# Relationship Between Ventriculoperitoneal Shunt Obstruction and Infection in Pediatric Patients with Hydrocephalus

Ali Şahin[1] (ID), Abdulfettah Tümtürk[2] (ID), Murat Çiftçi[3] (ID), Nimetullah Alper Durmuş[4] (ID), Ahmet Küçük[2] (ID), Halil Ulutabanca[2] (ID), İbrahim Suat Öktem[2] (ID)

## ABSTRACT

**Objective:** The most common ventriculoperitoneal shunt (VPS) complications in pediatric patients include shunt infections and obstructions. This study evaluated the relationship between shunt infection and obstruction in pediatric patients undergoing VPS placement for hydrocephalus at our clinic.

**Materials and Methods:** Altogether, 210 patients ≤16 years old who were diagnosed with hydrocephalus and who received VPS placement by the same surgeon between January 2012 and June 2017 were followed up for at least one year and were evaluated retrospectively. Patients' clinical and laboratory findings were evaluated, and computed tomography and magnetic resonance imaging were performed. Pearson's chi-squared and Fisher–Freeman–Halton tests were used for statistical data analysis.

**Results:** Among the 210 patients, shunt complications developed in 86; of these 86 patients, shunt infections, shunt obstructions, and other complications developed in 41, 53 (non-infection-related: 31 and infection-related: 22), and 14 patients, respectively. The infection rate in patients in whom VPS placement was performed from the frontal region was lower than those patients in whom it was performed from the occipitoparietal region. The obstruction rate was significantly higher in patients with shunt infection than in those without. Obstruction occurred in one-third of the patients with *Staphylococcus epidermidis* infection among patients with shunt infection.

**Conclusion:** The obstruction rate in patients with shunt infection was three times higher than those without. Considering that shunt infection may accompany obstruction, making the decisions regarding the treatment method for patients with shunt obstruction is appropriate, after determining whether a shunt infection exists.

**Keywords:** Hydrocephalus, infection, ventriculoperitoneal shunt

This manuscript was presented in the congress indicated below and was published in abstract form in the proceedings of the congress.
33. Turkish Neurosurgical Society Scientific Congress, April 11-14, 2019, Antalya, Turkey

[1]Department of Neurosurgery, Kayseri City Training and Research Hospital, Kayseri, Turkey
[2]Department of Neurosurgery, Erciyes University Faculty of Medicine, Kayseri, Turkey
[3]Department of Neurosurgery, Ağrı State Hospital, Ağrı, Turkey
[4]Department of Neurosurgery, Tokat Turhal State Hospital, Tokat, Turkey

Correspondence
Ali Şahin,
Kayseri City Training and Research Hospital, Department of Neurosurgery, Kayseri, Turkey
Phone: +90 352 315 77 00 /21059
e-mail: dralishn@gmail.com

## INTRODUCTION

Ventriculoperitoneal shunt (VPS) placement is the most common procedure for the treatment of hydrocephalus in pediatric patients (1–7). In the United States, approximately 30,000 VPS are placed per year (8). Shunt complications following VPS placement are a serious problem and, in pediatric patients, the most common are shunt infections and obstruction. These complications increase morbidity and mortality and have high economic costs (4, 9).

Shunt obstruction accounts for approximately half of all shunt complications in the pediatric population (5, 6). The risk of a shunt obstruction is highest in the early postoperative period. Debris or a clot in the cerebrospinal fluid (CSF) or at the ventricular catheter site is a common cause of early obstructions. In contrast, causes of late obstruction include choroid plexus adhesion to the ventricular end of the catheter and ependymal or immune reactions (10).

Shunt infections are one of the most common causes of central nervous system infections and one of the most serious complications of VPS placement (11). The rate of VPS infection is reported to be 5%–22% (6, 7, 12–15). Following shunt infection, repeated surgical interventions may be required, severe neurological deficits may occur, and prognosis may be negatively affected (4, 9, 16).

Several studies on shunt obstruction and infection as complications of VPS placement exist (5, 6, 17–21), but none evaluate the relationship between shunt obstruction and shunt infection in the pediatric population or the rate of shunt infection in obstruction cases. This study aimed to evaluate the relationship between shunt infections and obstruction in pediatric patients who underwent VPS placement due to hydrocephalus at our clinic.

## MATERIALS and METHODS

Patients aged 16 years and under who were diagnosed with hydrocephalus and underwent VPS placement performed by the same surgeon at our clinic between January 2012 and June 2017 were followed up for a minimum

of 1 year and were evaluated retrospectively. The following clinical and microbiological data were obtained from the medical records: age, sex, etiology of hydrocephalus, age at shunt insertion, shunt placement site, shunt complications, and infectious agents.

The diagnosis of hydrocephalus was established based on physical and neurological findings and imaging which included transfontanelle ultrasonography (USG) and computed tomography (CT) examinations. If necessary, magnetic resonance imaging (MRI) and CSF flow MRI were also performed.

Only patients who underwent initial VPS placement surgery were included in the study. Patients who underwent revision surgery were excluded. Neuronavigation was not used, and all surgical steps were performed by the neurosurgeon. Only fixed pressure shunts (without antibiotics) were used during the study period.

All patients underwent insertion of a VP shunt following a standard protocol. ''To avoid VP shunt infections, a strict aseptic surgery was performed. Patients received an IV antibiotic (cefazolin) 30 minutes before VPS placement, and the same antibiotic was maintained for 72 hours postoperatively. Cefazolin was used in prophylaxis as it is a good option for infections caused by skin flora (coagulase - or + *Staphylococcus*). Additionally, the shunt system was immersed in a solution of 500 ml 0.9% saline containing 500 mg vancomycin. Silicon pieces cut from the peritoneal catheter were attached to the tips of the metal instruments that were used to hold the catheters to avoid holding them by hand or with metal tools'' (3). The anesthetic time ranged between 45 and 75 minutes.

The diagnosis of shunt infection was established based on medical history, physical examination findings, CSF findings obtained from the ventricles, Gram staining of CSF, and CSF culture. The Department of Pediatric Infectious Diseases was consulted for all patients. The diagnosis of shunt obstruction was established based on medical history, physical examination, and radiological examination (CT and MRI) findings.

This study was approved by Erciyes University Faculty of Medicine, Ethics Committee (23.02.2018–2018/105). Informed consent was obtained from the legal guardians of the children.

### Statistical Analysis
Descriptive statistics were summarized as numbers and percentages for categorical variables in the summary of the data obtained. When the differences between categorical variables were com-

**Table 1.** Distribution of patients by hydrocephalus etiology

| Non-communicating | n=73 | Communicating | n=137 |
|---|---|---|---|
| Congenital | | Congenital | |
|   Aqueductal stenosis | 3 | Midline fusion defect | 65 |
|   Dandy–Walker syndrome | 19 | Other | 15 |
|   Other | 20 | | |
| Acquired | | Acquired | |
|   Aqueductal stenosis | 13 | Infection | 2 |
|   Mass | 14 | Germinal matrix haemorrhage | 52 |
|   Other | 4 | Other | 3 |

pared, Pearson's chi-squared test was used in 2×2 tables, and Fisher–Freeman–Halton Test was used in R×C tables. Statistical analyses were performed using the Jamovi project (2018) and Jamovi, version 0.9.0.3 (open-source computer software, https://www.jamovi.org), and the significance level in statistical analyses was considered as 0.05 (p-value).

## RESULTS

This study included 210 patients aged 16 years and under who were diagnosed with hydrocephalus and underwent VPS placement between January 2012 and June 2017. All patients completed a minimum of one year of follow-up. Of these, 97 (46.2%) and 113 (53.8%) patients were female and male, respectively. Of these patients, 168 (80%) and 42 (20%) were in the 0–1and 1–16 age groups, respectively, and 73 patients (34.7%) had noncommunicating hydrocephalus, while 137 (65.3%) had communicating hydrocephalus (Table 1).

Shunt complications developed in 86 patients (40.9%); of which, 69 (80.2%) and 17 (19.8%) were in the 0–1-year-old and 1–16-year-old age groups, respectively. Of the 210 patients, shunt infection, shunt obstruction, and other shunt complications were observed in 41 (19.5%), 53 (25.2%) (non-infection-related in 31 and infection-related in 22), and 14 (6.6%) patients, respectively (Table 2).

In 41 patients with shunt infection, the most common etiology of hydrocephalus was intraventricular hemorrhage (IVH) of germinal matrix origin (14/41; 34.1%).

**Table 2.** Distribution of the patients by age and shunt complications

| Age | Infection | | Obstruction | | | | Other* | |
| | | | Infection related | | Non-infection related | | | |
| | n | % | n | % | n | % | n | % |
|---|---|---|---|---|---|---|---|---|
| 0–1 | 34 | 16.2 | 18 | 8.5 | 28 | 13.4 | 7 | 3.3 |
| 1–16 | 7 | 3.3 | 4 | 1.9 | 3 | 1.4 | 7 | 3.3 |
| Total | 41 | 19.5 | 22 | 10.4 | 31 | 14.8 | 14 | 6.6 |

*: Shunt migration, subdural hematoma and effusion, pseudocyst

**Table 3.** Relationship between shunt infection and aetiology, shunt site and obstruction

| | Shunt infection | | |
|---|---|---|---|
| | Infection (+) n=41 (%) | Infection (−) n=169 (%) | p |
| **Aetiology** | | | |
| Midline fusion defect | 10 (24.39) | 55 (32.54) | |
| Dandy–Walker syndrome | 8 (19.51) | 11 (6.51) | 0.013** |
| Germinal matrix haemorrhage | 14 (34.15) | 40 (23.67) | |
| Other | 9 (21.95) | 63 (37.28) | |
| **Shunt site** | | | |
| Frontal | 31 (75.61) | 156 (92.31) | 0.005* |
| Occipitoparietal | 10 (24.39) | 13 (7.69) | |
| **Obstruction** | | | |
| Yes | 22 (53.66) | 31 (18.34) | <0.001* |
| No | 19 (46.34) | 138 (81.66) | |

*: Pearson Chi-Square test was used; **: Fisher–Freeman–Halton test was used. Descriptive statistics are expressed as number (%)

In 19 patients with Dandy–Walker syndrome, 8 patients developed shunt infection, while 11 patients did not develop shunt infection (Table 3).

In this series, 19.5% of the patients with shunt infection and 6.5% of those without presented with Dandy–Walker syndrome. The incidence of infection was significantly higher in patients with Dandy–Walker syndrome (p=0.013).

The rate of shunt infection was significantly higher in patients in whom VPS placement was performed from the occipitoparietal region (Frazier's point) than in those in whom it was performed from the frontal region (Kocher's point) (43.5% vs. 16.6%, respectively; p=0.005) (Table 3).

Obstruction occurred in 22 (53.6%) of the 41 patients with shunt infection, and the rate was significantly higher in patients with shunt infection than in those without (53.6% vs. 18.2% respectively; p<0.001) (Table 3).

In patients with shunt infection, the most common infectious agent was *Staphylococcus epidermidis* (41.5%) (17 of the 41 patients). No growth was observed in CSF culture in 14 of the 41 patients (34.1%) (Table 4).

Among the 41 patients with shunt infection, 8 of the 14 patients (57%) had obstruction without growth in CSF culture, and 6 of the 17 patients (35%) had *Staphylococcus epidermidis* infection. The types of microorganisms that grew in the CSF culture of patients with obstruction due to shunt infection are shown in Table 4.

## DISCUSSION

Congenital hydrocephalus ranks first in the etiology of hydrocephalus cases. In the literature, congenital hydrocephalus was the etiology in 286 (35%) of 820 patients in a study by McGirt et al., in 80 (54%) of 148 patients in a study by Habibi et al., and in 24 (50%) of 48 patients in a study by Raffa et al. (4, 12, 14). In contrast, 794 (77.8%) of 1,021 patients in a series by Arslan et al. and 109 (35.6%) of 306 patients in a series by Güzelbağ et al. presented with hydrocephalus caused by midline fusion defect (MFD) (2, 22). The etiologies of hydrocephalus in our series of 210 patients were MFD in 65 (30.9%) patients, congenital in 57 (27.1%) patients, IVH in 54 (25.7%) patients, and other causes (a mass or acquired aqueductal stenosis) in 34 (16.3%) patients. Our findings were consistent with those of Arslan et al. and Güzelbağ et al. (2, 22).

Advances in shunt placement have reduced shunt complication rates. The complication rate at the end of the first year after shunt placement is approximately 40% (19, 23). In our series, 86 (40.9%) of the 210 patients developed shunt complications, which is consistent with previous studies.

While shunt obstructions rank first among shunt complications in childhood, shunt infections take second place (5, 6, 15, 20, 21). In a study by Salat et al. (15), 54 (16%) of the 338 patients developed shunt obstruction, and 38 (11.2%) developed shunt infection. Shahi et al. (20) reported that 57 (60%) of 95 patients with shunt complications developed shunt obstruction in their

**Table 4.** Relationship between obstruction associated with shunt infection and infectious agents

| Agent | Obstruction as-sociated with shunt infection (+) | | Obstruction associated with shunt infection (−) | | Total | |
|---|---|---|---|---|---|---|
| | n | % | n | % | n | % |
| No growth | 8 | 57.1 | 6 | 42.9 | 14 | 34.1 |
| *Staphylococcus epidermidis* | 6 | 35.3 | 11 | 64.7 | 17 | 41.5 |
| *Staphylococcus aureus* | 2 | 100 | 0 | 0 | 2 | 4.9 |
| Coagulase(-)*Staphylococcus* | 2 | 100 | 0 | 0 | 2 | 4.9 |
| *Escherichia coli* | 0 | 0 | 1 | 100 | 1 | 2.4 |
| *Acinetobacter* | 1 | 50 | 1 | 50 | 2 | 4.9 |
| *Pseudomonas* | 2 | 100 | 0 | 0 | 2 | 4.9 |
| Stenotrophomonas maltophilia | 1 | 100 | 0 | 0 | 1 | 2.4 |
| Total | 22 | 53.6 | 19 | 46.4 | 41 | 100 |

study. In the present study, 53 (61.6%) of the 86 patients who developed shunt complications presented with shunt obstruction, and consistent with the literature, this was the most common shunt complication.

Some etiological factors for hydrocephalus are associated with an increased rate of VPS-associated infections. A study by Arslan et al. (2) reported that 180 of 198 patients with a shunt infection presented with myelomeningocele (MM) therefore showing a significant relationship between MM and shunt infection. Oktem et al. (3) confirmed the relationship and observed that it was more common than in patients with other etiologies. In their study of 290 patients with shunt infection, Yakut et al. (7) reported congenital causes as the most common etiology (65.5%). Habibi et al. (12) reported in their study that shunt infections in 42 (61.76%) of the 68 patients were due to congenital causes, that no relationship was found between IVH and shunt infection, and that the rate of shunt infection was low in patients with MM. Conversely, Lee et al. (13) reported that the most common etiology in 82 patients who developed shunt infection was IVH (17.1%). Similarly, McGirt et al. (14) reported IVH as a risk factor for shunt infection in their study. In this study, the most common etiology was IVH in 41 patients with shunt infection (14/41; 34.1%). Additionally, the rate of Dandy–Walker syndrome diagnosis was significantly higher in patients with shunt infection (19.51%) than in those without shunt infection (6.51%). Although no large series exist in the literature, immunodeficiency related to the Dandy–Walker syndrome was postulated to be the cause (24–26).

In VPS procedures, the best site for ventricular catheter placement is in the anterior of the lateral ventricle and the anterior of the foramen of Monro (27). The most commonly used entry points for this purpose are the frontal or occipitoparietal regions (28).

Several studies have indicated a relationship between the VPS site and shunt infection. In a comparative study of the frontal and parietal placement of ventricular catheters by Albright et al. (29), the infection rate was similar between the procedures. Whitehead et al. (30) examined 851 patients in their study (299 patients, anterior and 552 patients, posterior) and reported that 10% of the patients with anterior shunt placement and 9.2% of those with posterior placement developed an infection. A study by Bierbrauer et al. (31) reported that the posteriorly placed shunts functioned without infection a little longer than the anteriorly placed ones and concluded that neither placement showed any advantage in terms of infection. Maruyama et al. (17) reported in their 24-case study that no significant difference in shunt infection and dysfunction was found between the frontal and occipital entry sites. In this study, the rate of infection was higher in patients who underwent VPS placement from the occipitoparietal region than in those who underwent the frontal procedure (43.5% vs. 16.6%). The high rate of infection in shunts applied from the occipitoparietal region can be explained with several factors. First of all, in our series, the number of patients who underwent VPS placement from the frontal region was significantly higher than the patients with occipitoparietal procedure (187 vs. 23 patients, respectively). Therefore, since the number of patients with VPS placement from the occipital region is low, the rate of infection may be high. For this reason, large series in which the number of patients is close to each other is needed, with VPS placement from the frontal and occipital regions. Second reason

may be that some of our patients presented with the Dandy–Walker syndrome, which resulted in the use of a double shunt. In our series, all of the 19 patients with Dandy–Walker syndrome underwent VPS placement from the occipitoparietal region, and all of them had double shunt. Among the 19 patients with Dandy–Walker syndrome who underwent double shunt, 8 patients developed shunt infection, while 11 patients did not. Of the 23 patients who underwent VPS from the occipitoparietal region, 10 developed shunt infection, and 8 of the 10 patients with shunt infection had Dandy–Walker malformation. We think that the use of more occipitoparietal shunts, the use of double shunts, and the presence of immunodeficiency in patients with Dandy–Walker syndrome may increase the infection rates in patients who underwent VPS placement from the occipitoparietal region. Additionally, the length of procedures to implant two catheters and a longer operative course may have increased susceptibility to infection. Erps et al. (32) reported that increased operative time increases the risk of shunt infection.

Studies in the literature regarding the rate of obstruction in patients developing shunt infection are limited. However, Turhan et al. (6) reported that 36 patients had shunt infection in their study of 111 patients with shunt dysfunction. Piatt et al. (18) reported that 55 patients had shunt infection in their study of 248 patients with shunt dysfunction. In this study, 22 (41.5%) of the 53 patients who developed shunt obstruction had an associated infection. The increased risk of shunt obstruction in patients with shunt infection was statistically significant.

The most common pathogen isolated in the culture sensitivity reports was *Staphylococcus epidermidis* followed by *Staphylococcus aureus* which is in line with other reports in the literature (4, 7, 13, 14).

We have found no study regarding infectious agents in patients who develop shunt obstruction due to shunt infection. In this study, concomitant obstruction was observed in 6 (35%) of the 17 patients with *Staphylococcus epidermidis* infection and 8 (57%) of the 14 patients with shunt infection, but no growth in CSF culture was observed.

This study has some limitations. Firstly, it is a retrospective study reporting a single-center experience. Secondly, shunt revision patients were not included in this study, and a single type of shunt (fixed pressure without antibiotics) was used. Multicenter studies with more cases will contribute to defining the relationship between shunt infection and obstruction.

## CONCLUSION

In this study, the incidence of infection in patients who underwent VPS placement from the frontal region was lower than in patients who underwent the occipitoparietal approach. The rate of obstruction in patients with shunt infection was three times higher than in those without shunt infection. Among patients with shunt infection, obstruction was detected in approximately half of the patients with no growth in CSF culture and in one-third of the patients with *Staphylococcus epidermidis* infection, which was the most common cause of shunt infection. In conclusion, we believe that shunt infection increases the rate of shunt obstruction, and deciding on the treatment method by first determining the presence of shunt infection in patients who present with shunt obstruction would be appropriate.

## REFERENCES

1. Kumar R, Younus SM, Haseeb A, Bilal M, Zeeshan QM, Ashraf J. Frequency of infection associated with ventriculo-peritoneal shunt placement. J Pak Med Assoc 2016; 66(7): 815–8. [CrossRef]

2. Arslan M, Aycan A, Gulsen I, Akyol ME, Kuyumcu F. Relationship between hy-drocephalus etiology and ventriculoperitoneal shunt infection in children and review of literature. J Pak Med Assoc 2018; 68(1): 38–41.

3. Oktem IS, Menkü A, Ozdemir A. When should ventriculoperitoneal shunt placement be performed in cases with myelomeningocele and hydrocepha-lus?. Turk Neurosurg 2008; 18(4): 387–91.

4. Raffa G, Marseglia L, Gitto E, Germanò A. Antibiotic-impregnated catheters reduce ventriculoperitoneal shunt infection rate in high-risk newborns and in-fants. Childs Nerv Syst 2015; 31(7): 1129–38.

5. Reddy GK, Bollam P, Caldito G. Long-term outcomes of ventric-uloperitoneal shunt surgery in patients with hydrocephalus. World Neurosurg 2014; 81(2): 404–10. [CrossRef]

6. Turhan T, Ersahin Y, Dinc M, Mutluer S. Cerebro-spinal fluid shunt revisions, importance of the symptoms and shunt structure. Turk Neurosurg 2011; 21(1): 66–73. [CrossRef]

7. Yakut N, Soysal A, Kepenekli Kadayifci E, Dalgic N, Yılmaz Ciftdo-gan D, et al. Ventriculoperitoneal shunt infections and re-infections in children: a multi-centre retrospective study. Br J Neurosurg 2018; 32(2): 196–200. [CrossRef]

8. Simon TD, Riva-Cambrin J, Srivastava R, Bratton SL, Dean JM, Kestle JR; Hy-drocephalus Clinical Research Network. Hospital care for children with hy-drocephalus in the United States: utilization, charges, comorbidities, and deaths. J Neurosurg Pediatr 2008; 1(2): 131–7. [CrossRef]

9. Kanik A, Sirin S, Kose E, Eliacik K, Anil M, Helvaci M. Clinical and economic results of ventriculoperitoneal shunt infections in children. Turk Neurosurg 2015; 25(1): 58–62. [CrossRef]

10. Boch AL, Hermelin E, Sainte-Rose C, Sgouros S. Mechanical dysfunc-tion of ventriculoperitoneal shunts caused by calcification of the silicone rubber catheter. J Neurosurg 1998; 88(6): 975–82. [CrossRef]

11. Choux M, Genitori L, Lang D, Lena G. Shunt implantation: reducing the inci-dence of shunt infection. J Neurosurg 1992; 77(6): 875–80.

12. Habibi Z, Ertiaei A, Nikdad MS, Mirmohseni AS, Afarideh M, Heidari V, et al. Pre-dicting ventriculoperitoneal shunt infection in children with hydrocephalus using artificial neural network. Childs Nerv Syst 2016; 32(11): 2143–51. [CrossRef]

13. Lee JK, Seok JY, Lee JH, Choi EH, Phi JH, Kim SK, et al. Incidence and risk factors of ventriculoperitoneal shunt infections in children: a study of 333 consecutive shunts in 6 years. J Korean Med Sci 2012; 27(12): 1563–8. [CrossRef]

14. McGirt MJ, Zaas A, Fuchs HE, George TM, Kaye K, Sexton DJ. Risk factors for pediat-ric ventriculoperitoneal shunt infection and predic-tors of infectious patho-gens. Clin Infect Dis 2003; 36(7): 858–62.

15. Rashid QT, Salat MS, Enam K, Kazim SF, Godil SS, Enam SA, et al. Time trends and age-related etiologies of pediatric hydrocephalus: results of a groupwise analysis in a clinical cohort. Childs Nerv Syst 2012; 28(2): 221–7. [CrossRef]

16. Chapman PH, Borges LF. Shunt infections: prevention and treat-ment. Clin Neurosurg 1985; 32: 652–64.

17. Maruyama H, Nakata Y, Kanazawa A, Watanabe H, Shigemitsu Y, Iwasaki Y, et al. Ventriculoperitoneal shunt outcomes among infants. Acta Med Okayama 2015; 69(2): 87–93.

18. Piatt JH Jr, Garton HJ. Clinical diagnosis of ventriculoperitoneal shunt failure among children with hydrocephalus. Pediatr Emerg Care 2008; 24(4): 201–10. [CrossRef]

19. Riva-Cambrin J, Kestle JR, Holubkov R, Butler J, Kulkarni AV, Drake J, et al; Hydro-cephalus Clinical Research Network. Risk fac-tors for shunt malfunction in pediatric hydrocephalus: a multicenter prospective cohort study. J Neurosurg Pediatr 2016; 17(4): 382–90.

20. Shahi MV, Noorbakhsh S, Zarrabi V, Nourozi B, Tahernia L. The Neuroimaging Stud-ies in Children with Ventriculoperitoneal Shunt Complications: A 10 Years Descrip-tive Sudy in Tehran. Open Neu-roimag J 2018; 12: 1–9. [CrossRef]

21. Yılmaz A, Haci AG, Müslüman AM, Çolak I, Şahin Y, Aydın Y. Ven-triculoperitoneal shunt dysfunctions. Turk Neurosurg 2006; 16(3): 150–5.

22. Guzelbag E, Ersahin Y, Mutluer S. Cerebrospinal fluid shunt compli-cations. Turk J Pediatr 1997; 39(3): 363–71.

23. Weinzierl MR, Rohde V, Gilsbach JM, Korinth M. Management of hydrocephalus in infants by using shunts with adjustable valves. J Neurosurg Pediatr 2008; 2(1): 14–8. [CrossRef]

24. Dinakar C, Lewin S, Kumar KR, Harshad SR. Partial albinism, im-munodeficiency, hy-pergammaglobulinemia and Dandy-Walker cyst--a Griscelli syndrome vari-ant. Indian Pediatr 2003; 40(10): 1005–8.

25. Lauener R, Seger R, Jörg W, Hallé F, Aeppli R, Schinzel A. Im-munodeficiency asso-ciated with Dandy-Walker-like malformation, congenital heart defect, and cranio-facial abnormalities. Am J Med Genet 1989; 33(2): 280–1. [CrossRef]

26. Litzman J, Bucková H, Ventruba J, Holcíková A, Mikyska P, Lokaj J. A concurrent oc-currence of cutis laxa, Dandy-Walker syndrome and im-munodeficiency in a girl. Acta Paediatr 2003; 92(7): 861–4. [CrossRef]

27. Drake JM, Sainte Rose C. The Shunt Book. Cambridge: Blackwell Science Inc, 1995.p.193–220.

28. Kemp J, Flannery AM, Tamber MS, Duhaime AC; Pediatric Hydro-cephalus Systemat-ic Review and Evidence-Based Guidelines Task Force. Pediatric hydrocephalus: sys-tematic literature review and ev-idence-based guidelines. Part 9: Effect of ventricu-lar catheter entry point and position. J Neurosurg Pediatr 2014; 14 Suppl 1: 72–6.

29. Albright AL, Haines SJ, Taylor FH. Function of parietal and fron-tal shunts in child-hood hydrocephalus. J Neurosurg 1988; 69(6): 883–6. [CrossRef]

30. Whitehead WE, Riva-Cambrin J, Kulkarni AV, Wellons JC 3rd, Roz-zelle CJ, Tamber MS, et al; for the Hydrocephalus Clinical Research Network. Ventricular catheter entry site and not catheter tip location predicts shunt survival: a secondary analy-sis of 3 large pediatric hy-drocephalus studies. J Neurosurg Pediatr 2017; 19(2): 157–67.

31. Bierbrauer KS, Storrs BB, McLone DG, Tomita T, Dauser R. A prospective, random-ized study of shunt function and infections as a function of shunt place-ment. Pediatr Neurosurg 1990; 16(6): 287–91. [CrossRef]

32. Erps A, Roth J, Constantini S, Lerner-Geva L, Grisaru-Soen G. Risk factors and epi-demiology of pediatric ventriculoperitoneal shunt infection. Pediatr Int 2018; 60(12): 1056–61. [CrossRef]