomas	10/67	14.9%	2/69	2.9%	12/136	8.8%
Brain stem gliomas	5/23	21.7%	4/21	19.0%	9/44	20.5%
Ependymomas	2/11	18.2%	1/16	6.3%	3/27	11.1%
Other tumours	2/5	40.0%	2/27	7.4%	4/32	12.5%
Other lesions	4/17	23.5%	2/30	6.7%	6/47	12.8%
Total	28/181	15.5%	15/248	6.0%	43/429	10.0%

[a] One case of lethal venous air embolism

Table 3 Posterior fossa lesions in 25 children treated by lateral suboccipital craniectomy; comparison of postoperative mortality in pre-CT and CT eras

D/O	Total	1954–1977 Pre-CT era		1978–1994 CT era
Diagnosis	No.	D/O	M	D/O
Neurinomas VIII	8	0/4	0.0%	0/4
Astrocytomas	6	1/5	20.0%	0/1
Medulloblastomas	3	3/3	100.0%	0/0
Ependymomas	1	0/1	0.0%	0/0
Brain stem tumours	2	0/2	0.0%	0/0
Aqueduct stenosis	2	1/2	50.0%	0/0
Other lesions	3[a]	0/0	0.0%	0/3
Total	25	5/17	29.4%	0/8

[a] These were 1 cerebellar trauma, 1 pontine lipoma, 1 aneurysm of vertebral artery

ting position and with a midline or lateral vertical incision. Only in a few cases of large hydrocephalus was the prone or lateral decubitus position used. Posterior fossa craniectomy or craniotomy (in 7 cases) with removal of arch of the atlas were performed. In the pre-CT era a fronto-parietal burr-hole was used for ventriculography or external ventricular drainage. If preoperative ventriculography was not needed, a parieto-occipital burr-hole was made in case peroperative or postoperative ventricular puncture was necessary. To diminish metastatic dissemination, via the CSF, the craniospinal region was gently blocked peroperatively with surgical patties. Security of surgery and tumour removal was facilitated initially by self-retaining retractors, suction, bone wax and bipolar coagulation, and later by the use of magnification with binocular loupes or operating microscope, cardiac echography for early diagnosis of venous air embolism, cavitron ultrasonic surgical aspirator and/or CO_2 laser. The dura mater was initially (1948–1954) left open, later (1955–1958) also sutured, and from 1958, especially from 1961, reconstructed via a medial approach, using various types of grafts. Meticulous aseptic surgical technique and manipulation of the grafts or drainage catheters is necessary to prevent inflammatory complications. Broad-spectrum antibiotics have also been used for this purpose [29].

The results of posterior fossa surgery in children were evaluated in three categories and are presented mostly in the tables and figures:

1. The results of surgery in the pre-CT and CT eras are displayed in Tables 2 and 3. The postoperative mortality with the medial suboccipital approach decreased from 15.5% to 6.0%, and that with the lateral suboccipital approach, from 29.4% to zero.

2. Results of surgery were compared in cases with the dura mater sutured, left open and reconstructed. According to the different surgical approaches two separate groups were evaluated: (1) Medial suboccipital craniectomy/craniotomy; and (2) Lateral suboccipital craniectomy (Table 4). Tables 3 and 4 show that the initial high mortality was due to insufficient intracranial decompression, brain oedema, and disturbance of the cerebrospinal fluid (CSF) circulation in cases when only a small craniectomy was performed and the dura mater was sutured or left open. Better results were recorded in cases with sufficient intracranial decom-

Table 4 Reoperation and postoperative mortality following surgery by the medial approach (439 cases), and the lateral approach (25 cases) with the various types of management of dura mater in 454 operated and 10 reoperated children

Dura mater management	Medial suboccipital craniectomy or craniotomy					Lateral suboccipital craniectomy		
	No.	Reoperation		Mortality		No.	Mortality	
Sutured	20	0	0%	4	20%	17	5	29.4%
Left open	48	2[a]	4.2%	7[c]	14.6%	2	0	0%
Reconstructed	371	9[b]	2.4%	32	8.6%	6[d]	0	0%
Total	439	11	2.5%	43	9.8%	25	5	20.0%

[a] Included 1 case of transient venous air embolism; the child underwent reoperation 2 days later
[b] Included 1 case of bifrontal pneumocephalus
[c] Included 1 fatal case of venous air embolism
[d] A further four grafts were placed on mastoid cells

Table 5 Materials used for reconstruction of the dura mater in primary or secondary posterior fossa surgery in children (1958–1996)

Kind of graft	No.	(%)	No. and location of grafts used					
			Medial	Lateral	Mastoid	Medial	Lateral	Mastoid
Autogeneic	6	(1.6)						
Nuchal fascia			4	–	1	–	–	–
Pericranium			1	–	–	–	–	–
Allogeneic	274	(72.3)						
Fascia lata			207	3	2	–	–	–
Dura mater (including Lyodura 1)			49	–	–	1[a]	–	1[c]
Pericardium			9	–	–	–	–	–
Amnion, chorion			2	–	–	–	–	–
Xenogeneic	94	(24.8)						
Fascia endothoracica, bovine			13	–	–	–	–	–
Pericardium, bovine			57	2	–	–	1[b]	–
Pericardium, ovine			20	–	–	–	–	–
Dermis, porcine (Zenoderm)			1	–	–	–	–	–
Synthetic (Duratexol)	5	(1.3)	5	–	–	–	–	–
Total grafts	379	(100)	368	5	3	1[a]	1[b]	1[c]
Evaluation of grafts used			Success 376 (99.2%)			Failed 3 (0.8%)		

[a] 1 case with CSF leak (patient died of infection)
[b] 1 case with CSF leak (a new fascia lata graft was successfully inserted)
[c] 1 case with CSF leak through the mastoid cells (a new fascia lata graft was successfully inserted)

Table 6 Reoperation for early complications (up to 1 month after initial surgery) or for delayed recurrence (1 month to 13 years after initial surgery) Mortality early (up to 1 month) or delayed (1 month to 14 years after surgery) following posterior cranial fossa surgery in children (1948–1996)

Diagnosis in children	Total operations	Reoperation for				Mortality			
		Complication		Recurrence					
		Early		Delayed		Early		Delayed	
		No.	%	No.	%	No.	%	No.	%
Astrocytomas	149	2	1.3	5	3.4	10	6.7	15[c]	10.1
Medulloblastomas	139	8	5.8	1	0.7	15	10.8	60	43.2
Brain stem gliomas	46	0	0	0	0	9	19.6	7	15.2
Ependymomas	28	0	0	3	10.7	3	10.7	10	35.7
Other tumours	40	1	2.5	1	2.5	4	10.0	11[d]	27.5
Other lesions[a]	52	5	9.6	0	0	7	13.5	0	0
Total	454	17[b]	3.7	10	2.2	48	10.6	103	22.7

[a] Congenital aqueduct stenosis (24), arachnoid cysts (8), Dandy-Walker syndrome (4), AVM (3), Chiari (2), cerebellomedullary cistern arachnoiditis (3), cerebellar haematomas (2), cerebellar infarction (1), cerebellar expansive contusion (1), aneurysm of vertebral artery (1), 3 lesions located in the pontine tegmentum – benign cyst (1), missile injury from bullet (1), and abscess (1)
[b] Haematomas (intraparenchymal 8, subdural 4, and epidural 4), transient venous air embolism (1)
[c] Combined with brain stem infiltration
[d] 1 child with pontine lipoma died in a traffic accident

pression, reconstruction of dura mater, and restoration of CSF circulation. Nevertheless, the operative results also depended on preoperative diagnosis, peroperative anaesthesiology and postoperative care.

3. Materials used for posterior fossa duraplasty. The kinds of grafts, their number and location in posterior fossa are given in Table 5. Materials used for dura mater reconstruction were mostly prepared by the Tissue Bank, Hradec Králové; Lyodura by Braun Melsungen; Zenoderm by Ethnor, Division of Ethicon, Edinburgh; and Duratexol by VÚP Brno.

A diagram (Fig. 2) and operative photographs (Fig. 3) illustrate our own suture technique used for posterior fossa duraplasty.

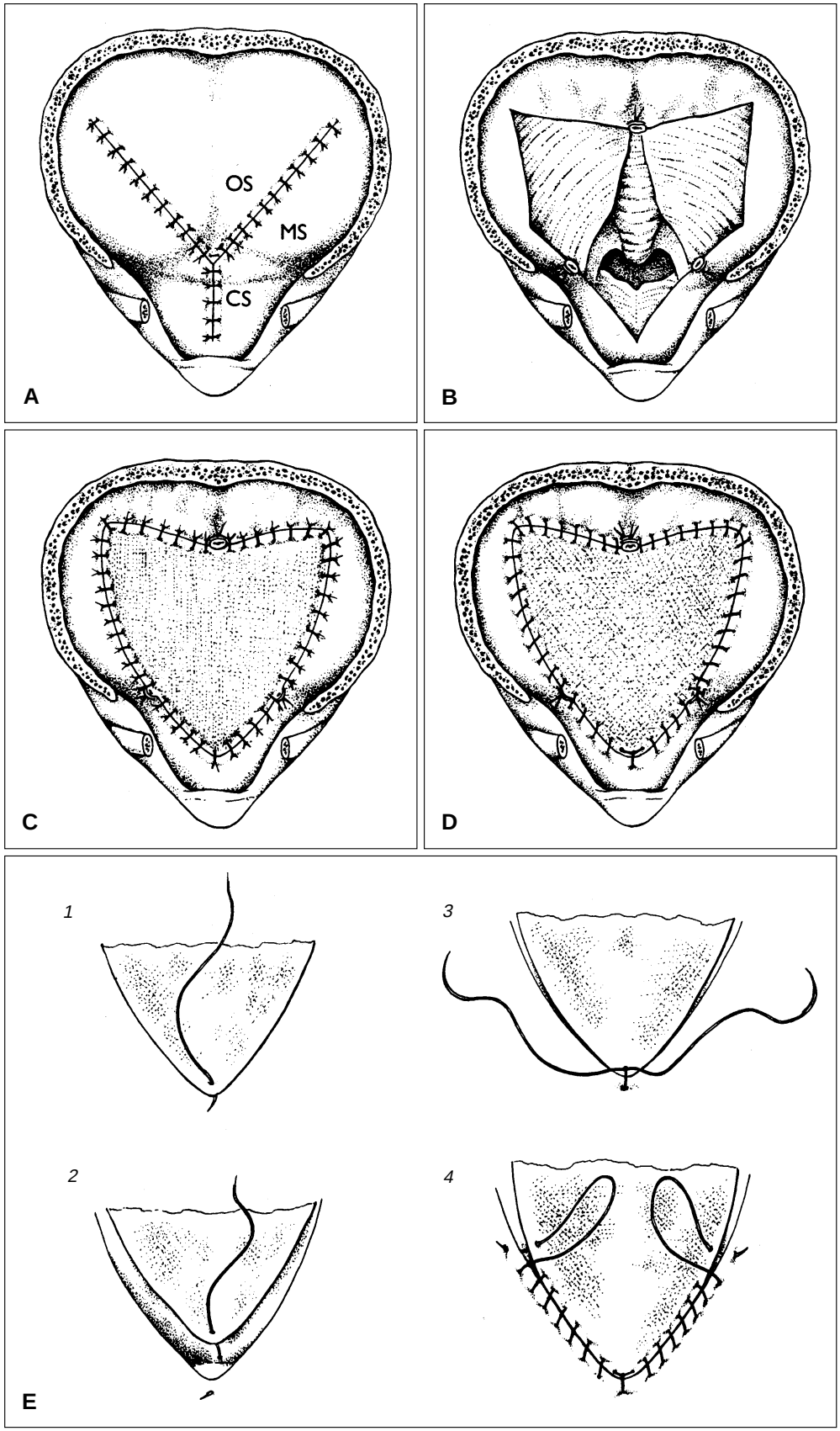

Fig. 2 A–E Various techniques using Y-shaped dura mater incision in posterior fossa surgery. **A** Suture of dural incision with interrupted stitches. *OS* Occipital sinus, *MS* marginal sinus, *CS* circular sinus. **B** External decompression results from craniectomy, Y-shaped dura mater incision and dural discision over the both cerebellar hemispheres at the level of their maximal tension. **C** Duraplasty performed with autogeneic or allogeneic fascia lata: the edges of these grafts are spontaneously well adapted to the edges of dura mater with interrupted or continuous sutures. **D** Duraplasty performed with allogeneic dura mater, allogeneic or xenogeneic pericardium, and/or synthetic materials: the rigid edges of these grafts should be subdurally buried for good adaptation. **E** Suture must be performed carefully and step by step: *1* Stitching the graft with an atraumatic needle. *2* Stitching the arachnoid and dura mater buries the apex of the graft subarachnoidally (in cases with open arachnoid). *3* Double-needled Ethibond 4/0 (90 cm) is tighted up in half of its length with a friction knot. *4* Continuous watertight suture should be performed gradually bilaterally, and after filling the subdural compartment with saline, the suture should be finished with a friction knot situated above the ligated occipital sinus (**D**). The total subdurally buried graft, including its three corners, should protect the duraplasty from CSF leakage and infections

Table 7 Postoperative complications by the various types of management of dura mater following posterior fossa surgery by a medial approach in 429 initial and 10 delayed revision operations in children (*CL* CSF leakage, *PS* pseudomeningocele, *IF* infected wound, *AM* aseptic meningitis, *HY* hydrocephalus, *IL* infection lethal, *BM* bacterial meningitis, *AD* adhesions, *TM* tumoral meningitis)

Dura mater	CL	AM	BM	TM	PS	HY	AD	IF	IL	Total
Sutured	4	0	2	0	0	4	0	0	0	20
Left open	2	1	1	1	4	2	2	1	1	48
Reconstructed	14	15	8	4	50	21	9	2	4	371
Total	20	16	11	5	54	27	11	3	5	439
Percentage	4.6	3.6	2.5	1.1	12.3	6.2	2.5	0.7	1.1	100.0

Table 6 presents the data on reoperation for early complications or delayed recurrences and on mortality, postoperative or delayed, with posterior fossa surgery in 454 children. Postoperative complications following the various types of management of the dura mater in medial posterior fossa surgery in 439 children are given in Table 7. Postoperative complications that occurred following the 439 medial posterior fossa explorations in children are shown in Table 8. The main complications were recorded in cases with the dura mater sutured: hydrocephalus in 20%, and CSF leakage also in 20% of cases. On the other hand, in cases with duraplasty we recorded hydrocephalus in 5.7% and CSF leakage in 3.8%. In contrast, pseudomeningocele was not recorded in cases with suture of the dura mater, but true pseudomeningocele (vera) was found in 8.3% of cases with the dura left open, and false pseudomeningocele (spuria), in 13.5% of cases with the dura mater reconstructed. In the majority of cases the pseudomeningocele resolved spontaneously or after lumbar or local punctures. Drainage procedures used for prevention or management of postoperative complications are shown in Table 9. CSF leakage in a 7-year-old boy operated on for medulloblastoma (first case of craniotomy performed in 1991) was successfully treated with continous external drainage for 6 days (Fig. 3). Obstructive hydrocephalus was treated in 53 children with tumours and 25 with aqueduct stenoses, with Torkildsen's ventriculocisternal drainage in 5.5%, and/or catheterisation of the aqueduct in 12.3%. Postoperative pseudomeningocele and hydrocephalus were treated with shunts in 8.2%.

Table 8 Postoperative complications by the various types of management of dura mater following posterior fossa surgery by a medial approach in 429 initial and 10 delayed revision operations in children. Diagnoses in the 30 children aged under 3 years

Dura mater	No.	Pseudo-mengingocele		Hydro-cephalus		CSF leakage	
Sutured	20	0	0%	4[c]	20.0%	4[e]	20.0%
Left open	48	4[a]	8.3%	2	4.2%	2	4.2%
Reconstructed	371	50[b]	13.5%	21[d]	5.7%	14[f]	3.8%
Total	439	54	12.3%	27	6.2%	20	4.6%

[a] 1 medulloblastoma
[b] 14 assorted tumours, 3 aqueduct stenosis, 1 arachnoid cyst
[c] 1 medulloblastoma, 1 aqueduct stenosis
[d] 4 assorted tumours, 1 arachnoid cyst
[e] 2 medulloblastomas, 1 aqueduct stenosis
[f] 1 medulloblastoma

Table 9 Drainage procedures used for prevention or management of complications mentioned in Table 8

Dura mater	No.	Torkildsen's drainage		Shunt, VP or VA		Catheterisation of aqueduct	
Sutured	20	5	25.0%	0	0%	0	0%
Left open	48	2	4.2%	2	4.2%	0	0%
Reconstructed	371	17	4.6%	34	9.2%	54	14.6%
Total	439	24[a]	5.5%	36[b]	8.2%	54[c]	12.3%

[a] 20 assorted tumours (6 in children aged under 3 years), 4 aqueduct stenoses (2 in children aged under 3 years)
[b] 29 assorted tumours (10 in children aged under 3 years), 5 benign aqueduct stenoses (3 in children aged under 3 years), 2 congenital malformations (1 in a child aged under 3 years)
[c] 33 partially resected tumours (5 in children aged under 3 years), 21 benign aqueduct stenoses (4 in children aged under 3 years)

Complementary operations performed were 16 tracheostomies (6 brain stem tumours, 4 medulloblastomas, 3 ependymomas, 1 ganglioglioma, 1 astrocytoma, and 1 neurinoma IX) and 21 resutures of the wound because of dehiscence or CSF leakage (13 medulloblastomas, 5 astrocytomas, 2 aqueduct stenoses, and 1 brain stem tumour).

The following other complications were diagnosed: (1) Gastrointestinal haemorrhage, mainly accompanying brain stem lesions. In 1 case in a 2-year-old girl, on the 16th day after partial resection of an ependymoma there was a fatal pyloric ulcer haemorrhage. (2) CSF metastases in 4 cases of medulloblastomas the spinal axis was affected and in 1 case of neuroblastoma, the right frontal lobe. (3) Venous air embolism occurred in 2 cases of astrocytoma. A 10-year-old boy underwent reoperation after 2 days; a 16-year-old girl died after release of a sharp self-retaining cerebellar retractor at the end of surgery. (4) Subdural frontal tense bilateral pneumocephalus, combined with a unilateral subdural haematoma, occurred in 1 case of aqueduct catheterisation in a 6-year-old boy. (5) Some rare complications (e.g. mutism) described in the literature were observed [5, 9, 21, 32, 33, 39] (Table 10).

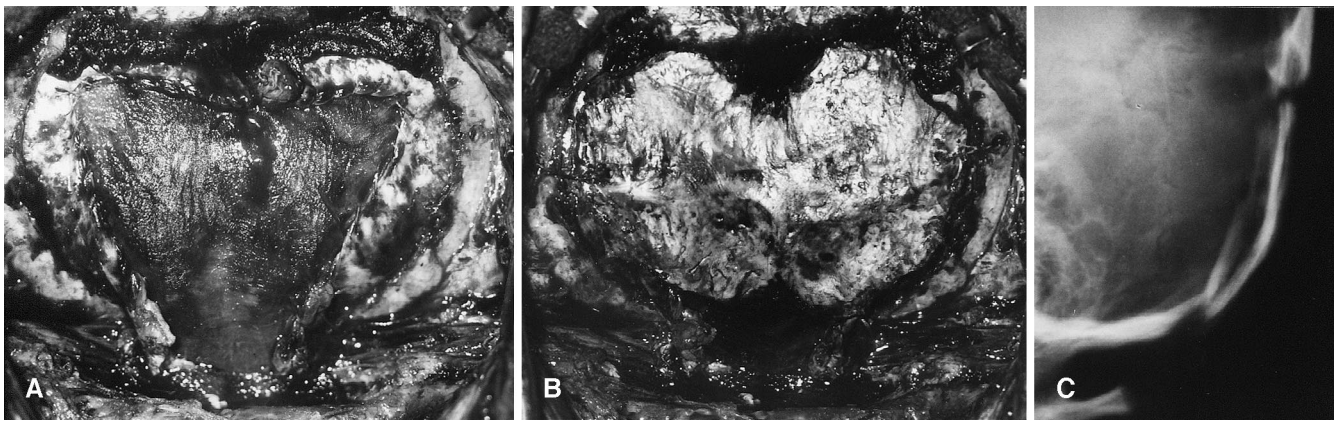

Fig. 3A–C Photographs obtained during surgery for medulloblastoma in a 7-year-old boy. The medial suboccipital craniotomy was combined with posterior arch atlantectomy. **A** Duraplasty was performed with the bovine pericardium sutured with continuous double-needled Ethibond 4-0 (Ethicon, a Johnson & Johnson company, Edinburgh). Inferior corner of the duraplasty as rims of craniectomy are covered with the strips of gelfoam. **B** Adapted bone plate was sewn on bilaterally. **C** Postoperative lateral X-ray shows a nearly anatomic location of the bone plate

Renewed signs of intracranial hypertension and growing tumour on CT scan were indications for reoperation. Posterior fossa tumours recurred after surgical treatment 2.5% of cases (Table 11).

In the majority of cases (143) the children died of their primary lesion. Other causes of death were also recorded (Tables 2–6): wound infections (3 cases), bacterial meningitis (2 cases), venous air embolism (1 case), gastrointestinal haemorrhage (1 case), and traffic accident (1 case).

The main preoperative clinical findings in the presence of posterior fossa lesions were those suggestive of raised intracranial pressure, papilloedema, cerebellar signs, nystagmus and cranial nerve palsies. Postoperatively, raised intracranial pressure and cerebellar signs disappeared in the majority of cases; nevertheless, the local neurological findings persisted in some cases, especially in the children with brain stem lesions.

Discussion

The most frequent lesions in the posterior cranial fossa in children were, according to our statistics, four types of

Table 10 Analysis of 3 cases of cerebellar mutism and 2 cases of dysarthria after resection of posterior fossa tumours (*V* vermis, *ASTR* astrocytoma, *IV V* IV ventricle, *MEDB* medulloblastoma, *EPEN* ependymoma, *A* alive, *D* dead)

No.	Age (years)/ sex	Tumour site	Tumour histology/ grading	Brain stem invasion	Latency of mutism (days)	Beginning/ completion of speech recovery	Other symptoms	Follow-up (published) time
1	8/F	V	ASTR/31	Roof of aqueduct L lateral wall of IV V	0	6 weeks/ 7 months	Gaze paresis R hemiparesis Ataxia	A 7 years
2	7/F	V	MEDB/34	Floor of IV V Rec. Luschkae	9[a]	?/7 weeks	Gaze paresis Nystagmus	D 2 years
3	9/M	V	MEDB/34	0	16	3/5 weeks	Ataxia Strabismus with Nystagmus	D 2 years
4	7/F	IV V	EPEN/32	R lateral wall of IV V Metastasis	2 Prevalently dysarthria	1/3 weeks	Gaze paresis Nystagmus L hemiparesis Ataxia	D 5 years
5	7/M	V	MEDB/34	?	0 Prevalently dysarthria	?/5 weeks	Ataxia Nystagmus Strabismus	A 5 years

[a] Semicomatose state owing to postoperative pneumocephalus treated with external ventricular drainage, which delayed the evaluation of mutism

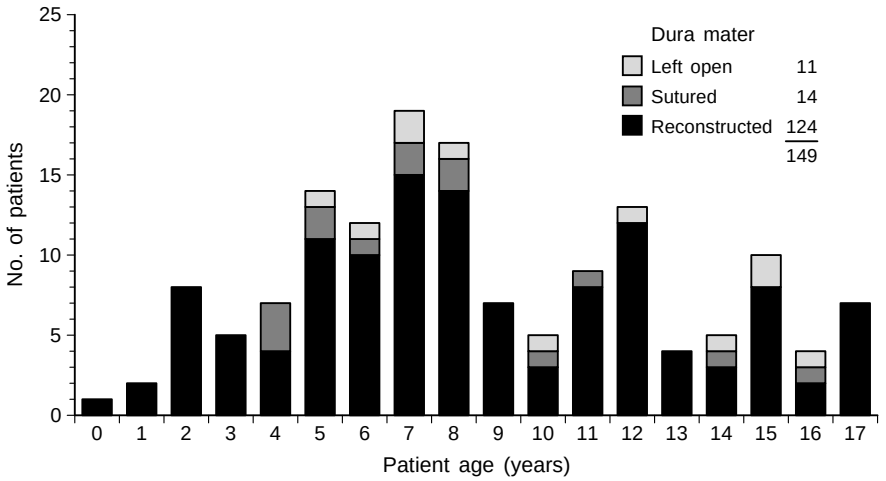

Fig. 4 Bar graph demonstrating age distribution of 149 children with cerebellar astrocytomas, by type of management of dura mater

Table 11 Delayed reoperations selected for extensive recurrences with follow-up in 10 children operated on for posterior fossa tumours (*GLSA* gliosarcoma, *G* grading at reoperation, *XRT* radiotherapy, *CHT* chemotherapy)

No.	Age (years)/ sex	Tumour histology/ grading	Reoperation (time after initial surgery)	Adjuvant therapy	Follow-up (published) time
1	8/M	GLSA/34-34 G	8 months	XRT–CHT	D 1 month
2	1/M	EPEN/31-32 G	9 months	XRT–CHT	D 2 years
3	3/M	ASTR/31-31 G	1 year	XRT	A 13 years
4	6/M	EPEN/32-32 G	1.5 years	XRT–CHT	D 1 year
5	10/M	MEDB/34-34 G	2 years	XRT	D 2 years
6	5/M	ASTR/?-32 G	4.5 years	?	?
7	7/F	EPEN/11-33 G	5 years	XRT–CHT	D 2 years
8	4/F	ASTR/31-32 G	7 years	?	A 8 years
9	3/F	ASTR/31-32 G	7 years	XRT	D 2 years
10	2/F	ASTR/31-32 G	13 years	XRT	A 12 years

brain tumours: cerebellar astrocytomas, medulloblastomas, brain stem gliomas, and ependymomas (Table 1). The patients were regularly followed up for 3 years after surgery by a neurosurgeon, and later by neurologists and/or oncologists. CT or MRI was used for detection of tumour recurrence [30, 36, 37]. Owing to the very long time lapse since the beginning of the period classed as the pre-CT era, calculation of the overall 5-year survival rate has only been attempted for the series in the CT era.

Cerebellar astrocytomas accounted for about one third of the posterior fossa tumours. On average, the patients had a mean age of 9 years (5–8) at diagnosis (Fig. 4). The male-to-female ratio was 1:1 (76:78). Reoperation for early complications was needed in 1.3%, and reoperation for delayed recurrence, in 3.4% (Table 6). The postoperative mortality was 6.7%, and delayed mortality, 10.1% (Table 6). Postoperative mortality after CT era surgery was 4.7% (Table 2). The postoperative mortality rates presented in the literature are between zero and 50% [8, 10, 15, 19, 22, 35]. The overall 5-year survival rate for the present series among children operated on in the CT era was 82.9% (Table 12). The corresponding survival rates reported in the literature are between 61% and 92% [10, 15, 22].

According to CT appearances and surgical observations, cerebellar astrocytomas can be separated into three types according to Lapras et al. [11, 19]: (1) On CT scan, cystic astrocytomas have a typical mural nodule; with contrast injection only the nodule becomes hyperdense; the wall of the cyst is not modified. In these cases, only the mural nodule should be removed since the wall does not contain tumour cells. (2) In contrast, false cystic astrocytomas present an irregular wall, diffusely enhanced and thick. In this case the wall is invaded by tumour cells, so it must be totally removed. (3) Solid astrocytomas may invade the peduncle, IV ventricle, and subarachnoid spaces. Total removal is sometimes difficult to confirm [19]. With total removal, pilocytic astrocytoma, has the best progno-

Table 12 Overall 5-year survival rates showing mortality of the most common posterior fossa tumours in children operated on in CT era (1978–1996)

Diagnosis	Surgery no.	Lost to follow-up	Evaluated	Died				Survival rates	
				Within 1 month	%	Within 5 years	%	No.	%
Cerebellar astrocytomas	86	4	82	3	3.7	11	13.4	68	82.9
Medulloblastomas	69	6	63	2	3.2	44	69.8	17	27.0
Brain stem gliomas	21	4	17	5	29.4	4	23.5	8	47.1
Ependymomas	16	1	15	1	6.7	5	33.3	6	40.0

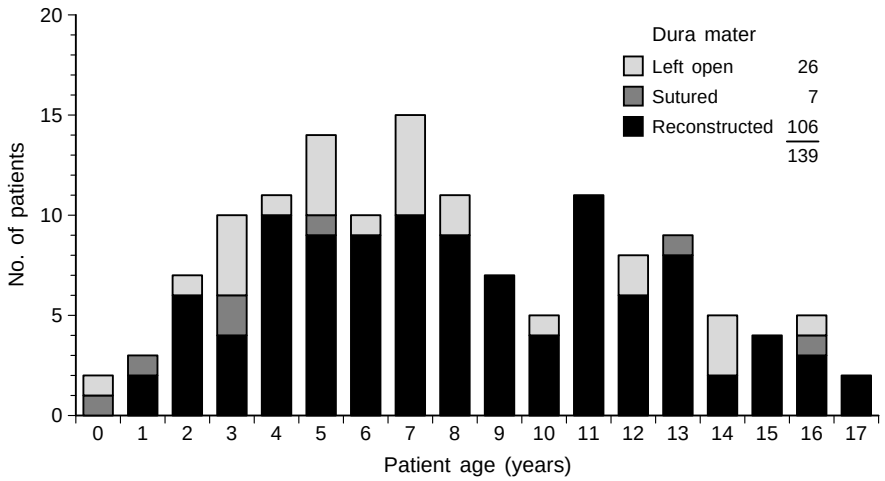

Fig. 5 Bar graph demonstrating age distribution of 139 children with medulloblastomas, by type of management of dura mater

Table 13 Details of tumour extension and of treatment and outcome in infants operated on for medulloblastoma before the end of the 2nd year of life (*V* cerebellar vermis, *HE* cerebellar hemisphere, *SU* sutured, *LO* left open, *AFL* allogeneic fascia lata, *ADM* allogeneic dura mater, *XFE* xenogeneic fascia endothoracica, *XP* xenogeneic pericardium)

Patient no.	Year of operation	Age/sex	Surgery	Management of dura mater	Tumour extension	Adjuvant therapy		Duration of survival
						XRT	CHT	
Nonsurvivors								
1	1958	1 month/M	Biopsy +	SU	V	XRT	–	1 month
2	1961	2 years/M	Biopsy –	AFL	V	XRT	–	1.5 months
3	1965	1 year/F	Partial	SU	HE	XRT	–	1 month
4	1979	2 years/M	Total	AFL	V	XRT	–	6 months
5	1981	1 year/F	Total	XFE	V + HE	XRT	–	1 month
6	1982	1 year/F	Total	ADM	V	–	–	3 days
7	1982	2 years/F	Total	AFL	V	XRT	CHT	2.5 years
8	1983	5 months/M	Total	LO	V + HE	XRT	–	3 months
9	1983	1.5 years/F	Total	LO	V	XRT	CHT	11 years
10	1987	2 years/M	Total	XP	V	XRT	CHT	1 months
11	1995	2 years/M	Total	XP	HE	XRT	CHT	1 year
Survivor								
12	1985	2 years/M	Total	XP	HE	XRT	CHT	12 years so far

sis of all brain tumours in childhood [22]. In these cases we have used radiotherapy only when only partial removal was possible in the presence of brain stem infiltration or after tumour recurrence [4, 8]. We no longer perform immediate postoperative radiotherapy, respecting the warning about the possibility of malignant transformation [4, 11, 18]. Nevertheless, except for common postirradiation atrophy and progressive calcifications and remote infarcts seen on CT, no such case has been observed by us.

Medulloblastomas also represented about one third of posterior fossa tumours. The patients were aged (mean) 8 and mainly 3–8 years at diagnosis (Fig. 5). The male-to-female ratio was 2:1 (92:47). Reoperation was needed for early complications in 5.8% and for delayed recurrence in 0.7% (Table 6). Postoperative mortality was 10.8%, and delayed mortality 43.2% (Table 6). Postoperative mortality among children treated in the CT era was 2.9% (Table 2). In the last 9 years no postoperative deaths have been registered (0/17). The postoperative mortality presented in the literature varies between 2% and 33% [3, 6, 13, 22, 34]. A special evaluation group is needed for medulloblastoma in infants. Di Rocco et al. [6] conclude that the current prognosis of infants with medulloblastoma is not necessarily any worse than that of older children. Analysis of our infants operated on before the end of the 2nd year of life, which is not so optimistic, is presented in Table 13. Nevertheless, chemotherapy was less frequently used in these cases. The overall 5-year survival rate for the children in the present series who were treated in the CT era was 27.0% (Table 12). The corresponding survival rate reported in the literature is between 25% and 73% [3, 6, 7, 18, 22, 34, 38].

When posterior fossa surgery was first started in our Department we only performed decompressive trepana-

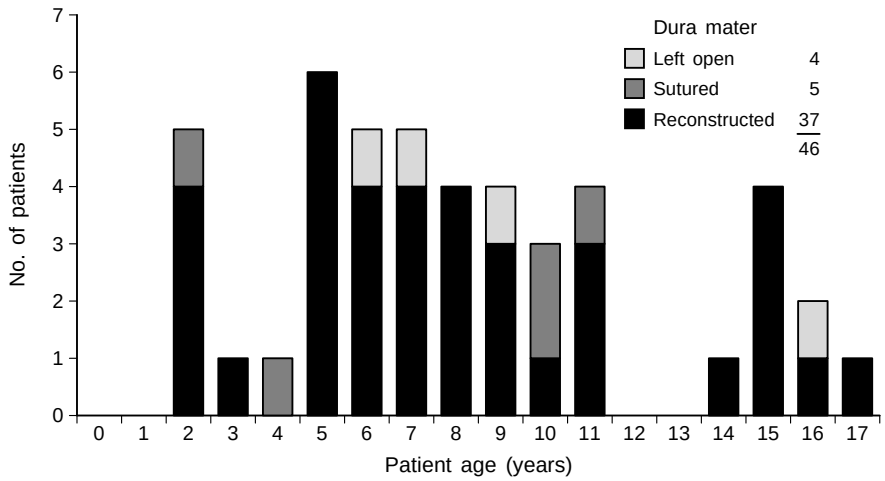

Fig. 6 Bar graph demonstrating age distribution of 46 children with brain stem tumours, by type of management of dura mater

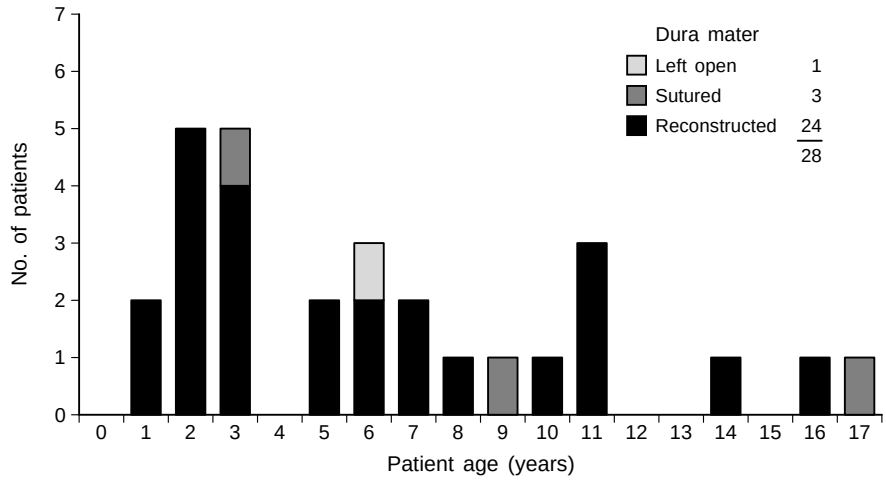

Fig. 7 Bar graph demonstrating age distribution of 28 children with posterior fossa ependymomas, by type of management of dura mater

tion, bioptic verification, and radiotherapy [31]. Since 1972 we have introduced the use of urea, followed by mannitol and hyperventilation, and "total" resection. Our strategy is now similar to the rules described by Sutton and Packer [38]: (1) Start with dexamethasone on admission. (2) Avoid preoperative shunting. (3) Perform surgery on the next elective operation day. If a child's condition deteriorates suddenly, the tumour is removed on an emergency basis. (4) Finish surgery with duraplasty, which we find important. Radiotherapy of the whole brain, with a local boost, and of the spinal cord should follow in all cases. Chemotherapy is used mainly at the time of disease recurrence. In children the vermis is the typical location, as against the hemispheric variant in adults [22, 34]. However, in our statistics the 139 cases of medulloblastomas included 9 cases of hemispheric and 7 cases of combined vermal and hemispheric variants. We suspected spinal metastases in 4 children on clinical examination, and myelography confirmed them in all 4. With reference to the survival of surgically treated children it has been suggested that survival for longer than their own age at diagnosis plus 9 months of gestational age is equivalent to a cure (Collins' rule) [3, 7, 22, 38]. In our series a 7-year-old (on admission) boy has survived for 15 years, a 3-year-old boy for 14 years, a 10-year-old boy for 13 years, and a 2-year-old boy with a desmoplastic hemispheric variant is alive 12 years later. Belza et al. [3], moreover, state that patients who survive a period of 8 years after radiotherapy are likely to remain disease free. Our statistics yielded the 4 above cases and a 16-year-old boy who has survived for 15 years, a 12-year-old girl still alive 10 years after treatment and an 11-year-old girl still alive after 8 years that support their rule. In contrast a 1.5-year-old girl, two 6-year-old girls and a 17-year-old girl died after 11 years.

Brain stem gliomas made up 10.6% of the posterior fossa tumours. The patients were mainly 5–11 (mean 8.5) years of age at diagnosis (Fig. 6). The male-to-female ratio was 1:1.4 (19:27). Postoperative mortality was 19.6%, and delayed mortality, 15.2% (Table 6). Postoperative mortality among children treated in the CT era was 19% (Table 2). The overall 5-year survival rate for the children in the present series treated in the CT era was 47.1% (Table 12).

We agree with the surgical classification based upon MR imaging of Abbott et al. [1]: brain stem tumours can be broadly divided into four categories: diffuse, focal, exophytic, and cervicomedullary. Brain stem lesions can show a heterogeneous histological pattern – WHO grade I and grade IV in the same tumour [22]. The most common brain stem neoplasm is diffuse glioma (60%–70%), and this is invariably a malignant astrocytoma. No treatment for these tumours has been shown to be effective [1]. We reviewed several cases of such tumours that had been treated in the pre-CT era to exclude a cystic lesion. According to the literature, the 1-year survival rate after radiotherapy is 45% and 18 months is the maximum survival [22]. In the other three categories of brain stem tumours surgical resection may be well tolerated and often beneficial [1].

Ependymomas accounted for 7.0% of posterior fossa tumours. Patients were 6.3 years of mean age at diagnosis on average, mainly in 2–3 years (Fig. 7). The male-to-female ratio was 1.3:1 (16:12). Postoperative mortality was 10.7%, and delayed mortality, 35.7% (Table 6). Postoperative mortality of children treated in the CT era was 6.3% (Table 2). The overall 5-year survival rate for those in the present series who were treated in the CT era was 40.0% (Table 12). The survival rates reported in the literature vary between 34% and 62% [14, 22]. We have used craniospinal radiotherapy in cases with partial removal of tumours, and chemotherapy mainly at the time of disease recurrence (Table 11).

Posterior fossa ependymomas can be classified into three types according to their origins and extension, as described by Ikezaki et al. [14]. (1) Midfloor type, tumours originating from the caudal half of the IV ventricular floor beneath the striae medullares. (2) Lateral type, tumours arising from the vestibular area and/or lateral recess. (3) Roof type, tumours originating from the roof of the ventricle. In our series only the first two types of tumours were present. We agree with Hoffman, that tumours which extend out into the cerebellopontine angle are frequently intermingled with the lower cranial nerves and with vessels, making total removal difficult and frequently impossible [12, 14]. Ikezaki et al. [14] have reported 5-year survival rates of 20.8% in such cases.

Posterior fossa duraplasty can be regarded as one of the main procedures in posterior fossa surgery [27, 28]. Various kinds of dural grafts have been used for this purpose [20, 23, 28] (Table 5). Duraplasty had a similar, favourable, outcome whether allogeneic fascia lata [16], allogeneic dura mater [26] or pericardium, and/or xenogeneic pericardium (bovine [27], or ovine [29] was used as source material for the graft. Fascia lata graft can be seen as a universal graft, but we prefer ovine pericardium for the posterior fossa because of its lesser thickness, its transparency, and its better workability and flexibility [30]. The duraplasty, as a reconstituted anatomical barrier using dense connective tissue grafts, provided (according to our previous evaluation): (1) a positive course of wound healing; (2) a decreased percentage of postsurgical or posttraumatic complications; and (3) a zone of cleavage in reoperations [29, 30]. The duraplasty also had a positive effect as a barrier during radiotherapy and chemotherapy [28]. For restoration of normal CSF circulation without hypertension, good healing of the wound and of the graft, drainage operations were used [28]. Torkildsen's ventriculocisternal drainage (in 5.5%; this technique has been used in children since 1958), and/or aqueduct catheterisation (in 12.3%; used since 1976) were performed at the time of the primary operation. Of the total 25.5% of patients who needed drainage postoperative shunts, used since 1960 (VA in 29 cases, VP in 6 cases, and ventriculoureteral shunt in 1 case), were placed in only 8.2% for the treatment of postoperative pseudomeningocele or hydrocephalus. A marked difference in the use of shunts in children under and over 3 years of age is seen from Table 14 [17]. We assume, that this low percentage of shunt usage is due to our frequent use of duraplasty and drainage installed at the primary operation (Table 9). The percentage of cases in which drainage is instituted in combination with posterior fossa surgery presented in the literature varies between 18% and 47% [3, 5, 13, 15, 17, 19, 22, 25, 34, 35]. Some authors have stated that in the majority of patients the dura was left open at the end of the procedure [35], while others closed the dura mater tightly, and it was often due to the shrinkage of the dura mater after coagulation that the duraplasty was required [11, 12, 25, 27, 28, 38]. We are endeavouring to perform more craniotomies (Fig. 3), because these improve the cosmetic result and, should reoperation be required, the replacement of the bone makes reopening much easier, by eliminating the risk of incising the dura during the muscle dissection [1].

Posterior fossa imaging methods are very useful in the postoperative evaluation of postcraniectomy sites and duraplasty. The location, defect of sutures, CSF fistulas, dynamic motion of the graft, and/or irregular septations in

Table 14 Evaluation of shunts used in children under and over 3 years of age operated on for posterior fossa tumours

Tumour type	Total no.	Surgery		Shunts	
		≤3 years	>3 years	≤3 years	> Over 3 years
Astrocytoma	149	16	133	5	7
Medulloblastoma	139	23	116	1	3
Brain stem glioma	46	5	41	1	4
Ependymoma	28	12	16	3	1
Other tumours	40	3	37	0	4
Total	402	59	343	10	19
Percentage		14.7	85.3	16.9	5.5

the pseudomeningocele due to infection, can be depicted by ultrasonography [30]. The greater sensitivity of MRI than of CT in the detection of posterior fossa tumours in paediatric patients has been demonstrated repeatedly [5, 18, 36, 40]. Nevertheless, we decided on CT for evaluation of two comparable groups of children operated on for posterior fossa lesions (198 children were operated on in the pre-CT era, and 256 in the CT era).

Conclusions

1. Posterior cranial fossa surgery performed in 454 children in the course of 49 years (1948–1996) revealed that the most frequent lesions (402) were tumours: cerebellar astrocytomas (37.1%), medulloblastomas (34.6%), brain stem gliomas (11.4%), ependymomas (7.0%), and other tumours (9.9%).

2. Duraplasty can be considered one of the main procedures in posterior fossa surgery in children, especially for those under 3 years of age. Duraplasty was performed in 81.6% of our operated cases, and in the majority of cases allogeneic or xenogeneic tissue grafts were used, with a 99.2% success rate.

3. Drainage operations were used in 25.5% of cases for stabilisation of the cerebrospinal fluid circulation. Torkildsen's drainage was instituted in 5.5%, and/or catheterisation of the aqueduct in 12.3%, at the primary operation in all cases, and shunts were placed in 8.2% of cases for the treatment of postoperative pseudomeningocele or hydrocephalus.

4. Computed tomography improved the detection of posterior fossa lesions as well as of postoperative complications, and also the evaluation of dural reconstruction. A valuable drop in postoperative mortality in the CT era was recognized, with medial suboccipital craniectomy from 15.5% to 6.0%, and with lateral suboccipital craniectomy from 29.4% to zero.

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