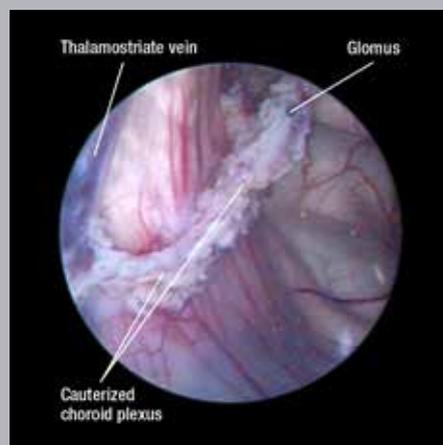
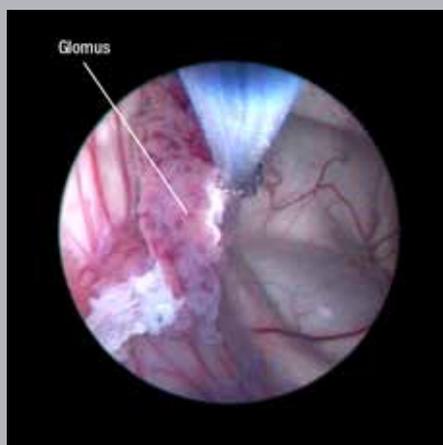
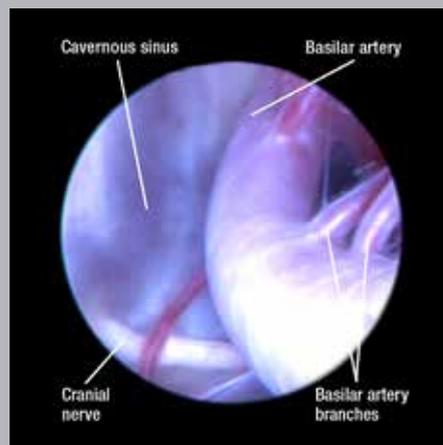


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# COMBINED ENDOSCOPIC THIRD VENTRICULOSTOMY AND CHOROID PLEXUS CAUTERIZATION (ETV/CPC)

For Infant Hydrocephalus with Special Emphasis on the Developing World



2<sup>nd</sup> Edition

Benjamin C. WARF



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**Combined Endoscopic Third Ventriculostomy  
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## 1

## Introduction

## 1.1 The Causes and Burden of Hydrocephalus in Developing Countries

Hydrocephalus in infants and children is an enormous burden in developing countries. In sub-Saharan Africa, we have estimated that each year 225,000–375,000 infants develop hydrocephalus in their first year of life.<sup>32</sup> This is because hydrocephalus is largely a disease of poverty in such countries. We have previously reported that bacterial infection (ventriculitis) accounts for 60% of the cases of hydrocephalus in Uganda, and that most of these infections occur during the neonatal period in

regular cycles between the rainy and dry seasons.<sup>6, 9, 12, 15.</sup> The risk factors for this problem are unknown, but may include obstetrical complications (such as prolonged labor and premature rupture of membranes) and unclean perinatal practices. More than 60% of births in Uganda occur in the absence of any skilled attendant.<sup>15</sup> Thus, more than half of the burden of hydrocephalus in the population is potentially preventable and based in the economic and political realities of the region.

## 1.2 The Problem with Ventricular Shunts in a Developing Country

Unlike the situation in developed countries, poverty and politics present barriers to the treatment of hydrocephalus in children. One problem is the lack of neurosurgical manpower. Another is the difficulty with transportation to a facility where care may be accessed. Most people do not own a vehicle, the funds for public transportation are often scarce, the roads in many areas are treacherous, and in some regions insecurity makes travel dangerous.

In a few hospitals, hydrocephalus is treated by general or pediatric surgeons with ventriculo-peritoneal shunt insertion; but, shunts are often too expensive for the family to purchase or are unavailable altogether. The latter problem would be alleviated if practitioners realized that expensive North American and European shunt products should not be the gold standard in this context,

and that a very inexpensive shunt can give the same results, as we have previously demonstrated.<sup>8, 16, 17</sup>

But even when inexpensive shunts are available, shunt dependence itself is more dangerous under such circumstances. First, for the reasons already stated, it is difficult for a child to acquire urgent treatment in the case of a shunt malfunction or infection. Given that scenario, it is sobering to consider that half of children in North America can expect a shunt failure within 2 years of its insertion.<sup>3</sup> Other common conditions such as severe macrocephaly from delayed treatment, malnutrition, and scalp sepsis incline toward skin erosion, shunt exposure, and infection (**Figs. 1, 2**). Thus, shunt dependence is even more life-threatening to children in this environment and should be avoided if possible.



1 Malnourished infant with macrocephaly, thin scalp, and prominent scalp veins.



2 Scalp sepsis and skin erosion with exposed shunt tubing.

### 1.3 The Problem with Ventricular Shunts in the Developed World

Shunt dependence exacts an enormous toll on the health care system in general and on patients and their families in particular. There is evidence that the North American shunt burden could be reduced by at least one-half if the endoscopic techniques presented here were broadly adopted as the primary treatment of infant hydrocephalus.<sup>13</sup> The resulting health care cost savings

for the US could ultimately be on the order of \$1 billion annually.<sup>13</sup> In addition, those who are successfully treated in this way forgo the concern for shunt malfunction with every headache or viral illness, the trips to the emergency room to “rule out shunt malfunction”, and – for many – the repeated shunt operations accumulated over a life time with the attendant risks and cost.

### 1.4 The Advantages of Neuroendoscopic Management of Hydrocephalus

In light of the foregoing, it is obvious that treating hydrocephalus definitively while avoiding shunt dependence would be safer, provided the operative mortality and morbidity were not significantly greater. The cost of purchasing the initial shunt (and subsequent shunt components in the event of infection or failure) can be avoided, as well as the life-long potential for mortality and morbidity from shunt failure and infection. We have demonstrated that endoscopic third ventriculostomy when combined with coagulation of the choroid plexus in the case of infants (ETV/CPC), has the potential for avoiding shunt dependence in the majority of children, with lower surgical mortality and morbidity.<sup>13, 18-23, 27-28, 31, 34,</sup>

<sup>36-38</sup> The main obstacles internationally to the implementation of this management strategy are:

- a lack of appreciation that shunt-dependence can be avoided in most children when ETV/CPC is implemented as the primary treatment; and
- a lack of training in the flexible ventriculoscopic techniques that are required.

The purpose of this monograph is to address these obstacles. Although there is no substitute for hands-on training, it is hoped that the information provided will present a challenge to the reigning standard of care for the treatment of hydrocephalus, especially in infants, and increase interest in the international neurosurgical community for acquiring these skills to the benefit of their patients. The observations reported here are based upon more than 5,000 ventriculoscopic procedures performed at the *CURE Children’s Hospital of Uganda* between June 2001 and July 2014 and our steadily growing experience in treating infant hydrocephalus by ETV/CPC in North America over the past 8 years.<sup>13, 30</sup>

Since 2001, KARL STORZ Company and the International Federation for Spina Bifida and Hydrocephalus<sup>5</sup> have been important partners with CURE International<sup>2</sup> in our work to bring optimal, evidence-based treatment for hydrocephalus to children everywhere.

From the outset it must be stated that a prospective randomized trial to compare the long-term benefit of neuroendoscopic versus shunt management of hydrocephalus in children has not yet been completed. It is an assumption (although, in my opinion, a reasonable one) that it is in the best interest of children to avoid life-long shunt dependence. It could be argued that the long-term risk of ETV/CPC failure is not yet clear. But late failure of a previously successful ETV appears to be rare<sup>4</sup> and in experience with follow-up periods of more than 10 years, the great majority of failures occur within months of the operation.<sup>19, 25-28, 31, 36, 38</sup> This contrasts with the persistent and repeated risk of shunt failure and infection over a lifetime. Furthermore there is currently equipoise in regard to the cognitive outcome in children treated with either shunt placement or ETV/CPC.<sup>24</sup>

Although the ETV/CPC procedure was developed at CURE Children’s Hospital of Uganda, we now have extensive experience with its use in the United States since 2006, and have had the opportunity to help introduce it to several major pediatric neurosurgery centers in North America.

The International Program to Advance the Treatment of Hydrocephalus (iPATH) initiated over a decade ago has now evolved into CURE Hydrocephalus, a specialty program within CURE International<sup>2</sup> that trains, equips, and provides ongoing support to low and middle income country neurosurgeons in comprehensive, evidence-based, and contextually-appropriate treatment of pediatric hydrocephalus.

It is my conviction that hydrocephalus could ultimately be successfully managed without shunt-dependence in the majority of the world’s children, and this monograph is intended as a stimulus toward that end, as well as an aid in the training of surgeons to perform these techniques.

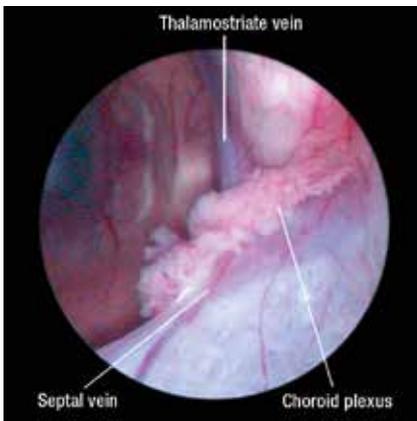
## 2

## Anatomic Considerations

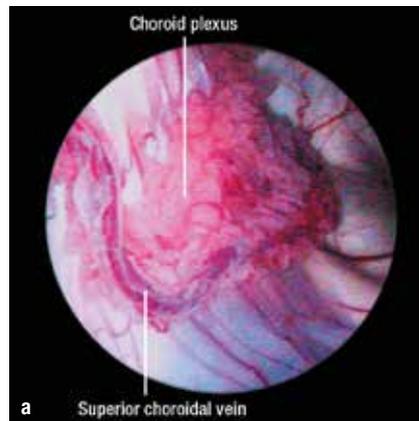
## 2.1 Relevant Normal Ventriculoscopic Anatomy

My technique is to position the infant as for a right frontal shunt, such that the child is supine with the head turned to the left. Thus, proper orientation after inserting the endoscope into the right frontal horn will have the anterior direction located towards 9 o'clock on the video image, posterior towards 3 o'clock, right towards 12 o'clock, and left towards 6 o'clock. With this orientation in mind and the endoscope pointing toward the foramen of Monro (interventricular foramen), the septum is at 6 o'clock and the prominent thalamostriate vein is easily noted as it courses towards its junction with the septal vein at the posterior margin of the foramen of Monro (Fig. 3). The choroid plexus of the lateral ventricle courses posteriorly from the foramen of Monro along the curve of the thalamus into the temporal horn (Figs. 4a, b).

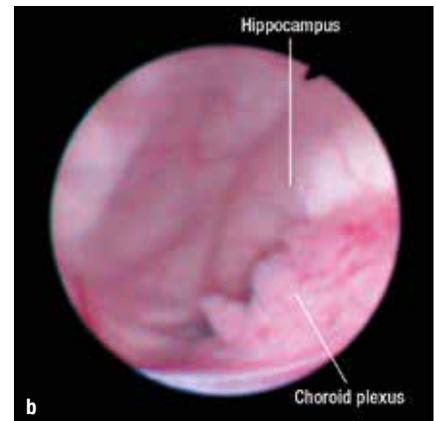
Advancing the scope through the foramen of Monro into the third ventricle, the following key landmarks are identified beginning from the anterior extreme and progressing posteriorly: the translucent lamina terminalis and optic chiasm (Fig. 5); the infundibular recess (or, as in this example – with flattening of the 3<sup>rd</sup> ventricular floor from hydrocephalus – the infundibulum, pituitary gland, and dorsum sellae can be clearly seen) (Figs. 6, 7); third ventricular floor overlying the interpeduncular cistern, mammillary bodies, and basilar apex often just visible through the translucent floor (Fig. 8); and the midbrain leading onto the ostium of the Sylvian aqueduct which is capped dorsally by the posterior (epithalamic) commissure, suprapineal recess, habenular commissure, and choroidal network, respectively (Figs. 9, 10). The third ventricle is bisected by the interthalamic adhesion (massa intermedia) (Fig. 9).



3 Foramen of Monro (HOPKINS® rod lens telescope).



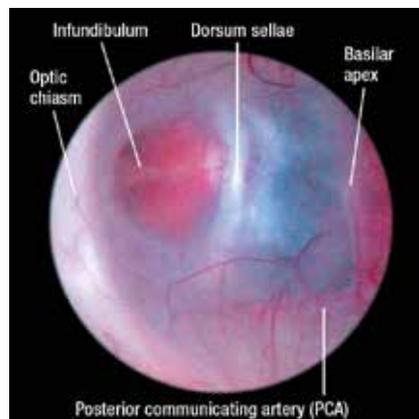
4 Choroid plexus in atrium (trigone) of the right lateral ventricle (HOPKINS® rod lens telescope).



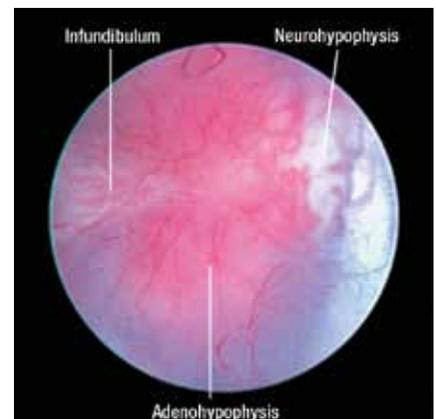
Anterior temporal horn of right lateral ventricle (fiberoptic endoscope).



5 Anterior 3<sup>rd</sup> ventricle (HOPKINS® rod lens telescope).



6 Third ventricular floor viewed through right foramen of Monro (HOPKINS® rod lens telescope).



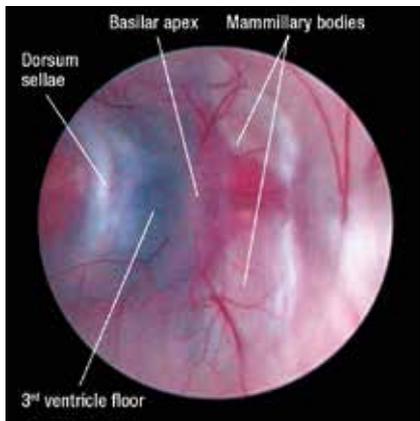
7 Closer view of infundibulum, adenohypophysis, and neurohypophysis (HOPKINS® rod lens telescope).

Note, that the images for **Figs. 4b** and **10** were obtained with the flexible fiberoptic endoscope, whereas **Figs. 3, 4a** and **5–9** were obtained using a rigid HOPKINS® rod lens telescope (see section 4.1.) The images from the fiberoptic endoscope are not as crisp as those taken with a HOPKINS® rod lens telescope; but, only the flexible fiberoptic endoscope can be safely maneuvered for visualization of the 3<sup>rd</sup> ventricular roof and the anterior temporal horn and for achieving adequate access to the entire choroid plexus in both lateral ventricles through a single frontal approach (see section 4.3). I have not found the quality of the fiberoptic endoscope images to impede the performance of any procedure.

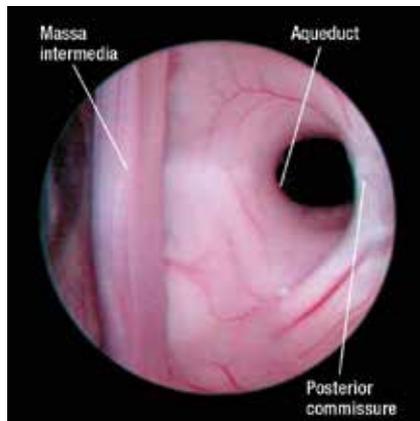
Familiarity with the anatomy of the interpeduncular and prepontine cisterns is also essential to performing the ETV properly. Upon penetrating the floor, the Liliequist membrane (LM) is often encountered as a separate barrier to entering the cisterns. This membrane is a complex of arachnoid sheets, and it is crucial to realize the presence of a horizontal component (the diencephalic leaf) and a vertical component (the mesencephalic leaf), as well as a pair of laterally positioned diencephalic-mesencephalic leaves.<sup>10</sup>

A medial ponto-mesencephalic membrane may also be noted inferiorly (**Fig. 11**). The insertion of the vertical component (mesencephalic leaf) of LM varies along the anterior-posterior axis, and penetration of the floor for the ETV occasionally leads into the space between the dura of the clivus and the mesencephalic leaf.<sup>1</sup> The latter presents as a translucent or opaque membrane covering the basilar artery in the prepontine cistern, and its fenestration is necessary for entry into the cistern. Anteriorly, the clivus and dorsum sellae, the pituitary, and often the pituitary stalk are visualized (**Fig. 12**).

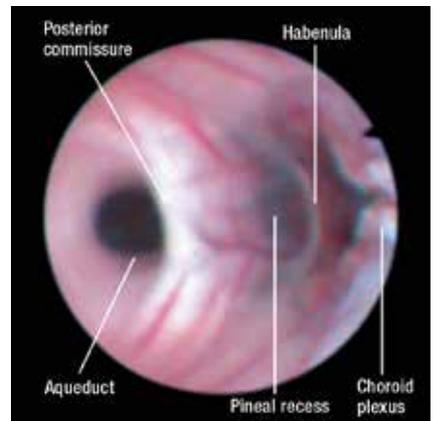
I have found that entry into the subdural space can often be avoided if one notes the subtle white line crossing the floor of the third ventricle from right to left just posterior to the dorsum sellae that marks the anterior-posterior position of the vertical component (mesencephalic leaf) of the LM as it makes its posterior deflection toward the mammillary bodies (**Fig. 11**, mesencephalic leaf of LM). Fenestrating the floor just posterior to this landmark, when it is visible, helps insure entry into the subarachnoid space of the prepontine cistern.



**8** Floor of 3<sup>rd</sup> ventricle with basilar apex and mammillary bodies (HOPKINS® rod lens telescope).

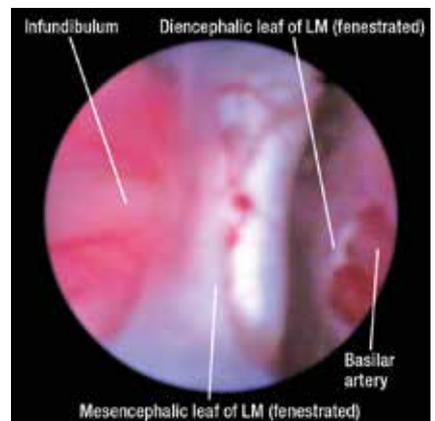


**9** Aqueduct of Sylvius and massa intermedia (HOPKINS® rod lens telescope).



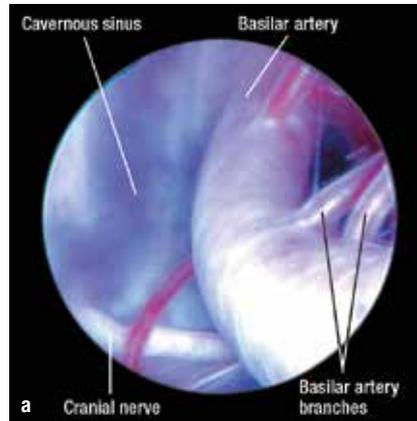
**10** Posterior 3<sup>rd</sup> ventricle (fiberoptic endoscope).

**11** View through the ETV stoma demonstrating components of the Liliequist membrane (The horizontal diencephalic leaf has already been penetrated and an intact medial ponto-mesencephalic membrane has been fenestrated to allow free communication with the pre-pontine cistern. A cranial nerve is seen traversing the mesencephalic leaf of LM as it courses towards the cavernous sinus.) (fiberoptic endoscope).

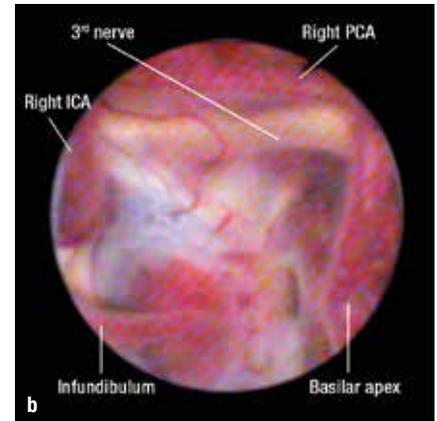


**12** View from below 3<sup>rd</sup> floor and above diencephalic leaf of LM, which has been fenestrated along with the mesencephalic leaf (fiberoptic endoscope).

The basilar artery with its branches, and cranial nerves coursing toward the cavernous sinus are visible in the prepontine cistern (**Fig. 13a**). The third cranial nerves lie close to the posterior communicating arteries, running superficially just beneath and along the lateral boundaries of either side of the 3<sup>rd</sup> ventricular floor (**Fig. 13b**).



**13** Prepontine cistern (HOPKINS® rod lens telescope);



View of parasellar region (fiberoptic endoscope).

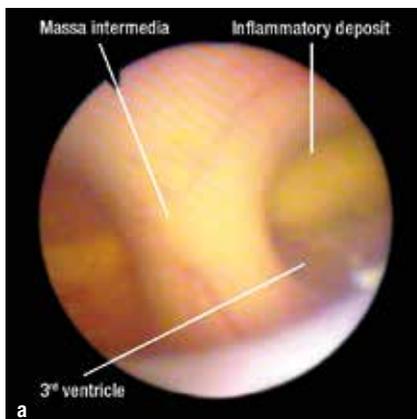
## 2.2 Anatomic Considerations in Post-Infectious Hydrocephalus (PIH)

The sequelae of ventriculitis, in addition to the resulting hydrocephalus, can cause severe anatomic distortion that on occasion obscures the anatomy severely enough to render the ETV procedure technically impossible. However, in most cases the anatomy is sufficiently preserved to perform the procedure. Depending upon the timing of the child's presentation, the CSF may still be too opaque for adequate visualization through the endoscope. In such cases, I place a ventricular catheter and subcutaneous reservoir (ventricular access device) for serial drainage of CSF (usually over several days) until the fluid is sufficiently clear to proceed with ventriculoscopy. Common ventriculoscopic findings in postventriculitis hydrocephalus include: yellow inflamma-

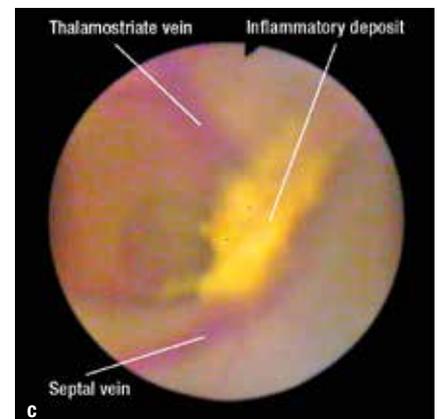
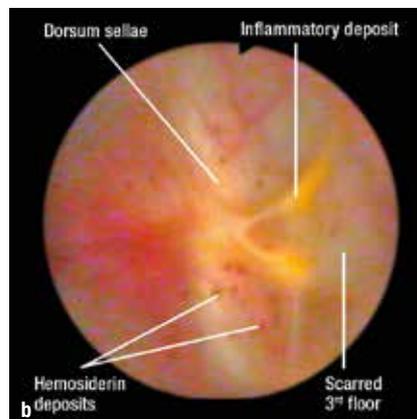
tory exudates (old pus), punctuate hemosiderin staining of the ependymal surfaces, and thickening of the 3<sup>rd</sup> ventricular floor (**Figs. 14a–c**).

Obstruction of the aqueduct by scar, pus, or hemosiderin was found in 2/3 of our PIH population<sup>15</sup> (**Figs. 15a, b**). Intraventricular septations may cause multicompartiment hydrocephalus that requires fenestration of the septations to allow free communication, even if the ETV is technically not feasible and a ventriculo-peritoneal shunt (VPS) is required (**Figs. 16a, b**).

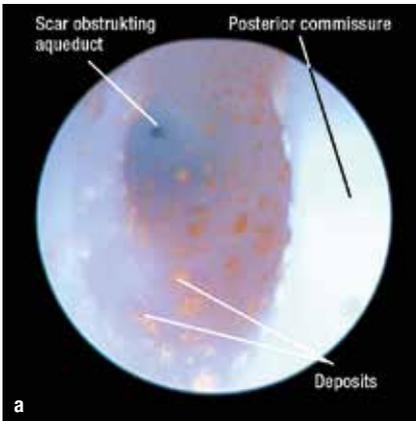
After the ETV is performed the cistern may be found to be scarred. The management of this situation will be discussed below.



**14** Inflammatory deposits on 3<sup>rd</sup> ventricular floor.



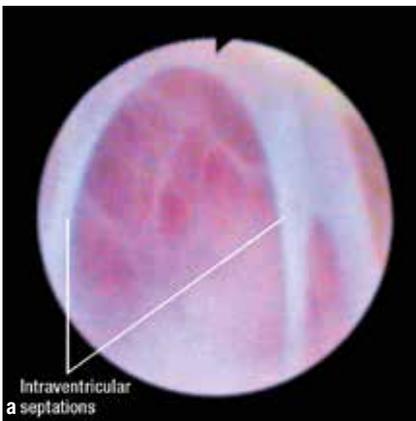
Inflammatory deposit coating the choroid plexus adjacent to right foramen of Monro (fiberoptic endoscope).



**15** Aqueduct of Sylvius obstructed by inflammatory scar (HOPKINS® rod lens telescope).



**17** Old thrombus obstructing the aqueduct in PHH (posterior commissure seen from 2 o'clock to 8 o'clock).



**16** Septations in lateral ventricle;



Endoscopically-placed ventricular catheter after communication among loculated compartments was established (fiberoptic endoscope).



**18** Sagittal T2 FIESTA MRI demonstrating obstruction by scar of the prepontine cistern, aqueduct, and fourth ventricle outlets.<sup>30</sup>

### 2.3 Anatomic Considerations in Post-hemorrhagic Hydrocephalus (PHH)

PHH, usually related to prematurity (PHHP) is rarely encountered in the setting of low-middle income countries (LMIC) because of the lack of intensive neonatal care required for the survival of severely premature infants. By contrast, this is one of the most common causes of infant hydrocephalus encountered in North American pediatric neurosurgical practice.<sup>13</sup> Conversely, PIH is one of the most common etiologies of hydrocephalus in LMIC, but is not a major cause in North America.

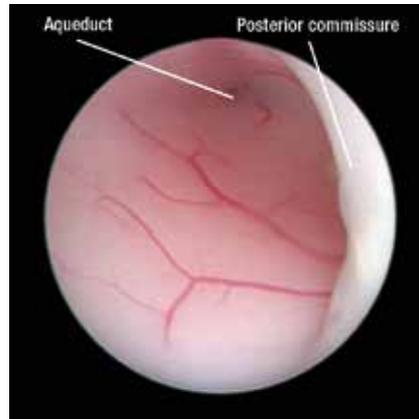
We have observed, though, that PHHP (a disease of prosperity) and PIH (a disease of poverty) are similar in their pathophysiology. Both can result in ependymal scar with intraventricular loculations and obstruction of the ventricular outlet foramina (e.g. the aqueduct of Sylvius, **(Fig. 17)**), destruction of periventricular brain parenchyma, and arachnoid scarring in the posterior fossa or basal cisterns **(Fig. 18)**.

## 2.4 Anatomic Considerations in Non-Post-Infectious Hydrocephalus (NPIH)

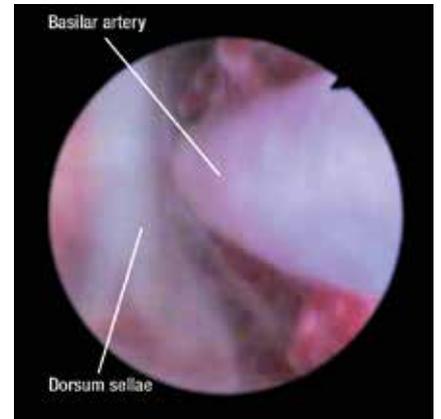
Although NPIH includes hydrocephalus secondary to an obstructing mass, such as a brain tumor, this etiologic category primarily refers to the various forms of congenital hydrocephalus, with the exclusion of that associated with Chiari II malformation/myelomeningocele (MM), which I consider separately. The varieties of abnormal anatomy that can be encountered are numerous, but a few are worth mentioning here. Congenital absence of the foramina of Monro is rare, but does occur. In this case, I have succeeded in entering the 3<sup>rd</sup> ventricle either through a thin membrane where it appears the foramen failed to form or directly through the columns of the fornix anterior to the venous angle. I have also encountered congenital fusion of the thalami with no access into a 3<sup>rd</sup> ventricle. Congenital aqueductal

stenosis is common (**Fig. 19**) and, in the case of long-standing hydrocephalus, the floor of the 3<sup>rd</sup> ventricle may be severely depressed and even molded over the contours of the dorsum sellae and basilar artery. In cases where the aqueduct is open and the 4<sup>th</sup> ventricle is dilated on the preoperative imaging study, the brainstem and basilar artery are predictably displaced anteriorly, sometimes with the basilar artery touching the dura of the clivus. This also is typical of patients with the Dandy-Walker and Chiari II malformations (**Fig. 20**).

When this situation is anticipated great care must be taken when penetrating the 3<sup>rd</sup> ventricular floor, which can be done right at the dorsum sellae and just lateral to the basilar bifurcation in such cases.



**19** Congenital aqueductal occlusion (HOPKINS® rod lens telescope).



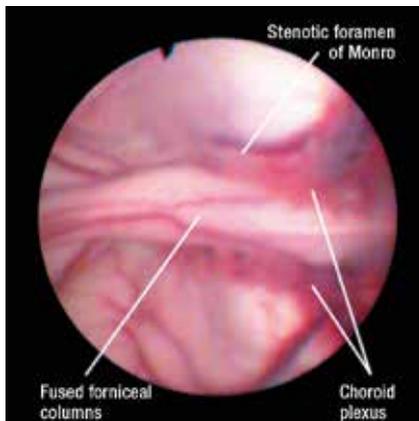
**20** Interpeduncular cistern of infant with Chiari II/myelomeningocele (MM) demonstrating basilar artery abutting the dura of the clivus (fiberoptic endoscope).

## 2.5 Anatomic Considerations in Hydrocephalus Associated with Myelomeningocele (MM)

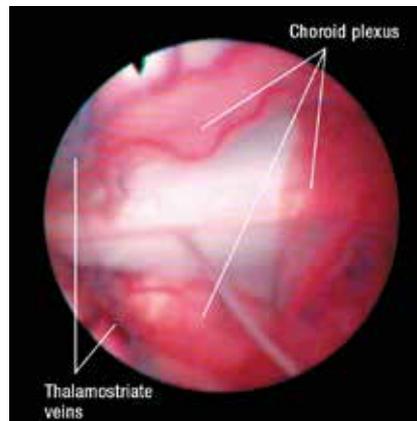
Performing the ETV/CPC in infants with hydrocephalus in association with myelomeningocele can be a particular challenge, but the results are rewarding. The intraventricular anatomy varies, but certain anomalies are especially common:

These are illustrated in **Figs. 21–25**. The intracisternal anatomy is often notable for:

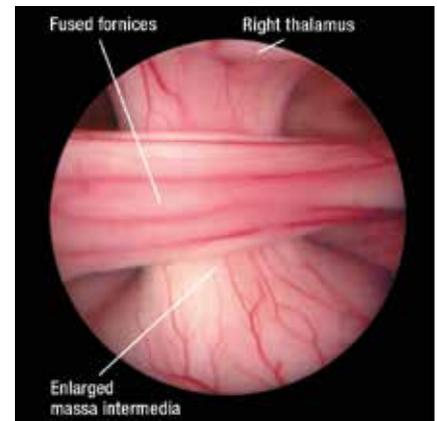
- absent septum pellucidum;
  - fused, thickened forniceal columns;
  - robust choroid plexus with the glomus usually loosely tethered by a pedicle of thin vascular membrane;
  - enlarged massa intermedia;
  - interhypothalamic adhesions that complicate the terrain of the 3<sup>rd</sup> ventricular floor, which is often thick and non-translucent;
  - aqueductal stenosis.
- anteriorly displaced basilar artery and brainstem, often abutting the clival dura;
  - downward displacement of the basilar apex which forms a “Y” shape;
  - thick membrane of Liliequist that often requires separate fenestration after the floor is penetrated; and,
  - cerebellar tissue visible in the lateral cisternal recesses near the occipital condyles (**Figs. 26–28**).



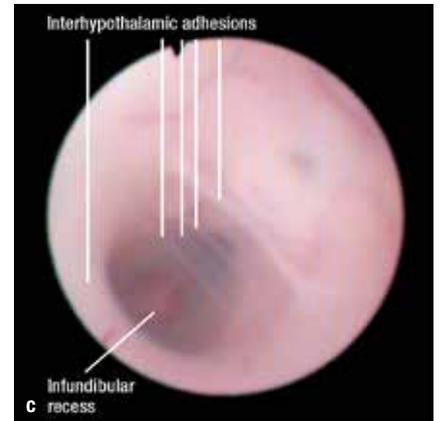
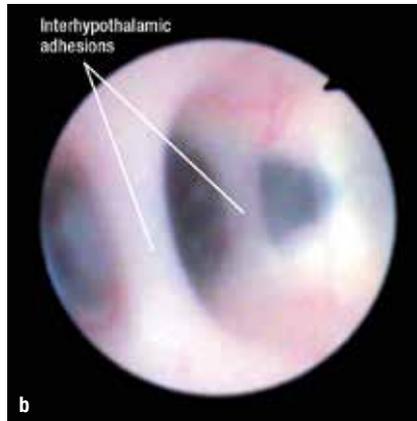
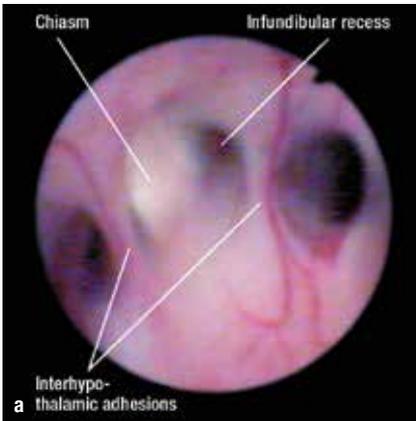
**21** Chiari II/MM with absent septum pellucidum, fused forniceal columns, and bilateral stenosis of the foramina of Monro (fiberoptic endoscope).



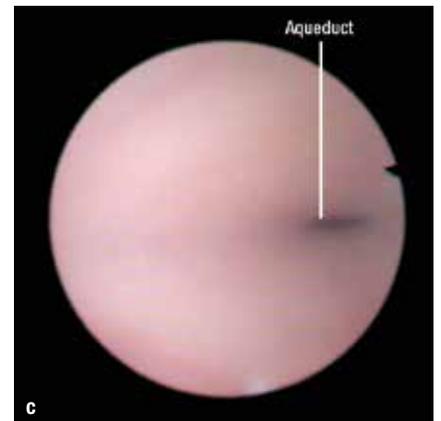
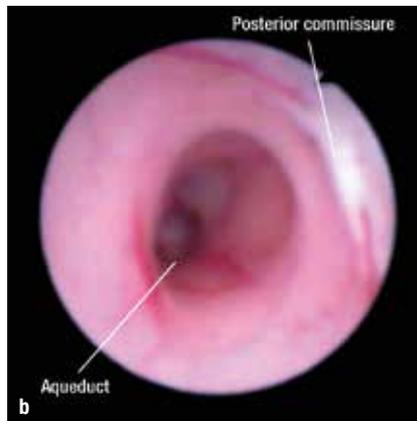
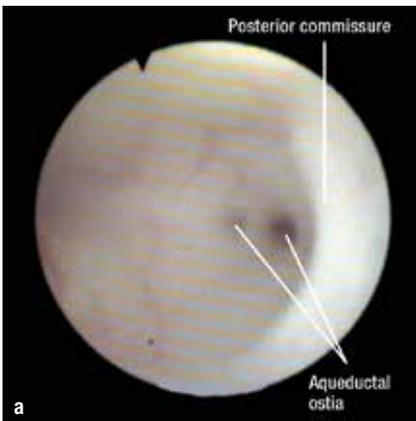
**22** More posterior view of same patient as **Fig. 21** (fiberoptic endoscope).



**23** Chiari II/MM with absent septum pellucidum, fused forniceal columns, and enlarged massa intermedia (HOPKINS® rod lens telescope).



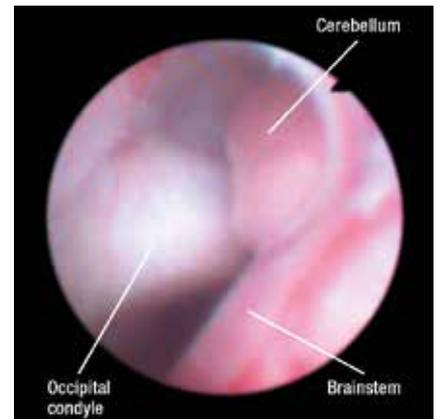
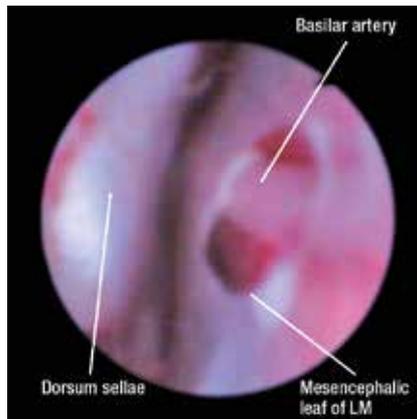
**24** Third ventricular floor in 3 patients with Chiari II/MM showing interhypothalamic adhesions (fiberoptic endoscope).



**25** Aqueductal stenosis in infants with Chiari II/MM: stenotic aqueduct with two ostia;

acutely angulated aqueduct just distal to open ostium;

very narrow aqueductal ostium (fiberoptic endoscope).



**26** Anteriorly and caudally displaced basilar artery in Chiari II/MM (fiberoptic endoscope).

**27** View through ETV stoma of infant with Chiari II/MM showing fenestrated mesencephalic leaf of LM (fiberoptic endoscope).

**28** Cerebellar tissue enveloping brainstem near foramen magnum in infant with Chiari II/MM (fiberoptic endoscope).

3

## ETV/CPC As the Primary Treatment for Hydrocephalus

### 3.1 Treatment Outcomes for ETV/CPC at CURE Children’s Hospital of Uganda

In 2005 I reported the initial experience with attempting ETV alone as the primary treatment for infant hydrocephalus in Uganda.<sup>15</sup> Similar to the experience reported by others in North America among patients younger than 1 year of age, only 40% of those with NPIH and MM and 45% of those with PIH (with an open aqueduct) were successful. An important exception was the group of infants less than 1 year of age with post-infectious obstruction of the aqueduct in whom ETV was successful in 70%. Thus, aside from this subgroup, ETV was successful in less than 50% of infants, and a better management solution was needed.

For reasons discussed below (in 3.3) a prospective study was undertaken in which CPC was added to the ETV procedure for all patients.<sup>19</sup> The difference in outcome for ETV alone and the combination ETV/CPC procedure are summarized in **Tables 1a, b**.<sup>19</sup>

We concluded from this study, that the addition of CPC to the ETV procedure was definitely beneficial for infants (< 1 year of age) with NPIH and MM and likely beneficial for infants with PIH. For all patients older than 1 year there were insufficient numbers to determine efficacy in those between 1 and 2 years of age, or other subcategories. Importantly, the ETV/CPC procedure proved safe in this initial series (< 1% operative mortality, morbidity, and infection rates).<sup>19</sup>

Since 2005, using survival analysis methods, we have had the opportunity to report longer-term follow up data from CCHU in larger numbers of infants one year of age or younger with more specific etiologies of hydrocephalus. These include aqueductal stenosis (82% success),<sup>36</sup> myelomeningocele (76% success),<sup>21,34</sup> PIH (63% success),<sup>33</sup> encephalocele (79% success),<sup>28</sup> Dandy-Walker complex (69%),<sup>31</sup> and congenital idiopathic communicating hydrocephalus (65% success).<sup>38</sup> **Figures 29 and 30** demonstrate the differences in treatment survival between ETV/CPC and ETV alone for aqueduct stenosis and for congenital idiopathic communicating hydrocephalus, respectively.

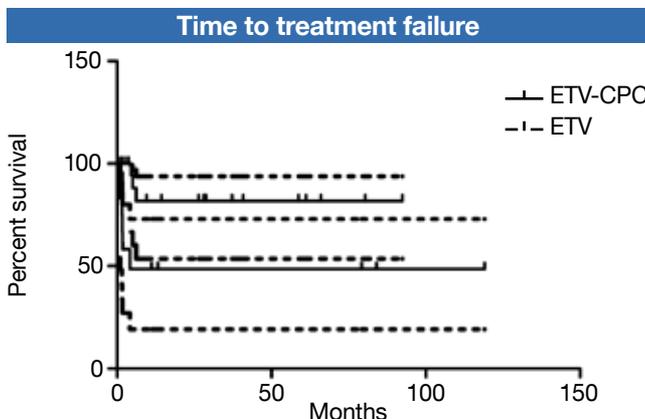
Factors affecting success of ETV/CPC at CCHU have also been analyzed in large numbers of children. Aside from very young age, the condition of the prepontine cistern in PIH (found at time of ETV) and the extent of CPC were found to predominate.<sup>25, 26</sup> The extent of choroid plexus cauterized mimics a “dose-response” pattern. If obstruction of the prepontine cistern by arachnoid scar is encountered at the time of ETV, the likelihood of failure is sufficiently high that we recommend proceeding with shunt placement at the time of the procedure (**Figs. 36–39**).

Differences in Outcome by Age			
	< 1 year	≥ 1 year	All ages
<b>ETV only (success/total)</b>	98/209 (47%)	47/59 (80%)	145/268 (54%)
<b>ETV/CPC (success/total)</b>	141/214 (66%)	33/41 (80%)	174/255 (68%)
<b>P =</b>	< 0.0001	1.0000	0.0012

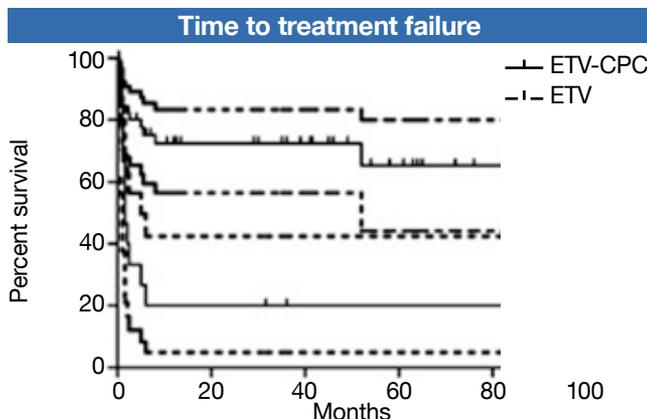
Tab. 1a

Differences in Outcome by Etiology for Patients of Less Than 1 Year of Age				
< 1 year	PIH	NPIH	MM	PHH
<b>ETV only (success/total)</b>	70/134 (52%)	21/55 (38%)	7/20 (35%)	—
<b>ETV/CPC (success/total)</b>	72/117 (62%)	32/46 (70%)	34/45 (76%)	2/5 (40%)
<b>P =</b>	< 0.1607	0.0025	0.0045	—

Tab. 1b



29 Treatment results for aqueduct stenosis.<sup>36</sup>

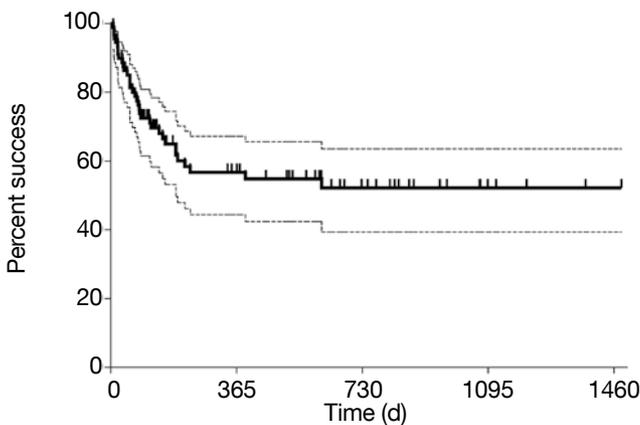


30 Treatment results for idiopathic communicating hydrocephalus.<sup>38</sup>

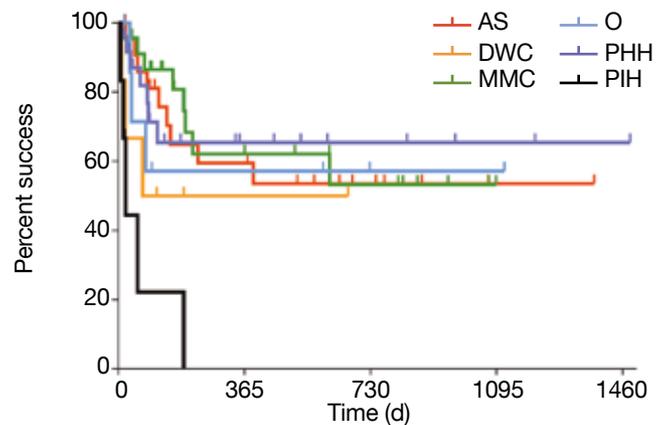
### 3.2 Treatment Outcomes for ETV/CPC at Boston Children's Hospital

In 2014 we reported results for treatment of infant hydrocephalus by ETV/CPC in a North American population at Boston Children's Hospital.<sup>13</sup> Of 100 consecutive infants presenting for treatment of hydrocephalus, 91 (98%) were treated with ETV/CPC at mean and median ages of 4.7 and 3.2 months. Post-hemorrhagic hydrocephalus, myelomeningocele, and congenital aqueduct stenosis each comprised about 25%. Infants routinely had preoperative sagittal FIESTA MRI imaging of the brain to assess the status of the prepontine cistern. Infants with PHH and evidence of cisternal obstruction were excluded from ETV/CPC based upon our previously reported experience in this population.<sup>30</sup> Kaplan-Meier analysis estimated overall 6 and 12-month success at 65% and 57% (Fig. 31),

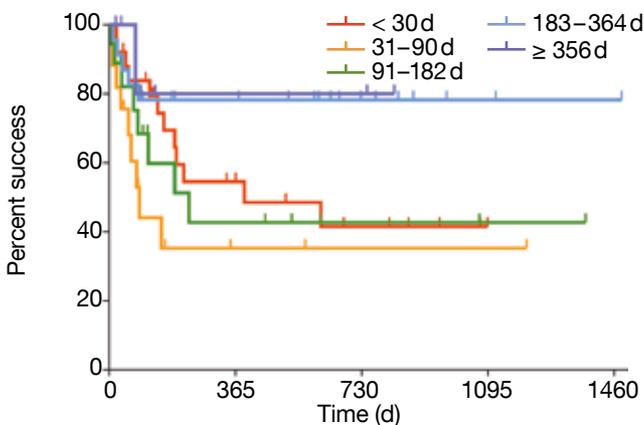
exceeding that predicted by the ETV success score. Predictors of failure (using Cox proportional hazards model) were infectious etiology (post-meningitis, Fig. 32), age less than 6 months (Fig. 33), cisternal scarring noted at the time of ETV, and prior CSF diversion. Six-month success for those without these risk factors was 67% for infants younger than 6 months and 79% for those older than 6 months (Fig. 34). There were no deaths, infections, or neurologic morbidity. The few post-infectious hydrocephalus cases encountered in this series were those following meningitis, in contrast to the PIH that predominates in Uganda, which is post-ventriculitis. We concluded that ETV/CPC may be a safer and more durable primary treatment than shunting for the majority of infants.



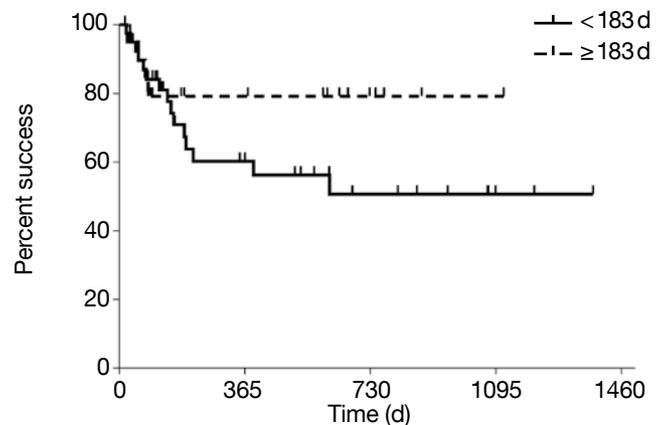
31 Kaplan-Meier-derived ETV/CPC success curve (95%CI) for all patients. **d** = days<sup>13</sup>



32 Kaplan-Meier-derived ETV/CPC success by etiology. **AS** = aqueduct stenosis; **DWC** = Dandy-Walker complex; **MMC** = myelomeningocele; **PHH** = post-hemorrhagic hydrocephalus; **PIH** = post-infectious hydrocephalus.<sup>13</sup>



33 Kaplan-Meier success curves by age at treatment. **d** = days<sup>13</sup>



34 Kaplan-Meier success curves by age at treatment excluding post-meningitis, prior CSF diversion, and scarred pre-pontine cistern.

### 3.3 How ETV and CPC Work

In 2005 I reported that ETV combined with CPC was more effective than ETV alone for treating infant hydrocephalus.<sup>19</sup> But understanding the mechanism for this is evolving. The endoscopic third ventriculostomy (or ventriculocisternostomy) provides direct communication between the 3<sup>rd</sup> ventricle and the subarachnoid spaces by way of the interpeduncular and pre-pontine cisterns. Traditional explanations for the affect of ETV assume the simplistic model that CSF is produced by choroid plexus in the ventricles and flows in bulk out the 4<sup>th</sup> ventricle foramina and into the subarachnoid spaces where it is absorbed at a rate that balances that of production. If that were the case, ETV could be understood as bypassing an obstruction at some point between the 3<sup>rd</sup> ventricle and the subarachnoid spaces (e.g. aqueduct stenosis or a posterior fossa obstruction).

ETV should be expected to function if there is no obstruction to flow from the interpeduncular/prepontine cisterns to and through the arachnoid granulations in the superior sagittal sinus and if the intravenous (superior sagittal sinus) pressure is normal. ETV would not be expected to be a sufficient treatment if extraventricular CSF circulation and absorption deficiencies were the primary cause (as assumed for post-meningitis, post-subarachnoid hemorrhage, and idiopathic communicating hydrocephalus). Similar reasoning suggests that ETV might fail in very young infants with congenital forms of hydrocephalus (such as that associated with myelomeningocele or aqueduct stenosis) if the CSF circulation and absorption mechanisms have not had sufficient opportunity to develop. In this traditional model, CPC could be understood as decreasing the rate of CSF production and in this way overcoming a relative deficiency in absorption among young infants. My original decision to add CPC to ETV was based upon these assumptions.

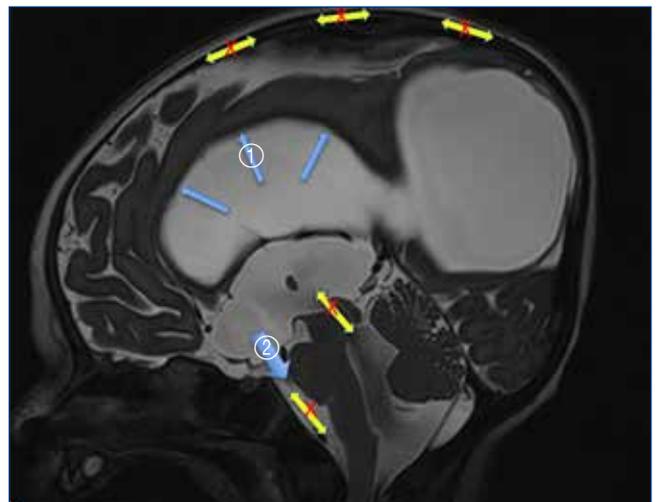
But this “bulk flow” paradigm seems – at least – incomplete, given evidence for water exchange across the ependymal surfaces and the association of hydrocephalus with elevated intraventricular pulsation amplitudes that are involved in driving progressive ventriculomegaly.<sup>38, 40</sup>

Hydrocephalus may result, at least in part, from pathologic distribution of intracranial cardiac pulsations. This may arise from post-inflammatory subarachnoid space scarring, ventricular outlet obstruction, or decreased venous compliance, each of which can increase the amplitude of intraventricular pulsations. I have previously suggested that ETV may function to augment intraventricular pulsation absorption and CPC may enhance this affect by direct reduction of the intraventricular pulsations generated by the choroid plexus.<sup>38, 40</sup> I have further suggested that, given evidence the infant brain has a relatively high compliance that diminishes with age (until senescence, when it increases again), ETV may be less successful in the early months of life because the ventricles are more easily expanded rendering pulsation absorption by ETV less likely to be sufficient to halt progressive ventriculomegaly. I have proposed that the addition of CPC in these infants makes ETV success more likely because of the additional reduction in intraventricular pulsation amplitude<sup>38, 40</sup> (Fig. 35).

With increasing age beyond infancy, ETV becomes more effective, and is so effective in the case of aqueduct stenosis that the addition of CPC for patients older than 2 years of age does not seem indicated. The use of ETV/CPC in older children and adults with other forms of hydrocephalus (including idiopathic normal pressure hydrocephalus, or iNPH) has not received sufficient study.

#### Pulsation absorption (ETV) and reduction (CPC)

- Increased intraventricular pulsations are a component of hydrocephalus.
  - Decreased pulse damping
    - Windkessel (e.g. SAH)
    - Venting (e.g. AS)
    - Venous capacitance (e.g. CIH)
- CPC reduces CP pulsations ①
- ETV increases pulse damping ②
- Higher ventricle compliance may require both



35 Pulsation absorption (ETV) and reduction (CPC).

### 3.4 Patient Selection for initial treatment and the role of redo ETV in managing failure

We have found that the addition of CPC helps “level the playing field” for ETV outcome in regard to age, etiology of hydrocephalus, and whether the aqueduct is open or closed. Although age is still a factor, the most important determinants of success are the degree of choroid plexus cauterization and the status of the prepontine cistern.<sup>25,26</sup>

Obstruction of the prepontine cistern by scar can occur with either PIH or PHH. When this can be detected by MRI, using sagittal FIESTA imaging, we have found it to be a contraindication to ETV, and recommend placement of a VP shunt.<sup>13, 30</sup>

In LMIC where MRI is not available, we recommend proceeding to placement of a VP shunt if – upon performing the ETV – it is discovered that the prepontine cistern is obstructed by arachnoid scar. In this case, the likelihood of failure is so high, it seems advisable to proceed with shunt placement under the same anesthesia, and thus patients undergoing ETV/CPC in this setting are routinely positioned, prepped, and draped for a right frontal VP shunt placement in case this becomes indicated.

Infants with PIH (or PHH) may have grossly distorted anatomy that technically precludes the procedure. If preoperative imaging (ultrasound, CT, or MRI) demonstrates this to be the case, then placement of a VP shunt may be indicated from the beginning.

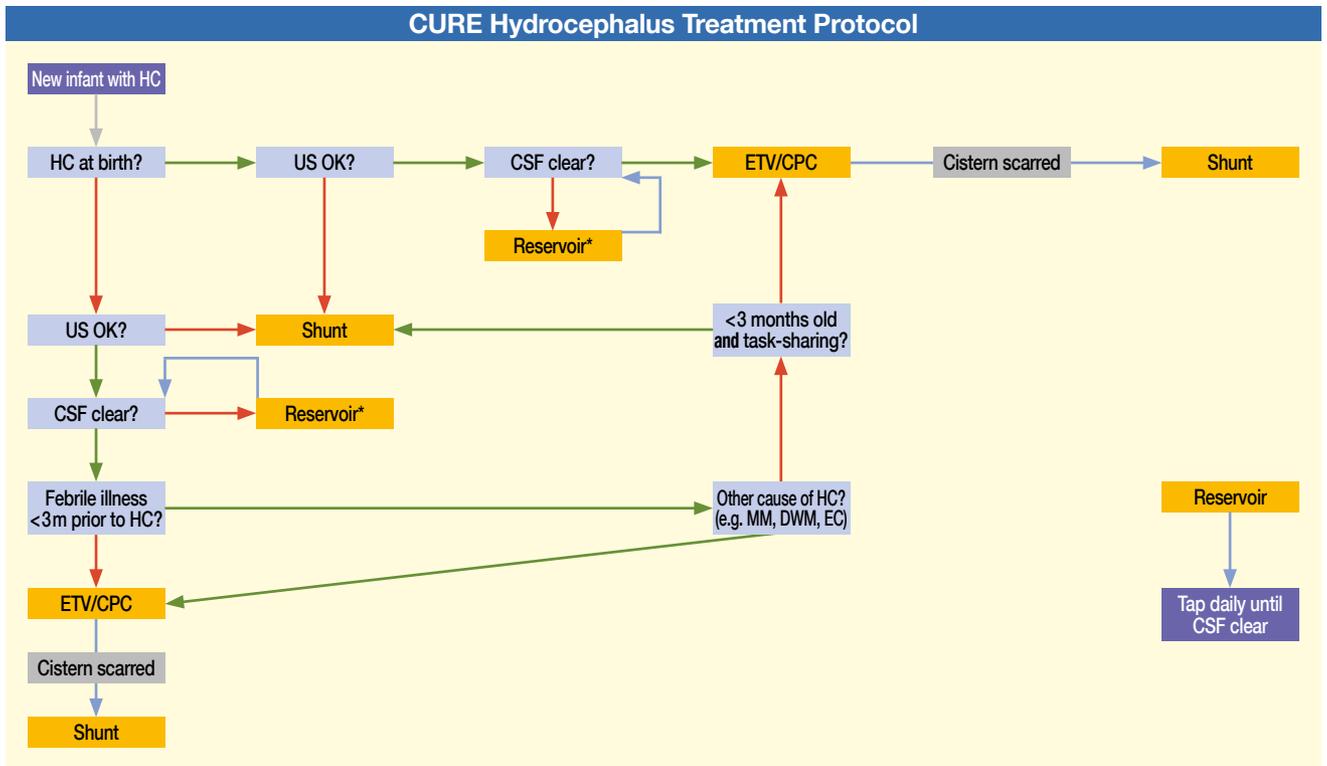
However, even when ETV is not technically possible, multiloculated hydrocephalus may dictate the need for endoscopic fenestration of septations and possible

fenestration of the septum pellucidum in order to create free communication within the ventricular system at the time of shunt placement.

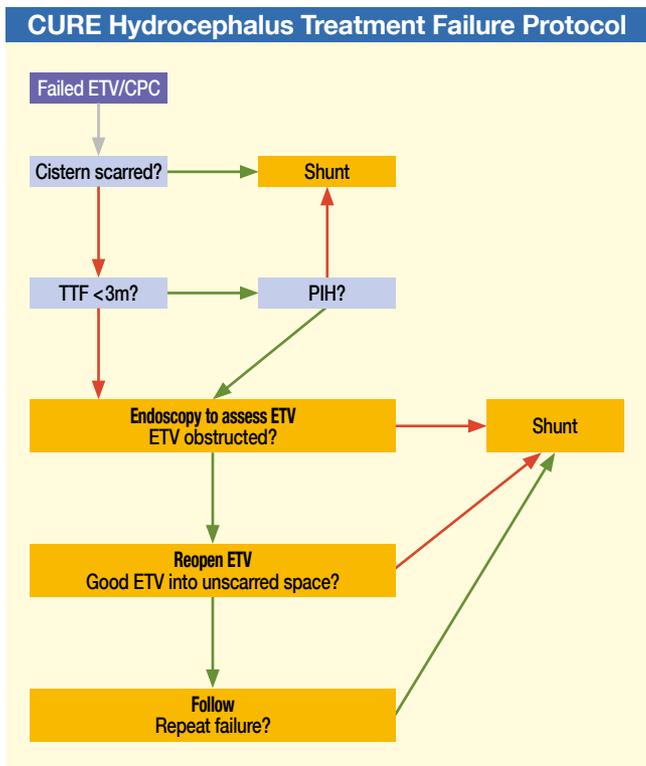
It is important to note that, aside from the situations noted above (cisternal obstruction and gross anatomic distortion), all infants with hydrocephalus are eligible candidates for ETV/CPC regardless of etiology. (Although, as noted above, we have had poor initial success with hydrocephalus resulting from neonatal meningitis).

We have demonstrated that shunt survival is not negatively affected by prior ETV (+/-CPC) or by shunting at the time of an abandoned ETV attempt.<sup>35</sup> We have also investigated the role of redo ETV in patients failing initial treatment because of subsequent ETV obstruction.<sup>11</sup> Those with a longer time to failure of initial ETV (> 6m 91%, 3–6m 60%, <3m 42%,  $p < 0.01$  Log-Rank), post-infectious etiology (PIH 58% vs. NPIH 42%,  $p = 0.02$ , Log-Rank, Wilcoxon) and prior CPC ( $p = 0.03$ ) had significantly better outcome ( $p$  values  $\leq 0.02$ , Cox regression).

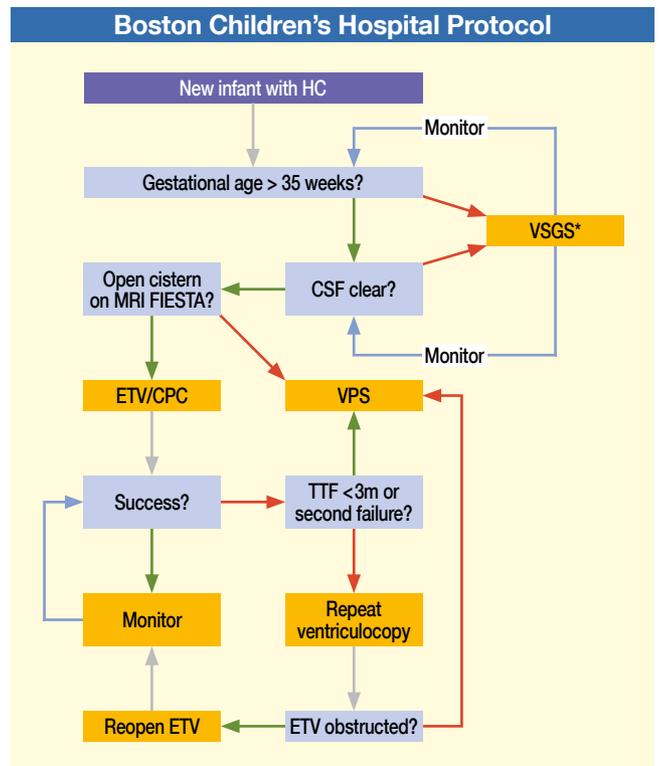
The algorithms below illustrate our current evidence-based recommendation for treatment of infant hydrocephalus in our CURE Hydrocephalus program and at Boston Children’s Hospital, respectively. **Figures 36** and **37** illustrate the algorithms for initial treatment and for management of ETV/CPC failure, respectively, in the CURE Hydrocephalus program. **Figure 38** illustrates the current overall management paradigm at Boston Children’s Hospital.



36 → = Yes → = No  
**US OK** = anatomy not severely distorted/ETV technically possible; **MM** = myelomeningocele; **DWM** = Dandy-Walker Malformation; **EC** = encephalocele; **Task-sharing** = some must be assigned to other providers for shunts due to high volume; **\*HC** may resolve in some cases.



37 → = Yes → = No  
**Cistern scarred** = noted at original ETV; **TTF** = time to failure from original ETV.



38 → = Yes → = No  
**HC** = hydrocephalus; **IVH** = intraventricular hemorrhage; **VSGS** = ventriculo-subgaleal shunt; **\*HC** may resolve in some cases; **VPS** = ventriculo peritoneal shunt.

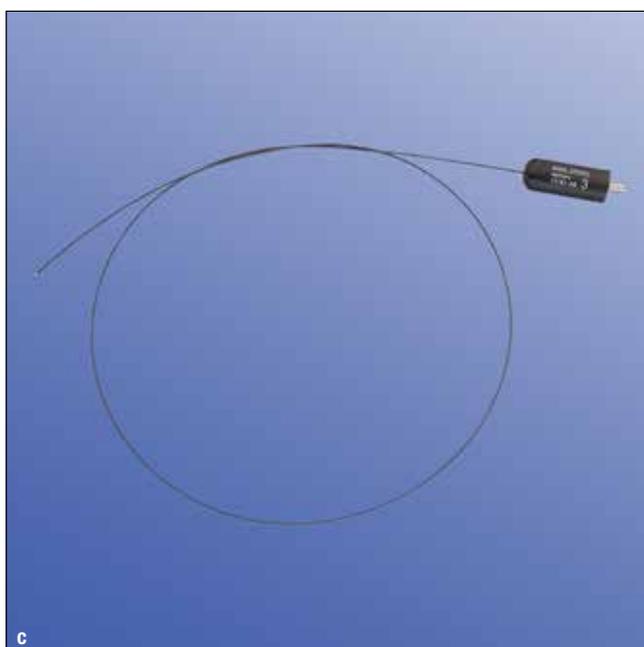
## 4

## Endoscopic Third Ventriculostomy/Choroid Plexus Cauterization

## 4.1 Equipment

The equipment used for the procedure includes the flexible neuroendoscope 11282 BN1\*, IMAGE1 H3-Z SPIES™ Camera Head, IMAGE1 SPIES™ CONNECT™ and IMAGE1 X-LINK™, Cold lightsource XENON 300 SCB, Bugby electrocautery wire and 27" Full HD monitor (Figs. 39a–c).

\* KARL STORZ, Tuttlingen, Germany



**39** Flexible-steerable neuroendoscope, (KARL STORZ, Tuttlingen, Germany) (a). Video cart showing setup, (KARL STORZ, Tuttlingen, Germany) (b). Bugby electrocautery wire, (KARL STORZ, Tuttlingen, Germany) (c).

In older children for whom an ETV alone is going to be performed, I have used the OI Handi-Pro® rigid pediatric neuroendoscope with 0° HOPKINS® rod lens telescope (**Fig. 40**). However, I prefer the flexible endoscope even in these cases because it affords the ability to make more subtle and controlled movements of the tip as well as much greater maneuverability.

Performing CPC in both lateral ventricles, including the plexus within the temporal horns, from a single frontal approach cannot be achieved with a rigid endoscope.

Furthermore, for the management of multi-compartment PIH, I find the flexible endoscope invaluable. The fiber-scope filter setting options for the camera aid in enhancing the image quality.\* The ventriculoscopic photographs in this publication were obtained using the KARL STORZ AIDA image capture system.

\* The development of a digital, “chip on the tip” flexible neuroendoscope should eliminate any previous concerns about image quality compared to that of rigid, rod lens endoscopes.



**40** OI Handi-Pro® rigid neuroendoscope with HOPKINS® rod lens telescope (KARL STORZ, Tuttlingen, Germany).

## 4.2 Operative Technique for ETV

The details of scope and camera sterilization, operative setup, and the ventriculoscopy procedure in the setting of a developing country have been reported.<sup>15, 19</sup> Since we have had to avoid the use of consumable items given cost constraints, none are used in this procedure. The endoscope and camera are both sterilized and placed directly on the operative field with the camera

and light cables exiting the field toward the video cart (accommodating the monitor, video box, light source, and image capture system) at the foot of the bed. We currently use a KARL STORZ autoclavable camera, and the flexible endoscope is sterilized in Cidex® and rinsed thoroughly with sterile water immediately prior to use.

After the set up and white balancing of the endoscope and video system, a gently curved 90° angle incision is made in the lateral corner of the anterior fontanel with the flap centered in the mid-pupillary line (**Fig. 41**). (In older children, the scalp flap and a burr hole are centered immediately anterior to the coronal suture in the mid-pupillary line.) The small scalp flap is reflected to expose the dura of the fontanel and is tacked back with a suture (**Fig. 42**). The dura is incised sharply, allowing for its primary closure to avoid CSF leak (**Fig. 43**). (In older patients, when operating through a burr hole, it is usually not feasible to close the dura; so, the endoscope tract through the cortex is plugged with a rolled piece of Surgicel® or dry Gelfoam and the burr hole is filled with the bone shavings and sealed

with bone wax.) After opening the dura, the pia and cortical surface are coagulated, then penetrated with the obturator of a peel-away sheath or a ventricular cannula (**Figs. 44a, b**). (A disposable peel-away sheath is helpful, but I have found them to be a non-essential expense. If a small amount of tissue obstructs the endoscope during its insertion, this is easily cleared away with a gentle flush through the irrigation port.) The endoscope is then inserted and the camera orientation is adjusted appropriately such that anterior is at 9 o'clock and posterior at 3 o'clock on the video image. **Fig. 45a** demonstrates the setup with the bulk of the endoscope resting on the field and the surgeon's right hand resting on the patient's head while the tip of the scope is inserted and subsequently manipulated.



41 Scalp incision.



42 Scalp flap tacked back.



43 Dural incision.



a



a



b



b



c



d

44 Cauterization (a) and penetration (b) of cortical surface.

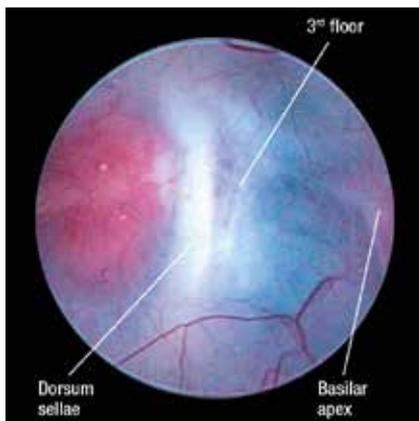
45 Insertion of the flexible endoscope (a). Endoscope holder (b-d).

I currently use a scope holder (KARL STORZ) that clamps to the operating table and suspends the endoscope above the field to facilitate its stability and manipulation (**Figs. 45b–d**). I control the endoscope with my right hand, which I stabilize by resting my 4<sup>th</sup> and 5<sup>th</sup> fingers lightly on the patients head, and manipulate the scope between my right thumb and index finger (for depth, gross angulation, and torque). I control the steering mechanism with my left hand (to flex the tip in either of two directions while simultaneously twisting the scope with my right thumb and forefinger to point the tip in any direction through 360°). The depth of the Bugby wire is also controlled with the left hand.

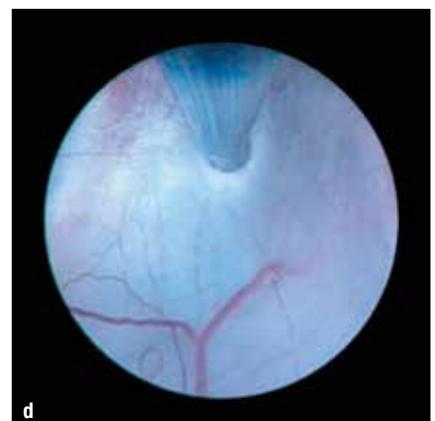
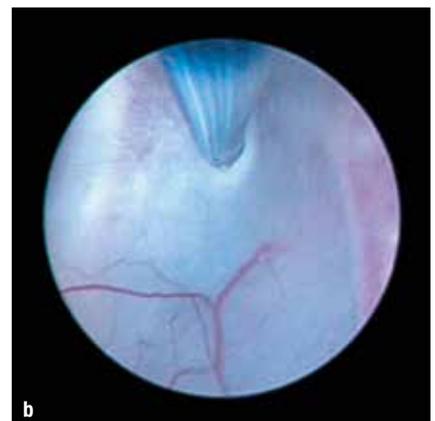
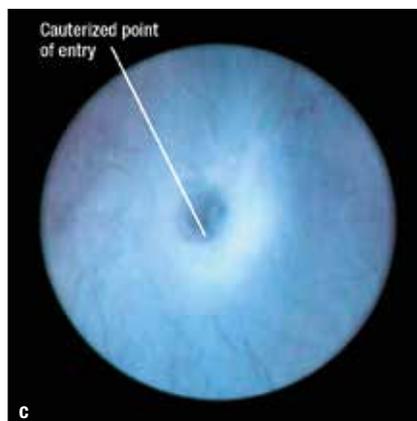
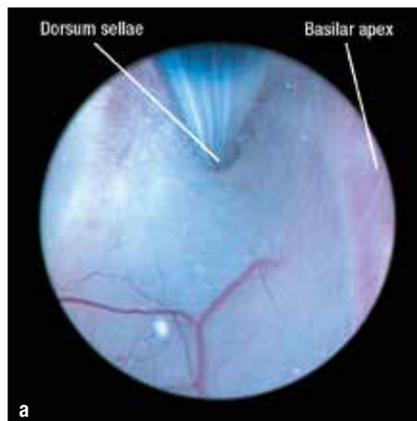
The flexible neuroendoscope has one working channel with two access ports – each with a stopcock. I do not use continuous irrigation, but rather intermittent manual irrigation with a 10cc syringe as needed.

If irrigation is required while the Bugby wire is occupying the working channel via port A, the syringe can be connected to port B and irrigation performed after the stopcock on port A is clamped down on the wire to prevent egress of the irrigant. The OI Handi-Pro® rigid neuroendoscope has a channel for irrigation that is conveniently separate from the working channel. This renders closure of the working channel port during irrigation unnecessary.

The floor (**Fig. 46**) is fenestrated with the Bugby wire just behind the dorsum sellae using brief pulses of electrocautery, if necessary, to weaken, but not penetrate, the surface (**Figs. 47a–c**). This is followed by blunt penetration through the floor (**Fig. 47d**).



**46** Floor of 3<sup>rd</sup> ventricle where the ventriculostomy is to be made (HOPKINS® rod lens telescope).



**47** Partial thickness cautery of 3<sup>rd</sup> ventricular floor with Bugby wire (**a–c**); Penetration of floor with Bugby wire (**d**); (HOPKINS® rod lens telescope).

The wire is used to gradually dilate the opening to at least 5–7 mm by gentle stretching of the ETV stoma in different directions (**Fig. 48**).

With the steerable tip of the flexible endoscope, the stoma dilation is easily done by flexing the tip with the left hand while torquing the scope in different directions with the right thumb and forefinger. This requires virtually no gross transit movements of the proximal portion of the scope. (However, the images for **Figs. 46–49** were taken using the OI Handi-Pro® rigid endoscope with the 0° Hopkins rod lens telescope).

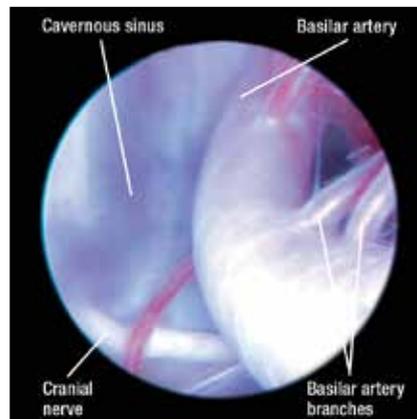
The scope is passed through the opening in the floor and, when necessary, additional membranes (e.g. Lilliequist's membrane or arachnoid adhesions resulting from prior inflammation) are penetrated until the scope can be passed freely into the interpeduncular and

pre-pontine cisternal spaces with visualization of a “naked” basilar artery (**Fig. 49**). If entry is made anterior to the vertical portion (mesencephalic leaf) of Lilliequist's membrane, which obscures the basilar artery, blunt dissection is accomplished with the tip of the wire to fenestrate the membrane (**Fig. 50**). I find that the flexible endoscope allows dissection within the cisterns to be accomplished delicately and safely. I do not recommend such maneuvers with a rigid endoscope because the required movements are too gross.

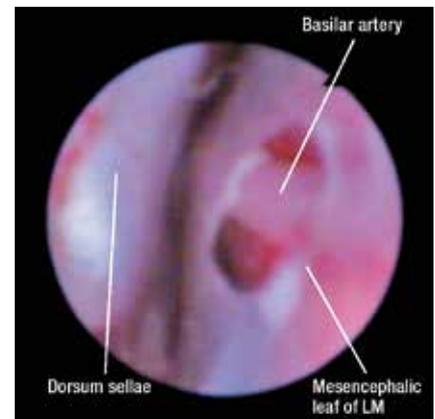
For patients with PIH, if the cisterns are found to have arachnoid adhesions from prior meningitis, a similar technique of blunt dissection can be undertaken to open up the cisterns; but, I have found the failure rate of ETV (+/-CPC) in PIH to be unacceptable when the cisterns are scarred significantly (**Figs. 51a–c**), and I place a VP shunt when this is found to be the case.<sup>13</sup>



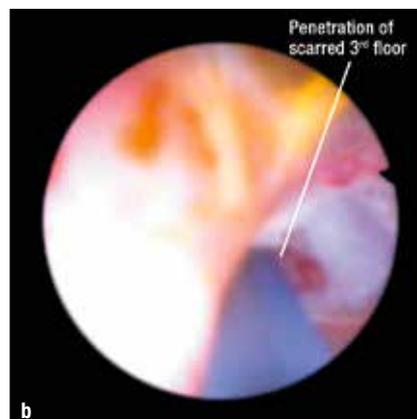
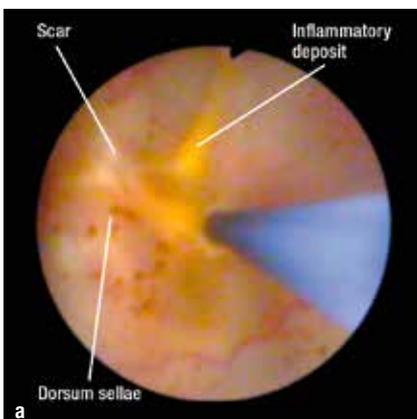
**48** Enlargement of ETV stoma (HOPKINS® rod lens telescope).



**49** View of pre-pontine cistern after endoscope was passed through ETV stoma (HOPKINS® rod lens telescope).



**50** Fenestrated mesencephalic leaf of the Lilliequist membrane in an infant with Chiari II/MM (fiberoptic endoscope).



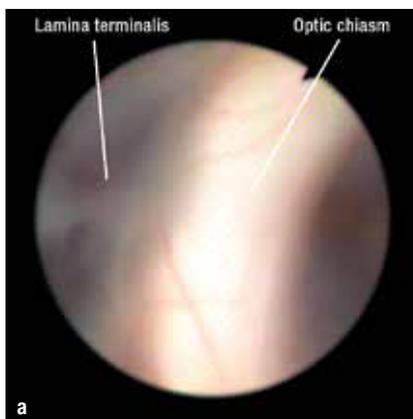
**51** Fenestration of scarred 3<sup>rd</sup> ventricular floor (**a, b**) and discovery of a severely scarred pre-pontine cistern below (**c**) in an infant with PIH (fiberoptic endoscope).

The goal of this intra-cisternal dissection is the direct visualization of a “naked” BA, its branches, and the cranial nerves. The scope is withdrawn from the ventriculostomy, and evidence for flow across the stoma is noted. In cases where the child presents with infected, turbid, or bloody CSF that precludes initial ventriculostomy, a reservoir is placed for serial tapping until the fluid has sufficiently cleared to allow endoscopy to be performed.

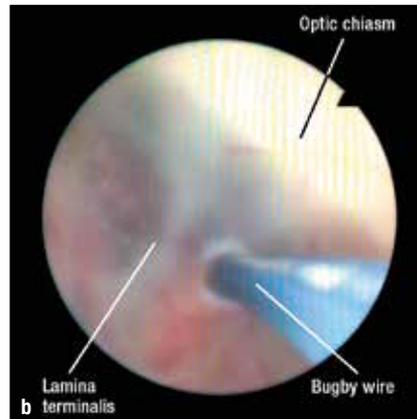
I have previously described the procedure of ETV through the lamina terminalis (LT) if an ETV in the floor is not technically feasible (usually secondary to scar from

prior ventriculitis), although this is not the preferred site, and the creation of an LT-ETV as a second opening in addition to the floor ETV was not found to confer any benefit<sup>15</sup>. The technique is similar to that for the floor, with partial thickness cauterization of the LT followed by penetration with the Bugby wire and subsequent stretching of the stoma (**Figs. 52a–c**).

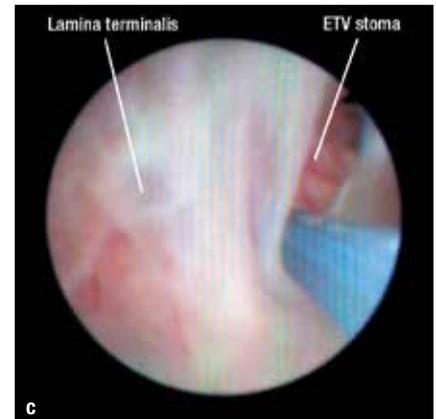
The flexible endoscope often needs to be rotated between the right thumb and index finger while simultaneously flexing the tip with the steering mechanism in order to achieve a more perpendicular angle of attack for the Bugby wire upon the LT.



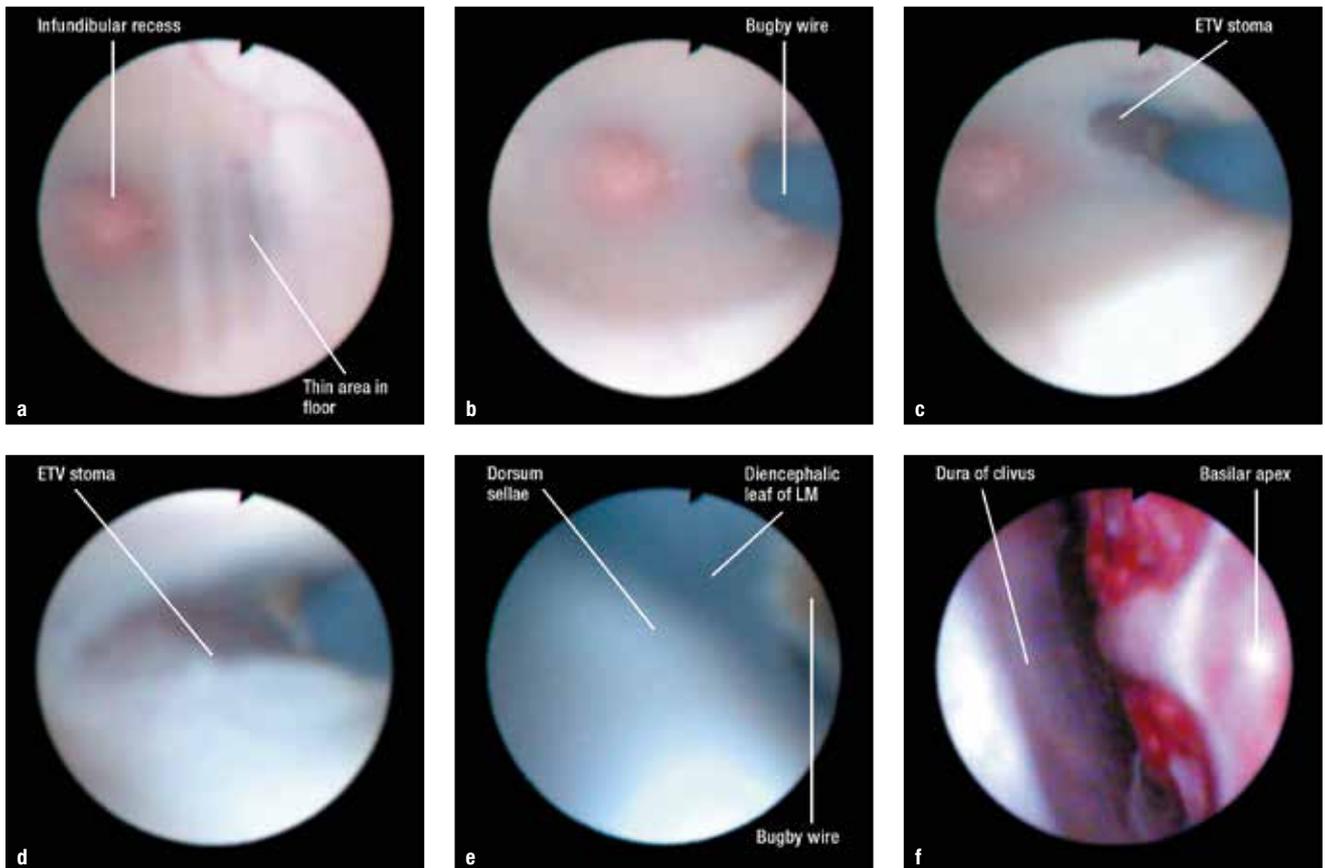
52 Lamina terminalis (LT);



Cauterizing LT;



Fenestration and widening of LT-ETV stoma.



**53** Sequential photographs demonstrating the steps in creating an ETV in the floor of an infant with Chiari II/MM (same patient as in Fig. 24c) (fiberoptic endoscope).

Special mention should be made of performing the ETV in MM patients, and this is demonstrated in **Figs. 53a–f**.

The variations in ventriculoscopic anatomy among these patients have been described above. The typically enlarged massa intermedia only rarely precludes access to the floor, which is almost always thickened with no evidence of the basilar artery (BA) position below. Inter-hypothalamic adhesions are common, but are usually preserved as the floor is approached around them *en passant*. The floor is gently and bluntly penetrated using the Bugby wire (but without the use of electrocautery) posterior to the infundibular recess and anterior to the mammillary bodies, taking advantage – if possible – of a small segment of the floor that is often thinned out.

### 4.3 Operative Technique for CPC

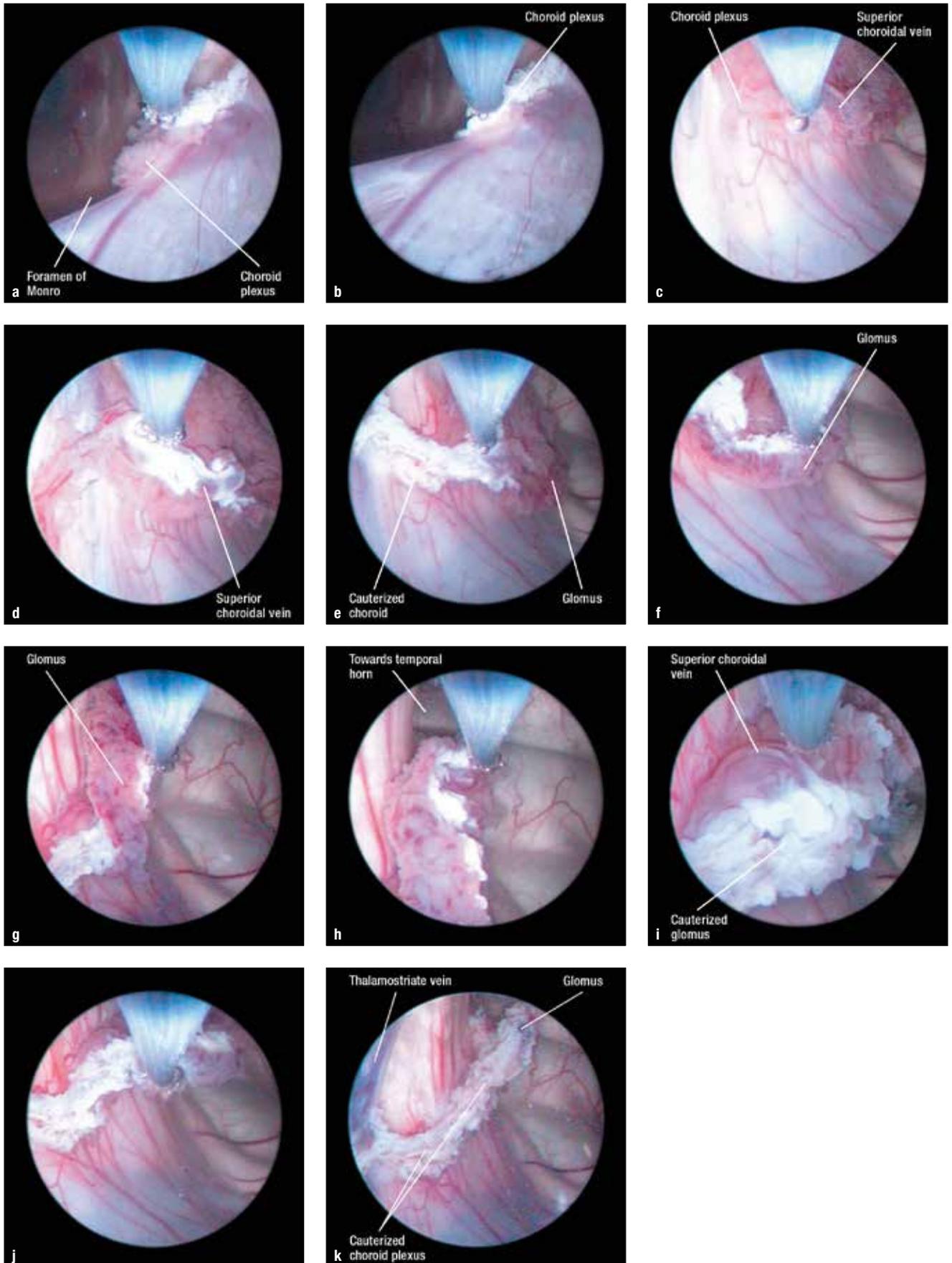
Following the ETV, attention is turned to the CPC as demonstrated in **Figs. 54**. Beginning at the foramen of Monro and gradually moving posteriorly, the CP of the lateral ventricle is thoroughly cauterized using the Bugby wire and low-voltage monopolar coagulating current (**Figs. 54a–c**). In cases of severe ventriculomegaly, a portion of the CP in the anterior roof of the third ventricle is often available for cauterization as well. Care is taken

There is commonly a prominent inter-hypothalamic adhesion crossing the floor in this vicinity. As the floor is gradually penetrated, the dorsum sellae, pituitary, and brainstem come into view. The flexible fiberoptic neuroendoscope is then gently threaded over the wire into the interpeduncular and prepontine cisternal spaces (after fenestration of Lilliequist’s membrane if needed), which are typically very crowded from anterior displacement of the brainstem and BA complex. In addition, the top of the BA is usually displaced caudally with its bifurcation forming a “Y”.

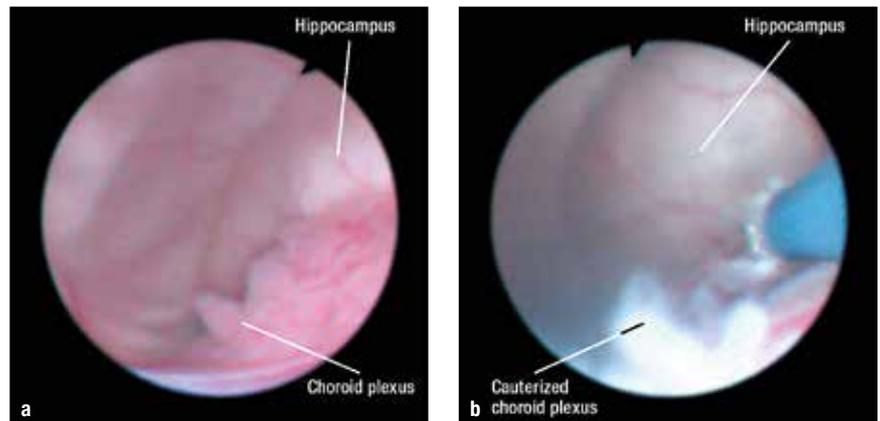
As in other cases, blunt dissection of arachnoid adhesions using the tip of the Bugby wire and the tip flexion control of the flexible endoscope is sometimes required to open up the cistern.

to avoid injury to the thalamostriate and internal cerebral veins or ependymal surfaces. Special attention is paid to the complete coagulation of all vessels within the plexus, including the superior choroidal vein along its entire length (**Figs. 54c, d**).

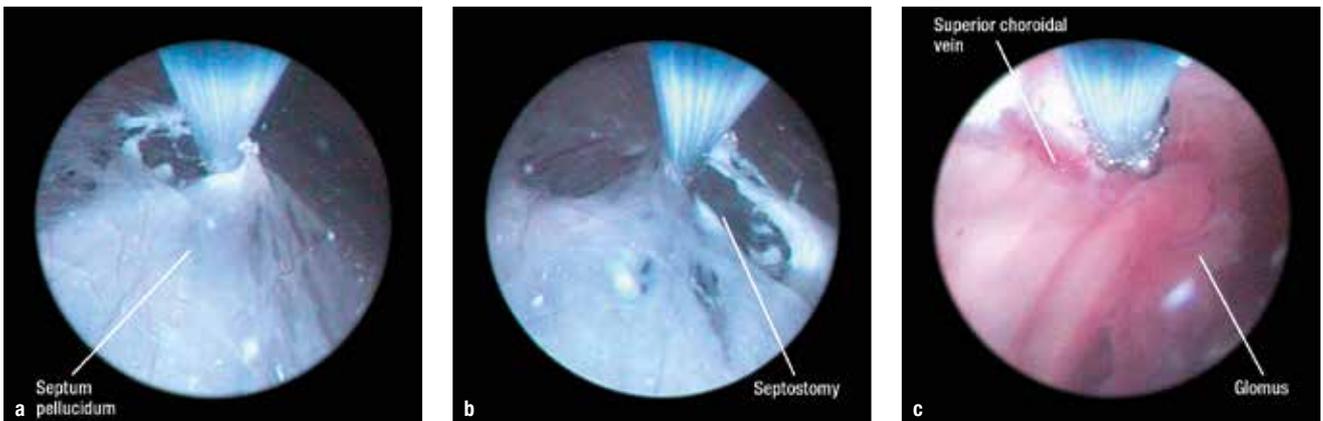
At the level of the atrium the glomus portion of the CP is thoroughly cauterized (**Figs. 54e–k**).



54 Sequential photographs demonstrating CPC in right lateral ventricle from the foramen of Monro to the atrium (refer to text) (HOPKINS® rod lens telescope).



55 CPC in right temporal horn (fiberoptic endoscope).

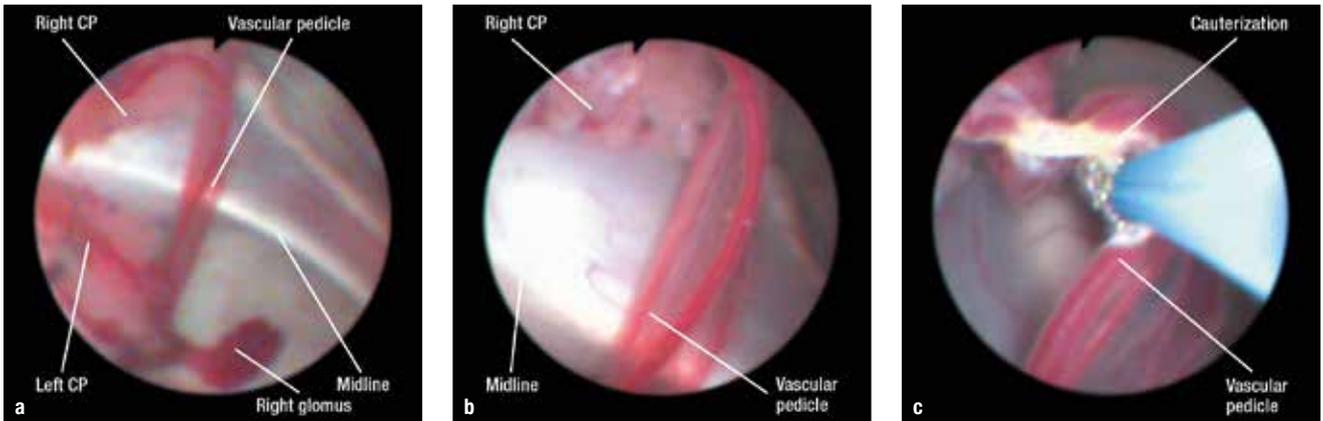


56 Septostomy to allow access into left lateral ventricle (a, b); beginning CPC in the left lateral ventricle (c); (HOPKINS® rod lens telescope).

Then, passing the scope posterior to the thalamus, its tip is flexed and turned to direct the procedure along the CP of the temporal horn, which is then cauterized in similar fashion beginning from its anterior extreme and advancing the wire posteriorly along its length (Figs. 55a, b).

Cautery is continued until all visible CP has been coagulated and shriveled. For cases in which the septum pellucidum is intact, a septostomy is performed

superior to the posterior edge of the Foramen of Monro to gain access to the contralateral CP, where the same procedure is carried out in the left lateral ventricle (Figs. 56a–c). Uncommonly, bleeding (usually venous) may be encountered from the CP. In such cases, I have found it most efficiently controlled by tamponading it with the Buggy wire while gently irrigating for a couple of minutes until it stops. The bilateral CPC typically adds from 20 to 30 minutes to the procedure.



**57** Cauterization of the vascular pedicle tethering a pendulous glomus of the right lateral ventricle choroid plexus which has dropped into the left lateral ventricle (Chiari II/MM patient) (fiberoptic endoscope).

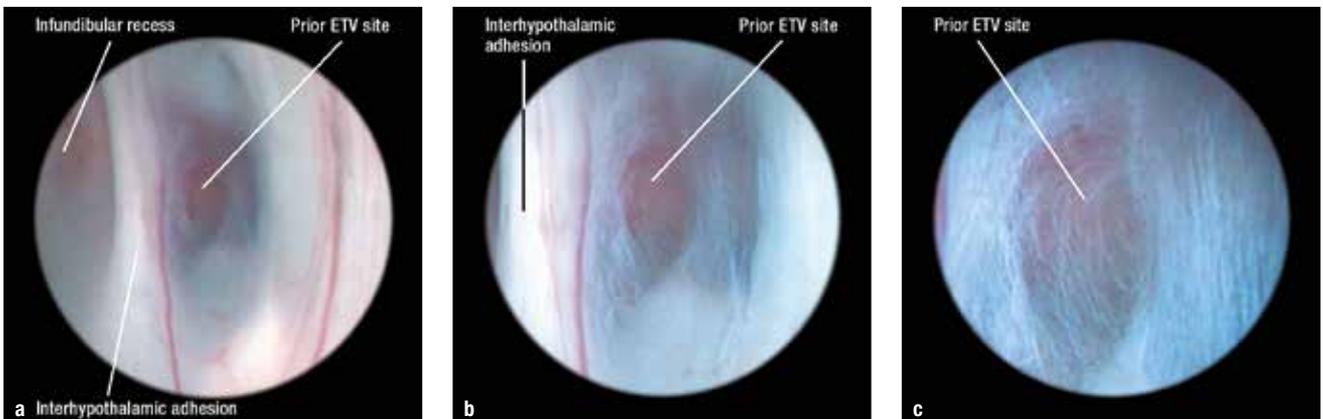
If the CP is partially scarred from prior inflammation, all residual CP is cauterized. In some PIH cases, the CP is sufficiently effaced by scar that no cauterization is possible. In the MM patients, there is typically redundant, robust CP loosely tethered by a thin vascular sheet-like membrane in addition to a carpet of CP adherent to the

ependymal surface along the curve of the thalamus. With the patient's head turned to the left, the right glomus choroideum often drops across the midline, dangling into the left lateral ventricle by this elongated vascular pedicle, which I thoroughly cauterize in addition to the glomus (**Figs. 57a–c**).

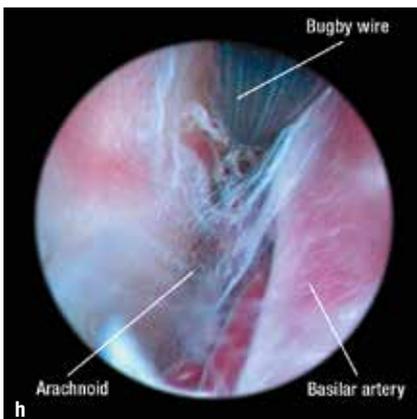
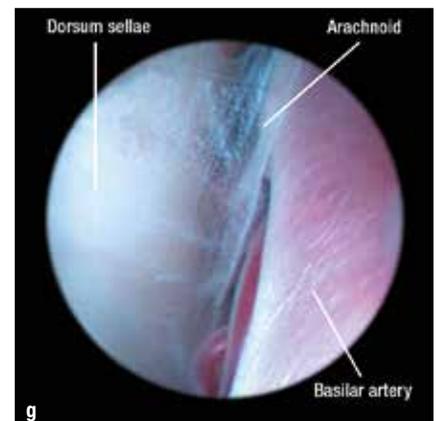
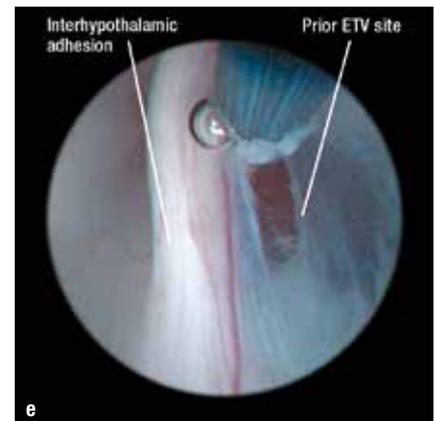
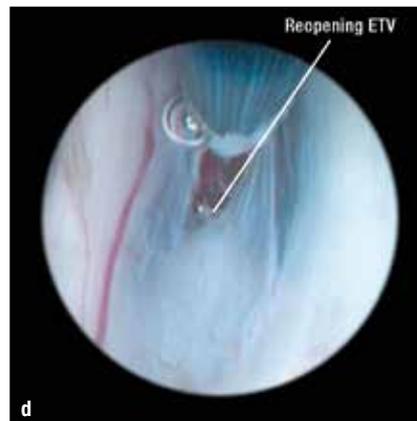
#### 4.4 Reopening of obstructed ETV

As noted above, we have established the indications and outcomes for reopening of a closed ETV stoma in cases of ETV failure.<sup>11</sup> If the ventriculocisternostomy is no longer patent, free communication between the 3<sup>rd</sup> ventricle and cisterns is re-established (**Figs. 58a–j**). Stoma obstruction can occur from simple healing (“virginal floor”), the formation of a membrane over an identifiable stoma, or scar within interpeduncular or

prepontine cisterns. In the latter case, dissection through the arachnoid scar and into unaffected, open, cistern must be achieved. If this is unsafe or not feasible, a new ETV through the lamina terminalis, as described above, can be considered. If the ETV is found to be patent at the time of repeat endoscopy with good communication into the cisterns, then a VP shunt is placed.



**58**



**58** Blunt dissection with Bugby wire to reopen the sealed ETV in a patient with Chiari II/MM and re-establish free communication between the 3<sup>rd</sup> ventricle and the prepontine cistern (HOPKINS® lens).

## 5

## Conclusion

Where the equipment and skills for providing ETV/CPC as the primary treatment for infant hydrocephalus are accessible, the shunt burden could eventually be reduced by at least one-half. This is most obviously desirable in those low and middle-income countries where shunt-dependent patients face difficult barriers to accessing urgent care for shunt malfunction. However, the potential long-term benefits to patients and healthcare systems everywhere seems evident. It is clear that our reported results for ETV/CPC are dependent upon the ability to cauterize the majority of the plexus in both lateral ventricles, including that in the temporal horns, and to manipulate the endoscope within the prepontine cistern to achieve an adequate ventriculocisternostomy even when the landscape is not straightforward. It is also clear that the ETV/CPC technique as described here cannot be properly or safely performed without using the flexible endoscope. There is currently no known benefit of

endoscopic treatment compared to shunt-dependence in regard to cognitive outcomes, and appropriate randomized prospective studies need to be performed to determine this. There are also no known adverse long-term consequences of cauterizing the lateral ventricle choroid plexus. There are, however, very well established risks to shunt-dependence (including failures, infections, and the consequences of over-drainage) and in the developing world these risks are magnified significantly. CURE Hydrocephalus is committed to increasing access to optimal evidence-based treatment for the children of the world with hydrocephalus by training and equipping developing world neurosurgeons to perform ETV/CPC (as well as shunt placements and revisions). It is my hope that this monograph will prove helpful in this process, as well as in that of introducing the technique to pediatric neurosurgeons everywhere.

## 6

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## CURE Hydrocephalus

The International Program to Advance the Treatment of Hydrocephalus (iPATH) was organized as a cooperative effort of CURE International, the International Federation for Spina Bifida and Hydrocephalus, and the KARL STORZ Company. The program has now evolved into a key specialty program within CURE International, called CURE Hydrocephalus (CH).

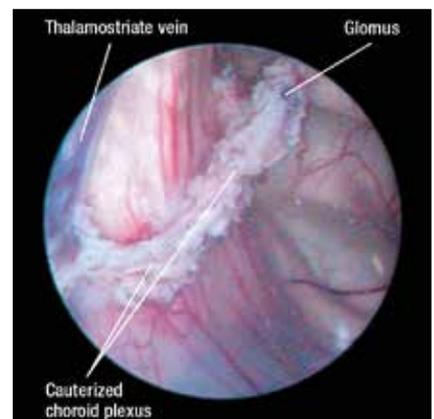
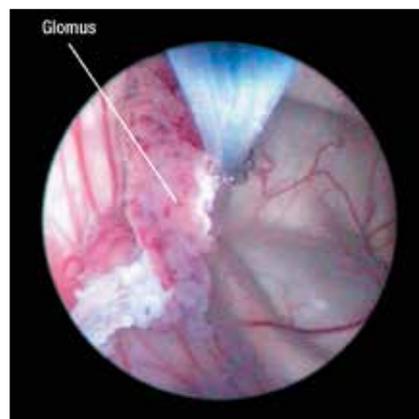
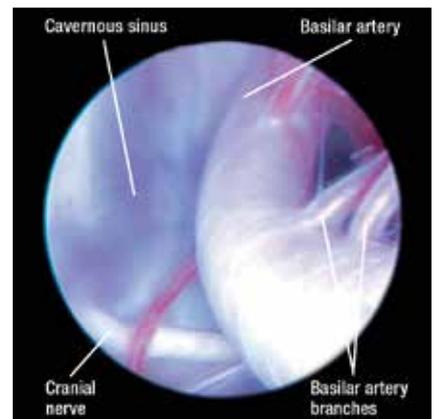
The program trains and equips neurosurgeons responsible for treating hydrocephalus in low and middle-income countries. In that practice context, shunt-dependence carries more risk for children with hydrocephalus because of the high probability of shunt malfunctions over time that require emergency treatment.

Unlike more developed countries where the existing economy, infrastructure, and health care system can readily support the emergency maintenance required for patients who are shunt-dependent, the lives of these patients in less developed countries are threatened because of the lack of prompt access to neurosurgical care.

Experience in Uganda suggests that, in the setting of an emerging country, at least half of all children with hydrocephalus can be adequately treated using endoscopic methods. In young infants, our experience was similar to that of others, in that ETV alone was not effective in avoiding shunt dependency for the majority. But we demonstrated that choroid plexus cauterization in combination with endoscopic third ventriculostomy (ETV/CPC) was extremely effective. The ETV/CPC technique requires the use of a flexible fiberoptic endoscope in order to access the choroid plexus throughout both lateral ventricles.



Malnourished infant with macrocephaly, thin scalp, and prominent scalp veins.

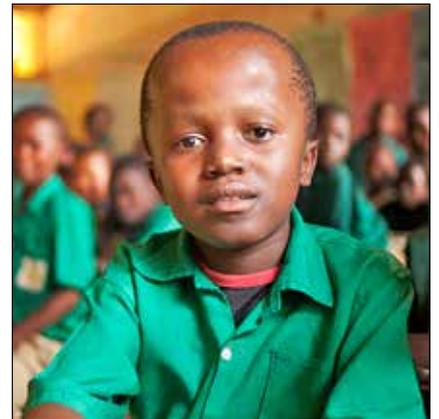


The CURE Children's Hospital in Mbale, Uganda, provides the high volume of patients necessary to master these techniques in a relatively short time.

Because of this, a number of developed world neurosurgeons already experienced in performing ETV have come to CCHU in order to be trained in the ETV/CPC technique, including the pediatric neurosurgeons of the North American Hydrocephalus Clinical Research Network (HCRN) who have begun a multi-site prospective trial of ETV/CPC in North America.

In 2 months of hands-on training at CURE Children's Hospital of Uganda, a CH Fellow can expect to perform 50 to 100 ETV/CPC procedures. The program is directed by Dr. *Benjamin Warf*, who developed the technique. CURE Hydrocephalus provides the Fellow's training and partners with his home institution in the development of a hydrocephalus treatment program. The goal of CH is to facilitate access to optimal evidence-based treatment of hydrocephalus for children around the world through training, collaboration, research, and quality assurance.

For more information go to: [www.curehydrocephalus.org](http://www.curehydrocephalus.org)



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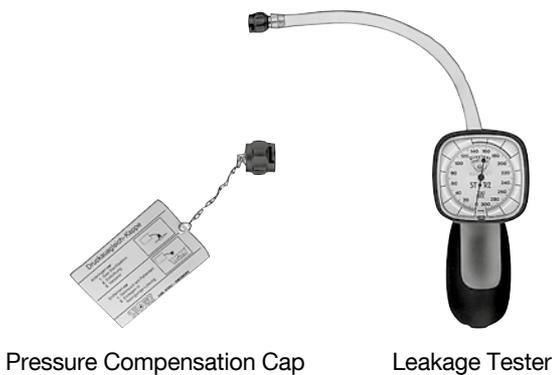
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**Pressure Compensation Cap**  
**Leakage Tester**  
**Cleaning Brush**

11161 AB **Coagulating Electrode**, unipolar, flexible, diameter 1 mm, length 73 cm

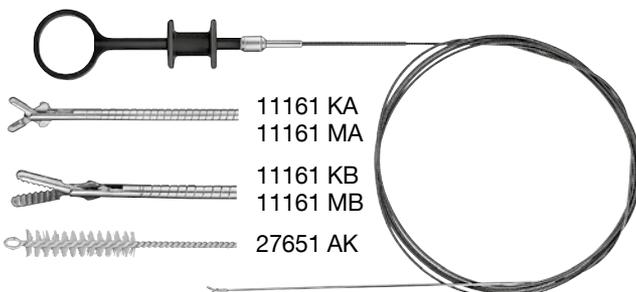
11161 KA **Biopsy Forceps**, flexible, double action jaws, diameter 1 mm, length 60 cm

11161 KB **Grasping Forceps**, flexible, double action jaws, diameter 1 mm, length 60 cm

11161 MA **Biopsy Forceps**, flexible, double action jaws, diameter 1 mm, working length 100 cm

11161 MB **Grasping Forceps**, flexible, double action jaws, diameter 1 mm, working length 100 cm

26002 M **Unipolar High Frequency Cord**, with 4 mm plug for models KARL STORZ, Erbe type T, older models and Ellman, length 300 cm



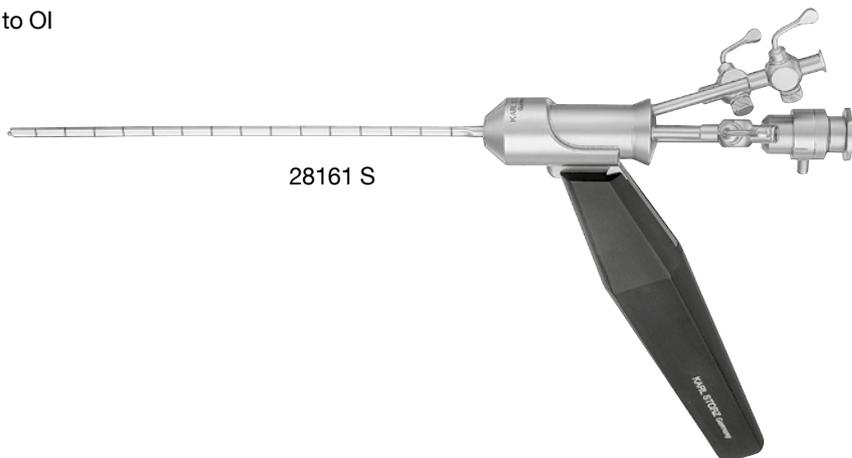
11161 KA  
11161 MA

11161 KB  
11161 MB

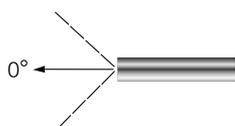
27651 AK

**OI “HandyPro®” Neuro-Endoscope**  
**Operating Sheath, size 2.6 x 4 mm and HOPKINS® Telescopes**

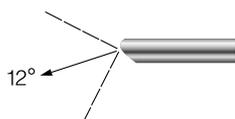
**Recommended Set** acc. to OI



28161 S **OI HandyPro® Neuro-Endoscope**, with removable handle, for free-hand surgical techniques, including:  
**Operating Sheath**, graduated, size 2.6 x 4 mm, working length 15 cm, with three working channels for irrigation/suction and for instruments size 1.3 mm, for use with HOPKINS® Telescopes 28008 AA and 28008 FA  
**Handle**, for Operating Sheath 28161 SS  
**Mandrel**, for Operating Sheath 28161 SS



28008 AA **HOPKINS® Straight Forward Telescope 0°**, enlarged view, diameter 2 mm, length 26 cm, **autoclavable**, fiber optic light transmission incorporated, color code: green



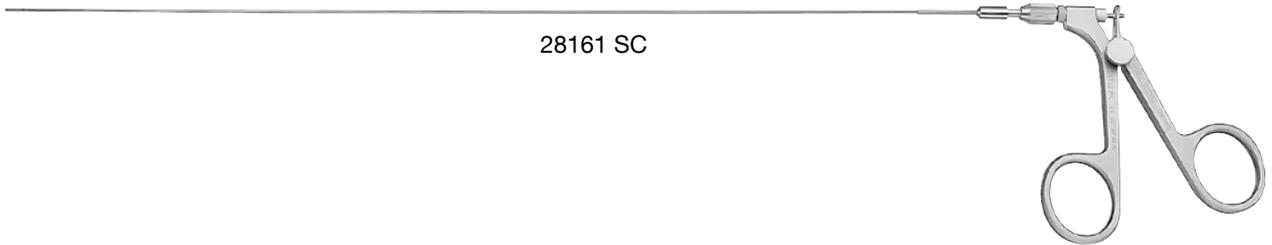
28008 FA **HOPKINS® Telescope 12°**, enlarged view, diameter 2 mm, length 26 cm, **autoclavable**, fiber optic light transmission incorporated, color code: black

**It is recommended to check the suitability of the product for the intended procedure prior to use.**

## OI "HandyPro<sup>®</sup>" Neuro-Endoscope

### Operating instruments, size 1.3 mm – semirigid

Recommended Set acc. to OI



28161 SC



28161 SC **Scissors**, single action jaws,  
diameter 1.3 mm, length 30 cm



28161 SB **Biopsy Forceps**, double action jaws,  
diameter 1.3 mm, length 30 cm



28161 SG **Grasping Forceps**, double action jaws,  
diameter 1.3 mm, length 30 cm



28161 SE **Coagulating Electrode**, unipolar,  
diameter 1.3 mm, length 30 cm



28161 SF **Coagulating Electrode**, bipolar,  
diameter 1.3 mm, length 30 cm



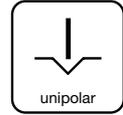
28162 SB **Balloon Catheter**, volume 0.05 ml,  
diameter 0.7 mm, length 40 cm, sterile,  
for single use, package of 10

## Accessories

### Unipolar and Bipolar High Frequency Cords

#### Unipolar High Frequency Cords

KARL STORZ Instrument High Frequency Surgery Units



- |   |         |   |
|---|---------|---|
|  | 26002 M | <b>Unipolar High Frequency Cord,</b><br>with 4 mm plug for models KARL STORZ, Erbe type T, older models and Ellman, length 300 cm   |
|  | 26004 M | <b>Unipolar High Frequency Cord,</b><br>with 4 mm plug for models Berchtold and Martin, length 300 cm   |
|  | 26005 M | <b>Unipolar High Frequency Cord,</b><br>with 5 mm plug for AUTOCON® II 400 SCB system (111, 115, 122, 125), AUTOCON® II 200, AUTOCON® II 80, KARL STORZ AUTOCON® system (50, 200, 350) and Erbe type ICC, length 300 cm |
|  | 26006 M | <b>Unipolar High Frequency Cord,</b><br>with 8 mm plug, length 300 cm, for use with HF units, models KARL STORZ AUTOCON® II 400 SCB (112, 116) and Valleylab  |

#### Bipolar High Frequency Cords

KARL STORZ Instrument High Frequency Surgery Units



- |   |          |   |
|---|----------|---|
|  | 26176 LE | <b>Bipolar High Frequency Cord,</b><br>for AUTOCON® II 400 SCB system (111, 113, 115, 122, 125), AUTOCON® II 200, AUTOCON® II 80, KARL STORZ Coagulator 26021 B/C/D, 860021 B/C/D, 27810 B/C/D, 28810 B/C/D, AUTOCON® series (50, 200, 350), Erbe-Coagulator, T and ICC series, length 300 cm |
|  | 26176 LM | <b>Bipolar High Frequency Cord,</b><br>for Martin and Berchtold coagulators, length 300 cm  |
|  | 26176 L  | <b>Bipolar High Frequency Cord,</b><br>with 2 x 4 mm banana plug for KARL STORZ Coagulator 26020 XA/XB and Ellman, length 300 cm  |
|  | 26176 LA | <b>Bipolar High Frequency Cord,</b><br>with 2 x 4 mm banana plug for KARL STORZ Coagulator 26020 XA/XB and Valleylab, length 300 cm   |
|  | 26176 LV | <b>Bipolar High Frequency Cord,</b><br>for KARL STORZ AUTOCON® II 400 SCB system (112, 114, 116, 122, 125) and Valleylab coagulators, length 300 cm   |

**Please note:** All high frequency cords of this page are delivered with a length of 300 cm. If a length of 500 cm is requested please add letter **L** to the part number, e. g. 26002 **ML**, 26176 **LVL**.

## Plastic Containers for Sterilizing and Storage of Telescopes



39301 B

39301 B

### Plastic Container for Sterilizing and Storage of Telescopes,

perforated, with transparent lid, with silicone telescope holder, external dimensions (w x d x h): 446 x 90 x 45 mm, for 4 mm Cystoscopy Telescopes or 10 mm Laparoscopy Telescopes and similar

including:

**Bottom Part**

**Lid**

**Silicone Telescope Holder**

**Silicone Telescope Holder**

## Plastic Containers <sup>NEW</sup> for Sterilizing and Storage of Variable Instrument Sets

The plastic containers may be used for sterilization with steam, gas and plasma.



39360 AK

39360 AK

### Plastic Container for Sterilizing and Storage of Variable Instrument Sets,

perforated, with transparent lid, with silicone mat, two-level storage, 1 additional insert, external dimensions (w x d x h): 545 x 260 x 115 mm

including:

2x **Snap-in Clip**, package of 12

2x **Silicone Tie-Downs**, package of 12

**Tool**

**Please note:** The instruments displayed are not included in the plastic containers.

# IMAGE 1 SPIES™ Camera System <sup>NEW</sup>



## Economical and future-proof

- Modular concept for flexible, rigid and 3D endoscopy as well as new technologies
- Forward and backward compatibility with video endoscopes and FULL HD camera heads

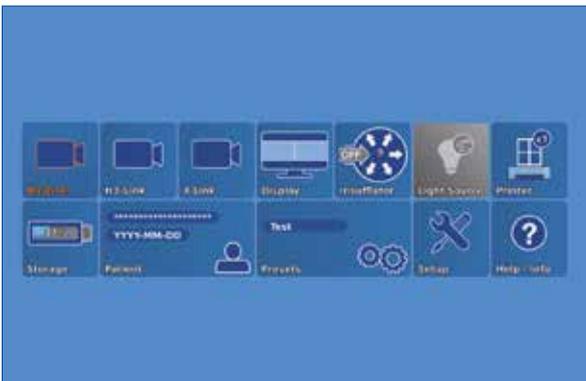
- Sustainable investment
- Compatible with all light sources



## Innovative Design

- Dashboard: Complete overview with intuitive menu guidance
- Live menu: User-friendly and customizable
- Intelligent icons: Graphic representation changes when settings of connected devices or the entire system are adjusted

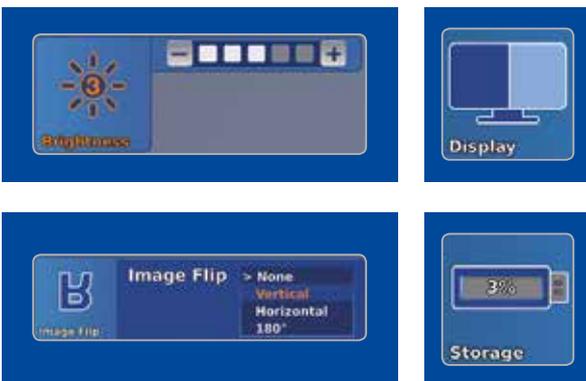
- Automatic light source control
- SPIES™ VIEW: Parallel display of standard image and the SPIES™ mode
- Multiple source control: IMAGE 1 SPIES™ allows the simultaneous display, processing and documentation of image information from two connected image sources, e.g., for hybrid operations



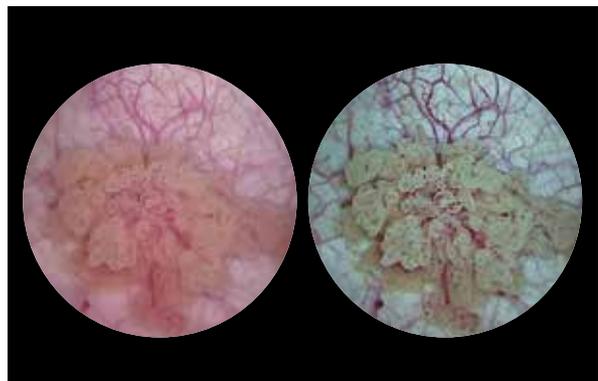
Dashboard



Live menu



Intelligent icons



SPIES™ VIEW: Parallel display of standard image and SPIES™ mode

## IMAGE 1 SPIES™ Camera System <sup>NEW</sup>



### Brilliant Imaging

- Clear and razor-sharp endoscopic images in FULL HD
- Natural color rendition
- Reflection is minimized
- Three SPIES™ technologies for homogeneous illumination, contrast enhancement and color shifting



FULL HD image



SPIES™ CLARA



FULL HD image



SPIES™ CHROMA



FULL HD image



SPIES™ SPECTRA A



FULL HD image



SPIES™ SPECTRA B

# IMAGE 1 SPIES™ Camera System <sup>NEW</sup>



TC 200EN

TC 200EN\* **IMAGE 1 CONNECT™**, connect module, for use with up to 3 link modules, resolution 1920 x 1080 pixels, with integrated KARL STORZ-SCB and digital Image Processing Module, power supply 100 – 120 VAC/200 – 240 VAC, 50/60 Hz including:  
**Mains Cord**, length 300 cm  
**DVI-D Connecting Cable**, length 300 cm  
**SCB Connecting Cable**, length 100 cm  
**USB Flash Drive**, 32 GB, USB silicone keyboard, with touchpad, US  
 \* Available in the following languages: DE, ES, FR, IT, PT, RU

**Specifications:**

HD video outputs	- 2x DVI-D - 1x 3G-SDI	Power supply	100 – 120 VAC/200 – 240 VAC
Format signal outputs	1920 x 1080p, 50/60 Hz	Power frequency	50/60 Hz
LINK video inputs	3x	Protection class	I, CF-Defib
USB interface	4x USB, (2x front, 2x rear)	Dimensions w x h x d	305 x 54 x 320 mm
SCB interface	2x 6-pin mini-DIN	Weight	2.1 kg

**For use with IMAGE 1 SPIES™  
IMAGE 1 CONNECT™ Module TC 200EN**



TC 300

TC 300 **IMAGE 1 H3-LINK™**, link module, for use with IMAGE 1 FULL HD three-chip camera heads, power supply 100 – 120 VAC/200 – 240 VAC, 50/60 Hz, **for use with IMAGE 1 CONNECT™ TC 200EN** including:  
**Mains Cord**, length 300 cm  
**Link Cable**, length 20 cm

**Specifications:**

<b>Camera System</b>	<b>TC 300 (H3-Link)</b>
Supported camera heads/video endoscopes	TH 100, TH 101, TH 102, TH 103, TH 104, TH 106 (fully SPIES™-compatible)  <b>22220055-3, 22220056-3, 22220053-3, 22220060-3, 22220061-3, 22220054-3, 22220085-3</b> (compatible without SPIES™ function)
LINK video outputs	1x
Power supply	100 – 120 VAC/200 – 240 VAC
Power frequency	50/60 Hz
Protection class	I, CF-Defib
Dimensions w x h x d	305 x 54 x 320 mm
Weight	1.86 kg

## IMAGE 1 SPIES™ Camera Heads <sup>NEW</sup>



For use with IMAGE 1 SPIES™ camera system  
**IMAGE 1 CONNECT™ Module TC 200EN, IMAGE 1 H3-LINK™ Module TC 300**  
 and with all IMAGE 1 HUB™ HD Camera Control Units



TH 100

TH 100

**IMAGE 1 H3-Z SPIES™ Three-Chip FULL HD Camera Head,** 50/60 Hz, SPIES™ compatible, progressive scan, soakable, gas- and plasma-sterilizable, with integrated Parfocal Zoom Lens, focal length  $f = 15 - 31$  mm (2x), 2 freely programmable camera head buttons, for use with IMAGE 1 SPIES™ and IMAGE 1 HUB™ HD/HD

### Specifications:

IMAGE 1 FULL HD Camera Heads	H3-Z SPIES™
Product no.	TH 100
Image sensor	3x 1/3" CCD chip
Dimensions w x h x d	39 x 49 x 114 mm
Weight	270 g
Optical interface	integrated Parfocal Zoom Lens, $f = 15-31$ mm (2x)
Min. sensitivity	F 1.4/1.17 Lux
Grip mechanism	standard eyepiece adaptor
Cable	non-detachable
Cable length	300 cm



TH 104

TH 104

**IMAGE 1 H3-ZA SPIES™ Three-Chip FULL HD Camera Head,** 50/60 Hz, SPIES™ compatible, **autoclavable**, progressive scan, soakable, gas- and plasma-sterilizable, with integrated Parfocal Zoom Lens, focal length  $f = 15 - 31$  mm (2x), 2 freely programmable camera head buttons, for use with IMAGE 1 SPIES™ and IMAGE 1 HUB™ HD/HD

### Specifications:

IMAGE 1 FULL HD Camera Heads	H3-ZA SPIES™
Product no.	TH 104
Image sensor	3x 1/3" CCD chip
Dimensions w x h x d	39 x 49 x 100 mm
Weight	299 g
Optical interface	integrated Parfocal Zoom Lens, $f = 15-31$ mm
Min. sensitivity	F 1.4/1.17 Lux
Grip mechanism	standard eyepiece adaptor
Cable	non-detachable
Cable length	300 cm

## Monitors



9619 NB

9619 NB

**19" HD Monitor,**  
color systems **PAL/NTSC**, max. screen resolution 1280 x 1024, image format 4:3, power supply 100 – 240 VAC, 50/60 Hz, wall-mounted with VESA 100 adaption, including:  
**External 24 VDC Power Supply**  
**Mains Cord**



9826 NB

9826 NB

**26" FULL HD Monitor,**  
wall-mounted with VESA 100 adaption, color systems **PAL/NTSC**, max. screen resolution 1920 x 1080, image format 16:9, power supply 100 – 240 VAC, 50/60 Hz including:  
**External 24 VDC Power Supply**  
**Mains Cord**



9627 NB/NB-2

9627 NB

**27" FULL HD Monitor,**  
wall-mounted with VESA 100 adaption, color systems **PAL/NTSC**, max. screen resolution 1920 x 1080, image format 16:9, power supply 85 – 265 VAC, 50/60 Hz including:  
**External 24 VDC Power Supply**  
**Mains Cord**

9627 NB-2

**Same,** with double video inputs

## Monitors

KARL STORZ HD and FULL HD Monitors	19"	26"	27"	
Wall-mounted with VESA 100 adaption	9619 NB	9826 NB	9627 NB	9627 NB-2
<b>Inputs:</b>				
DVI-D	●	●	●	●●
Fibre Optic	-	-	optional	optional
3G-SDI	-	●	-	optional
RGBS (VGA)	●	●	●	●●
S-Video	●	●	●	●●
Composite/FBAS	●	●	●	●●
<b>Outputs:</b>				
DVI-D	●	●	●	●
S-Video	●	-	●	●
Composite/FBAS	●	●	●	●
RGBS (VGA)	●	-	-	-
3G-SDI	-	●	-	optional
<b>Signal Format Display:</b>				
4:3	●	●	●	●
5:4	●	●	●	●
16:9	●	●	●	●
Picture-in-Picture	●	●	●	●
PAL/NTSC compatible	●	●	●	●

### Optional accessories:

9826 SF      **Pedestal**, for monitor 9826 NB

9626 SF      **Pedestal**, for 96xx monitor series

### Specifications:

KARL STORZ HD and FULL HD Monitors	19"	26"	27"
Desktop with pedestal	optional	optional	optional
Product no.	9619 NB	9826 NB	9627 NB/NB-2
Brightness	200 cd/m <sup>2</sup> (typ)	500 cd/m <sup>2</sup> (typ)	240 cd/m <sup>2</sup> (typ)
Max. viewing angle	178° vertical	178° vertical	178° vertical
Pixel distance	0.29 mm	0.3 mm	0.3 mm
Reaction time	5 ms	8 ms	12 ms
Contrast ratio	700:1	1400:1	3000:1
Mount	100 mm VESA	100 mm VESA	100 mm VESA
Weight	7.6 kg	7.7 kg	9.8 kg
Rated power	28 W	72 W	45 W
Operating conditions	0–40°C	5–35°C	5–35°C
Storage	-20–60°C	-20–60°C	-20–60°C
Rel. humidity	max. 85%	max. 85%	max. 85%
Dimensions w x h x d	469.5 x 416 x 75.5 mm	643 x 396 x 87 mm	776 x 443 x 114 mm
Power supply	100–240 VAC	100–240 VAC	85–265 VAC
Certified to	EN 60601-1, protection class IPX0	EN 60601-1, UL 60601-1, MDD93/42/EEC, protection class IPX2	EN 60601-1, UL 60601-1, MDD93/42/EEC, protection class IPX2

**Accessories for Video Documentation**  
**Fiber Optic Light Cable and Cold Light Fountains**



495 NA

**Fiber Optic Light Cable,**  
 with straight connector,  
 diameter 3.5 mm, length 230 cm

**Cold Light Fountain XENON 300 SCB**



20133101-1 **Cold Light Fountain XENON 300 SCB**  
 with built-in antifog air-pump, and integrated  
 KARL STORZ Communication Bus System SCB  
 power supply:  
 100–125 VAC/220–240 VAC, 50/60 Hz  
 including:

**Mains Cord**

**SCB Connecting Cable,** length 100 cm

20133027 **Spare Lamp Module XENON**  
 with heat sink, 300 watt, 15 volt

20133028 **XENON Spare Lamp,** only,  
 300 watt, 15 volt

**Cold Light Fountain XENON NOVA® 175**



20131501 **Cold Light Fountain XENON NOVA® 175,**  
 power supply:  
 100–125 VAC/220–240 VAC, 50/60 Hz  
 including:

**Mains Cord**

20132026 **XENON Spare Lamp,**  
 175 watt, 15 volt

## Data Management and Documentation

### KARL STORZ AIDA® – Exceptional documentation



The name AIDA stands for the comprehensive implementation of all documentation requirements arising in surgical procedures: A tailored solution that flexibly adapts to the needs of every specialty and thereby allows for the greatest degree of customization.

This customization is achieved in accordance with existing clinical standards to guarantee a reliable and safe solution. Proven functionalities merge with the latest trends and developments in medicine to create a fully new documentation experience – AIDA.

AIDA seamlessly integrates into existing infrastructures and exchanges data with other systems using common standard interfaces.



WD 200-XX\* **AIDA Documentation System**,  
for recording still images and videos,  
dual channel up to FULL HD, 2D/3D,  
power supply 100-240 VAC, 50/60 Hz  
including:

**USB Silicone Keyboard**, with touchpad  
**ACC Connecting Cable**  
**DVI Connecting Cable**, length 200 cm  
**HDMI-DVI Cable**, length 200 cm  
**Mains Cord**, length 300 cm



WD 250-XX\* **AIDA Documentation System**,  
for recording still images and videos,  
dual channel up to FULL HD, 2D/3D,  
**including SMARTSCREEN® (touch screen)**,  
power supply 100-240 VAC, 50/60 Hz  
including:

**USB Silicone Keyboard**, with touchpad  
**ACC Connecting Cable**  
**DVI Connecting Cable**, length 200 cm  
**HDMI-DVI Cable**, length 200 cm  
**Mains Cord**, length 300 cm

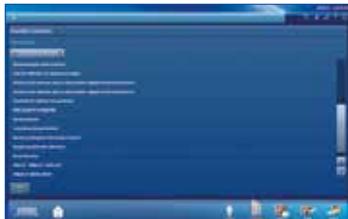
\*XX Please indicate the relevant country code  
(DE, EN, ES, FR, IT, PT, RU) when placing your order.

## Workflow-oriented use



### Patient

Entering patient data has never been this easy. AIDA seamlessly integrates into the existing infrastructure such as HIS and PACS. Data can be entered manually or via a DICOM worklist. All important patient information is just a click away.



### Checklist

Central administration and documentation of time-out. The checklist simplifies the documentation of all critical steps in accordance with clinical standards. All checklists can be adapted to individual needs for sustainably increasing patient safety.



### Record

High-quality documentation, with still images and videos being recorded in FULL HD and 3D. The Dual Capture function allows for the parallel (synchronous or independent) recording of two sources. All recorded media can be marked for further processing with just one click.



### Edit

With the Edit module, simple adjustments to recorded still images and videos can be very rapidly completed. Recordings can be quickly optimized and then directly placed in the report. In addition, freeze frames can be cut out of videos and edited and saved. Existing markings from the Record module can be used for quick selection.



### Complete

Completing a procedure has never been easier. AIDA offers a large selection of storage locations. The data exported to each storage location can be defined. The Intelligent Export Manager (IEM) then carries out the export in the background. To prevent data loss, the system keeps the data until they have been successfully exported.



### Reference

All important patient information is always available and easy to access. Completed procedures including all information, still images, videos, and the checklist report can be easily retrieved from the Reference module.

## Units and Accessories

High Frequency Electrosurgical Generator AUTOCON® II 200, Type A  
Suction and Irrigation System ENDOMAT® LC

### AUTOCON® II 200 Type A, High Frequency Electrosurgical Generator



- 20532501 **AUTOCON® II 200, Type A High Frequency Electrosurgical Generator**, power supply: 220–240 VAC, 50/60 Hz, including:  
**AUTOCON® II 200, Type A Mains Cord**  
**Adaptor** for unipolar HF-output diameter 4 mm/5 mm
- 20532501-1 **AUTOCON® II 200 SCB Type A** power supply: 100–120 VAC, 50/60 Hz, including:  
**AUTOCON® II 200 SCB Type A Mains Cord**  
**SCB Connecting Cable**, length 100 cm

**Subject to the needs of the customer, additional accessories must be ordered and acquired separately.**

## ENDOMAT® LC

Suction and Irrigation System



- 203303 01-1 **ENDOMAT® LC Set, Suction and Irrigation System**, power supply: 100–240 VAC, 50/60 Hz, including:  
**Endomat LC Mains Cord**  
**Silicone Tubing Set** for irrigation, sterilizable  
**Silicone Tubing Set** for suction, sterilizable  
**SCB Connecting Cable**, length 100 cm

**Subject to the needs of the customer, additional accessories must be ordered and acquired separately.**

## Equipment Cart



UG 220

### Equipment Cart

wide, high, rides on 4 antistatic dual wheels equipped with locking brakes 3 shelves, mains switch on top cover, central beam with integrated electrical subdistributors with 12 sockets, holder for power supplies, potential earth connectors and cable winding on the outside,

*Dimensions:*

*Equipment cart: 830 x 1474 x 730 mm (w x h x d),*

*shelf: 630 x 510 mm (w x d),*

*caster diameter: 150 mm*

including:

**Base module equipment cart,** wide

**Cover equipment,** equipment cart wide

**Beam package equipment,** equipment cart high

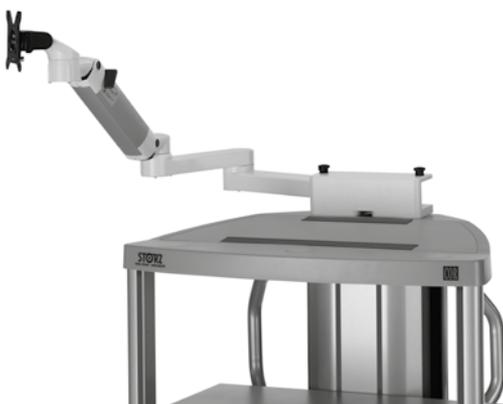
3x **Shelf,** wide

**Drawer unit with lock,** wide

2x **Equipment rail,** long

**Camera holder**

UG 220



UG 540

### Monitor Swivel Arm,

height and side adjustable, can be turned to the left or the right side, swivel range 180°, overhang 780 mm, overhang from centre 1170 mm, load capacity max. 15 kg, with monitor fixation VESA 5/100, for usage with equipment carts UG xxx

UG 540

## Recommended Accessories for Equipment Cart



UG 310

UG 310

### Isolation Transformer,

200 V–240 V; 2000 VA with 3 special mains socket, expulsion fuses, 3 grounding plugs, dimensions: 330 x 90 x 495 mm (w x h x d), for usage with equipment carts UG xxx



UG 410

UG 410

### Earth Leakage Monitor,

200 V–240 V, for mounting at equipment cart, control panel dimensions: 44 x 80 x 29 mm (w x h x d), for usage with isolation transformer UG 310



UG 510

UG 510

### Monitor Holding Arm,

height adjustable, inclinable, mountable on left or right, turning radius approx. 320°, overhang 530 mm, load capacity max. 15 kg, monitor fixation VESA 75/100, for usage with equipment carts UG xxx

**Notes:**

**Notes:**