CE 1.5 HOURS Continuing Education

Nursing Care of Infants With a Ventriculoperitoneal Shunt

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ABSTRACT

Background: Infants with congenital or posthemorrhagic hydrocephalus may require a ventriculoperitoneal (VP) shunt to divert the flow of cerebrospinal fluid, thus preventing increase in intracranial pressure. Knowledge on various aspects of caring for a child with a VP shunt will enable new and experienced nurses to better care for these infants and equip parents for ongoing care at home.

Purpose: To review the nurses' role in care of infants with hydrocephalus, care after VP shunt placement, prevention of complications, and parental preparation for home care.

Methods/Search Strategy: A literature review involving electronic databases, such as CINAHL and MEDLINE, Cochrane Database Systematic Reviews, and resources from the Web sites of the National Hydrocephalus Foundation and Hydrocephalus Association, was performed to gather evidence for current practice information.

Findings and Implications for Practice and Research: Vigilant care can help with early identification of potential complications. The younger the infant at VP shunt placement, the higher the occurrence of complications. All neonatal intensive care unit nurses must be equipped with knowledge and skills to care for infants with hydrocephalus and those who undergo VP shunt placement. Monitoring for early signs of increased intracranial pressure can facilitate timely diagnosis and prompt surgical intervention. Equipping families will be helpful in early identification and timely management of shunt failure. Research on infants with VP shunt placement is essential to develop appropriate guidelines and explore experiences of families to identify caregiver burden and improve parental preparation.

Key Words: cerebrospinal fluid, home care, hydrocephalus, infant, parent education, shunt, ventriculoperitoneal shunt, VP shunt

Hydrocephalus (HC), a condition in which an excessive amount of cerebrospinal fluid (CSF) accumulates within the cerebral ventricles and/or subarachnoid spaces, results in ventricular dilation and increased intracranial pressure (ICP).[1,2] An imbalance in production, absorption, and/or obstruction of CSF flow leads to HC. The incidence and causes of HC vary with geographical location globally. For example, in East Africa, the incidence of HC secondary to infection is high.[3] The National Hydrocephalus Foundation (2014) reports that 1 in 500 babies in the United States is born with HC.[3] In addition, about 6000 children younger than 2 years develop HC annually, and some of these are secondary to injury sustained during the perinatal period. Hydrocephalus is one of the most common causes of surgery in infants who receive care in the neonatal intensive care unit (NICU).[4] Therefore, it is important to review different aspects of HC, treatment approaches, and nursing care.

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METHODS

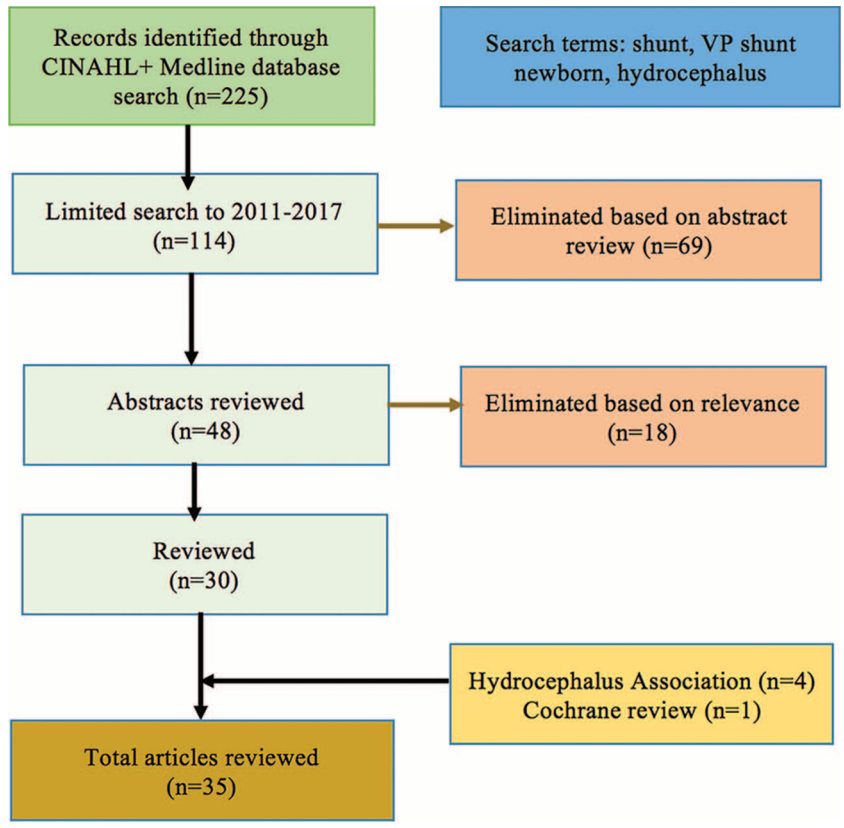
A literature review was conducted in CINAHL, MEDLINE database, and Google Scholar using terms "infant" or "newborn," "hydrocephalus," and "shunt," which yielded 225 articles; when the search was narrowed by the years of publication 2011-2017, 114 articles were available. Abstracts of available articles were reviewed and 69 were eliminated on the basis of applicability, resulting in 45 articles. These articles were further screened to eliminate 18 articles that pertain to surgical techniques. Web sites of National Hydrocephalus Foundation and Hydrocephalus Association, along with Cochrane Database System Reviews, were explored to obtain 5 more publications. Overall 35 research articles were examined along with other resources. Figure 1 shows the process used for the articles selected for the literature.

LITERATURE REVIEW

Background

Produced in the brain, primarily by the choroid plexus and absorbed by subarachnoid villi, CSF is a clear fluid that helps nourish the brain, removes debris from the brain, and protects the brain and spinal cord from injury.[4] A newborn may have an estimated 5 mL of CSF in the ventricular system and it is produced at a rate of or 0.33 mL/kg/h.[1] The

FIGURE 1



Literature review strategy. VP indicates ventriculoperitoneal.

majority of the CSF is produced in the 2 lateral ventricles that circulates through the interventricular foramen (Foramen of Monro) to the third ventricle, and through the aqueduct of Silvius into the fourth ventricle. From the fourth ventricle, CSF leaves the brain to the subarachnoid space and spinal canal through foramen Luschka and forman Magendie (see Figure 2).[1,4] There are different types of HC that can impact the outcome of the newborn: communicative or noncommunicative, congenital, or acquired.[4,5] Some forms of communicative HC may recover spontaneously without treatment within 18 months of age.[4]

Causes

The actual cause of congenital HC is not clear as it has been linked to different conditions. Congenital HC results from conditions such as neural tube defects, X-linked HC, central nervous system (CNS) malformations, intrauterine infection, choroid plexus carcinoma, or in association with a syndrome.[2] About 70% to 90% of infants with neural tube defects (Arnold-Chiari malformation, myelomeningocele, meningocele, or spina bifida) develop HC.[1,4,6] Acquired HC occurs secondary to intraventricular hemorrhage (IVH), particularly in preterm infants, and is the most common cause of HC in the NICU.[2,7,8] When fragile infants develop bleeding into the cerebral ventricles, a resulting clot may block circulation of CSF. This causes the pressure of the ventricles to increase, leading to HC.[9] The bleeding may be of varying degrees—grades 1 to 4, with grades 3 and 4 with the worst outcomes.[9] Infection is a

FIGURE 2

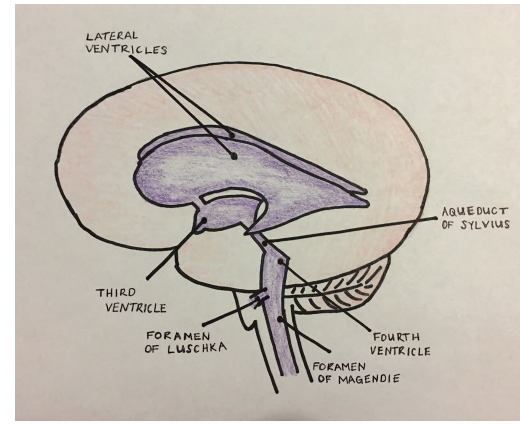


Illustration of cerebral ventricles (drawing courtesy of Michaela Killian).

common cause of HC in infants in developing countries.[8] Table 1 gives a list of conditions that can result in HC, both congenital and acquired. The signs and symptoms manifested by the infants with HC are the results of increased ICP and resulting injury to the brain (Table 2). Early manifestations include (*a*) irritability or restlessness, (*b*) lethargy, (*c*) poor feeding, (*d*) vomiting, and (*e*) enlarged head. Late signs consist of (*a*) enlarged bulging fontanel, (*b*) "sunset eyes," (*c*) distended scalp veins, (*d*) high-pitched cry, (*e*) hypertonicity, and (*f*) seizures.[1,3] Early diagnosis and treatment can prevent damage to the brain and achieve adequate neurodevelopmental outcome.

Diagnosis and Treatment

Antenatal diagnosis is usually made while performing a routine fetal ultrasonography. In the newborn period, HC is diagnosed clinically and confirmed by a lumbar puncture, magnetic resonance image, computed tomographic scan, or ultrasonogram.[1,4,5] A spina bifida repair in utero, though risky for mother and fetus, may reduce the incidence of HC.[10] Hydrocephalus, if left untreated, will progress and can result in permanent brain damage or even death. Several treatment modalities such as repeated lumbar punctures, serial ventricular taps, diuretic therapy, streptokinase, and VP shunt placement are documented in literature.[11] However, current practice is surgical intervention to divert the CSF flow to another body cavity, such as the peritoneal cavity (VP), right atrium (VA), gallbladder, or pleural cavity, thus reducing accumulation of CSF in the cerebral ventricles.[5,12,13] More than 40,000 surgical procedures are performed in the United States annually for surgical correction of HC.[5] Of these surgical procedures, only 30% of patients are undergoing their first surgical procedure, revealing that the 70% are shunt revisions. This annual statistics includes older patients, and the literature is unclear on the number of surgical procedures for VP shunt placement in infants.

TABLE 1. Conditions That May Result in Hydrocephalus

Type	Conditions
Congenital hydrocephalus	• Neural tube defects (eg, spina bifida, myelomeningocele, meningocele, Arnold-Chiari malformation) • Genetic abnormality in brain • Intrauterine infections (eg, Rubella) • Neonatal stroke
Acquired hydrocephalus	• Infections (eg, meningitis, encephalitis) • Trauma • Tumor • Intraventricular hemorrhage

TABLE 2. Signs and Symptoms of Increased Intracranial Pressure From Hydrocephalus

Timing	Signs and Symptoms
Early	Bulging anterior fontanel
	Widened sutures
	Rapid increase in head circumference
	Irritability
	Lethargy
	Vomiting
	Poor feeding
	Hypotonia
Late	Extreme irritability
	Seizures
	Regression of development
	Bulging tense fontanel
	High-pitched cry
	Loss of consciousness
	Frequent vomiting
	Weakness of one side of the body
	Worsening vital signs
	Hypertonicity
	Distended scalp veins
	"Sunset" eyes

An endoscopic third ventriculostomy (ETV) is another method of surgical intervention. In this procedure, a hole is made in the floor of the third ventricle for the CSF to bypass the obstruction in the aqueduct of Sylvius.[14] A Cochrane review did not show any evidence of reduction of neurological disability or the need for shunt in those infants who received ETV; however, an increased risk for infection was revealed, which can potentially lead to poor neurological outcome.[15,16] Repeated CSF drainage is also associated with hyponatremia.[17] Studies on ETV indicated varying levels of success in eliminating dependence on a VP shunt.[3,18,19]

In the past, temporary subgaleal shunts were placed until the infant grew, then the temporary shunt was replaced with a permanent VP shunt.[1] However, this practice was also associated with a high infection rate.[20,21] Some hospitals may have a minimum weight requirement to qualify infants for a VP shunt placement.[22] While placement of a VP shunt has potential complications, it is the most common and effective procedure for HC. Caring for an infant with a VP shunt will be the focus of this article.

VP Shunt: The Treatment of Choice

There are several types of shunt devices designed with a 1-way valve to regulate the flow of CSF based

upon the ICP. The shunt system has 3 main components: an inflow catheter that drains CSF from the ventricles, a valve mechanism to control the flow that is usually located behind the ear once in place, and an outflow catheter that runs under the skin and directs CSF from the valve to the peritoneal cavity.[23] The inflow catheter is placed in the ventricle through a small scalp incision, and connected to the valve, thereafter the outflow catheter is passed down behind the ear, down the side of the neck to the abdomen subcutaneously and that end is placed in the peritoneal cavity via another incision.[10] An illustration of VP shunt in an infant is given in Figure 3. The valve itself is one way and can have either fixed or adjustable pressure.[23] The pressure in the adjustable pressure valve device can be adjusted noninvasively by using magnetic tools.[23] Both these devices can have siphon control to prevent overdrainage of CSF that can occur with position changes. To prevent infection associated with shunt placements, antibiotic-impregnated shunt systems are increasingly being used.[24]

Ferguson et al[25] reported an increased incidence of shunt failure when shunts in infants are placed earlier in life. These failures have led to debates on the ideal time for the VP shunt placement in infants. However, other studies indicate better neurological outcomes with early shunt placement for the management of HC.[10]

FIGURE 3

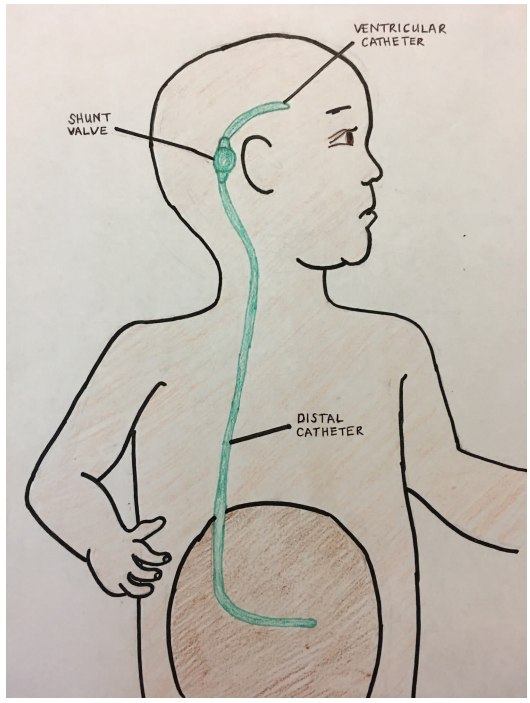


Illustration of ventriculoperitoneal shunt in situ. (drawing courtesy of Michaela Killian).

NURSING CARE

Congenital HC, if not identified in utero, can be discovered by timely observation for signs of increased cranial pressure. Measuring the head circumference and documenting feeding tolerance may appear routine but are key observations that help in early diagnosis. Infants born with neural tube defects such as spina bifida must be stabilized carefully and observed continually for signs of increased ICP. Prone positioning prevents injury to the affected site of spina bifida or myelomeningocele, and the addition of sterile plastic drapes protects the site from fecal contamination.[10]

Caring for the preterm infant by gentle handing, midline head positioning, and minimization of surges in ICP (eg, careful suctioning, analgesic administration to control pain prior to procedures, comfort measures) may reduce incidence of IVH and subsequent HC.[26] Seizures, which can be subtle in nature, are a potential complication of HC that requires vigilant observation. As a family and infant advocate, the nurse coordinates communication and collaboration of care with the multidisciplinary team. The responsibilities include preparing infant for surgery, caring for immediate postoperative infant, monitoring shunt function, preventing complications, and educating family for ongoing care. The ongoing care of an infant with VP shunt is crucial for long-term clinical outcomes; therefore, emphasis is placed on the education of family members.

Communicating to the Family

Once the diagnosis is confirmed and the medical team discusses the plan with the family, nurses must be prepared to educate the families. Parent education is important to ensure the development of the skills necessary for ongoing care of the infant following discharge. Furthermore, education about the condition can alleviate family anxiety and emotionally prepare them for the challenges they may face. Detailed handouts with illustrations and explanations are helpful documents that can guide families to ask appropriate questions. Each hospital or neurosurgical team may have its own educational literature, such as those from Memorial Sloan Kettering Cancer Center (see link in the list of resources).[27] Kidshealth, a resource site used by many hospitals, also has easy-to-learn information on this topic, which includes audio files (see link in the list of resources).[28] For many reasons, the admission of infant to NICU and the environment of the intensive care unit are stressful for parents.[29,30] Parental concerns about long-term neurodevelopmental outcomes, intellectual or physical challenges, complications, and need for shunt revisions should be addressed as they pertain to the uniqueness of the child and the reason for shunt procedure.

Preparing the Family for the Surgery

Premature birth resulting in prolonged hospitalization can induce stress in parents in many ways. Additional problems such as HC and impending surgery may add to that stress. Therefore, parental preparation must be timely and incremental. They must be taught about the pros and cons of surgery and expected outcomes. Opportunities to ask questions must be provided before obtaining the informed consent for surgery. If possible, arrangements to meet with a family of similar experiences, with permission, may be beneficial to decrease anxiety. Parents who experience severe stress must be counseled and supported with frequent updates. Furthermore, repetition of questions may occur for clarification, and it is important to address these concerns with compassionate listening to effectively support the family emotionally.

Preparation of Infant for Surgery

General preparation for a VP shunt is similar to any other surgery. However, the decision to use a particular type of shunt system may be an institutional practice choice or surgeon preference. The surgeon should discuss with the parents the pros and cons, and function of each type of catheter, and why the chosen type is the best fit for their infant. The parents may have questions and the nurses should be knowledgeable about the types of catheters to provide relevant answers. Information regarding types of catheters or shunt systems is available on the Web site of the manufacturer or from the Hydrocephalus Foundation. A handout on reliable resources and support groups (local, regional, and national) can be made available to share with the parents (Table 3: "Parent Resources").

Postoperative Care

Immediate postoperative care includes positioning, pain management, ensuring proper function of the shunt device, monitoring, and care of the surgical site. The infant should be positioned on the unaffected side or on the back with head elevated at 15° to 30° to minimize rapid drainage of CSF.[10] Nurses, as well as parents, must carefully maintain the angle of head elevation while holding the infant during early postoperative days. Once the incision heals, the infant can be placed on the affected side with a "donut" pillow for site protection. Throughout the postoperative period, it is essential to monitor for the symptoms of increased ICP to rule out shunt failure. Nurses must measure the head circumference at a frequency prescribed by the surgeon.[10] In addition, observe for seizures and assess surgical sites for signs of infection. Assess the abdomen for any signs of ileus. The shunt valve should be "pumped" (apply pressure to specific reservoir site on the valve to ensure effective functioning, ie, emptying and filling of the valve device) only if recommended by the surgeon. Although the infant should be handled carefully during the initial postoperative period, the infant can resume normal newborn activity when cleared by the surgeon on an individual basis. Complications can occur even with the best of precautions, and literature states that younger infants are at a higher risk.[25] Vigilant observation of the postoperative infant and teaching parents to notify any unusual symptoms they notice to the care team will help identify problems early.

COMPLICATIONS

Infection

The shunt, being a foreign object in the body, increases the risk for infection. Shunt infection rates vary with the age of the infant at the time of the surgery[20,22] as well as hospital and surgeon factors.[20] Following a strict perioperative protocol for care was found to lower the risk for postoperative infection.[31] Hommelstad et al[31] found that the use of chlorhexidine gluconate (4%) washes reduced infection rates significantly from 18.4% to 5.7% among children younger than 1 year ($P = .016$).[31] Raffa et al[24] used antibiotic impregnated catheters and found lower infection rate in the antibiotic impregnated catheters group (34% vs 9%).[24] Those infants with myelomeningocele tend to have a higher risk for infection in general due to fecal contamination, and VP shunt infection in particular, possibly due to wound dehiscence and shunt disconnections.[32,33] The most common organism identified in VP shunt infection is *Staphylococcus aureus*, which warrants antibiotic therapy.[31,34] Indications of site infection include redness or swelling at the incision site, fever or hypothermia, pallor, lethargy or irritability, poor appetite, and poor feeding.[10]

Apart from incision site infection, peritonitis is a common complication, in part due to the small peritoneal cavity and peritoneal response to the foreign object.[35] Abdominal pain, or tenderness, may be present in addition to signs of erythema and warmth and tenderness over the shunt tubing.[36] Cerebrospinal fluid malabsorption from the peritoneal cavity can lead to frank ascites. Peritoneal pseudocysts and hernias are other possible complications.[35] Cerebrospinal fluid leakage and shunt revisions may increase the risk for infection.[34]

Any sign of infection must be reported to the provider as soon as possible. Broad-spectrum antibiotics should be initiated to cover aerobic and anaerobic bacteria until culture results become available.[36] Every effort must be made to prevent any infection as infections increase morbidity and mortality and impact the neurologic outcome of these infants. Precautions such as limiting the number of people in the operating rooms, performing shunts as the first case

TABLE 3. List of Resources for Additional Information

BRAIN Initiative (Brain Research through Advancing Innovative Neurotechnologies) PO Box 5801 Bethesda, MD 20824 800-352-9424 http://www.ninds.nih.gov	**National Hydrocephalus Foundation (a partner with Hydrocephalus Association)** Office Phone: **(562) 924-6666** E-mail: debbifields@nhfonline.org Web site http://nhfonline.org/
Hydrocephalus Association 4340 East West Highway Suite 905 Bethesda, MD 20814 Hydrocephalus Association 01-202-3811 888-598-3789 Web site: http://www.hydroassoc.org E-Mail: info@hydroassoc.org	**Children's Hydrocephalus Support Group** Lori Poliski/Paul Gross P.O. Box 1611 Woodinville, WA 98071 425-482-0479 (Lori Poliski) Web site: http://www.hydrosupport.org Email: lpoliski@hydrosupport.org
Cure Hydrocephalus https://cure.org/hydrocephalus/?gclid=CIz-ovG2xdQCFRmBswodeYMPgg	**Maddie's Fund for Hydrocephalus & Associated Neurosurgical Research** 6150 Stoneridge Mall Road, Suite 125 Pleasanton, CA 94588 Phone: (925) 310-5450 Web site: http://www.maddiesfund.org/basic-research-grants.htm E-mail: info@maddiesfund.org
Hydrocephalus Support Group MDJunction (A community of patients, family members, and friends dedicated to dealing with hydrocephalus, together. 1.800.273.TALK (8255) http://www.mdjunction.com/hydrocephalus	**Pediatric Hydrocephalus Foundation** 2004 Green Hollow Drive Iselin, NJ 08830 732-634-1283 Web site: http://www.hydrocephaluskids.org E-Mail: info@hydrocephaluskids.org
STARS-Kids (Nonprofit to raise awareness and funds for research to advance shunt technologies). 33006 Seven Mile Rd, Suite 113 Livonia, MI 48152 313-384-3232 https://www.causes.com/starskids http://www.Stars-kids.org	**Spina Bifida & Hydrocephalus Association of Ontario, Canada** Suite 111, 16 Four Seasons Place Toronto, Ontario M9B 6E5 Toll free: 800-387-2575 http://www.sbhao.on.ca
CEREBRA (Working wonders for children with brain conditions) 2nd Floor Offices, The Lyric Buildings, King Street, Carmarthen, SA31 1BD Phone: 0**1267 244200** http://w3.cerebra.org.uk/	**Hydrocephalus Support Association, Australia** http://hydrocephalus.org.au/
Memorial Sloan Kettering Cancer Center VP Shunt Manual: A Resource for Parents https://www.mskcc.org/sites/default/files/node/35212/document/024-vp-shunt-3.pdf	**Kidshealth** http://kidshealth.org/en/parents/hydrocephalus.html#

in operating rooms, meticulous skin preparation, prophylactic antibiotics, avoiding CSF leaks, double gloving during surgery, and antibiotic-impregnated catheters may potentially reduce infections.[36] Infants who require temporary external drainage of CSF will stay in the NICU until their shunt revision. However, this will prolong hospitalization and impact cost associated with VP shunt placement.[37,38]

Shunt Malfunction

Shunt malfunction leads to retention of CSF, resulting in increased ICP. Malfunction may be due to obstruction, disconnection/displacement/migration, or failure of the shunt system. Incidence of shunt failure is high in the first 6 months after shunt placement.[39] Obstruction can result from protein and chemical buildup in the CSF, or tissues within the brain or peritoneal (or other) cavity blocking the tube.[10] Observing for symptoms of increased ICP will help the clinician to alert the neurosurgeon to take prompt action, thus preventing irreversible damage.[39,40] In addition to teaching the signs and symptoms of increased ICP, parents should be educated about the importance of identifying these

symptoms early, so they seek healthcare quickly once symptoms appear. Malfunction can also occur from shunt disconnection, displacement, or migration. Catheter migration to intracranial spaces, pulmonary vasculature, intestines, mouth, or the urethra has been reported subsequent to catheter disconnection or fracture.[41,42] Bowel perforation can occur during surgery (to place the shunt tip in the perioral cavity) or later as a spontaneous episode resulting in shunt migration.[35]

Sharma et al[41] describe malnourishment, anemia, sepsis, and a thin cortical mantle as causes of shunt migration. In addition, excessive neck movements, dilated ventricles with negative suctioning pressure, or a positive intra-abdominal pressure may be responsible for the migration.[41] Other technical factors such as a large burr hole, larger dural opening, reexploration leading to poor local tissue availability for anchorage, and an improper shunt securing can cause shunt migration.[43] In addition, as the child grows, the catheter becomes relatively shorter, potentially displacing the catheter from the peritoneal cavity.[35] The shunt system itself may fail because of valve malfunction, which requires replacement of the valve system. If there is a problem with the pressure gradient, the pressure can be changed noninvasively, if magnetically programmable valves are used. It is important to teach the parents to avoid contact with extremely strong magnetic fields including magnetic resonance imaging, as magnetic fields can change the programming of CSF flow.[41] As children with shunt placement get older, they should avoid contact sports to prevent potential damage to the shunt system.[44]

Excessive CSF Drainage

Excessive drainage of CSF is seen in children shunted early in life, which may be evident by a sunken fontanel, increased urine output, and increased sodium loss.[10,35] Therefore, monitoring intake and output is an important aspect of postoperative care. Complications associated with overdrainage is certainly a problem, and antisiphon devices may help prevent this.[45] When excess CSF is drained, the ventricles will shrink to become extremely small, a condition called slit ventricle.[39] Acute intermittent headache, relieved by lying down, is an indicator of a slit ventricle in older children.[46] Changing the pressure (increase) of the system can help reduce CSF drainage.[35]

In addition to the major complications described, bleeding can also occur as a complication of VP shunt placement.[22] Delayed intracranial hemorrhage can be a result of erosion of vasculature by catheter cannulation or sudden CSF pressure reduction after VP shunt.[47] Nurses should monitor the patient for signs of bleeding such as pallor, need for higher respiratory support, or decline in blood pressure, and refer to the care team quickly. Routine care of the infant, care of the shunt sites, and specific shunt-related information should be part of the discharge teaching. Parents should be given a copy of the medical report, a list of resources, follow-up plan, and information on whom to contact in case of emergency.

HOME CARE

Continued care is required for the proper healing of a newly placed VP shunt. Caregivers should know that all visible staples or stitches will be removed within 1 to 2 weeks, and that the head should not be showered or shampooed until those staples or stitches are removed. The surgical wound should not be submerged or soaked before it is completely healed. Once the swelling from surgery goes down, a raised area will remain visible. Parents should be taught to protect these areas and that when the hair grows over, it is usually unnoticeable.[9,48] Apart from the initial recovery required after the placement of the VP shunt, the infant will not have positioning or activity restrictions unless specified by the healthcare provider. Tylenol may be administered for pain.[9] Caregivers should keep the contact information and telephone numbers of healthcare providers in easy reach for quick access. They should know the signs and symptoms that indicate shunt failure or infection and must call their assigned clinic if any issues are suspected.[48]

Signs and symptoms of shunt failure or infection include signs of increased ICP as well that of local and generalized infection[9,27,48] In addition, informal caregivers should be trained how to care for a child during a seizure, as some children have seizures before and/or after shunt placement.[48] Parents should also be aware of the type of model and valve of the shunt for several reasons. Strong magnetic fields should be avoided to prevent malfunction of externally programmable valves. Knowledge of the type of shunt system is essential, particularly during emergencies, when manipulation of the pressure valve is crucial. Although the likelihood of a cell phone interfering with the settings of the valve is minimal, caregivers should be aware to keep cell phones and other magnetic devices away from the implanted shunt and notify the care team in case of magnetic resonance imaging.[49] Resources for additional information can be shared with parents. Multimodal training using audiovisual aids may help achieve better understanding in parents who are overwhelmed with the care of the infant. A summary of teaching points for parental education is given in Table 4.

IMPLICATIONS FOR NURSING PRACTICE, EDUCATION, AND RESEARCH

Practicing nurses must receive continuing education on newer devices and related changes in practice.

TABLE 4. Parental Discharge Education for an Infant With a Ventriculoperitoneal Shunt

- Watch your infant for changes that indicate change in intracranial pressure that can result from complications such as infection or shunt malfunction. These include
  - change in behavior;
  - nausea;
  - vomiting;
  - sleepiness;
  - poor feeding;
  - fever;
  - weakness of an extremity;
  - seizures;
  - unusual eye movement;
  - bulging fontanel (or sunken fontanel for overdrainage of CSF); and
  - increase in head size.
- Remember to report anything unusual to the pediatrician/provider.
- Inspect the operative areas for any redness, swelling, warmth, or drainage; this may indicate infection.
- Do not apply powder, soap, any lotion on the incision site until well healed.
- Observe for any abdominal distention or changes in bowel habits.
- Protect the incision site carefully to avoid "banging" somewhere.
- Avoid tight hats.
- Follow your doctor's instruction for care of stiches/staples.
- Follow your doctor's recommendation for activities.
- Always keep the contact information of your doctor handy.
- Know the type of shunt device placed in your child.
- If it is an externally programmable shunt device, make sure that you do not use other devices with magnetic field in close proximity to the child.
- Always use reliable resources to learn more about the care or condition of your child.
- Always keep the follow-up appointments with your doctor.
- When to call the doctor:
  - When you have any concerns
  - When you notice any symptoms mentioned earlier
  - When you see any leakage of CSF (fluid from the site)

Abbreviation: CSF, cerebrospinal fluid.

For example, nurses should be aware of newer procedures such as ETV, devices such as magnets to change pressure, or programs or applications to change pressure noninvasively. Nurses should be equipped to teach parents on care of infants with special attention to devices. In addition, nurses should teach novice nurses precautions to prevent surges in ICP, the risk factors for IVH and potential HC, in preterm infants. As more preterm infants survive with complications such as IVH and consequent HC, that may require surgical interventions and long-term care, nursing educators should prepare students to care for these infants by including these topics in the curriculum. Nursing-specific parental education materials can be created by collaborative efforts between educators and bedside clinicians. Nurses must take leadership roles in developing interdisciplinary resources for families caring for infants with HC and VP shunt placement. Research should explore existing guidelines and develop new evidence-based guidelines on care of children with shunts and emerging methods of conservative management. Current literature lacks evidence on nursing care of infants with HC and VP shunt placement. Nurse researchers could study consistency of current nursing practice on care of infants with HC and develop evidence-based guidelines to address this gap. Emerging technology to change pressure noninvasively or remotely should be researched. In addition, exploring cost of long-term care can contribute to the health economics of this nation.

Follow-up by a multidisciplinary team that includes nurses, rehabilitation specialists, neurologists, developmental specialists, pediatrician, and educational experts is critical for a positive outcome. The extent of the team will vary with comorbidities and development of the child. Success of shunts and incidence of complications vary from person to person; some recover completely and have a good quality of life. Early diagnosis, timely treatment, regular follow-up, and continued care may offer an optimum outcome.

CONCLUSION

Hydrocephalus, if identified and treated early, can result in positive neurodevelopmental outcomes in infants. A VP shunt is a common procedure performed in infants with HC, and proper monitoring and timely action by an interdisciplinary team are essential for the best results. However, complications occur even with careful management. Teaching parents for continued home care, monitoring, and

Summary of Recommendations for Practice and Research	
What we know:	• Premature infants are at a higher risk for developing posthemorrhagic hydrocephalus. • Neural tube defects such as spina bifida can result in congenital hydrocephalus. • Ventriculoperitoneal shunt is the most common procedure for CSF diversion.
What needs to be studied:	• Devices with magnetic fields and their impact on altering settings of shunt valves. • Devices with remote control ability to change valve pressure for home use. • Ideal age for surgery, long-term outcome, and cost analysis. • Develop educational materials for family. • Research on nursing care of infants with hydrocephalus with and without VP shunt placement.
What we can do today:	• Educate nurses on emerging treatment methods and devices. • Monitor head circumference and observe for signs and symptoms of increased intracranial pressure. • Evidence-based practice to reduce the risk of complications and poor outcomes.

follow-up care improves long-term results in infants. The NICU nurses are in a pivotal position to guide families adapt to the new skills necessary to care for their infant with special needs. Although comorbidities may impact prognosis, careful monitoring and early recognition of symptoms by a nurse or an empowered parent are essential for positive outcomes. If managed well, children with HC can have a productive life. Furthermore, prevention of complications and timely management can save costs associated with readmissions and shunt revisions and eliminate a high amount of distress in parents.

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