Childs Nerv Syst
DOI 10.1007/s00381-009-0844-4

INVITED PAPER

On the changing epidemiology of hydrocephalus

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Received: 2 February 2009

Abstract
Purpose The purpose of this study is to evaluate the changing epidemiology of paediatric hydrocephalus over the past three decades in a single institution.
Methods All children treated for newly diagnosed hydrocephalus during the 1985–1990 (group A) and the 2000–2005 periods (group B) were enrolled and classified according to the associated cause of hydrocephalus.
Results A significant 8.8% decrease of the incidence of hydrocephalus was noticed between the two time periods, resulting from the reduction of hydrocephalus associated to myelomeningocele, aqueduct stenosis ($p=0.04$), CNS infection ($p=0.03$), cranio-cerebral malformation and head injuries; post-haemorrhagic hydrocephalus remained stable, while the tumour-associated one increased ($p<0.0001$). No consistent differences in terms of rate of adjunctive surgery (30.3% versus 23.9%) and number revision procedures (200 versus 104) were recorded.
Conclusions The present study confirmed data from the literature about the declined incidence of paediatric hydrocephalus, which mainly results from the decrease of congenital malformations. In spite of the recent advances in neuroendoscopy and in the shunting valve design, the impact of hydrocephalus in the paediatric neurosurgical practice remains high.

All the authors approve the present submission and declare that this paper has not been published before and it is not under consideration elsewhere.

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Keywords Hydrocephalus · Epidemiology · Myelomeningocele · Preterm haemorrhage · Aqueduct stenosis

Introduction

Hydrocephalus represents one of the most common pathologic condition affecting children requiring neurosurgical treatment. The success in its management in terms of survival and quality of life recorded in the modern surgical era have been often quoted as the best even achieved in the treatment of any surgical disease. In spite of these results, the need of frequent surgical adjustments in the course of patient's life related to the development of the child, the induced changes in the cranio-cerebro-ventricular spatial relationships, the frequent CSF shunting device malfunctions and complications have affected the patients' life as well as the neurosurgeons' practice heavily.

Aim of this study is to evaluate whether the recent progresses in diagnosis and management of hydrocephalus as well as the changes in epidemiology has had a significant impact in the daily clinical practice. For such a purpose, we have taken into consideration the hydrocephalic population surgically treated at a single institution in two 5-year periods in the last two decades at a temporal distance of 15 years. Several bias limit the significance of the study: namely the hospital-based source of information, which does not necessarily reflects the absolute changes in epidemiology and aetiology of the hydrocephalus in the considered period of time and the lack of population-based epidemiological studies to be utilised for comparative purposes. Furthermore, the series here analysed does not necessarily correspond to what observed elsewhere, taking into account the epidemiological features and distributions

Published online: 24 February 2009

of the various types of hydrocephalus depending on geographic and social differences.

Materials and methods

For this retrospective study, all the patients affected by hydrocephalus and surgically treated at the Paediatric Neurosurgical Department, Policlinico Gemelli, Catholic University, Rome, in the periods 1985–1990 and 2000–2005 were considered.

The information utilised for this has been obtained by the clinical and neuroradiological archives, as well as from the operative reports and the outpatients' registry. In particular, age at surgery, sex, aetiology of hydrocephalus, modality of surgical treatment, and incidence of additional revision procedures in the first 3 post-operative years have been considered. The aetiologies of hydrocephalus were defined as follows: (associated to) myelomeningocele, idiopathic aqueduct stenosis, post-haemorragic ventricular dilatation (namely preterm newborns), brain tumour, infection, head injury, and miscellaneous of cranio-encephalic malformation (mainly including Dandy-Walker malformation and its variants, arachnoid cysts, holoprosencephaly, malformations of cortical development, achondroplasia and syndromic craniosynostoses).

The patients were divided into two groups, the first (group A) consisting of the children operated on between 1985 and 1990, the second (group B) composed by those treated from 2000 to 2005.

Chi-square and *t*-student tests have been used for the statistical analysis; p value<0.05 was considered as significant.

Patients and results

During the overall 10-year examination period (1985–1990, 2000–2005), a total of 4,375 children were admitted at our institution for surgical treatment. Out of them, 639 were affected by hydrocephalus (14.9%). Four hundred five children were treated during the 1985–1990 period (group A); they represented 19.1% of the 2,115 children admitted in the same period. Two hundred thirty-four children were operated on in the 2000–2005 period (group B); they represented 10.3% of the 2,260 subjects admitted for surgical management in the same period. The decrease in incidence of hydrocephalic children in the group B was statistically significant ($p<0.0001$). A synopsis of the etiologic and demographic characteristics of the two groups is reported on Table 1.

No significant differences were noticed with regards to the age and the sex distribution. Myelomeningocele represented the predominant aetiology (22.6%) in the group A, followed by haemorrhage (21.2%), tumours (20%), cranial/cerebral malformations (19.5%), infections (9.6%), aqueduct stenosis (5.6%) and traumas (1.5%). The tumoural aetiology was predominant among the subjects of group B (40.5%) while the relative incidence of haemorrhage (22.2%) was comparable to that recorded for group A. On the other hand, the relative incidence of myelomeningocele (14.9%), malformations (14.6%), infections (4.8%), aqueduct

Table 1 Demographic and etiologic comparison between the two groups of patients

	Group A	Group B	Total
No. of patients	405	234	639
Mean age at surgery (months)	39.5	43.3	41.4
Sex (M: male, F: female)	227 M, 178 F (M/F: 1.27)	130 M, 104 F (M/F: 1.25)	357 M, 282 F (M/F: 1.26)
Myelomeningocele	91 (22.6%)	35 (14.9%)	126 (19.8%)
Aqueduct stenosis	23 (5.6%)	5 (2.2%)	28 (4.3%)
Malformation miscellaneous	79 (19.5%)[a]	34 (14.6%)[b]	113 (17.8%)
Haemorrhage	86 (21.2%)	52 (22.2%)	138 (21.5%)
Tumour	81 (20%)	95 (40.5%)	176 (27.6%)
CNS infection	39 (9.6%)	11 (4.8%)	50 (7.8%)
Head injury	6 (1.5%)	2 (0.8%)	8 (1.2%)

[a] Dandy-Walker m. (21), holoprosencephaly (15), arachnoid cyst (nine), encephalocele (seven), Crouzon s. (six), acondroplasia (four), hydranencephaly (three), monoventricular Hy (two), haemimegalencephaly (two), Chiari type I m. (two), Sturge-Weber s. (one), Apert s. (one), Chiari type III m. (one), myelodisplasia (one), trisomy-8 (one), lissencephaly (one), coagulation alteration with sinuses thrombosis (one), unknown syndrome (one)

[b] Dandy-Walker m. (12), holoprosencephaly (four), arachnoid cyst (four), Crouzon s. (two), undefined syndrome (two), haemimegalencephaly (one), posterior quadrantic cortical dysplasia (one), encephalocele (one), acondroplasia (one), monoventricular Hy (one), Apert s. (one), Pfeiffer III s. (one), Chiari type I m. (one), Chiari type III m. (one), Sotos s. (one)

Table 2 Surgical modalities and incidence of revisions versus etiology in group A (mean follow-up, 5.6 years)

Etiology	No. of patients	Mean age	VP shunts	Other shunts	Re-operations
Myelomeningocele	91	1.3 months	90	1	56 (35 pts, 38%)
Aqueduct stenosis	23	35 months	23	/	10 (5 pts, 21.7%)
Malformation miscellaneous	79	24 months	74	5	32 (22 pts, 27.8%)
Haemorrhage	86	18 months	85	1	47 (25 pts, 29%)
Tumour	81	84 months	81	/	22 (17 pts, 20.9%)
CNS infection	39	18 months	39	/	31 (17 pts, 43.6%)
Head injury	6	96 months	6	/	2 (2 pts, 33.3%)
Total	405	39.4 months	398	7	200 (123 pts, 30.3%)

stenosis (2.2%) and head injuries (0.8%) was decreased. The difference between the two groups was found to be statistically significant for tumours ($p<0.0001$), aqueduct stenosis ($p=0.04$) and CNS infection ($p=0.03$). It was statistically significant for all the aetiologies except for tumours and head injuries when matching aetiology and admissions.

All the children here considered underwent surgery. The children of group A (Table 2), operated on before the re-introduction of neuroendoscopy, underwent the placement of an extrathecal CSF shunting device, near always a ventriculo-peritoneal shunt. Ventriculo-atrial or ventriculo-pleural shunts were carried out in six patients only. The mean age at CSF shunt insertion was 39.4 months. The lowest age was recorded among the children with myelomeningocele (1.3 months) and post-haemorrhagic or post-infectious hydrocephalus (18 months each), the highest among those affected by tumours (84 months) or head injury sequels (96 months). Overall, 123 children of this group (30.3%) required one or more CSF shunt revision procedures for a total of 200 additional operations after a 5.6-year mean follow-up (range, 2.7–8.3 years). Children affected by post-infectious hydrocephalus or hydrocephalus associated to myelomeningocele were the most burdened by CSF shunt malfunctions (43.6% and 38% of the cases, respectively), the patients with other aetiologies ranging from 20.9% (tumours) to 33.3% (head injuries). However, no statistical correlation between type of hydrocephalus and shunt malfunctions was detected due to the low number of patients when distributed in subgroups.

One hundred thirty-eight children belonging to the group B were treated by CSF shunting devices (133 V-P shunts) and 96 by means of endoscopic third ventriculostomy (Table 3). The mean age at surgery was 36.6 months. The patients with myelomeningocele were the youngest (mean age, 3.3 months), followed by children with cranial/cerebral malformations (11 months) and post-haemorrhagic hydrocephalus (20.5 months). Differently from group A, children with post-infectious hydrocephalus (50 months, $p=0.005$) and aqueduct stenosis (58 months, $p=0.07$) were among the oldest at surgery following those with brain tumour (78 months). A total of 104 revision procedures were performed in 56 patients (23.9%; no statistical difference with group A) during a 5.1-year mean follow-up (range, 2.4–7.6 years). No statistical variations among the different aetiologies were recorded, the rate of shunt malfunction/third ventriculostomy closure or failure ranging from 19% among the children with tumours to 28.8% in those with post-haemorrhagic hydrocephalus.

Table 3 Surgical modalities and incidence of revisions versus etiology in group B (mean follow-up: 5.1 years)

Etiology	No patients	Mean age	VP shunts	Other shunts	ETV	Re-operations
Myelomeningocele	35	3.3 months	20	/	15	16 (10 pts, 28%)
Aqueduct stenosis	5	58 months	/	/	5	1 (1 pt, 20%)
Malformation miscellaneous	34	11 months	24	2	8	15 (9 pts, 26.5%)
Haemorrhage	52	20.5 months	33	3	16	29 (15 pts, 28.8%)
Tumour	95	78 months	47	/	48	40 (18 pts, 19%)
CNS infection	11	50 months	7	/	4	3 (3 pts, 27.3%)
Head injury	2	36 months	2	/	/	/
Total	234	36.6 months	133	5	96	104 (56 pts, 23.9%)

ETV endoscopic third ventriculostomy

Discussion

The real incidence of paediatric hydrocephalus is hard to assess because of the divergences in the definition of the aetiology and the exclusion/inclusion criteria and in the prevalence in the different geographic areas [4, 8, 18, 20, 23, 26, 28]. Therefore, only a little number of studies addressing this topic is available in the literature when the changes of epidemiology are concerned. The most reliable epidemiological data have been obtained by studies regarding congenital/infantile hydrocephalus, since this definition reduces the bias related to the choice of the diagnostic criteria and the population denominators. In their analysis on congenital hydrocephalus between 1940 and 1979 in Utah, Blackburn and Fineman [2] found an 85% increase of the incidence in the 1966–1975 period compared with the early period of the study. Such a difference was mainly explained on the grounds of the improved diagnostic tools utilised in the late years of this investigation. Similarly, Fernell et al. [8] recorded a significant increase in the prevalence of infantile hydrocephalus in the Western Sweden population in the late phases of their study (1979–1982 and 1983–1990) as compared with the early one (1973–1978). Such a divergence was considered by the authors as the result of the enhanced survival of preterm infants with post-haemorrhagic hydrocephalus. However, more recent investigations on the Western Sweden population pointed out a decreasing prevalence of hydrocephalus (0.82/1,000 live births in 1989–1998 versus 0.66/1,000 in 1999–2002) mainly resulting from a decreased incidence of myelomeningocele [25, 26]. A similar trend was noticed in England and Wales [31] and in Japan [21]. On the other hand, other studies report the absence of significant changes in the incidence of congenital hydrocephalus with current figures ranging around 1/1,000 lives and stillborns (range, 0.2–3.5/1,000) according to the different countries [2, 12, 17, 20, 27]. Such a stability would result by the considerable improvement in the survival of extremely preterm babies (higher incidence of post-haemorrhagic hydrocephalus) counterbalanced by the decreased incidence of hydrocephalus associated to myelomeningocele [9, 25].

The present, hospital-based study cannot provide information concerning variations in incidence of hydrocephalus in our Country and even the decrease in admission of children requiring surgery for hydrocephalus cannot be considered necessarily a reliable index. However, this kind of investigation allows the addition of some information about aetiology and treatment of hydrocephalus compared with population-based studies. We recorded a significant decrease of the admissions for hydrocephalus in the 2000–2005 period (10.3%) compared with the 1985–1990 period (19.1%). In the same periods of time, natality rate in Italy did not present any significant change [14]. The declined incidence that we observed in our clinical practice is easily interpreted on the grounds of three main factors. The first one is related to the development of a more diffuse paediatric neurosurgical network, available in our country in the second epoch of the study, which allows avoiding the referral of hydrocephalic patients to tertiary centres, like our institution. Such an interpretation is supported by the parallel increase in the same period of patients treated for tumoural hydrocephalus. The second one refers to the improvement in the prenatal diagnosis which resulted in a raised rate of terminated pregnancies in case of malformative hydrocephalus. Actually, this study demonstrated important reduction in the congenital/perinatal hydrocephalus, as myelomeningocele ($p<0.0001$), cranio-cerebral malformations ($p<0.0001$) and pure aqueduct stenosis ($p=0.0007$). The third factor is related to an improved quality of surveillance and management of difficult pregnancies and deliveries and perinatal care of preterm newborns, which accounted for the observed decrease in the relative incidence of preterm-baby haemorrhage ($p=0.001$). The same considerations can be made to explain the decreased incidence of CNS infections ($p=0.0001$). Subsequently, the rate of hydrocephalus associated to congenital aetiologies dropped, while that associated to tumours significantly increased (see Table 1). These results fit those from similar series in the literature [11, 18, 30] and corroborate data from the population-based studies. According to the aforementioned Swedish studies [25, 26], indeed, the prevalence of hydrocephalus associated to myelomeningocele fell from 0.33/1,000 live births in 1989–1998 period to 0.18/1,000 live birth in the 1999–2002 period as result of the improved prenatal diagnosis and assistance. In the present series, a 7.7% reduction of hydrocephalus associated to myelomeningocele was noticed (22.6% in group A versus 14.9% in group B). In the USA, a 19% decline of neural tube defects was obtained in the 1990–1999 period by means of maternal folate supplementation [13].

Despite of the reduction of the rate of preterm infants developing haemorrhage [32], currently ranging from 20% to 59% [15], the incidence of post-haemorragic hydrocephalus remains stable, as proved by the present study (21.2% and 22.2% in group A and B, respectively) and by other authors [8, 10]. This phenomenon is justified by the considerable advances in the perinatal assistance of extremely preterm babies, since these two subgroups of children develop hydrocephalus (8.5/1,000 and 23.1/1,000, respectively) much more frequently than at term or moderately preterm infants (0.26/1,000 and 0.96/1,000, respectively) [25]. However, it is worth noting that, in some centres, the rate of post-haemorrhagic hydrocephalus has decreased over the time just due to the advances in neonatal care [11].

The same considerations on enhanced perinatal care and prophylaxis apply to the congenital cranio-cerebral malfor-

mations and CNS infections. Differently, the pure, congenital aqueduct stenosis has to be regarded as a rare cause of hydrocephalus. The high number of patients belonging to group A (23 children) may result from an inappropriate diagnosis due to the absence of MRI that could have point out small tectal gliomas or other causes of the stenosis undetectable at CT scan. According to the International Infant Hydrocephalus Study [29], only 116 children with aqueduct stenosis have been recruited in the last 3 years among the 38 countries enrolled in the study (about 1/patient/year in each country) (S. Constantini, unpublished data), thus validating these observations. The progresses in the neuroimaging technology together with the admission of children harbouring brain tumours to tertiary units are at the base of the increased incidence of tumoural hydrocephalus experienced in our as well as in other centres [24].

The aforementioned trends mainly involve developed countries as the incidence of infantile hydrocephalus remains significantly higher in the developing ones due to the higher frequency of congenital disease and malformations as well as syndromes and perinatal acquired forms [20]. The comparison between the Oxford and Cape Town paediatric series demonstrated a distinction in the number children treated for hydrocephalus (about 25 children/year in Oxford versus 48/year in Cape Town) other than in the occurrence of the different aetiologies [24]. The authors actually observed major differences about the occurrence of hydrocephalus due to infection (35% in Cape Town versus 6% in Oxford), myelomeningocele (19% vs 6%) and brain tumours (13% vs 24%) between the two communities.

A mild prevalence of the male sex is usually reported in paediatric hydrocephalic patients, the male/female sex ratio ranging from 1.11 to 1.48, that is independent from the age and stable over the time [2, 11]. The total male/female sex ratio of the present series (1.26) as well as the ratios in group A (1.27) and B (1.25) confirm these figures. As to the age, we found only a slight prolongation of the age at surgery in the late group of children, compared with the early one (see Table 1–**3**), as result of the improvement in the pre-operative management and imaging monitoring and/or the increase of patients with tumours (higher age at diagnosis) in group B. Actually, the age at diagnosis of hydrocephalic children mainly depends on the aetiology of hydrocephalus, patients with post-haemorrhagic hydrocephalus usually presenting with the lowest age (preterm babies), followed by those with myelomeningocele and, then, by other aetiologies [19, 26]. Of course, the age at diagnosis is nowadays significantly lower (and without major changes in the recent years) than in the past due to the advanced diagnostic tools [8, 11, 25]. Our attitude to delay as much as possible the definitive surgical procedure in children with post-haemorrhagic hydrocephalus by using transient external drainage or endoscopic brain wash is responsible of the higher age at surgery of these children in both group A and B compared with those with myelomeningocele.

Conclusions

The management of hydrocephalus still has a significant epidemiological impact worldwide. In USA, it accounts for about 69,000 discharges/year, 36,000 shunting procedures/year and 14,000 shunt revisions/year [3], requiring an estimated cost of one billion American dollars/year [22]. In the last two decades, the technology supporting the treatment of hydrocephalus has made considerable advances with regards either to shunts and endoscopy. CSF shunting devices nowadays count several innovative tools, like adjustable valves, flow-controlled valves and anti-siphon devices, other than different systems to assist the surgeon during the shunt insertion (endoscopy, ultrasounds, neuronavigator). Similarly, neuroendoscopy has quickly developed up to offer a complete and sophisticated instrumentation. In spite of these advances, however, "in terms of overall patient outcomes, one can conclude that things are little better, but not much", as noticed by Drake in his review on the surgical management of paediatric hydrocephalus [7]. In the present experience, the more recent group of children showed a reduction of re-operated patients (23.9% versus 30.3% of group A), while the rate of re-operations remained grossly unchanged between the two groups (104 in group B and 200 in group A). No significant changes were found among the different etiologies (Tables 2 and **3**).These figures confirm in part the Drake's statement and match data from the literature about shunt and endoscopy failures [5, 28, 30].

The absence of a considerable decrease of failures can be explained by the still high risk of malfunction of both endoscopy and shunts in the infantile population. In this subset of patients, the role of endoscopic third ventriculostomy (ETV) is quite limited just because of the young age [16]. The combination of obstructive and absorptive problems, indeed, is responsible of the failure of ETV in newborns and infants regardless the aetiology [1]. The same concepts apply to the shunting devices, since the younger the child the higher the risk of malfunction, especially when considering shunt infections in post-haemorrhagic hydrocephalus [6]. Therefore, it is possible to conclude that hydrocephalus will keep on exerting a significant impact on the paediatric neurosurgical practice in spite of its slowly decreasing absolute incidence.

References

1. Beni-Adani L, Biani N, Ben-Sirah L, Constantini S (2006) The occurrence of obstructive vs absorptive hydrocephalus in

newborns and infants: relevance to treatment choices. Childs Nerv Syst 22:1543–1563
2. Blackburn BL, Fineman RM (1994) Epidemiology of congenital hydrocephalus in Utah, 1940–1979: report of an iatrogenically related "epidemic". Am J Med Genet 52:123–129
3. Bondurant CP, Jimenez DF (1995) Epidemiology of cerebrospinal fluid shunting. Pediatr Neurosurg 23:254–258
4. Casey AT, Kimmings EJ, Kleinlugtebeld AD, Taylor WA, Harkness WF, Hayward RD (1997) The long-term outlook for hydrocephalus in childhood. A ten-year cohort study of 155 patients. Pediatr Neurosurg 27:63–70
5. Di Rocco C, Cinalli G, Massimi L, Spennato P, Cianciulli E, Tamburrini G (2006) Endoscopic third ventriculostomy in the treatment of hydrocephalus in pediatric patients. Adv Tech Stand Neurosurg 31:119–219
6. Di Rocco C, Massimi L, Tamburrini G (2006) Shunts vs endoscopic third ventriculostomy in infants: are there different types and/or rates of complications? A review. Childs Nerv Syst 22:1573–1589
7. Drake JM (2007) The surgical management of pediatric hydrocephalus. Neurosurgery 62(Suppl. 2):633–640
8. Fernell E, Hagberg G, Hagberg B (1994) Infantile hydrocephalus epidemiology: an indicator of enhanced survival. Arch Dis Child 70:F123–F128
9. Frey L, Hauser WA (2003) Epidemiology of neural tube defects. Epilepsia 44(Suppl 3):4–13
10. Futagi Y, Suzuki Y, Toribe Y, Nakano H, Morimoto K (2005) Neurodevelopmental outcome in children with posthemorrhagic hydrocephalus. Pediatr neurol 33:26–32
11. Green AL, Pereira EAC, Kelly D, Richards PG, Pike MG (2007) The changing face of pediatric hydrocephalus: a decade's experience. J Clin Neurosci 14:1049–1054
12. Heisenbergen I, Rotteveel J, Roeleveld N, Grotenhuis A (2002) Outcome in shunted hydrocephalic children. Eur J Ped Neurol 6:99–107
13. Honein MA, Paulozzi LJ, Mathews TJ, Erickson JD, Wong LY (2001) Impact of folic acid fortification of the US food supply on the occurrence of neural tube defects. JAMA 285:2981–2986
14. ISTAT (2008) Natalità e fecondità della popolazione residente: caratteristiche e tendenze recenti. Anno 2006. www.demo.istat.it
15. Kadri H, Mawla AA, Kazah J (2006) The incidence, timing, and predisposing factors of germinal matrix and intraventricular hemorrhage (GMH/IVH) in preterm neonates. Childs Nerv Syst 22:1086–1090
16. Koch-Wiewrodt D, Wagner W (2006) Success and failure of endoscopic third ventriculostomy in young infants: are there different age distributions? Childs Nerv Syst 22:1537–1541
17. Lemire RJ (1988) Neural tube defects. JAMA 259:558–562
18. Moritake K, Nagai H, Miyazaki T, Nagasako N, Yamasaki M, Tamakoshi A (2007) Nationwide survey of the etiology and associated conditions of prenatally and postnatally diagnosed congenital hydrocephalus in Japan. Neurol Med Chir (Tokyo) 47:448–452
19. Moritake K, Nagai H, Nagasako N, Yamasaki M, Oi S, Hata T (2008) Diagnosis of congenital hydrocephalus and delivery of its patients in Japan. Brain Dev 30:381–386
20. Murshid WR, Jarallah JS, Dad MI (2000) Epidemiology of infantile hydrocephalus in Saudi Arabia: birth prevalence and associated factors. Pediatr Neurosurg 32:119–123
21. Nakashima S, Watanabe K, Negoro T, Aoki K, Kikuchi H (1996) Clinico-epidemiological features of infantile hydrocephalus in Japan. Acta Pediatr Jap 38:567–575
22. Patwardhan RV, Nanda A (2005) implanted ventricular shunts in the United States: the billion-dollar-a-year cost of hydrocephalus treatment. Neurosurgery 56:139–145
23. Peacock WJ, Currer TH (1984) Hydrocephalus in childhood. A study of 440 cases. S Afr Med J 66:323–324
24. Pereira EAC, Fieggen AG, Kelly D, Richards PG, Pike MG (2004) The etiology of pediatric hydrocephalus: Oxford and Cape Town compared. Childs Nerv Syst 20:266
25. Persson E-K, Anderson S, Wiklund L-M, Uvebrant P (2007) Hydrocephalus in children born in 1999–2002: epidemiology, outcome and ophthalmological findings. Child's Nerv Syst 23:1111–1118
26. Persson E-K, Hagberg G, Uvebrant P (2005) Hydrocephalus prevalence and outcome in a population-based cohort of children born in 1989–1998. Acta Paediatrica 94:726–732
27. Schrander-Stumpel C, Fryns JP (1998) Congenital hydrocephalus: nosology and guidelines for clinical approach and genetic counselling. Eur J Pediatr 157:355–362
28. Serlo W, Fernell E, Heikkinen E, von Wendt L (1990) Functions and complications of shunts in different etiologies of childhood hydrocephalus. Childs Nerv Syst 6:92–94
29. Sgouros S, Kulkharni AV, Constantini S (2006) The International Infant Hydrocephalus Study: concept and rational. Childs Nerv Syst 22:338–345
30. Tuli S, Drake J, Lawless J, Wigg M, Lamberti-Pasculli M (2000) Risk factors for repeated cerebrospinal shunt failures in pediatric patients with hydrocephalus. J Neurosurg 92:31–38
31. Weatherall JAC (1982) A review of some effects of recent medical practices in reducing the numbers of children born with congenital abnormalities. Department of Health & Social Security, Welsh Office. Health trends 14:85–88
32. Whitelaw A, Thoresen M, Pople I (2002) Posthaemorrhagic ventricular dilatation. Arch Dis Child Fetal Neonatal Ed 86: F72–F74