CSF shunting procedures

Last updated: February 5, 2026

SHUNT TIE-OFF

- use thick silk.
- place sleeve of rubber (e.g. opened rubber shod) on catheter – if later will need to untie, will cut on rubber and not on catheter.

VENTRICULOPERITONEAL (VP) SHUNT

RESOURCES

R. **Jandial** "Core Techniques in Operative Neurosurgery" (2011)

Pending read: Connolly ch. 118-121, 123
Karl Storz NeuroEndoscopes and Instruments >>

INDICATIONS

1. Hydrocephalus, communicating or obstructive:
    a) not amenable to endoscopic third ventriculostomy
    b) not amenable to treatment of primary etiology (e.g. removal of 4th ventricle neoplasm).
2. Failure of previously placed shunt system

CONTRAINDICATIONS

1. Fevers
2. Any evidence of active intracranial infection
3. Abnormal CSF rheology (pleocytosis, intraventricular hemorrhage or SAH with still bloody CSF)
    N.B. high protein (e.g. > 100) does not affect shunt performance!
4. Body weight < 2 kg (relative)
5. Peritoneal cavity with reduced absorptive capacity (e.g. multiple operations, recent abdominal sepsis, known malabsorptive peritoneal cavity).

SPECIAL SITUATIONS

GASTROSTOMY

Khalid, Syed et al. Gastrostomy Sequence With Ventriculoperitoneal Shunting—Does It Matter? Neurosurgery 93(5):p 1154-1159, November 2023

- if patient will also need gastrostomy, best to place shunt concurrently or after gastrostomy (lower infection rate):
    - revision rates at 30 months were significantly lower among patients who received VPS and gastrostomy procedures on the same day compared with gastrostomy after VPS (odds ratio [OR] 0.61, 95% CI 0.39-0.96).
    - patients who received gastrostomy before VPS compared with those after had lower revision rates (OR 0.61, 95% CI 0.39-0.96) and infection (OR 0.46, 95% CI 0.21-0.99).
    - no significant differences were noted in mechanical complication or shunt displacement rates.

PREOPERATIVE

1. Check CSF (protein content, pleocytosis, infection)
2. Clamp EVD at midnight to expand ventricles (for pediatric / critical patient may raise EVD instead of clamping)
3. Recent CT / MRI for navigation

EQUIPMENT FOR OR

Valve and programming device
Catheters
Manometer
for optional verification: X-ray (for air ventriculogram) / ventricular endoscope / O-arm
C-arm – for finding old catheters (in revision cases).
Laparoscopic tower

PROCEDURE

POSITIONING

- supine with **head turned** to left.
- JRC - **bump under shoulders** (Holloway – only for kids – large head) to allow for straight trajectory from right occiput, across clavicle, to abdomen.
- Tye, Collins place large bump under shoulders to get good neck extension; Collins covers entire prep zone perimeter with self-adhesive clear plastic drape "3M 1010" (keeps patient dry and warm – allows to keep lower temperature in OR and keep sheets dry)

Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

PREP

- Ritter uses alcohol → Betadine → ChloraPrep.
  Ritter may not use local anesthetic to prevent introducing skin flora.
- Tye uses Betadine for kids < 2 months.
- remove EVD (unless doing soft pass or on opposite side – may leave EVD until end of case – remove all stitches, pull EVD a little bit until you see sterile part and tie long silk string on it; drop silk down so that anesthesia can pull it in the middle of case; prep and drape so that catheter is hidden).
- Tye does not use staples to keep drapes! Collins uses lots of staples. Ritter uses few staples.

CRANIAL PORTION

- curvilinear (horseshoe or C*) scalp **incision** over planned bur hole; very little horseshoe radius for infants; Ritter creates opposite direction horseshoe flap in pericranium.
- with knife/needle electrocautery; may incorporate EVD incision (unless infected).
  *base towards shunt direction
  N.B. use shallow C (complete C is suboptimal for blood supply)

Entry and trajectory

Frontal – see p. Op6 >>
Parieto-occipital – see p. Op6 >>

Dr. Day:
1) use stylet always; *never soft pass* (catheter easily gets deflected).
2) use **bur-hole ultrasound** to guide the catheter!

Frontal vs Parieto-occipital

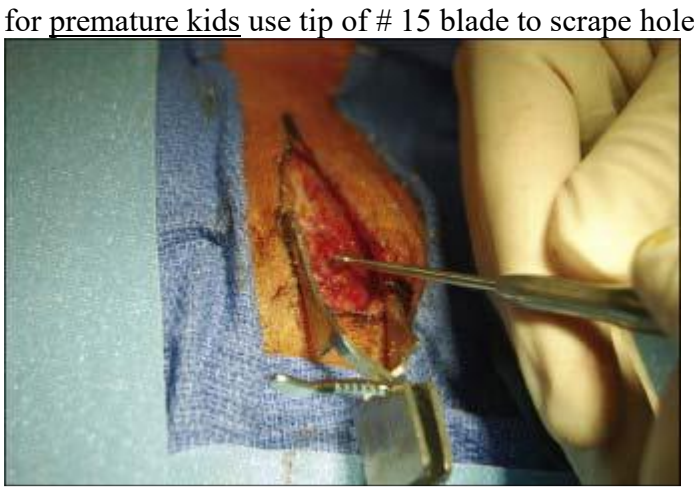
Effect of cranial entry site on the rate of proximal catheter misplacement in ventriculoperitoneal shunt insertion. Florian Ebel et al. JNS: 10 May 2024

- 539 consecutive patients, 55.8% were in the frontal group Kocher's point) and 44.2% in the parietal group (Keen's point).
- groups were comparable (frontal vs parietal):
  - revision surgery due to **misplacement** (4.7% vs parietal 4.6%, p = 0.987).
  - revision surgery for **VPS dysfunction** (4.7% vs 4.2%, p = 0.802).
  - **infection** (7.3% vs 4.2%, p = 0.13).
  - **functional outcomes** (mRS score ≤ 2) (76.3% vs 79.5%, p = 0.058).
  - **early mortality** (1.7% vs 2.5%, p = 0.483).

Bur hole:

a) with 14 mm perforator (Young saves bone dust and replaces back to bur hole at the end)
b) with M8 bit – better small hole, esp. for little kids to prevent CSF leak (Ritter)

- for newborns, insert shunt via lateral corner of open anterior fontanel:
  a) Tye – coagulate soft tissue membrane with bipolar layer by layer until entering CSF space
  b) Collins – incise scalp skin over mosquito (advanced under galea), then open dural membrane by gentle incision with #15 blade.
- for premature kids use tip of # 15 blade to scrape hole in cranium.



Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

Valve

- create subcutaneous pocket with blunt dissection (spreading tonsillar clamp or large Kelly clamp) to accommodate reservoir and valve.
- pump valve in saline bucket so no air inside remains (vs. Tye connects temporary short piece of catheter on proximal valve to protect from blood entry into valve and flushes with saline via blunt needle in catheter tip).
- inline valve is secured (with silk tie*) to proximal end of distal catheter.
  - Tye, JRC, Holloway like fixed medium-low pressure Codman valve (without Rickham)
  - Graham uses exclusively Medtronic (Codman has spiral antisiphon device that clogs very often)
  - for NPH patients use programmable valves

*knot on undersurface of valve to prevent skin erosion

Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

- small hole in dura, same diameter as ventricular catheter, is made by electrocautery applied to blunt needle.
- antibiotic-impregnated Bactiseal ventricular catheter is cut* to age-appropriate length and passed over stylet into right lateral ventricle

*JRC, Holloway leave catheter intact but move blue angle bender to 6 cm mark

  - "perpendicular to skull" catheter trajectory usually results in prompt entry into ventricle, and if catheter is advanced while removing stylet, tip of catheter heads toward frontal horn.
  - intraoperative US/CT/MRI, intracatheter endoscopy (Neuropen®; need to make slits in catheter tip beforehand), frameless stereotaxy can be useful adjuncts for ventricles that are difficult to cannulate.
  - ventricular cannulation failure:
    a) admit to ICU with hope of progressive ventricular dilation → reoperation
    b) if patient's life is in jeopardy, place shunt in CT scanner suite (or use O-arm)
- always send CSF for culture ± other studies (e.g. cytology).
- Young measures opening pressure with saline-filled **manometer**.
- may flush and aspirate valve chamber with **25G needle**.
- Young injects 4-5 mL of air inside ventricles (for air ventriculogram in PACU or in OR).
- ventricular catheter is (cut and) secured* to valve, and valve is placed in previously created subcutaneous scalp pocket.

*never secure ventricular catheter to valve unless CSF is clear (H: gentle irrigation through catheter can resolve issues with blood or debris in ventricular catheter).

Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

N.B. for difficult anatomy / revisions for malpositions – consider intraop verification (air ventriculogram, endoscope, or O-arm).

TUNNELING

- subcutaneous tunneler* (with plastic stylet within) is passed from cranial to abdominal incision (or opposite - JRC, Tye – much easier to negotiate tissues).

*alternatively, create path and pocket with tonsillar forceps / uterine sound

  - may need additional incision in neck (most attendings prefer transverse [less chances violating shunt tubing when closing with staples] incision right above tunneler tip) – then use uterine sound from scalp incision to neck incision → tie catheter tip with thick silk to probe and pass to scalp.
  - Dr. Tye tries to tunnel as posterior from auricle as possible for small kids.
  - Dr. Collins uses nondisposable long metal tunneler (very stiff – allows long tunnels and tip steering) with plastic sheath over it.
- antibiotic-impregnated Bactiseal distal catheter is passed through tunneler (may continuously spray saline into tunneler lumen to facilitate passage), and tunneler is removed.

Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

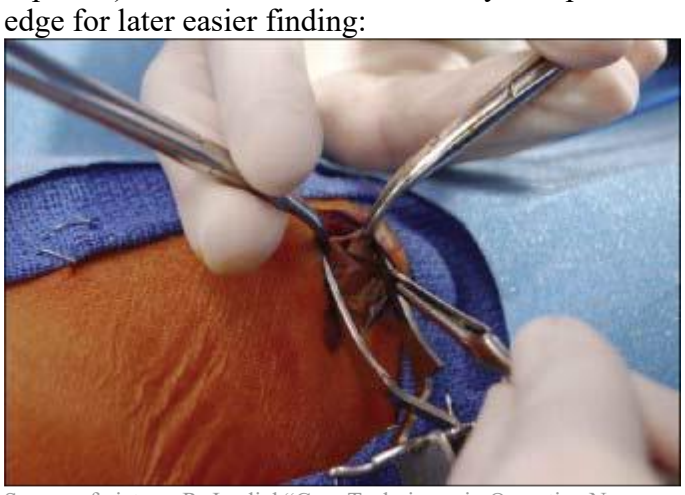
- if SHUNT ASSISTANT is needed, it is placed at postauricular incision level (tie silk on catheter to mark location, then pull catheter to scalp incision, place SHUNT ASSISTANT and pull catheter back into position – SHUNT ASSISTANT must be vertical in position).

SHUNT ASSISTANT prevents oversiphoning thus must be selected according to patient's height

- after confirmation of **steady* CSF egress** from distal catheter, catheter is fed into peritoneal cavity under direct vision.
  *do not implant peritoneal catheter unless continuous CSF egress is observed.
  Correctable issues:
  1) "air blocks" in tubing (H: aspirate with blunt tip needle from distal end).
  2) "kinking" of distal tubing at level of attachment to valve in insufficiently capacious subcutaneous scalp pocket (H: never push valve in, rather pull on distal catheter end distally to advance valve into pocket).

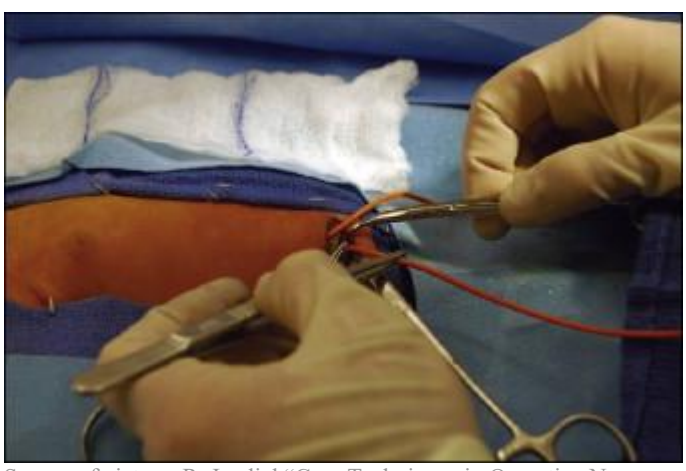
ABDOMINAL PORTION

- aim to place behind falciform ligament, between liver and diaphragm (do not place around omentum → high risk of distal obstruction).
- probably best – laparoscopically.
- if open, make incision:
  - Tye, Young - horizontal incision close to midline in right mid-abdomen → cricket retractor → cut anterior rectus sheath vertically and split muscle fibers bluntly longitudinally → see peritoneum
  - Ritter - vertical incision in right mid-abdomen with needle electrocautery.
  - JRC, Broaddus – 4-5 cm midline* incision 2 finger breadths below xiphoid: large Weitlaner → linea alba (where fascial fibers cross) incised sharply → two perpendicular (to each other and to the floor) small Weitlaners → see peritoneum
    *muscle fiber division is minimized!
- peritoneum is gently elevated with mosquito clamps and incised with No. 11 blade; avoid bowel injury (insert tip of scissors under peritoneum fold before cutting to make sure no bowel is captured); visual confirmation of entry into peritoneal cavity is made; leave mosquito on fascial edge for later easier finding:



Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

- last step – verify CSF flow (so everything proximally is OK).



Source of picture: R. Jandial "Core Techniques in Operative Neurosurgery: Expert Consult - Online and Print", 1st ed (2011), Saunders; ISBN-13: 978-1437709070 >>

- place redundant tubing into abdomen to allow for future child growth (may trim tubing in adults)

Dr. Collins uses trocar technique:
- stab incision with #15 blade (for obese adults may need longer incision).
- use special trocar (**Codman disposable split trocar** – has C shape in cross-section; make sure plastic stylet is locked in place at the end) – advance through subcutis, Scarpa, until feel gritty – it is abdominal muscle aponeurosis; direct trocar cranially and pressing on it down direct it caudally (this way aponeurosis is made taught – it is attached to rib cage) and pop through aponeurosis; continue pressure down (anesthesia gives Valsalva) and pop two more times – get inside peritoneum.
- verify inside peritoneum – saline syringe inject easily in and nothing comes back; plus, catheter is inserted easily without resistance.
- insert catheter (make sure trocar is rotated so C opening faces cranially).
- advance catheter through trocar with DeBakey forceps.

N.B. if there is any *concern regarding placement of peritoneal tubing* (i.e., morbidly obese patient, history of laparotomy and excessive scarring), obtain **KUB** before patient leaves OR.

To minimize infection rate:
- surgical sponges should be avoided
- create pericranial flap over bur hole.
- implants should not be opened from sterile packaging until immediately before use.
- implants should be handled with surgical instruments using "no touch" technique.
- extraneous room traffic should be minimized.
- expedite surgical time from incision to closure.
- keep catheters wrapped in the gauze with bacitracin solution.
- inject antibiotics ("shunt meds" – vancomycin + tobramycin) into tubing.
- vancomycin powder into wound.

Laparoscopy advantages
1) smaller abdominal incision → lower incidence of both wound dehiscence/infection and incisional hernia, decreasing postoperative pain and length of hospital stay.
2) release of focal adhesions
3) direct visual confirmation of distal catheter placement.

Laparoscopic-Assisted Versus Mini-Open Laparotomy

Syed I. Khalid et al. Laparoscopic-Assisted Versus Mini-Open Laparotomy for Ventriculoperitoneal Shunt Placement in the Medicare Population. Neurosurgery 88:812–818, 2021

- 1966 (3.2%) patients underwent laparoscopic-assisted VPS and 60 030 (96.8%) patients underwent non-laparoscopic-assisted VPS placement – Medicare population over 10 years (2004-2014).
- laparoscopic approach was associated with decreased odds of distal revision at 6- and 12-mo postoperatively (6 mo: OR = 0.41, 95% CI: 0.21-0.74; 12 mo: OR = 0.60, 95% CI: 0.39-0.94).
- at 6- and 12-mo postoperatively, multivariable regression analysis demonstrated increased odds of **distal revision** in patients with a BMI > 30 kg/m2, history of open abdominal surgery, and history of laparoscopic abdominal surgery.

— history of prior abdominal surgery and BMI > 30 kg/m2 were significantly associated with increase odds of **shunt infection** at 6 and 12-mo, respectively.

CLOSURE

- may inject "shunt meds" into valve reservoir using 25G needle: 10 mg of VANCOMYCIN + 4 mg of TOBRAMYCIN solution.
- **abdominal incision** – close peritoneum, fascia, subcutaneous layer, skin.
- **scalp** – close galea, skin.
  - — use running 4-0 Monocryl for scalp and neck incision with ± Dermabond* on top.
    N.B. nonabsorbable monofilament simple running suture to skin minimizes wound breakdown and CSF-cutaneous fistulas, particularly in active child.
  - — poor alternative: use staples for scalp and neck incision.

*Ritter never places Dermabond on scalp!!!!!!!!

N.B. if placing shunt because of unable to wean EVD, pull EVD now but think twice – if patient was ***very sensitive to EVD clamping*** during wean trial (or if ***ventricles dilate significantly even at low level of EVD drainage***), may leave EVD catheter in and clamped and watch patient postop – EVD will work as a safety valve and can be pulled on POD1-2 after postop CT shows good position and no ventricle increase; may also think of installing Rickham reservoir at bur hole (will allow to aspirate CSF and flush with alteplase if system clots off).

REVISION CASES

See below >>

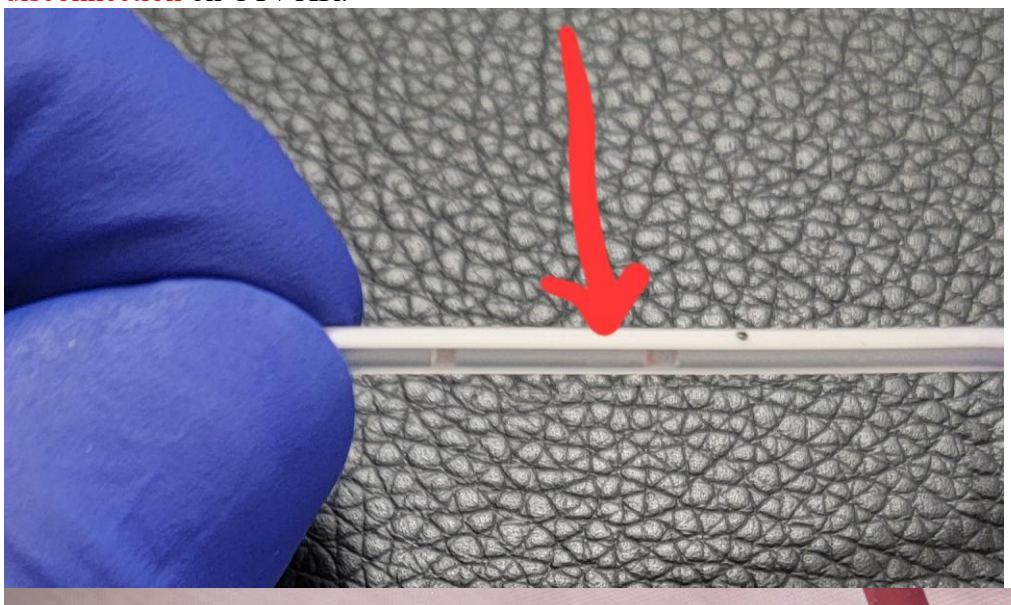
POSTOPERATIVE

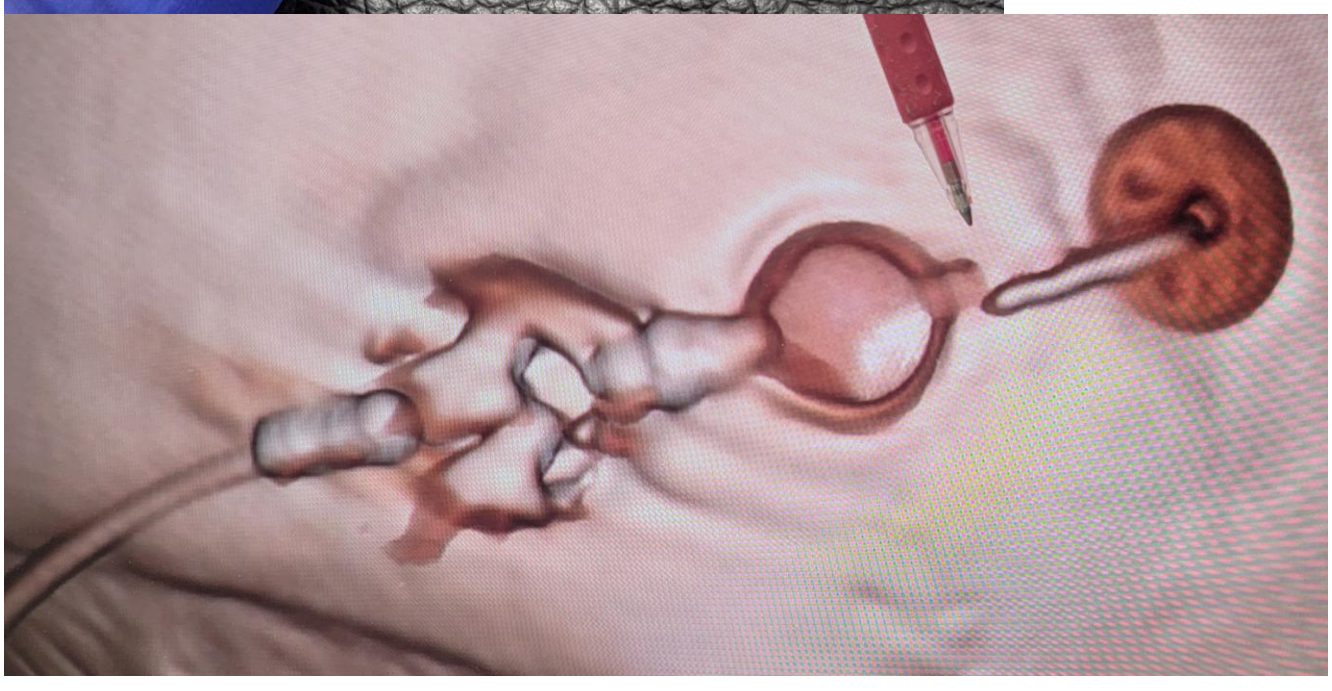
- next day:
  1) **head CT** (Ritter*, JRC do not use it) or head US
     *it takes 3-4 months for ventricles to equilibrate to new true baseline size
  2) **plain radiographs of entire hardware system s. shunt series** (Tye does not use it – "if you have concerns, do intraop fluoroscopy"; Ritter may not use as well) - confirm good position + baseline for future.

- wounds should remain dry for at least 3 days postoperatively, until epithelialization has occurred.
- monitor children every 6-12 months:
  1) ***head growth*** in infants (occipitofrontal head circumference)
  2) detailed ***funduscopy***
  3) ***distal tubing length*** (with plain radiographs) when child grows.
  4) ***neuropsychological testing*** or ***developmental assessment*** (in younger children)
- although some children cease to need shunt as they become older, determination of this is difficult, thus *shunts are rarely removed*.

CATHETERS

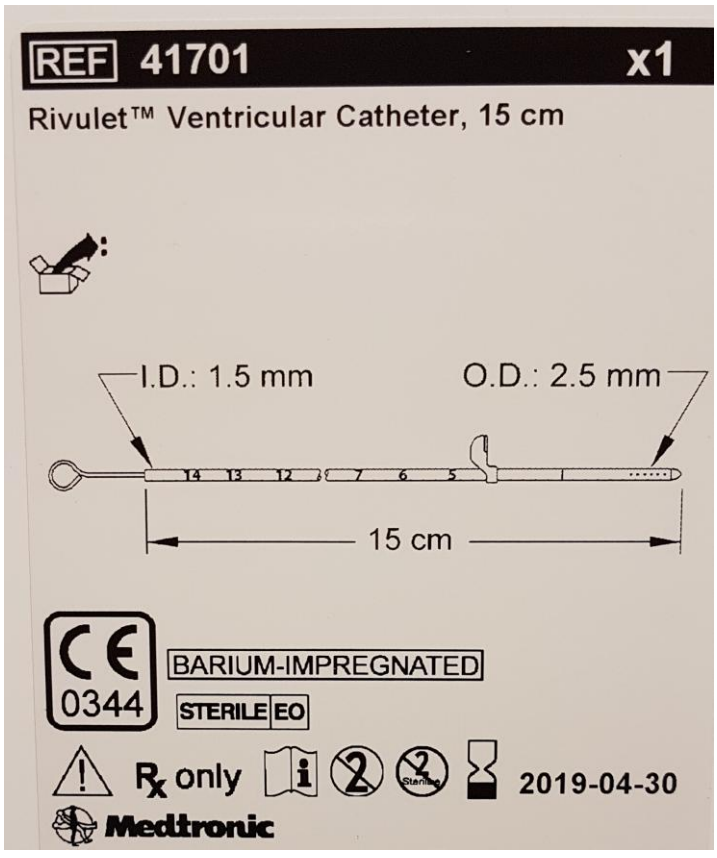
Careful – some catheters have radiopaque strip on one side that can give false impression of disconnection on CT / XR:

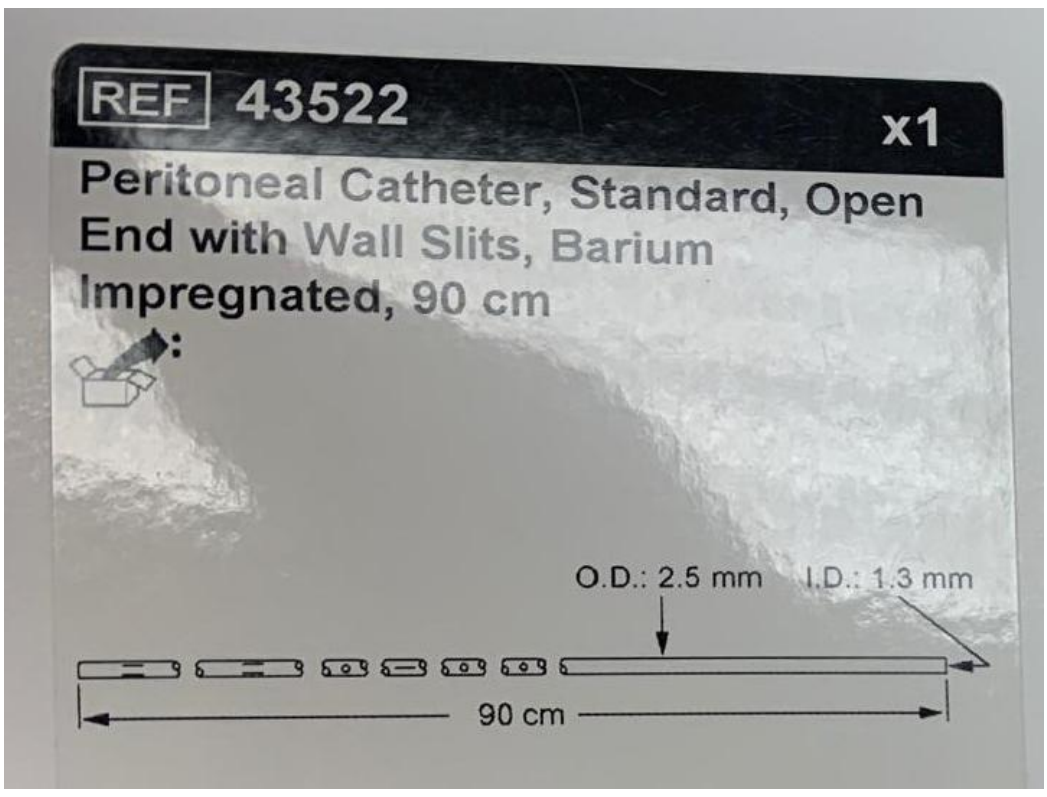




MEDTRONIC RIVULET (41701)

– 141 USD each catheter





ANTIBIOTIC IMPREGNATED

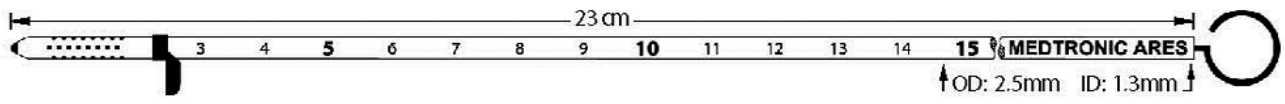
CNS Systematic Review and Evidence-Based Guidelines on the Treatment of Pediatric Hydrocephalus (2021 Update):
Level 1 recommendation: **antibiotic-impregnated** shunt tubing reduces the risk of shunt infection (compared with conventional silicone hardware) and should be used for children who require placement of a shunt.

CODMAN BACTISEAL

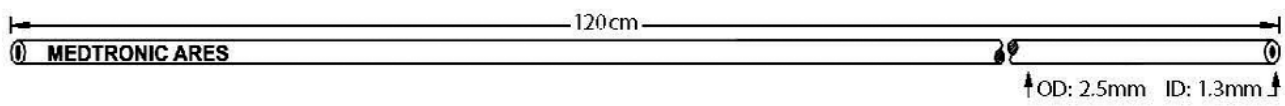
MEDTRONIC ARES

- impregnated with two antibiotics: **rifampicin and clindamycin** - very low risk of resistance mutation due to dual antibiotics that are hard to resist simultaneously.
- laboratory tests show the catheters provide antimicrobial activity for at least 156 days.

91101 = VENTRICULAR CATHETER (353 USD):

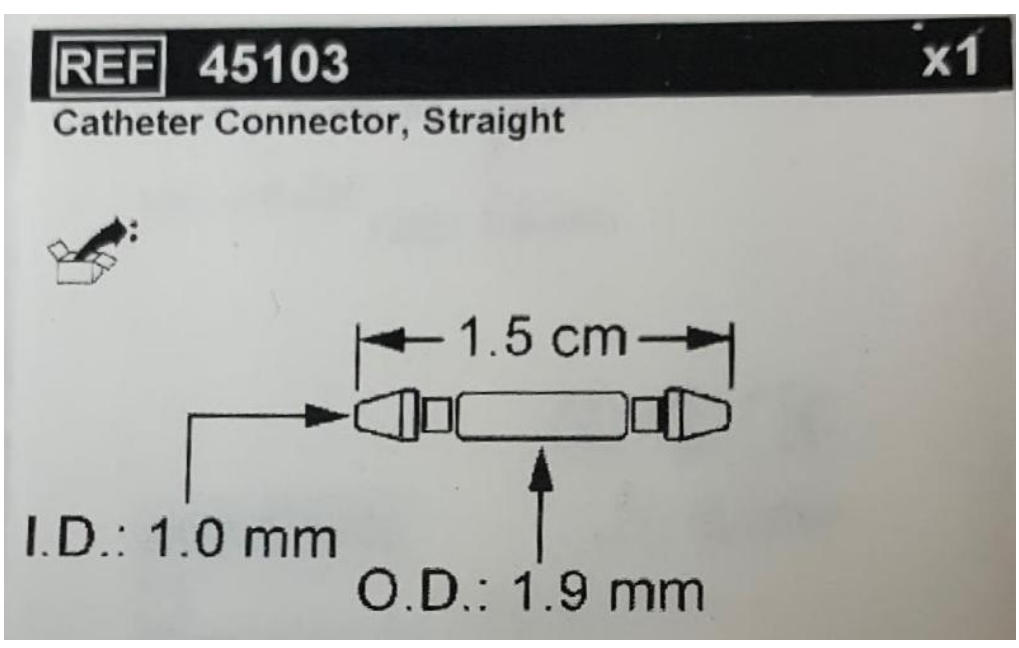


93092 = PERITONEAL CATHETER (353 USD):



95001 = Kit including both ventricular and peritoneal catheter together (620 USD).

CATHETER CONNECTORS



VALVES

CHOICE OF VALVE

Best valve:

NPH: Aesculap ProGAV + Pro ShuntAssist ← does not regulate flow, only prevents siphoning.

Small babies: Codman Certas with SiphonGuard ← regulates flow independent of position.

Bloody CSF (e.g. after SAH) – need the simplest design (most patients don't need shunt after several months): fixed medium pressure valve.

Shunt Design Trial

Drake JM , Kestle JRW , Milner R , Cinalli G , Boop F , Piatt J , Haines S , Schiff S , Cochrane DD , Steinbok P , MacNeil N for the collaborators . Randomised trial of cerebrospinal fluid shunt valve design in pediatric hydrocephalus . Neurosurgery 1998 ; 4 3: 2 94– 3 03.

Standard differential pressure valve versus Delta valve (PS Medical-Medtronic) versus Sigma valve (NMT Cordis).

- 344 pediatric patients (age ≤ 18 yrs), 12 centers in North America and Europe.
- overall shunt failure at 1 year was 39% with all three valves.
- no significant differences in causes of shunt failure between the three valves.
- no significant advantage with any of the three valves.

CNS Systematic Review and Evidence-Based Guidelines on the Treatment of Pediatric Hydrocephalus (2014):
Level 1 recommendation: There is insufficient evidence to demonstrate an advantage for one shunt hardware design over another in pediatric hydrocephalus.
Level 2 recommendation: There is insufficient evidence to recommend the use of a programmable versus a nonprogrammable valve for pediatric hydrocephalus.

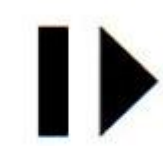
FIXED PRESSURE

MEDTRONIC PS MEDICAL DELTA valve

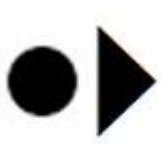
Cannot be implanted below ventricle level!

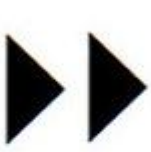
Delta Chamber – closed mechanism which opens in response to positive ventricular pressure, but stays closed in response to negative distal pressure – allows pressure in the brain to be maintained within a certain range, regardless of body position – i.e. antisiphon feature.

Radiographic Markers


Performance Level 0.5

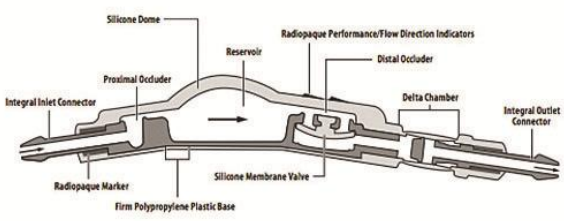

Performance Level 1.0

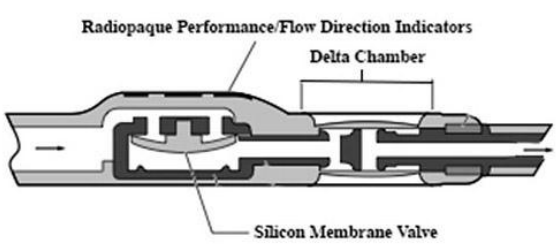

Performance Level 1.5

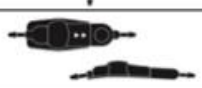

Performance Level 2.0

Valve Opening Pressures

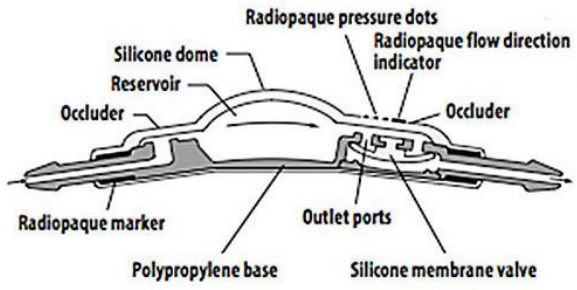
Valve Performance Level	Opening Pressure (cm H_2O)	Opening Pressure (cm H_2O)
	Lying	Standing
0.5	1.5	3.0
1.0	3.5	5.0
1.5	7.0	8.5
2.0	10.5	12.0

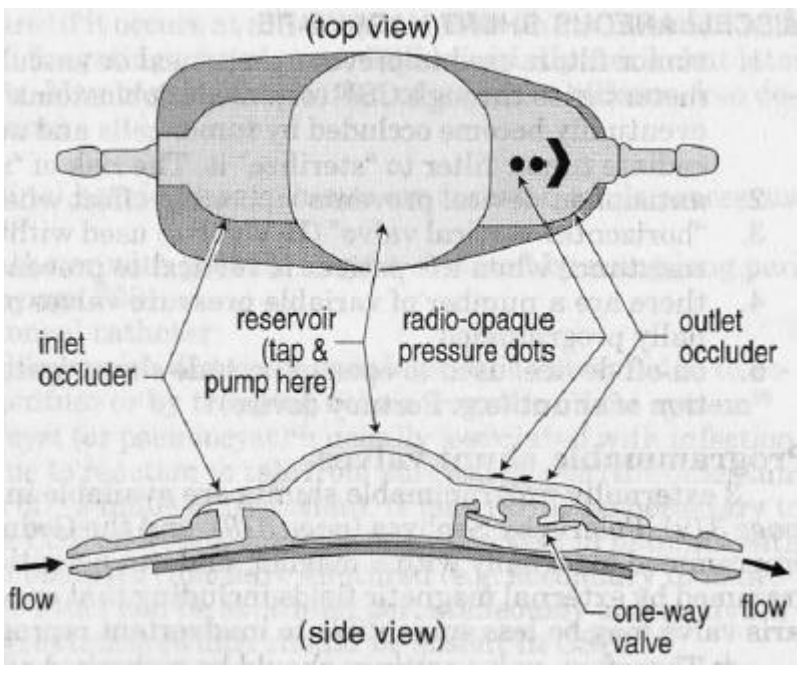


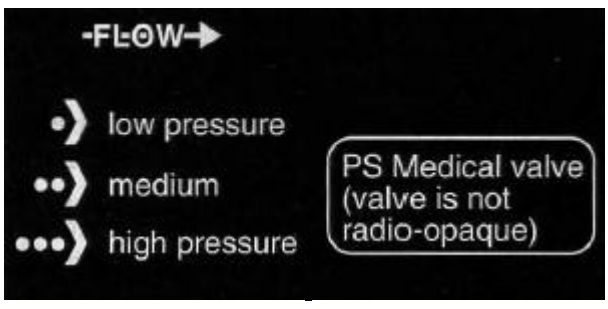


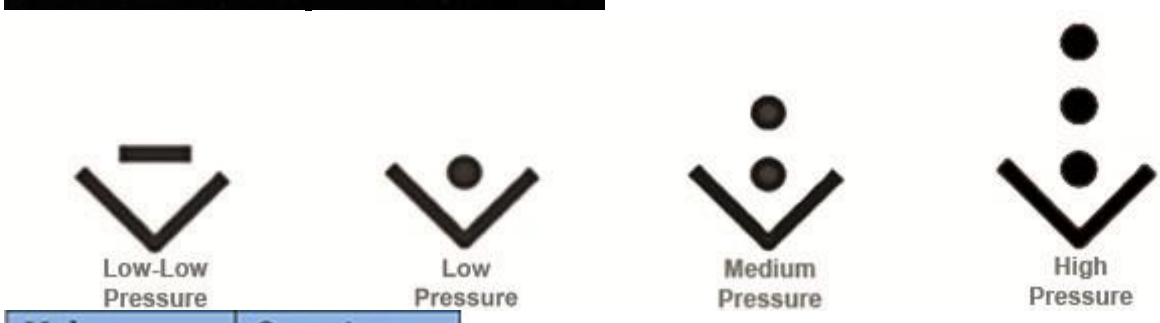
Design	Profile	Dimensions Valve		
		Length	Width	Height
Delta, Regular		40mm	16.5mm	8mm
Delta, Burr Hole		31mm	12mm	6 mm
Delta, Small		36mm	13mm	6mm
Delta, Neonatal		20mm	10mm	5.5mm
Delta Chamber		16 mm	11mm	4mm

MEDTRONIC PS MEDICAL CSF-FLOW CONTROL valve









Valve	Opening Pressure (cm H_2O)
Low-Low	1.0
Low	3.0
Medium	8.5
High	14.5

HOLTER valve

(dual slit valve mechanism)

- usually used in combination with Rickham or SALMON-RICKHAM reservoir:

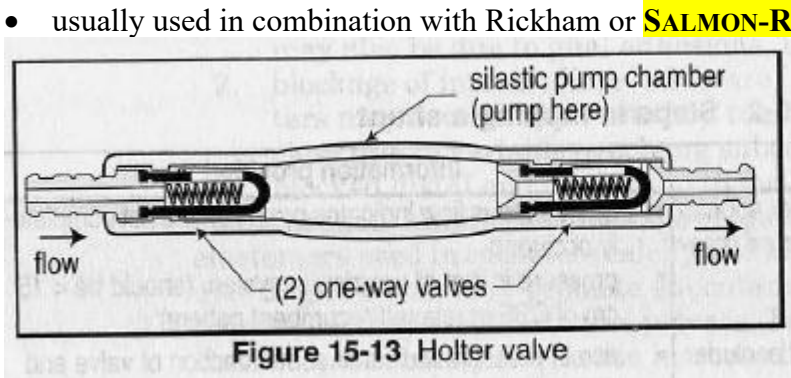


Figure 15-13 Holter valve

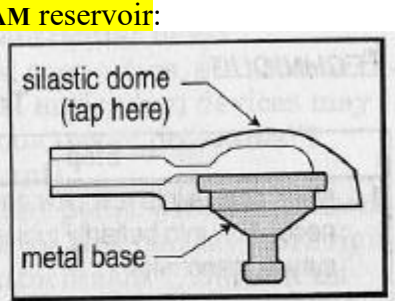
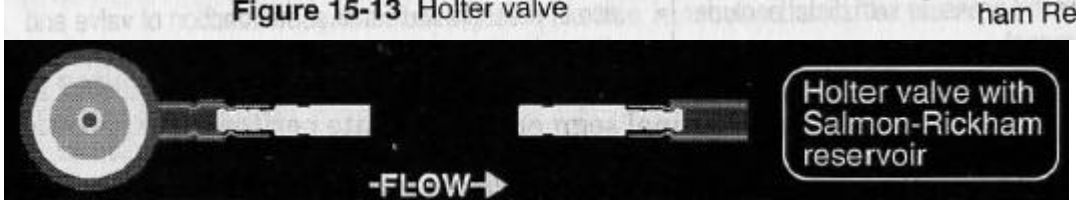
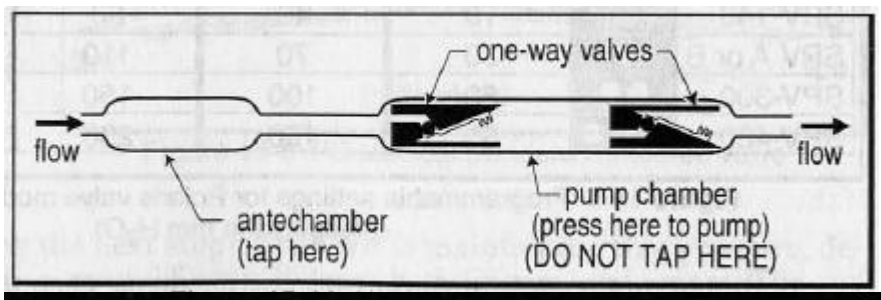


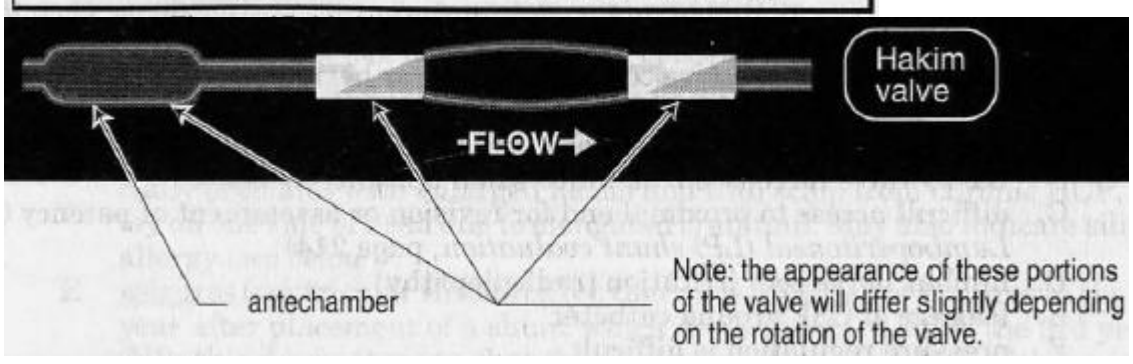
Figure 15-14 Salmon-Rickham Reservoir



Radiographic Markers

HAKIM valve



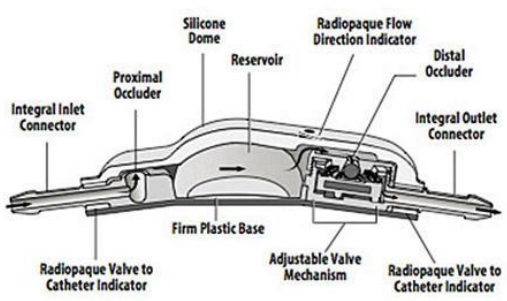


SOPHY MINI (SOPHYSA)

PROGRAMMABLE, NON-MRI-RESISTANT (1ST GENERATION)

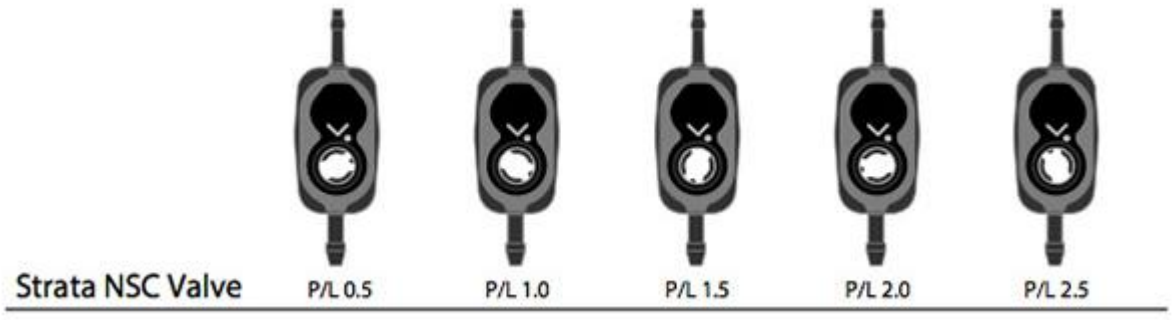
MEDTRONIC (PS MEDICAL)

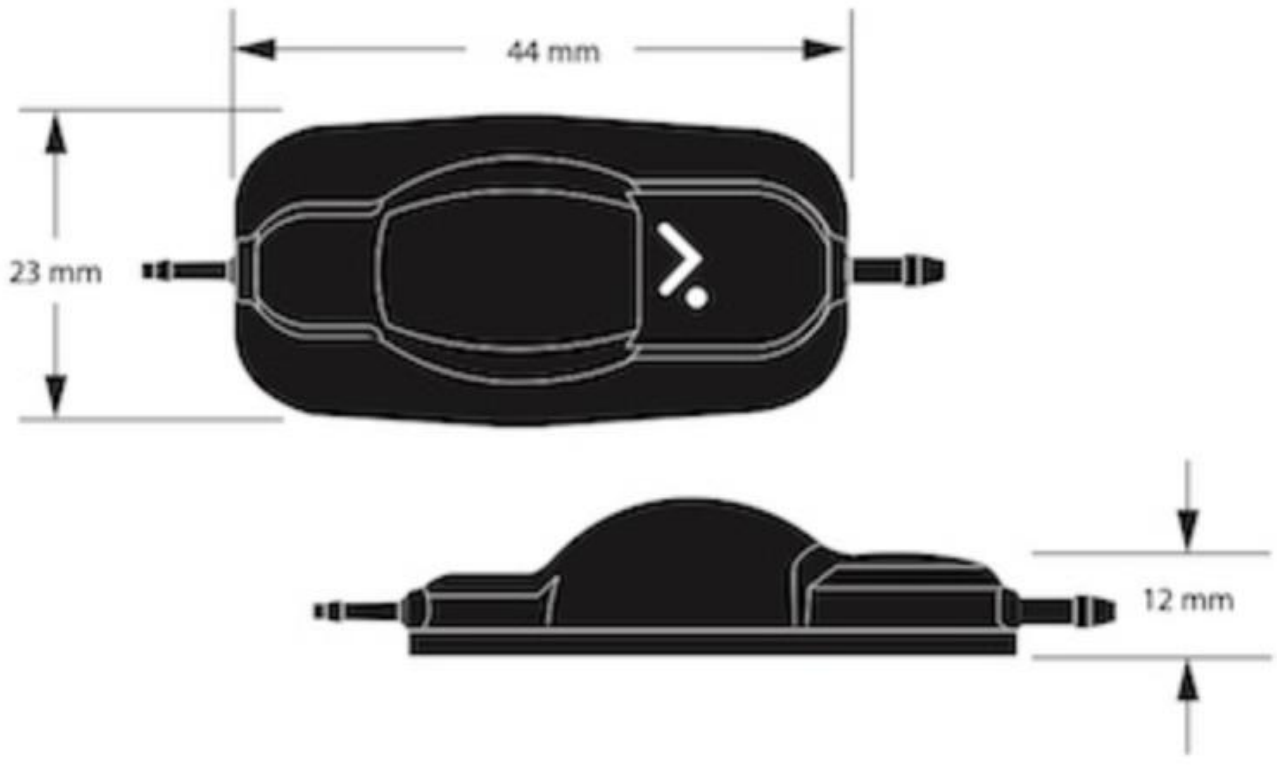
STRATA NSC (NON-SIPHON-CONTROL)



Valve	Opening Pressure (cm H_2O)
0.5	1.5
1.0	3.5
1.5	9.0
2.0	14.5
2.5	20.0

Strata NSC





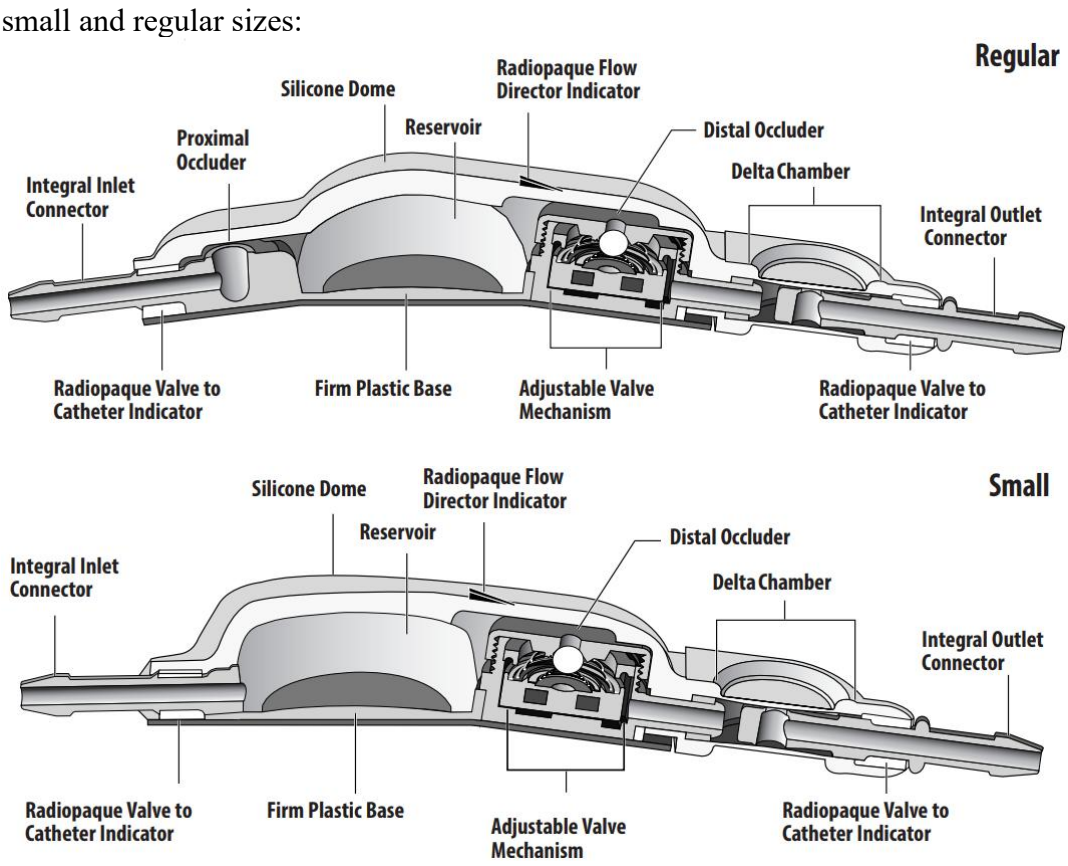
STRATA II

- contains Delta siphon control device.

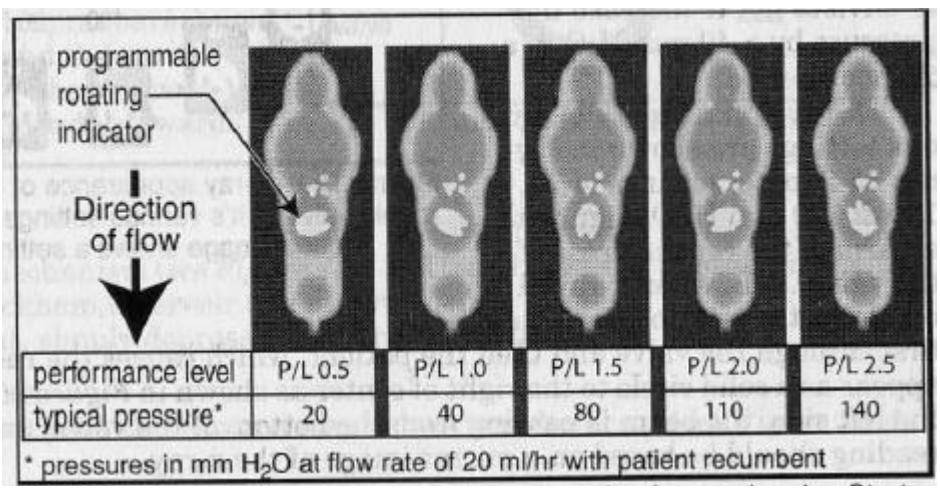
Strata II

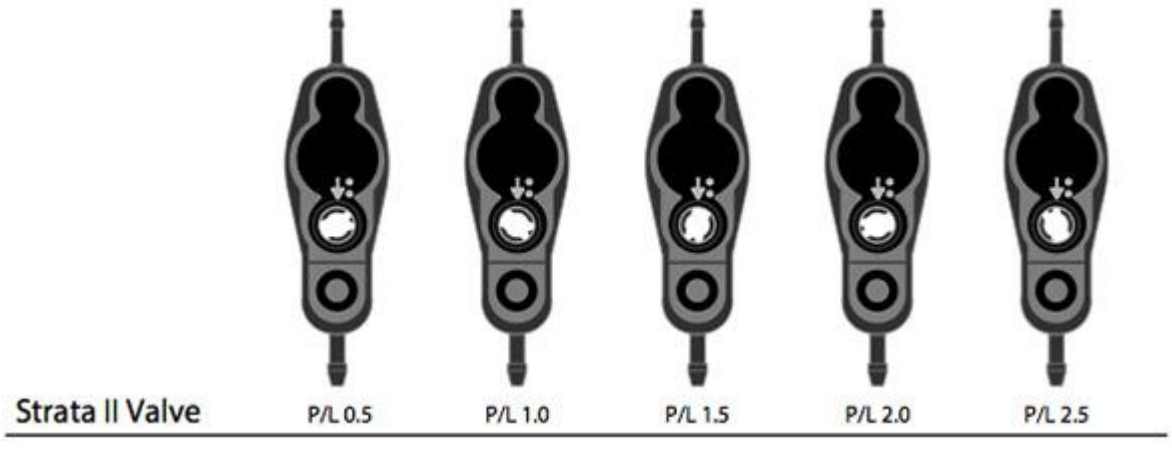
Delta Chamber – mechanism which opens in response to positive ventricular pressure, but stays closed in response to negative distal pressure – allows pressure in the brain to be maintained within a certain range, regardless of body position – i.e. antisiphon feature.

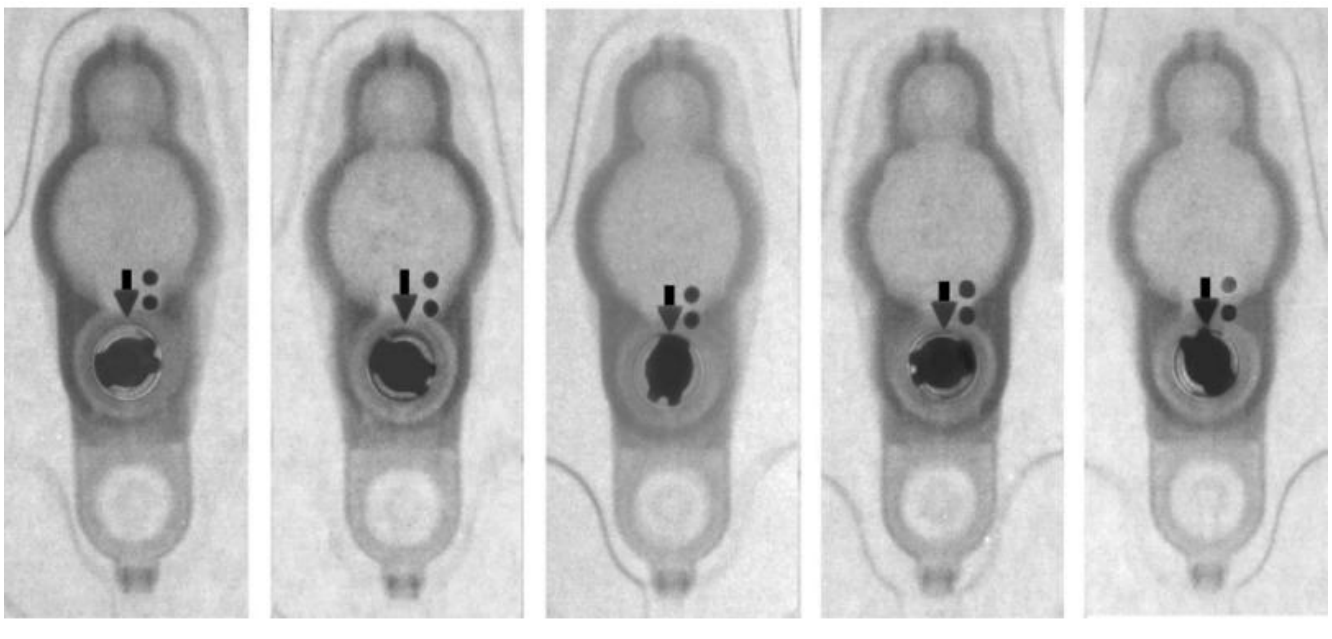
- small and regular sizes:



- MRI up to 3.0 T may be used any time after implantation and will not damage the Strata II valve mechanism, but can change the performance level setting.
- provide the full range of Performance Levels: 0.5, 1.0, 1.5, 2.0, and 2.5:



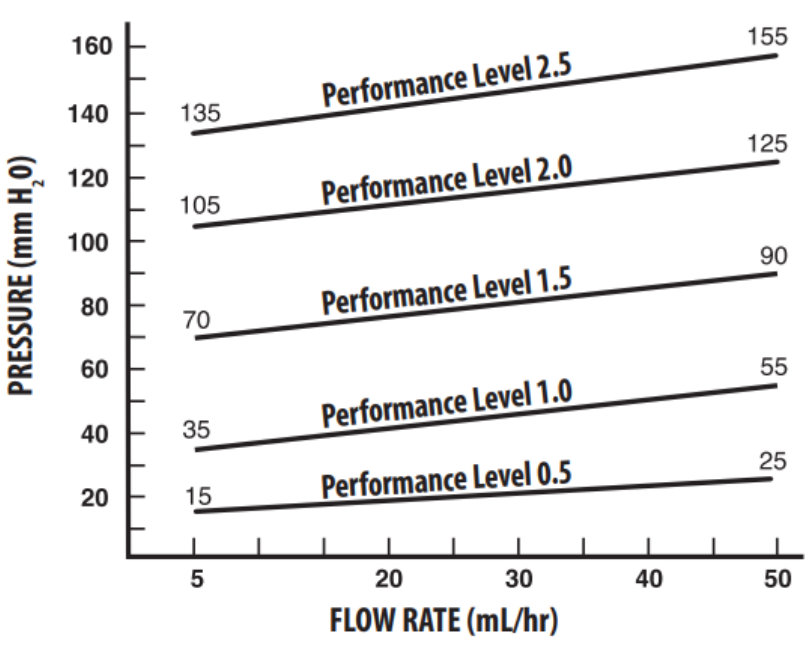




P/L 0.5 P/L 1.0 P/L 1.5 P/L 2.0 P/L 2.5

Valve Performance Level	Opening Pressure (cm H_2O)	Opening Pressure (cm H_2O)
	Lying	Standing
0.5	1.5	3.0
1.0	3.5	5.0
1.5	7.0	8.5
2.0	10.5	12.0
2.5	13.5	14.7

Strata II Valve Performance at 0 cm H_2O Distal Hydrostatic Pressure



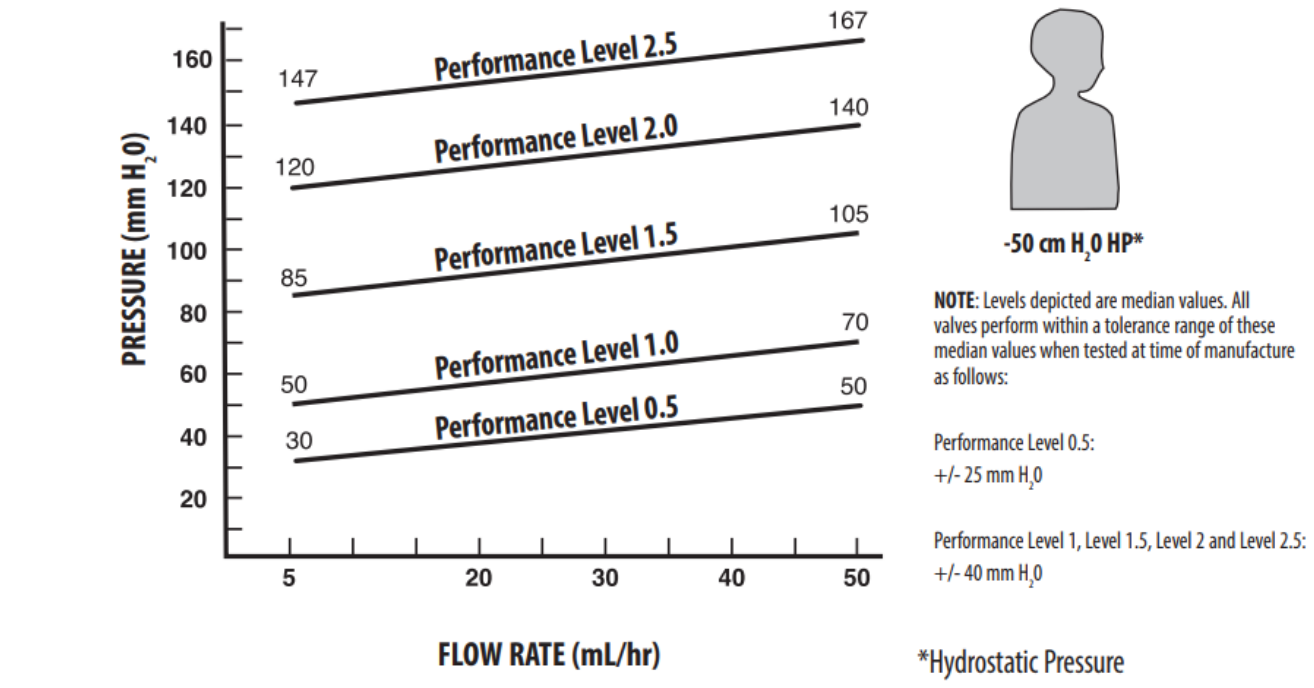
0 cm H_2O HP*

NOTE: Levels depicted are median values. All valves perform within a tolerance range of these median values when tested at time of manufacture as follows:

Performance Level 0.5:
+/- 15 mm H_2O (5 mL/hr)
+/- 25 mm H_2O (50 mL/hr)

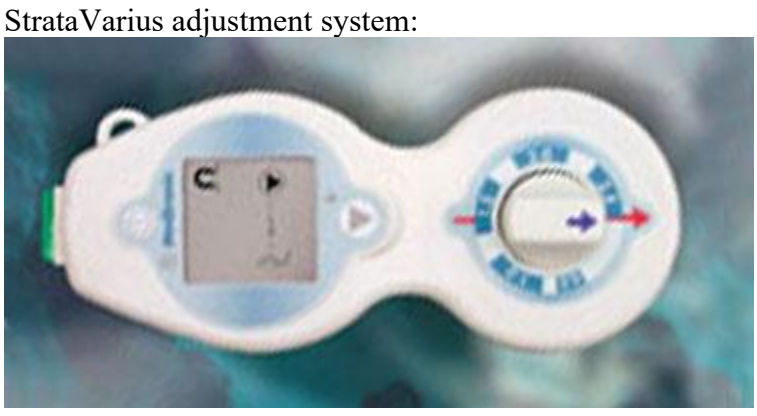
Performance Level 1, Level 1.5, Level 2, and Level 2.5:
+/- 25 mm H_2O

*Hydrostatic Pressure



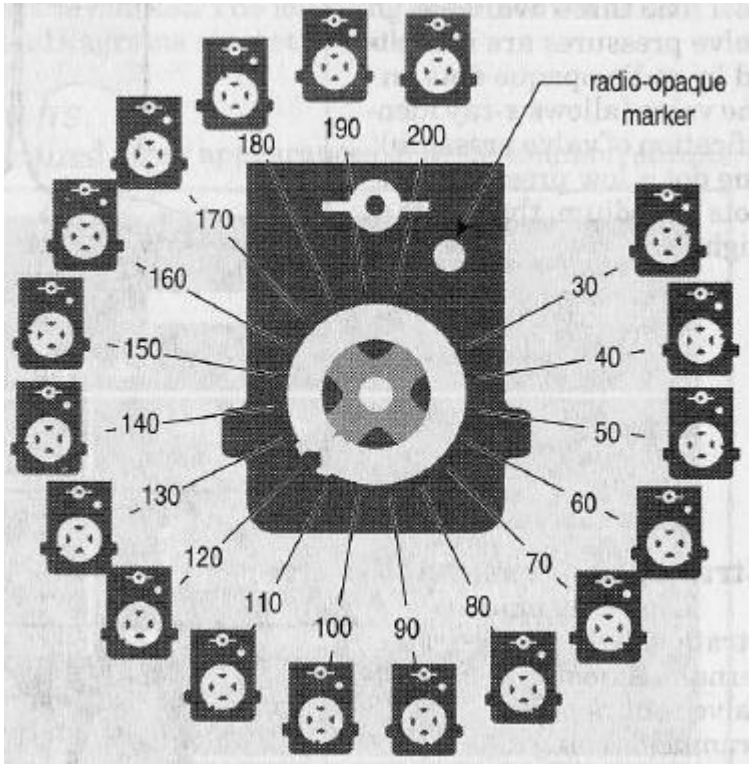
Strata Adjustment Kit:

StrataVarius adjustment system:



CODMAN HAKIM PROGRAMMABLE VALVE

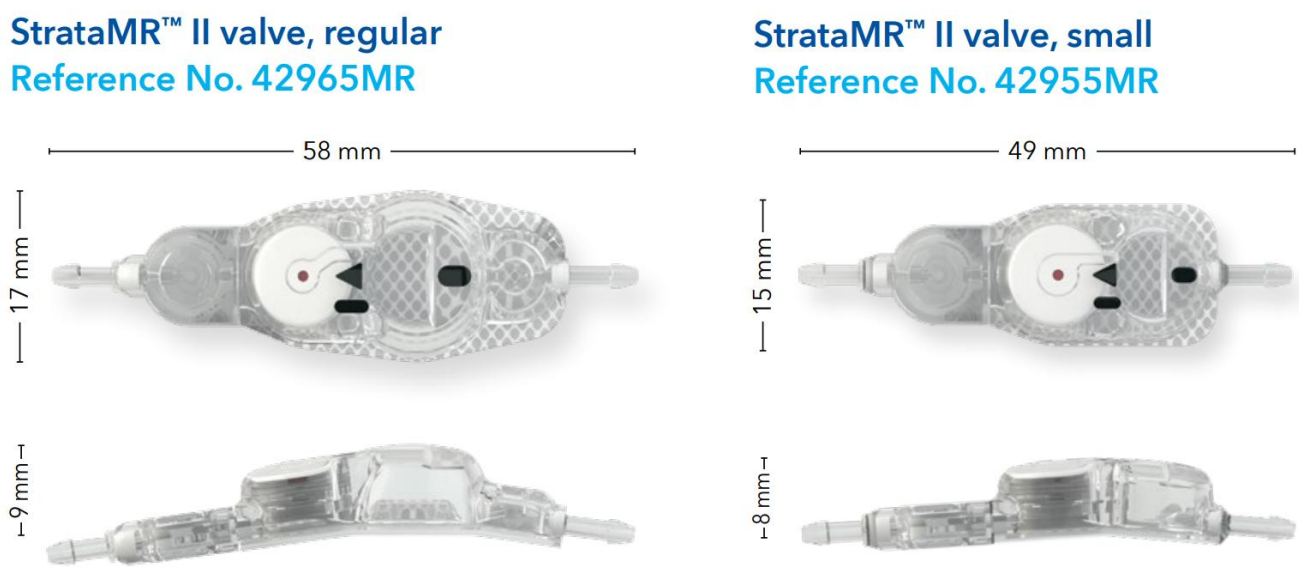
Hakim Programmable Valve >>



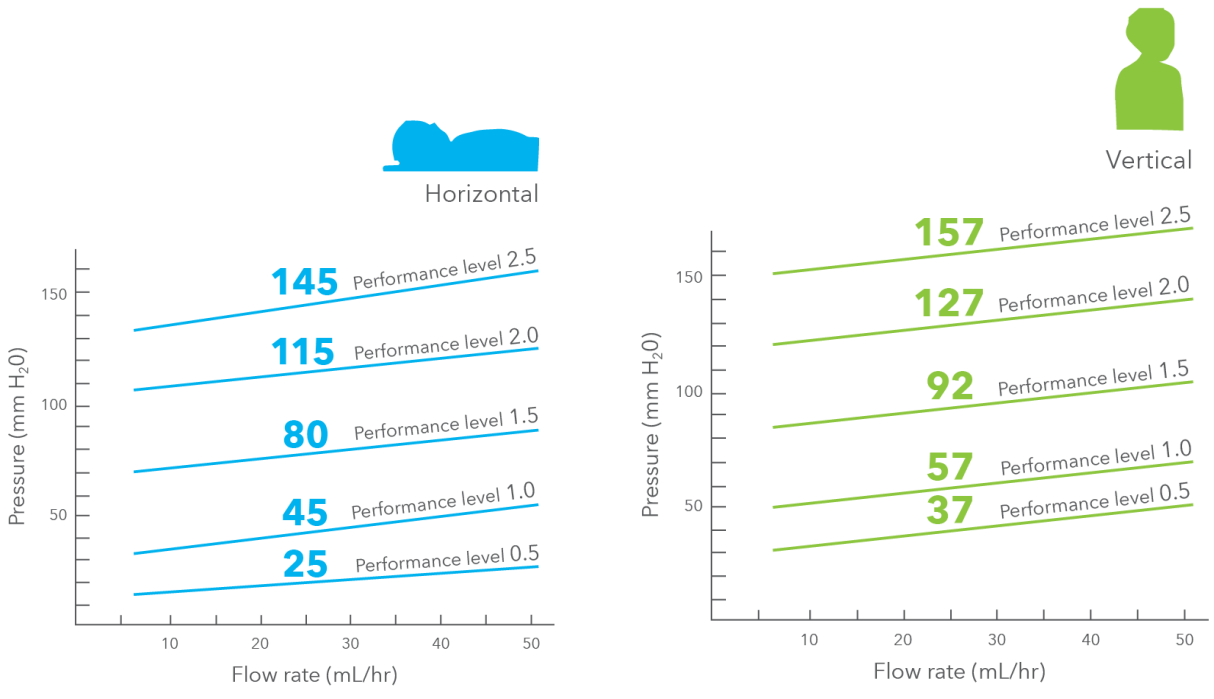
PROGRAMMABLE, MRI-RESISTANT (2ND GENERATION)

MEDTRONIC

STRATAMR II



- MRI resistant up to 3 T.
- five performance levels:



- four-tool <u>adjustment system</u> (tools are not dependent upon position - no need to reposition the patient!) - dual movement sequence: valve mechanism must be consecutively lifted then turned to change the performance level setting.

AESCULAP

Full catalog >>

MIETHKE PROGAV

- MRI compatible – do not need valve resetting.
- come preset at 5 cmH2O.
- two metal instruments ("sticks") to adjust valve; approach valve with button depressed – magnet will help to localize valve (may be hidden under scalp edema); valve setting can also be verified on XR.

SHUNTASSIST

<u>ShuntAssist</u> - antisiphon device choice according to patient height:

≥ 6 feet – 30 cmH2O
5-6 feet – 20 cmH2O
≤ 5 feet – 10 cmH2O.

<u>ProSA</u> – programmable antisiphon device.

- needs to be implanted in strictly vertical position – closes system when in vertical position and, thus, prevents siphoning.

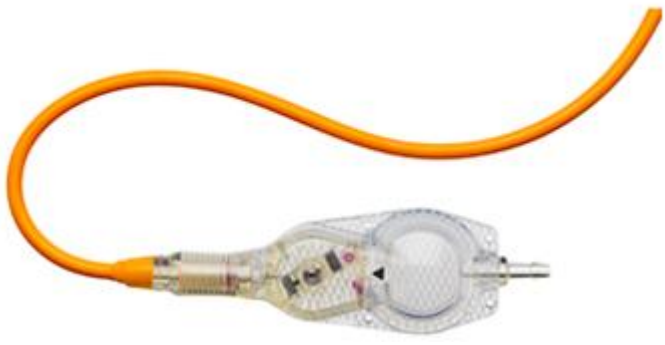
CODMAN

CODMAN CERTAS PLUS

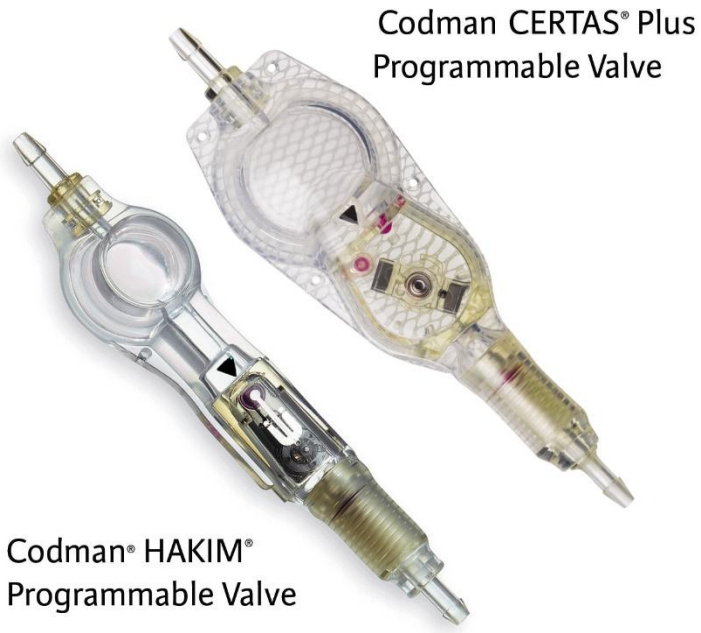
CERTAS Plus MRI Resistant Valve >>

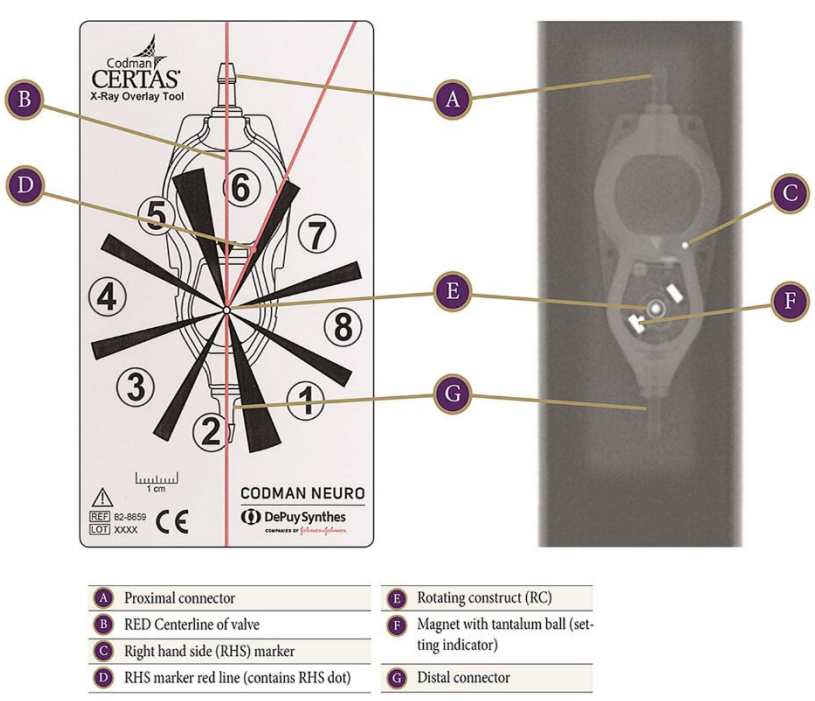
1. A range of 8 settings including a 'Virtual Off' (Virtual Off ensures operating pressure setting 8 is consistently greater than 400 mm H20); can be adjusted and verified at bedside!
2. MRI Resistant up to 3 Tesla
3. Has flow regulating unit – spiral tiny canal – opens when pressure differential suddenly increases; N.B. it is more than just antisiphon device (prevents CSF overdrainage when distal pressure drops in vertical position), as it also prevents CSF overdrainage when proximal pressure suddenly increases (e.g. when child cries – CSF dump would cause slit ventricles); thus, "SiphonGuard" is a misnomer – it is more than just a guard against siphoning, it is a true **flow regulator**!
4. Position INDEPENDENT - can be placed anywhere (occipital, frontal, retro auricular, sub clavicular)
5. Has model with UNITIZED BACTISEAL Distal Catheter

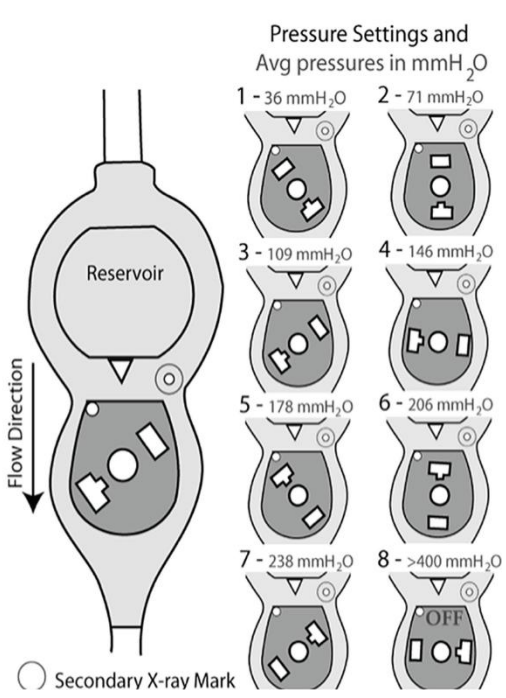
CERTAS Plus Inline Valve with SiphonGuard Anti-Siphon Device:



CERTAS Plus without the SiphonGuard Device:







SOPHYSA

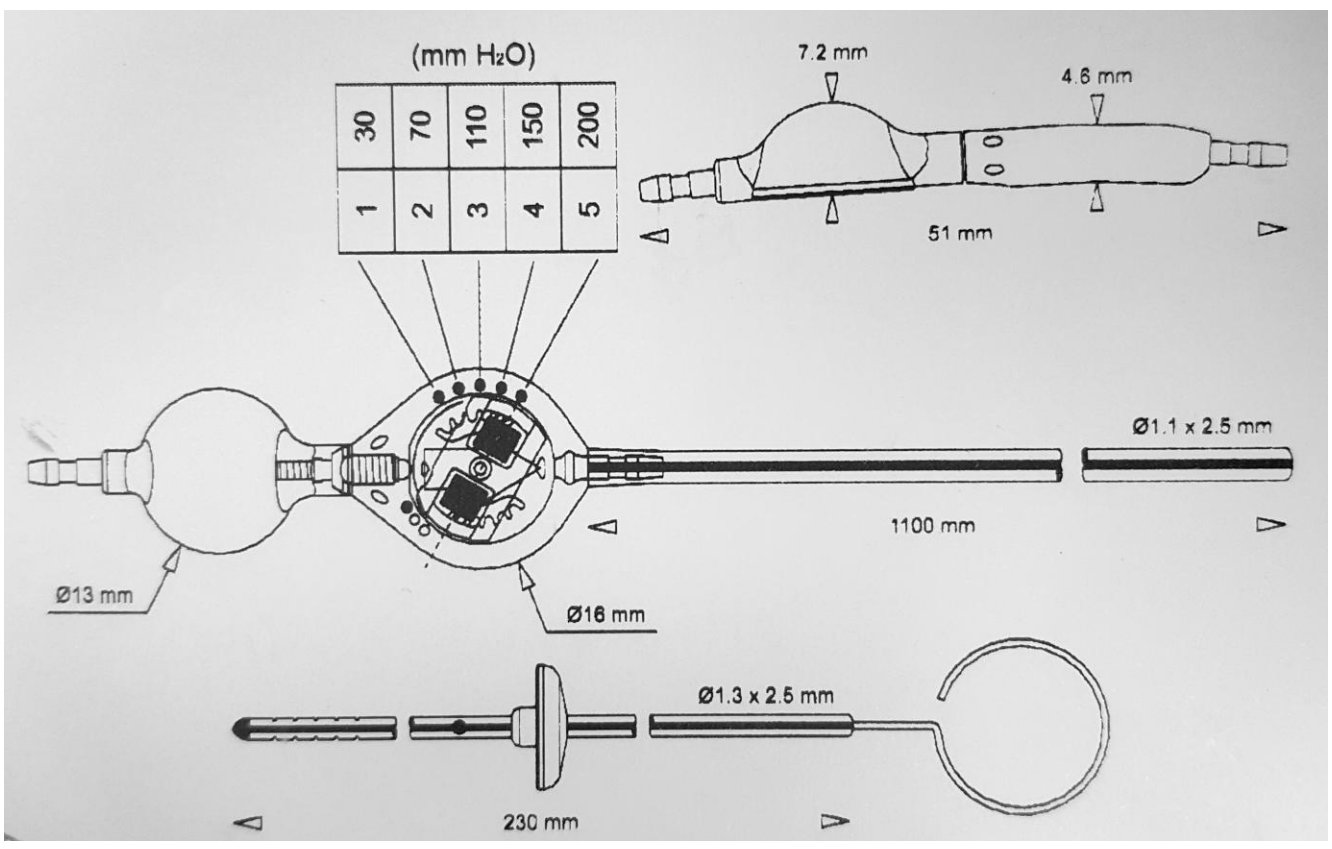
POLARIS

Manual >>

MRI resistant up to 3T!

Valve	SPV-140	SPV	SPV-300	SPV-400
Identification of the pressure range	0 dot	1 dot •	2 dots ••	3 dots •••
X-ray identification of the pressure range				
mmH_2O	10-140	30-200	50-300	80-400

Direction of flow	Position 1	Position 2	Position 3	Position 4	Position 5
Model / Radioopaque dots					
SPV-140 none	10	40	80	110	140
SPV A or B ●	30	70	110	150	200
SPV-300 ●●	50	100	150	220	300
SPV-400 ●●●	80	150	230	330	400



Pressure range indicators

X-ray identification of the pressure range among the 4 ranges available: 10-140, 30-200, 50-300, 80-400 mmH_2O.

Magnetic rotor

Drives flat spring position which allows direct pressure reading and pressure adjustment

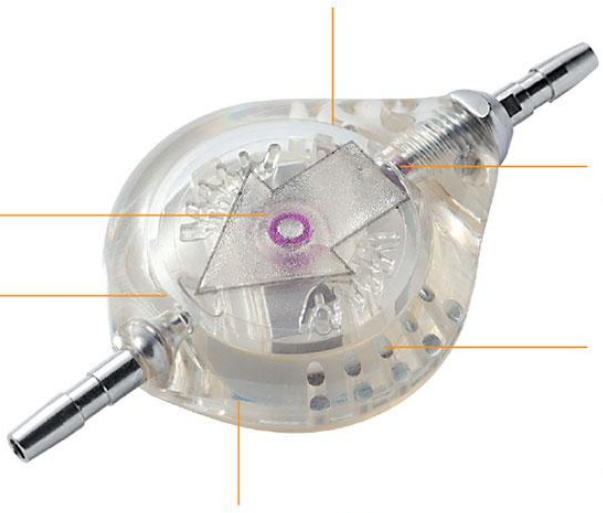
+

Magnetic lock

Avoids unintentional pressure changes due to knocks or magnetic fields.

Polysulfone transparent body

Direct visualization of the pressure level before implantation.



Ball-in-cone and flat spring mechanism

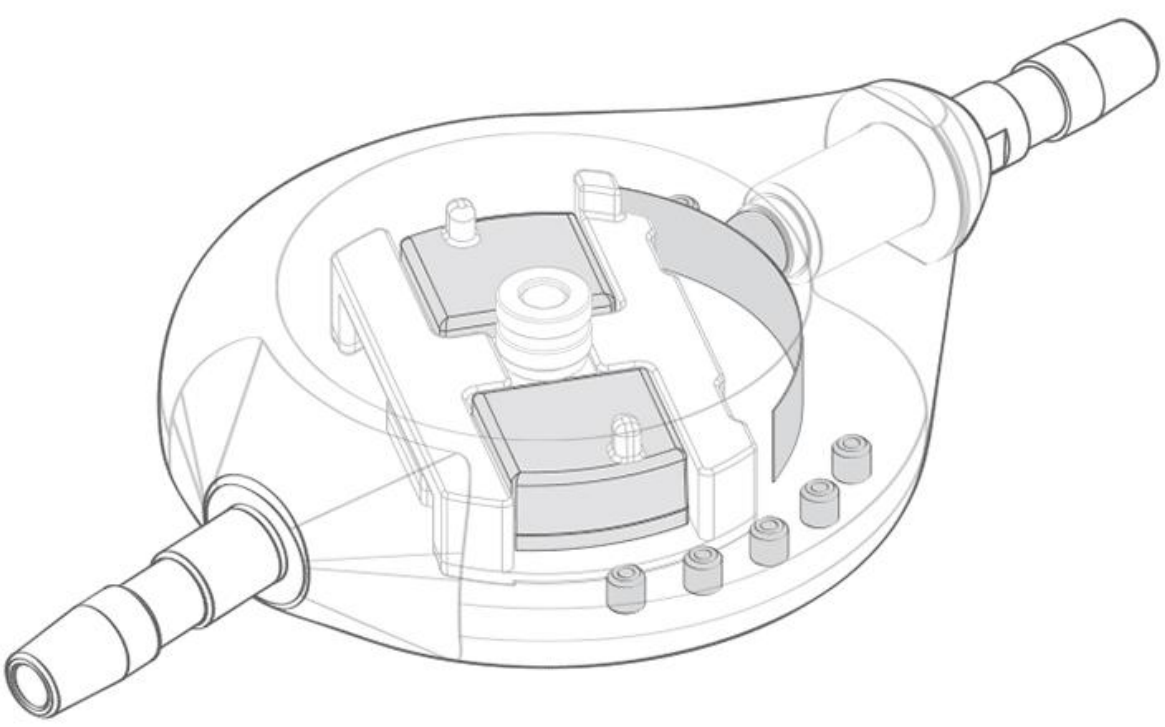
Exceptional precision and proven reliability.

Radiopaque dots

Reliable and intuitive X-ray reading of the 5 pressure levels, without the need for a chart.

Low profile valve

Discreet and comfortable for both adults and children.



Valve only

		Position 1	2	3	4	5
SPV	**Polaris® Adjustable Valve, 30-200**	**30**	**70**	**110**	**150**	**200**
SPV-140	Polaris® Adjustable Valve, 10-140	10	40	80	110	140
SPV-300	Polaris® Adjustable Valve, 50-300	50	100	150	220	300
SPV-400	Polaris® Adjustable Valve, 80-400	80	150	230	330	400

Pressure (mmH_2O)

Valve with antechamber

		Position 1	2	3	4	5
SPVA	**Polaris® Adjustable Valve, 30-200, Antechamber**	**30**	**70**	**110**	**150**	**200**
SPVA-140	Polaris® Adjustable Valve, 10-140, Antechamber	10	40	80	110	140
SPVA-300	Polaris® Adjustable Valve, 50-300, Antechamber	50	100	150	220	300
SPVA-400	Polaris® Adjustable Valve, 80-400, Antechamber	80	150	230	330	400

Pressure (mmH_2O)

Valve with burr-hole reservoir

SPVB	Polaris® Adjustable Valve, 30-200, Burr-Hole Reservoir, (30, 70, 110, 150, 200 mmH_2O)

SIPHONX

The Polaris® valve can be associated with SiphonX®, an anti-siphon device, which adds 200 mmH2O in vertical position:

Arrow

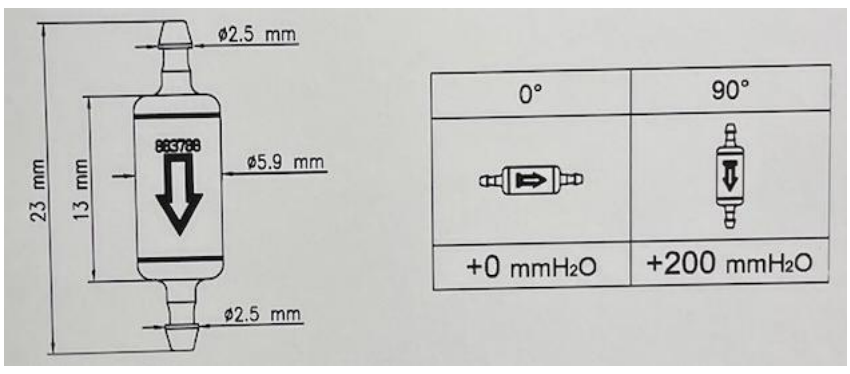
Shows the direction of CSF flow through the device. This helps to orientate the SiphonX® correctly during implantation.

Rigid body

The device is not affected by the pressure exerted by the sub-cutaneous tissues.

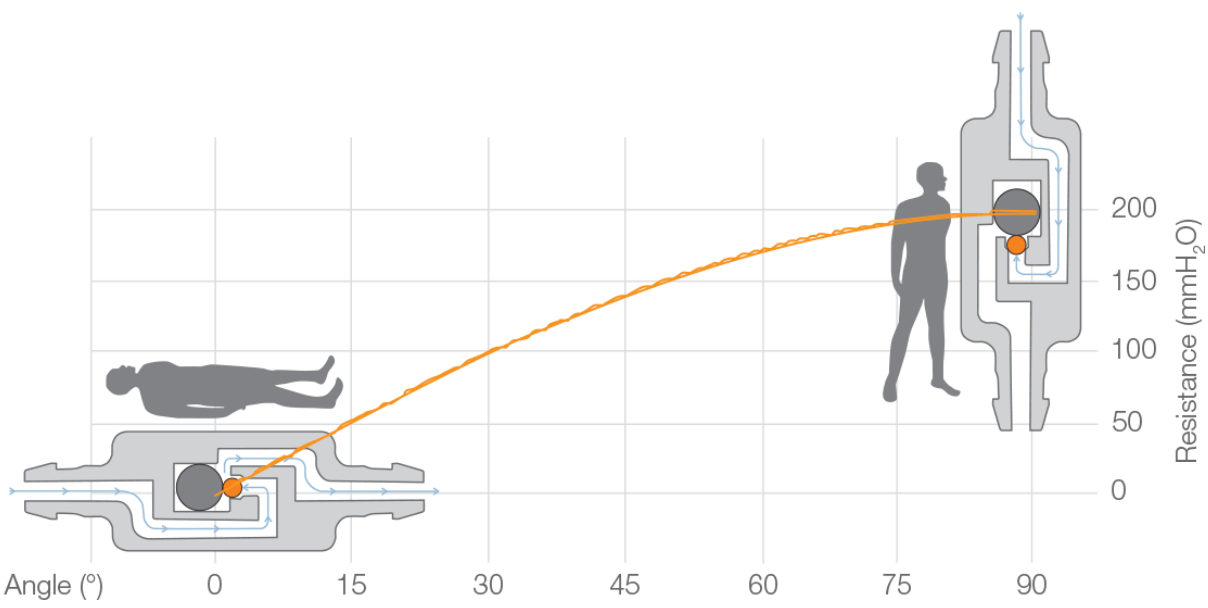
Tantalum weight ball

Calibrated to add 200 mmH_2O in the vertical position. Radiopaque for easy location of the device.



Reference	Designation
SX-200	Gravitational anti-siphon device SiphonX®
SPV-SX	Polaris® Adjustable Valve, 30-200 with SiphonX®
SPV140-SX	Polaris® Adjustable Valve, 10-140 with SiphonX®
SPVA-SX	Polaris® Adjustable Valve, 30-200, Antechamber and SiphonX®
SPVA140-SX	Polaris® Adjustable Valve, 10-140, Antechamber and SiphonX®

- tantalum weight ball presses on a ruby ball, which occludes the aperture for the passage of the CSF - when SiphonX® is in the ***vertical*** position, the ruby ball is subjected to the full weight of the tantalum ball, occludes the anti-siphon aperture and the device adds 200 mmH2O to the operating pressure of the valve; when SiphonX®is in the ***horizontal*** position, the ruby ball is not subjected to the weight of the tantalum ball and so does not occlude the aperture of the anti-siphon device (i.e. in horizontal position, the device is open and does not add any additional resistance to the operating pressure of the valve); for all ***intermediate*** positions, SiphonX® adds a resistance which depends on the angle of inclination.
- by design SiphonX®is not affected by the implantation height relatively to cerebral ventricles.



SOPHY® MINI SM8

N.B. it is an older valve (now replaced by Polaris) – physical dimensions are the same as Polaris; plus, it is not MRI resistant!

Manual >>

4 references each offering 8 positions: a standard model (30-200 mmH_2O), one low pressure valve and two high pressure valves.

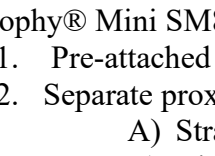
Valve	SM8-140	SM8	SM8-300	SM8-400
Identification of the pressure range	0 dot	1 dot •	2 dots ••	3 dots •••
X-ray identification of the pressure range				
mmH_2O	10-140	30-200	50-300	80-400

Valve only

			Position 1	2	3	4	5	6	7	8
	SM8	**Sophy® Mini Adjustable Valve, 30-200**	**30**	**50**	**70**	**90**	**110**	**140**	**170**	**200**
	SM8-140	Sophy® Mini Adjustable Valve, 10-140	10	25	40	60	80	100	120	140
	SM8-300	Sophy® Mini Adjustable Valve, 50-300	50	75	100	125	150	180	220	300
	SM8-400	Sophy® Mini Adjustable Valve, 80-400	80	120	150	190	230	270	330	400

Pressure (mmH_2O)

Valve with antechamber / with burr-hole reservoir

			Position 1	2	3	4	5	6	7	8
	SM8A	Sophy® Mini Adjustable Valve, 30-200, Antechamber	30	50	70	90	110	140	170	200
	SM8B	Sophy® Mini Adjustable Valve, 30-200, Burr-Hole Reservoir	30	50	70	90	110	140	170	200

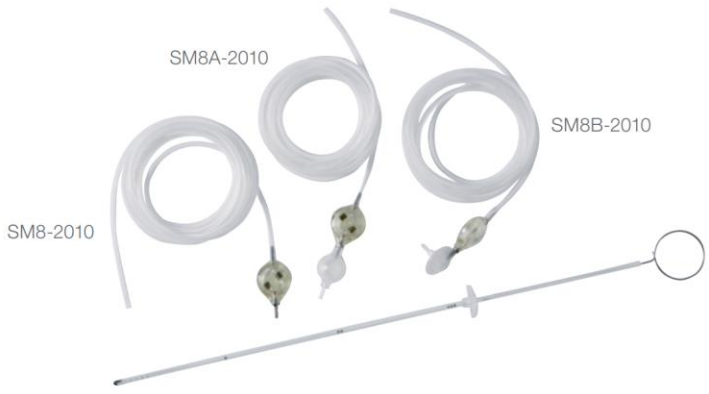
Pressure (mmH_2O)

Kits

The Sophy® Mini SM8 kits include:

1. Pre-attached distal catheter (length = 110 cm)
2. Separate proximal catheter:
    A) Straight (length = 23 cm)
    B) Right angle with a reservoir (intracranial length = 6 or 7 cm)

Kits with Straight Ventricular Catheter



Kits with Right Angle Ventricular Catheter

For intracranial implantation

For pectoral implantation

Complete valve kits Sophy® Mini valve kits include a separated ventricular catheter and a preconnected distal catheter

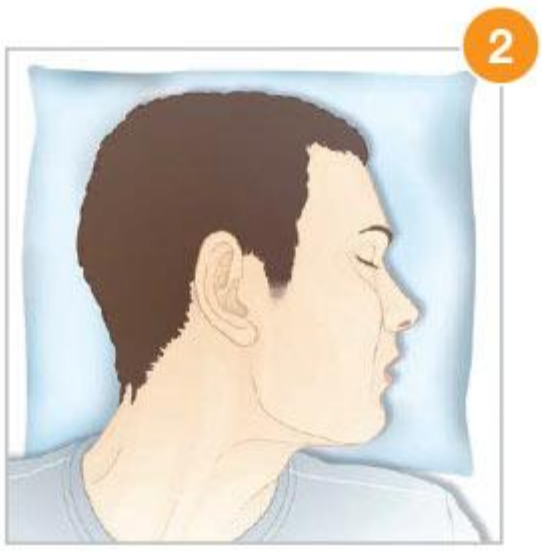
Straight ventricular catheter	SM8-2010	Sophy® Mini SM8 Kit
	SM8A-2010	Sophy® Mini SM8A Kit
	SM8B-2010	Sophy® Mini SM8B Kit
Right angle ventricular catheter for intracranial implantation	SM8-2020	Sophy® Mini SM8 Kit (Intracranial length = 6 cm)
	SM8-2021	Sophy® Mini SM8 Kit (Intracranial length = 7 cm)
Right angle ventricular catheter for pectoral implantation	SM8-2030	Sophy® Mini SM8 Kit (Intracranial length = 6 cm)
	SM8-2031	Sophy® Mini SM8 Kit (Intracranial length = 7 cm)
Lumbo-peritoneal shunting	SM8-2040	Sophy® Mini SM8 LP shunt kit

PROGRAMMING

N.B. mini valves need a different programmer!

1 - Operating pressure range visible on Locator MUST match valve range:

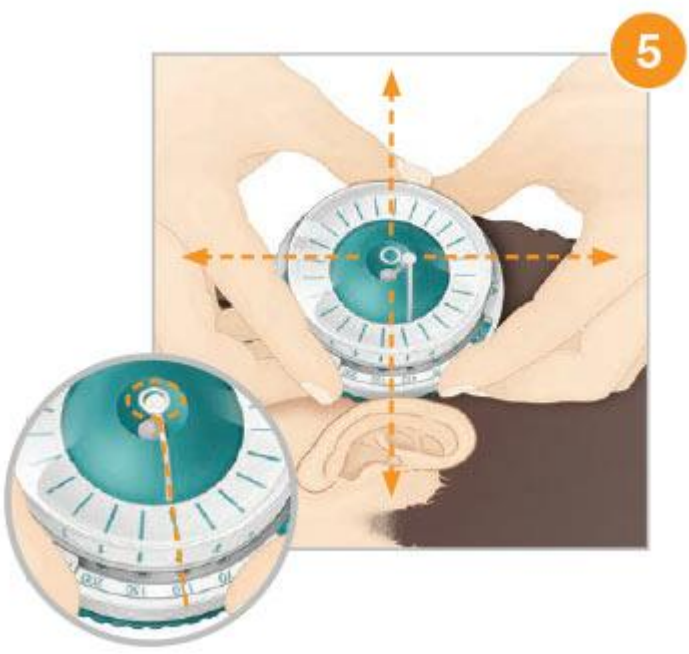
2 - Valve location should determine optimum patient position for adjustment. Having valve horizontal is recommended.



3 - Position Locator parallel to valve, with valve seated in center cut-out, and green arrow pointing in direction of CSF flow path, aligning Locator with valve axis.

4 - Place Compass within Locator.

5 - Adjust Locator orientation, in same horizontal plane as valve, so that Compass needle centers within white target circle, and aligns with current operating pressure setting. Note the valve's current operating pressure setting.

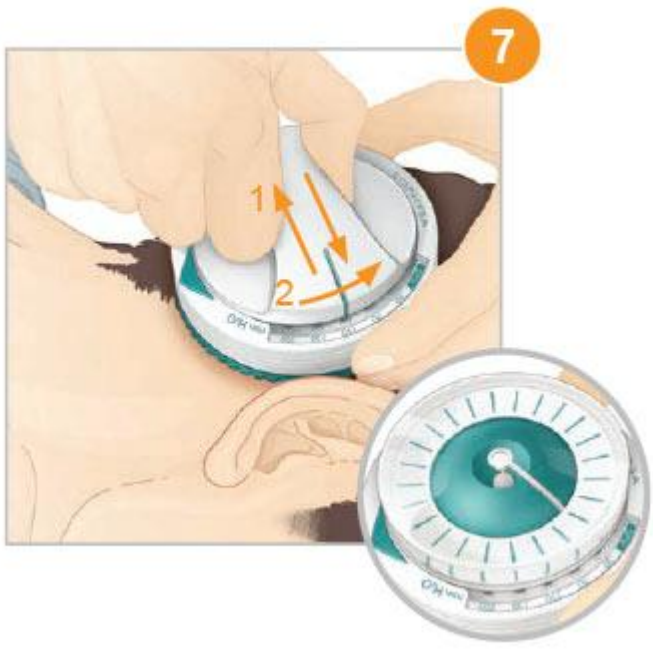


6 - Without moving Locator, remove Compass, then insert Magnet, with center line of Magnet aligned with current operating pressure setting.

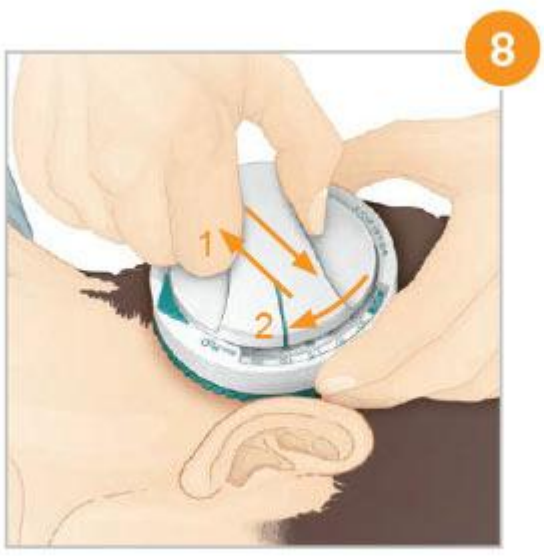
7 - Without moving Locator, quickly slide Magnet, with back and forth motion, along the current operating pressure setting axis. With Magnet again centered inside Locator, turn magnet slowly, just beyond the highest or lowest operating pressure setting, whichever is furthest from the initial operating pressure setting.

Without moving Locator, remove Magnet vertically, and place Magnet 0.5 meters away from valve, then insert Compass into Locator. If Locator orientation is accurate, Compass needle aligns exactly with the highest or lowest operating pressure setting, providing a reference point for calibration of the Locator along the valve's axis. If the Compass needle does not align exactly with the highest or lowest operating pressure

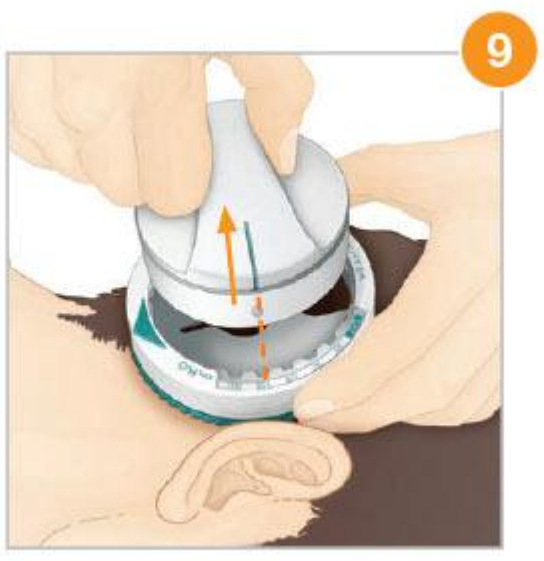
setting, re-calibrate Locator, by turning it slightly, in same plane as valve, until the Compass needle does align exactly with the highest or lowest operating pressure setting.



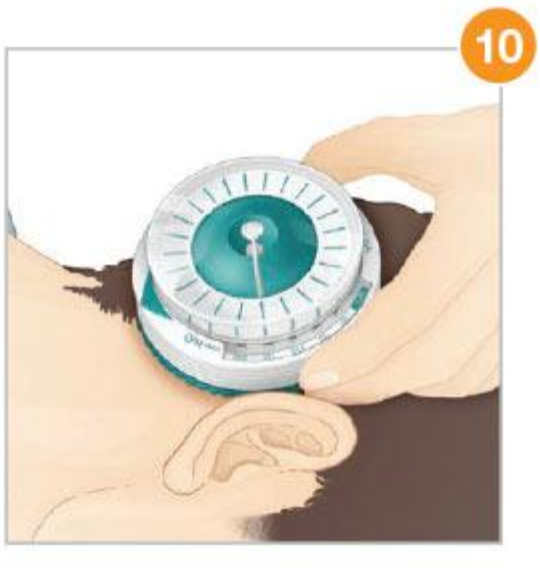
8 - Without moving Locator, remove Compass, then re-insert Magnet, with center line of Magnet aligned with current (highest or lowest) operating pressure setting. Without moving Locator, quickly slide Magnet, with back and forth motion, along the current operating pressure setting axis, and, with Magnet once again centered inside Locator, turn Magnet slowly to new operating pressure setting.



9 - Without moving Locator, remove Magnet vertically (place Magnet 0.5 meters away from valve).



10 - Without moving Locator, re-insert Compass, confirming that needle aligns with new operating pressure setting.



ANTI-SIPHON FEATURE

- prevents overdrainage in vertical position (i.e. keeps intraventricular pressure within physiological range when patient is upright) – especially for tall slender elderly people (brain atrophy predisposes to SDH from overdrainage). Caution in obese people – may impede CSF flow.

Position INDEPENDENT implantation

Codman Certas with SiphonGuard – spiral canal opens when pressure differential suddenly increases - regulates flow independent of position (i.e. not just anti-siphon as also prevents overdrainage due to sudden ICP increase);

Medtronic valves with **Delta Chamber** (e.g. Delta valves, Strata II valves) – closed mechanism which opens in response to positive ventricular pressure, but stays closed in response to negative distal pressure – allows pressure in the brain to be maintained within a certain range, regardless of body position – i.e. antisiphon feature.

Must be implanted in strictly vertical position

Sophysa SiphonX – true anti-siphon device, which adds 200 mmH2O in vertical position

Aesculap ShuntAssist

Aesculap ProSA - programmable

VALVES WITH NO ANTI-SIPHON FEATURE

Medtronic Strata NSC (non-siphon-control) *see below >>*
Sophysa Polaris

VALVES WITH VERY HIGH SETTINGS ("VIRTUAL OFF")

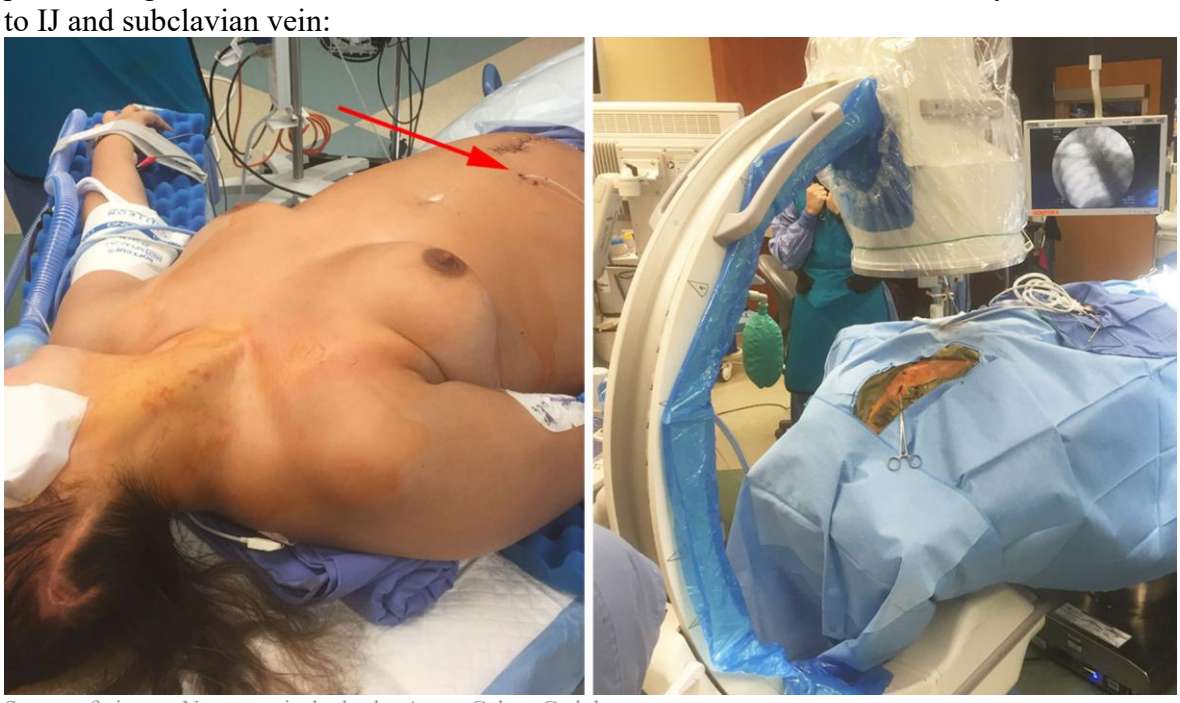
Sophysa Polaris SPV-400, SPV-300
Codman Certas

VENTRICULO-PLEURAL SHUNT

- perform early postoperative chest radiograph - large effusions can occur in short periods (→ respiratory problems), esp. in children < 10 yo.

VENTRICULO-ATRIAL SHUNT (VAS)

- consider preop cardioECHO.
  N.B. any condition that causes ***significant elevation in central venous pressure*** can hinder the function of VA shunt.
- it is better to place proximal system and get it ready so distal catheter, when placed into atrium, is ready to be connected – lower chances of backflow and thrombosis.
- *fluoroscopic guidance* - to prevent catheter thrombosis (short distal catheter) or cardiac arrhythmias (long distal catheter) - before preparing the field, perform a trial fluoroscopy to be certain that the appropriate anatomic landmarks are easily visualized; prefer radiolucent head positioner.
- place a longitudinal roll between shoulders - shoulders allowed to fall laterally to facilitate access to IJ and subclavian vein:



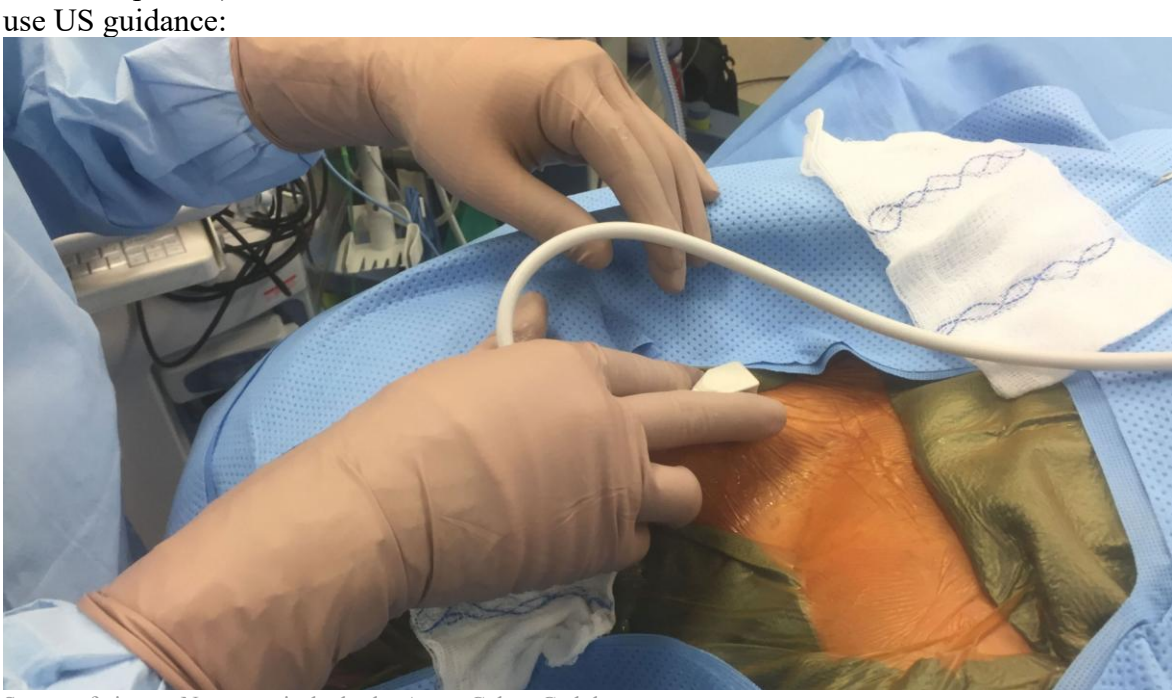
Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

A. Percutaneous Seldinger technique (preferred) into **INTERNAL JUGULAR** as if placing central line – may use IR (interventional radiologist) help; use standard central venous catheter kit. also see p. Op910 >>

– may use right or left IJ.

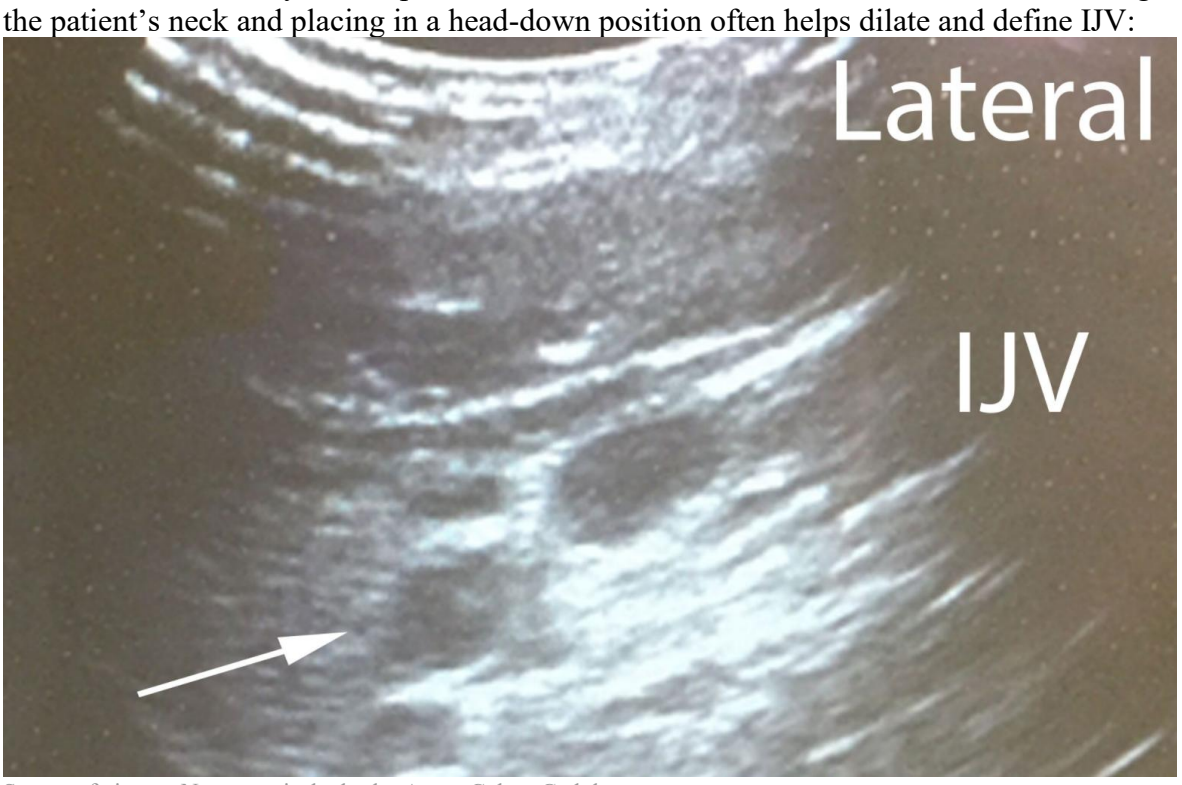
– **20-22G needle with attached syringe** is used to puncture the skin 1-3 fingerbreadths (depending on the size of the patient) above the clavicle, between the heads of the sternocleidomastoid muscle.

  - use US guidance:



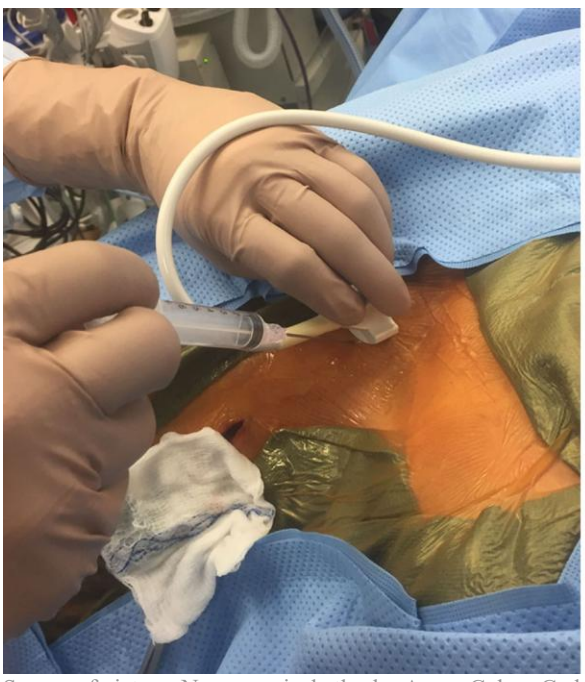
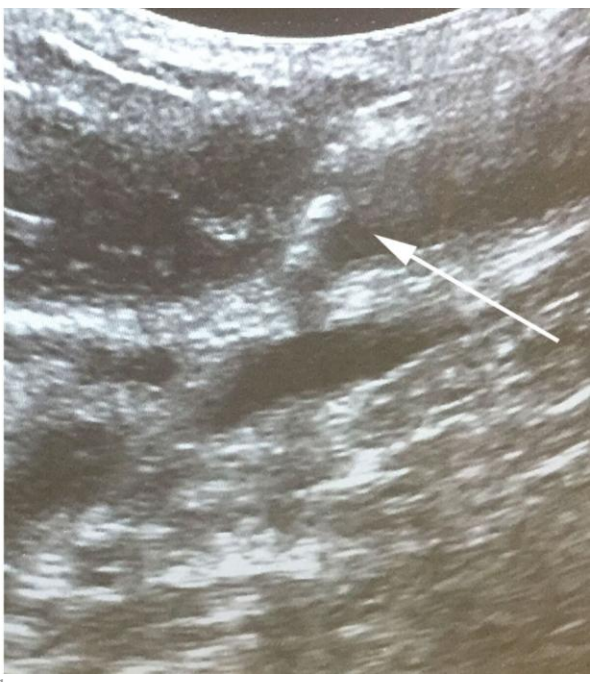
Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

  - IJV is distinguished from common carotid artery (arrow) in that it generally appears lateral or anterior to the artery, is compressible, and dilates with a Valsalva maneuver; extending the patient's neck and placing in a head-down position often helps dilate and define IJV:



Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

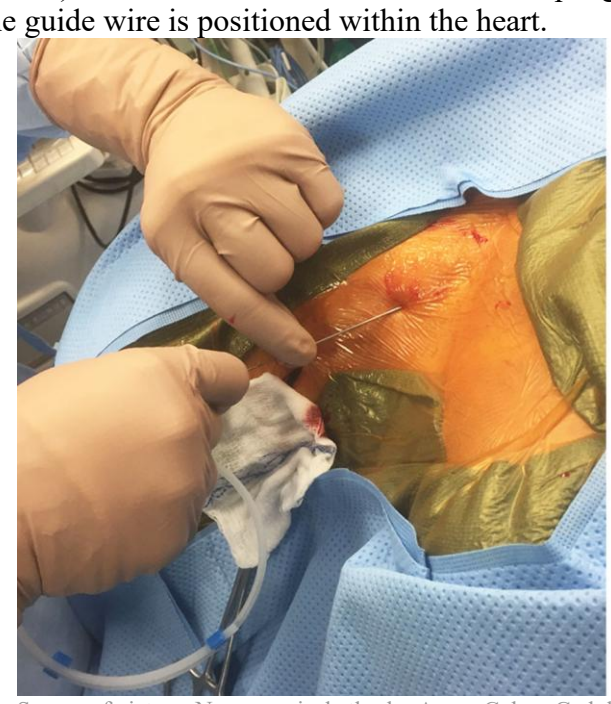
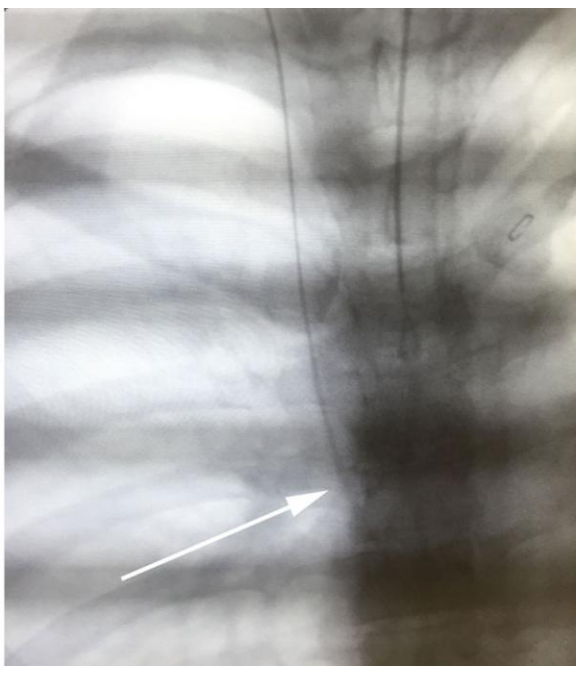
  - needle is inserted at an approximately 45° angle; needle insertion is accomplished with the aid of ultrasound visualization; tip of arrow points to shadow of the needle:

Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

- if subclavian vein access is chosen (preferred over IJ on left side?), the entry site is inferior to the clavicle, at the junction of the middle and lateral third of the bone.

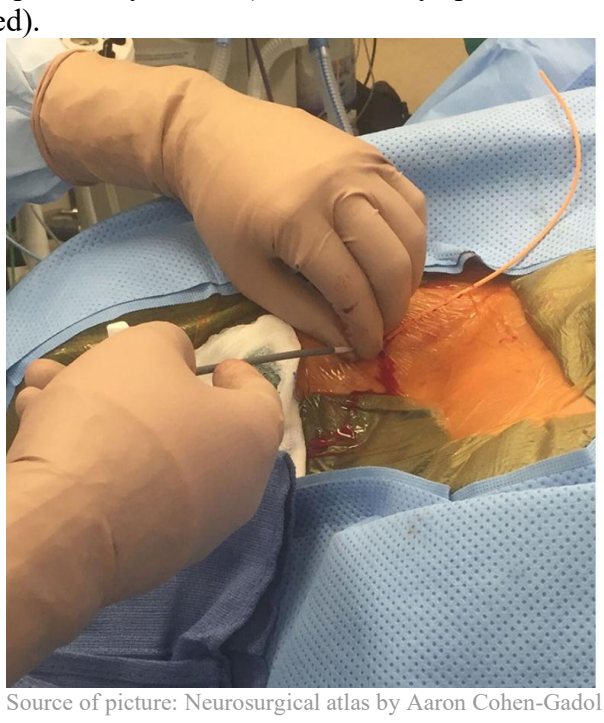
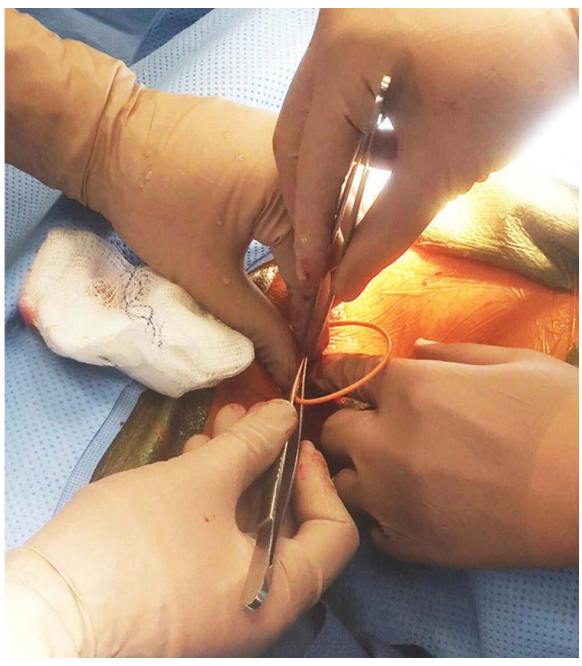
– after penetrating the vessel, venous blood is confirmed with gentle aspiration of a syringe - venous blood should draw easily and have a characteristic darker color than arterial blood.
– **flexible J guide wire** is passed through the needle, and the tip is positioned in the superior vena cava (SVC) or the cardiac atrium under fluoroscopic guidance; instability on ECG may indicate that the guide wire is positioned within the heart.

Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

– needle is then removed, and a ***nick incision*** is made to facilitate dilator entry and also distal catheter exit at the same incision; may mark (with permanent marker) the guidewire flush to the skin – to know the length of distal shunt catheter.
– load the **peel-away sheath** on the **dilator** and pass them together over guide wire into the vessel.
  - occasional advancing and retracting of the guide wire ensures that the dilator is following the wire's subcutaneous course.
  - veins of most adults and larger children are large enough to accept a standard distal shunt catheter (outer diameter of approximately 2.2 mm - fits through a 7-9 French sheath – but test size of the sheath with the distal catheter before inserting it!).
  - *smaller catheter might be required in premature infants*; in this case, there are commercially available "step-down" connectors that can be used to attach a smaller-caliber catheter to a standard catheter.

– tunnel distal catheter from cranium into neck and exit at guidewire skin entry site (→ flush entire shunt system with heparinized saline)
– guide wire is removed → trim distal catheter to the measured length on marked guidewire (may also measure on preoperative CTA if available).
– dilator is removed (observe brisk venous blood return through the sheath) → ***shunt tubing (distal catheter) is passed down the peel-away sheath*** into vein until it is at ***target position*** → split and remove peel-away sheath (it is not always possible to advance the shunt tubing once the sheath is removed).

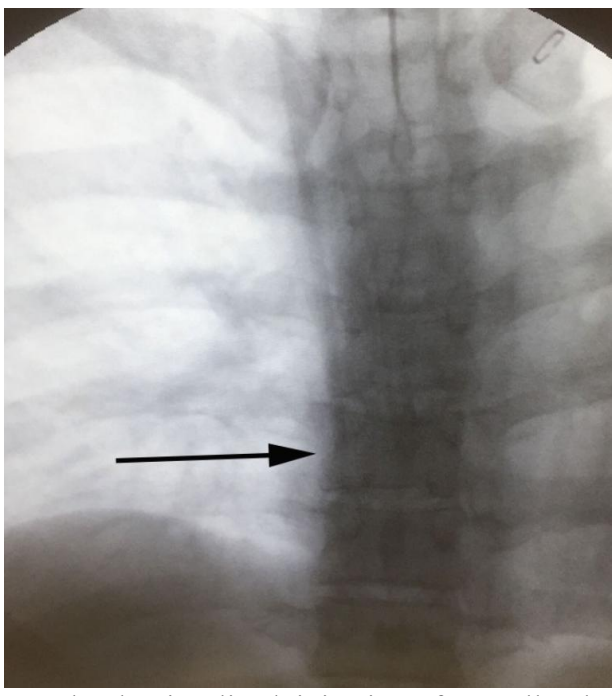
Source of picture: Neurosurgical atlas by Aaron Cohen-Gadol >>

  - if difficult vascular anatomy, may place separate distal catheter over the guide wire (in that case will need straight connector to connect separate distal and proximal parts of catheter).
    - advance distal shunt well beyond the lower atrium before splitting and removing the peel-away sheath; catheter is then pulled back to an appropriate final position, flushed with heparinized saline, and connected to the proximal shunt system.

    N.B. heparinize catheter before placing it into vessel! (not needed if not using separate distal catheter as CSF constant flow prevents thrombosis)

B. Open vascular cutdown technique into **transverse FACIAL VEIN** (esp. for small children – percutaneous technique is more difficult) – may use vascular surgeon help:
– incision parallel to SCM medial border and 2 fingerbreadths below mandible (at the angle).
– open platysma
– find facial vein – IJV junction.
– ligate distal venous inflow.
– obtain control of proximal vein (pass silk loop), longitudinal incision, insert "hockey stick" (yellow) shunt passer into vein → flush distal catheter (special **VA** [needs stepdown connector due to smaller diameter] or **Bactiseal**) with heparinized saline and occlude it until it is connected to proximal system → advance catheter into IJ until it is at ***target position*** (see below) → tie lightly silk loop (holds catheter in place and stops venous bleeding).

- ***target position*** - **atrium-SVC junction or midatrium** – approx. T6-8 (use XR to verify):



  - if the tip is not clearly visualized, injection of a small volume of radiopaque contrast material may facilitate fluoroscopic visualization.
  - venous anatomy on the right side is often easier to navigate than that on the left.
  - be aware of the head position - if the *neck is turned sharply*, the *catheter might migrate* deeper when the neck straightens.
- laminar flow through the atrium may impart a negative pressure through "wicking" - valve with an **antisiphon** feature can be considered to prevent overshunting.
- additional tubing cannot be inserted to allow for growth – anticipate electively scheduled VAS lengthening procedures (educate patient parents about it!).

COMPLICATIONS

- complications are serious - renal failure (shunt nephritis), great vein thrombosis & pulmonary embolism, septicemia (shunt gets exposed at any bacteremia), cardiac arrhythmia, pulmonary hypertension (due to addition of CFS volume), and even atrial perforation, thromboembolic complications, and cardiac tamponade have been reported.

Thrombosis associated with ventriculoatrial shunts

Wu D, Guan Z, Xiao L, Li D. Thrombosis associated with ventriculoatrial shunts. Neurosurg Rev. 2022 Apr;45(2):1111-1122.

- shunting-associated thrombosis is a potentially life-threatening complication after VAS insertion: atrial or venous thrombosis with associated pulmonary embolism (PE), pulmonary hypertension (PH), and cor pulmonale
- etiology of thrombosis may be multifactorial, including shunt catheter itself, contents of CSF, shunt infection, and genetic disorder.
- clinical presentation: from asymptomatic to a life-threatening condition.
- thromboembolic complications present clinically in 0.3% of patients, whereas autopsy series reveal an incidence of up to 60%.
- thrombus formation ***could occur at any time***, even decades after VAS insertion: Hemmer found intraoperatively that thrombosis occurred in 20% of patients after indwelling catheters were left in situ for 2 years, in 67% if the catheter was left in for up to 6 years, and in 85% if it was left for up to 14 years
- **PE** is another severe complication of the VAS: incidence of clinically significant PE is 3.2%; encountered in 50–100%; may lead to potentially increased incidence of PH and cor pulmonale. In VAS patients, PH were recognized clinically in 0.3%, whereas postmortem diagnoses of PH were established in 6.3%.
- **optimal placement is in the right atrium**; when the tip of the catheter moves out of the atrium and into the great vessels, increasing the risk of thrombosis.
- treatment:
  - when imaging of the neck, subclavian, and brachial veins identify presence of thrombus and without risk factors for bleeding, empiric **anticoagulation** should be advocated; also of interest, anticoagulation therapy may help to rectify a shunt malfunction and reduce the incidence of distal catheter complications by preventing further clot formation
  - **intrareservoir administration of thrombolytic therapy** can be a useful nonoperative treatment strategy for shunt malfunction associated with thrombosis; recombinant tissue-type plasminogen activator, streptokinase, and urokinase have been successfully used in management of many patients having an intracardiac thrombus.
    - Timely diagnosis by echocardiography before a thrombus gets bigger or organized leads to effective, safe, and rapid thrombolysis by use of thrombolytic drugs.
    - risk of thrombus fragmentation with secondary embolization, especially in cases of large, mobile thrombi.
  - **surgical removal of the thrombus** has been the treatment of choice since shunting-related thrombosis was reported. The most direct form of therapy, namely, cardiotomy and removal of thrombus, would presumably be the best treatment.
  - **simple withdrawal of the distal end of a VAS** on which there is a thrombus is contraindicated because it would free the thrombus and the risk of embolization would be very high with the possibility of sudden death.
  - recommendations are to treat catheter-related thrombosis for 3 months with anticoagulation therapy followed by removal of catheter, or to directly remove the catheter by surgery
  - Dudiy et al. reported a novel technique for percutaneous removal of the right heart thrombi using a suction cannula.
  - Anticoagulation therapy for confirmed acute **PE** is the mainstay of treatment.
  - The cornerstone of the treatment of **cor pulmonale** in the patient with a VAS is the prompt removal of the offending atrial catheter; lifelong anticoagulation therapy is currently recommended with the rationale to prevent in situ thrombosis and recurrent venous thromboembolism.

VPS VS. VAS

- historically, VAS was 1st choice over VPS until polyethylene distal catheters were replaced by silicone distal catheters – choice shifted back to the peritoneum as the preferred terminus for CSF reabsorption in 1970s.

VPS vs. VAS

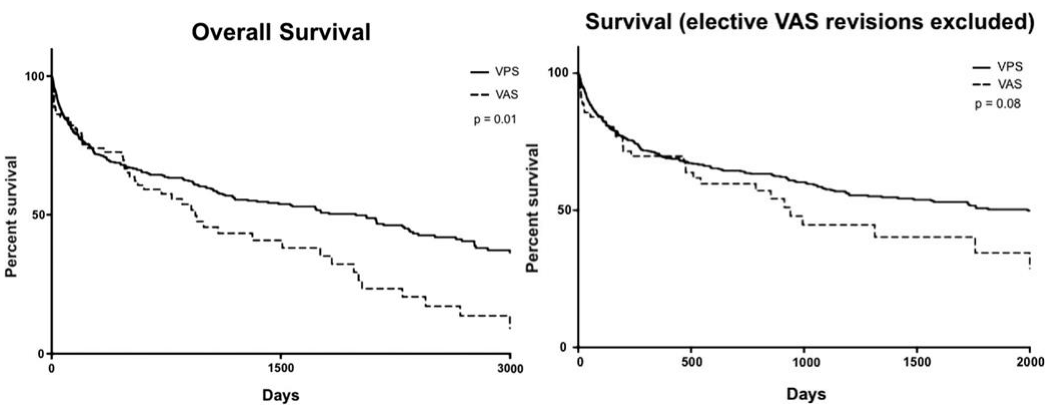
Ventriculoatrial Shunt Versus Ventriculoperitoneal Shunt: A Systematic Review and Meta-Analysis. Oliveira, Leonardo de Barros et al. Neurosurgery 94(5):p 903-915, May 2024.

- 4304 patients, with 1619 undergoing VAS and 2685 receiving VPS placement.
- revision surgeries: no significant difference between VAS and VPS (risk ratio [RR] = 1.10, 95% CI: 0.9-1.34; I2 = 84%, random effects).
- infections: no significant difference between the groups (RR = 0.67, 95% CI: 0.36-1.25; I2 = 74%, random effects).
- shunt-related deaths: no statistically significant disparity (RR = 2.11, 95% CI: 0.68-6.60; I2 = 56%, random effects); studies after 2000 showed no VAS led to cardiopulmonary complications, and only 1 shunt-related death could be identified.

VPS vs. VAS

Rymarczuk et al. A Comparison of Ventriculoperitoneal and Ventriculoatrial Shunts in a Population of 544 Consecutive Pediatric Patients. Neurosurgery, Volume 87, Issue 1, July 2020, Pages 80–85

- retrospective analysis
- 544 pediatric shunt patients (459 VPS and 85 VAS) followed for at least 90 d (VPS: 5.9 yr; VAS: 5.3 yr).
- **VPS** has significantly greater survival in patients < 7 yo ($P = .001$), but showed no difference in older children ($P = .4$), more frequent shunt infection (4.0% vs 0.01% VAS; $P < .05$).
- **VAS** had a significantly lower rate of infection ($P < .05$) and proportion of proximal failure as a reason for shunt failure (29% vs 53% with VPS, $P < .001$).
- no statistical difference in rate of distal catheter failure ($P = .08$) or valve malfunction ($P = .9$).
- complications related to placement occurred at a rate of 5.5% VPS vs 3% VAS.
- no mortality attributed to shunt insertion.
- 54% of VPS and 60% of VAS required at least 1 revision. VPS demonstrated superior survival overall; however, if electively scheduled VAS lengthening procedures are not considered true "failures," no statistical difference is noted in overall survival ($P = .08$):



Authors, Year	Population	Findings	Conclusions
Ignelzi and Kirsch, 1975	300 adult and pediatric patients.	VAS required fewer revisions: 58% vs 48%.Infections occurred 1.6x as frequently in VAS.	VPS exhibited a trend towards more revisions being necessary. VAS was prone to more serious complications. **VPS** is preferable due to ease of insertion and more favorable complication profile.
Keucher and Mealey, 1979	288 pediatric patients with nontumoral etiologies.	22% overall rate of infection.97% of VAS vs 62% VPS required revision at last follow-up.	If a child reaches 5 yr of age without a shunt infection, **VPS** performs better than VAS (41% vs 17% nonrevision rate).
Mazza et al, 1980	165 pediatric patients.	VAS associated with greater morbidity.45.8% vs 51% revision rate in favor of VAS. Greater reliability of VPS overall.	**VPS** is preferable to VAS due to greater morbidity from VAS.
Borgbjerg et al, 1980	884 adult and pediatric patients.	Statistically greater rate of VAS revision (51 vs 38.5).Trend towards greater durability of VPS. Rate of revision declined with age: 69% in infants, 31% in adults.	Young children are the most likely to require revision. Pudenz shunts are less durable than Hakim models. VPS may not be superior in all facets due to patient variables.
Lam and Villemure, 1997	122 adults with NPH and carcinomatous meningitis	Overall complication rate of 40.5%, including 2 deaths.2.5% infection rate. Distal failure rates: 4.6% VPS, 6.8% VAS.	**VPS** is preferable due to ease of insertion and lower morbidity.

REMOVAL OF VAS

- it is OK to pull catheter from vein – hold neck pressure (until established tract thromboses).
- if catheter is stuck, may leave in place but need to suture to pericranium or other tissues – to prevent distal intravascular migration.

VENTRICULO-GALLBLADDER SHUNT

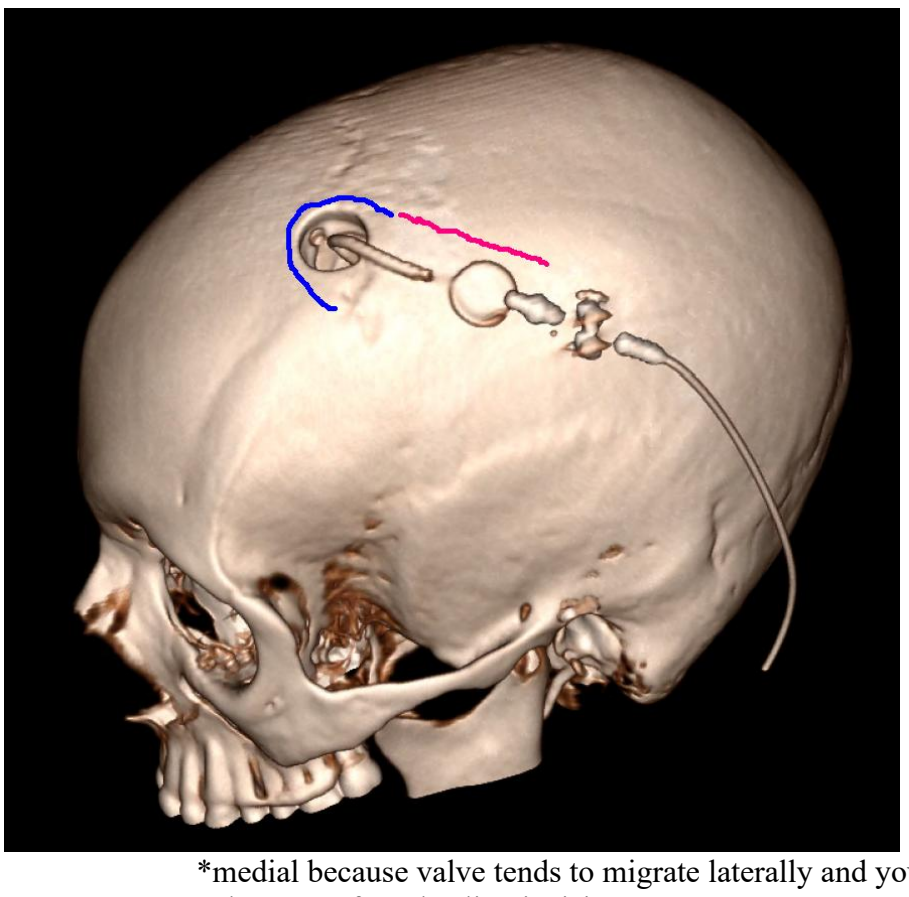
- check **HIDA scan** to make sure bladder empties.
- purse string suture on fundus.
- cut catheter and use **straight connector** where catheter goes through bladder wall – prevents dislodgement (→ bile peritonitis).

VENTRICULO-SUBGALEAL SHUNT

- temporary measure until newborn reaches 2 kg for a permanent VPS.
- repeated trans-fontanel taps – too high risk of infection

SHUNT REVISION

- prep entire system – may need to open abdomen.
- ***open scalp incision at valve and proximal catheter junction***, medial* and parallel to the valve (blue – old scar; red – current incision):



*medial because valve tends to migrate laterally and you want to keep valve away from healing incision

— check for CSF egress from proximal catheter.
— attach 14G Angiocath* to valve, then attach 3-way stopcock and manometer with saline syringe: fill manometer with saline, check for runoff through valve and distal catheter (may gently flush distally but not too forcefully – may damage valve mechanism).
*alternative - use blunt needle and small piece of catheter on valve inlet

- if distally no flow, ***extend cranial incision alongside of valve*** – can reach valve in situ – check distal runoff on catheter.
- replace obstructed component.
  — if unable to retrieve proximal catheter (stuck in parenchyma or with choroid plexus ingrowth), either leave it or insert Bugbee monopolar cautery and coagulate inside catheter lumen all catheter holes by advancing wire inside catheter (error to insert stylet and coagulate on it – electrical current is diverted through proximal hole!).
- replacing ventricular catheter – *never soft pass* (catheter easily gets deflected).
- replacing shunt in **slit ventricles**: Bugbee (to take out old catheter), navigation, Neuropen (to verify), consider valve with higher settings

VENTRICULAR ENDOSCOPY

Pending
Jandial, procedure 47

Dr. Collins, Dr. Ritter sometimes use Stealth navigation and pin patient into Mayfield
for infants – use Mayfield Infinity system – very shallow pins (Dr. Ritter always uses adult pins regardless of age) – just keep head steady without skull perforation while head weight rests on horseshoe.

- establish scalp entry point with navigation
- open skin:
  a) simple slit incision
  b) in horseshoe and pericranium in horseshoe in opposite direction (at the end will help to seal CSF leak)
- drill skull hole with matchstick just large enough to fit introducer sheath and perfectly aligned to trajectory.
- use "Dr. Collins' shunt passer" (hollow metal tube with attached SureTrak) to align to trajectory and pass Becker catheter to ventricle (note beforehand how deep catheter should go from shunt passer tip, then note were is stop mark on Becker catheter flush to shunt passer's port edge).
- remove Becker stylet and shunt passer.
- use 10F peel away introducer sheath (remove plastic stylet) – advance it over Becker catheter into ventricle; remove Becker catheter; some attendings would staple peel away sheath arms to scalp (Dr. Collins does not like it).
- use endoscope (continuous irrigation with warm (!!!) Lactated Ringer solution);
  about endoscopes – see p. Op140 >>
- align endoscope to 12 o'clock, adjust focus and white balance.
- select on camera "Flexiscope".
- monopolar cautery:
  1) soft, blunt ended (Bugbee) to coagulate – ***touch and twist*** (helps to shrink membranes).
  2) stiff and sharp ended
- hemostasis may be achieved with monopolar cautery and vigorous irrigation (to verify hemostasis, pinch irrigation hose to stop irrigation – watch for blood wisp in CSF).
- at the end, put dry Gelfoam (squeezed into cone) through the sheath – to plug parenchymal path and bur hole – to minimize CSF leak.
- postop – HOB up.

ENDOSCOPIC THIRD VENTRICULOSTOMY (ETV)

Pending video:
https://expertconsult.inkling.com/read/schmidek-sweet-operative-neurosurgical-quinones-6th/videos/chapter-96-video-1---endoscopic

INDICATIONS

Obstructive hydrocephalus
Persistent shunt infections (ETV allows to avoid hardware)

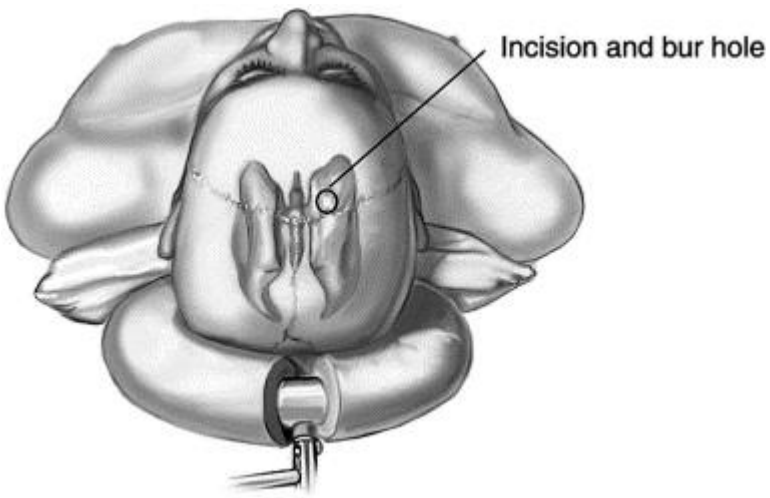
CONTRAINDICATIONS

ETV may not work if patient has extensive metastatic deposits in subarachnoid spaces (absorptive capacity↓) H: regular VP shunt.
Low success rate of ETV – after previous shunt, WBRT

Check size of 3rd ventricle floor on volumetric MRI – if distance between dorsum sellae and basilar artery is too small, think twice if shunt is not safer option!

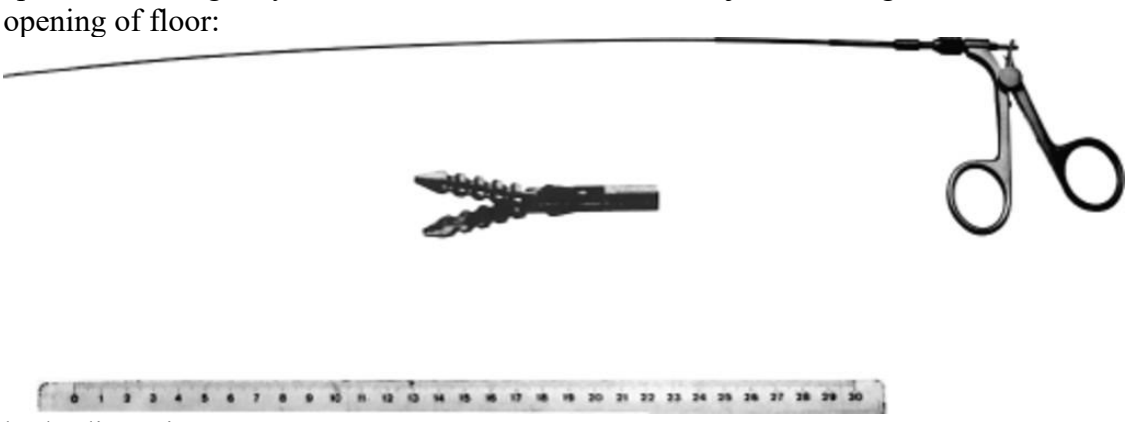
TECHNIQUE

Classical Kocher bur hole site – just in front of the right coronal suture, in midpupillary sagittal plane (allows straight trajectory via right lateral ventricle to foramen of Monro).



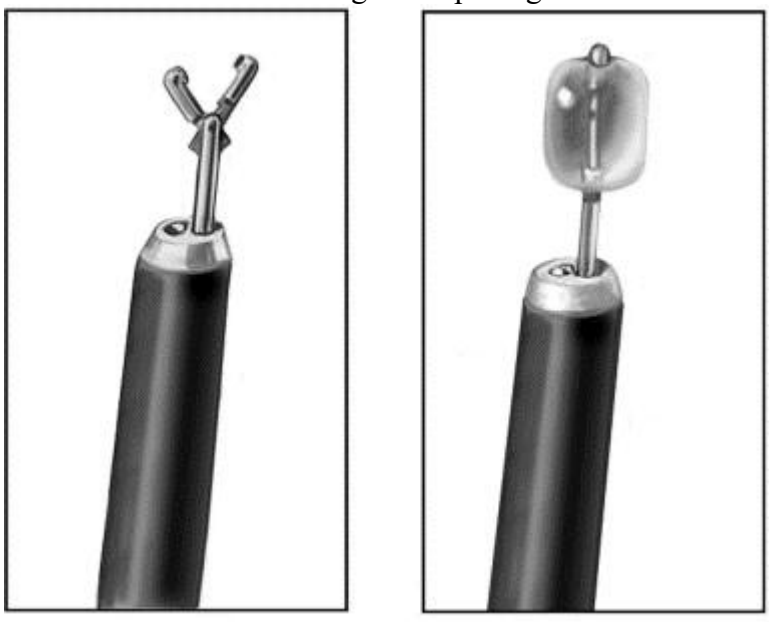
- use **rigid** endoscope.
- image guided stereotactic technology helps immensely with the trajectory, but once you've entered the third ventricle, you must navigate by visual landmarks.
- choroid plexus is the best guidance towards foramen of Monro.
- floor of third ventricle must be *thin and translucent enough to permit visualization of the basilar artery and mammillary bodies* - if these structures cannot be visualized then procedure should be aborted.
- target for opening:
  - in midline (avoids PCommA and PCA)
  - just anterior to mamillary bodies (through tuber cinereum)
  - posterior to infundibular recess
  - anterior to tip of basilar artery

  N.B. do not go too anterior – will damage pituitary stalk and cause DI!
- pierce mechanically ("rubbing through") with:
  a) **blunt Bugbee tip without cautery current**
  b) **Decq forceps** - new device for ETV: tip of the forceps is thin enough to allow easy perforation, inner surface of jaws is smooth to avoid catching vessels of basal cistern; and outer surface of jaws has indentations that catch edges of opening to prevent them from slipping along the instrument's jaws - ventricle floor is opened by gentle pressure of the forceps, which is slowly opened so that the edges of the aperture are caught by the distal outer indentation of the jaws, leading to 4-mm opening of floor:



  c) hydrodissection
  d) bipolar electrocautery

  N.B. no sharps, no electricity, no laser! – basilar tip!
- perforate 3rd ventricular floor in several spots → advance **2-3F Fogarty catheter ballon*** past opening → inflate and withdraw through the opening.



- keep inflated a little bit for hemostasis and tissue hole expansion (use 0.2 mL then may add 0.75 mL balloons); ± use microforceps to remove tissue debris.

  *alternative – double balloon (Neuroballoon™ catheter, Integra LifeSciences)
- opening does not need to be large (unlike e.g. fenestrating an arachnoid cyst) ≈ 4–5mm is usually adequate.
- may need to perforate Liliequist arachnoid membrane below 3rd ventricle floor – should clearly see dorsum sellae and basilar artery!

Liliequist membrane – see p. A40 >>

- may use monopolar cautery (Bugbee) to coagulate choroid plexus.
- consider injection of diluted intrathecal contrast agent into the lateral/third ventricle prior to removal of scope - CT head 1 hour after surgery will show diffuse subarachnoid contrast in cisterns and over convexity if ETV successful.
- may leave **Ommaya reservoir** with *catheter in ventriculostomy orifice* – keeps orifice open and also gives access to CSF in case ETV fails; alt - may leave clamped EVD in place postoperatively.
- may take *biopsy* during same procedure by endoscopic guidance.
- at the end, may close dura completely with running 2-0 silk.
- postop MRI will show drop out of T2 signal at stoma of ETV.

COMPLICATIONS

- hypothalamic injury: hyperphagia.
- injury to pituitary stalk or gland: diabetes insipidus, amenorrhea
- transient 3rd and 6th nerve palsies
- injury to basilar artery, PCommA, or PCA: a fixed endoscope sheath seated just distal to the foramen of Monro within the third ventricle may allow for safe egress of blood extacranially
- uncontrollable bleeding
- traumatic basilar artery aneurysm: possibly related to thermal injury
- cardiac arrest

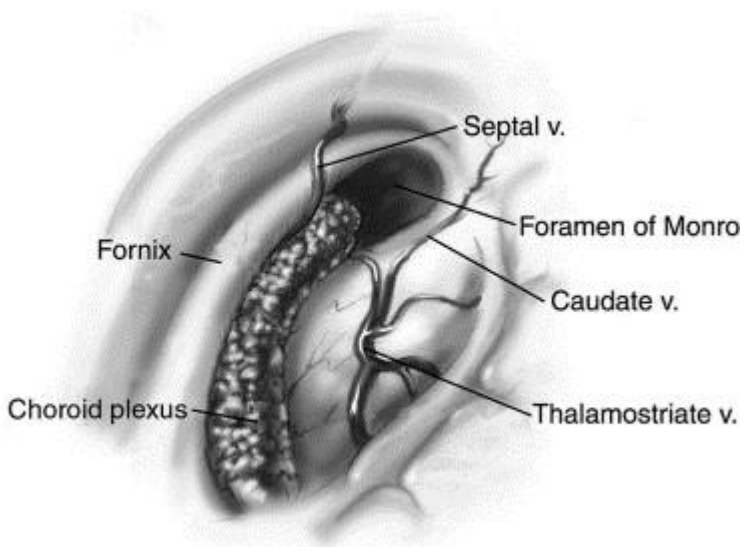
OUTCOME

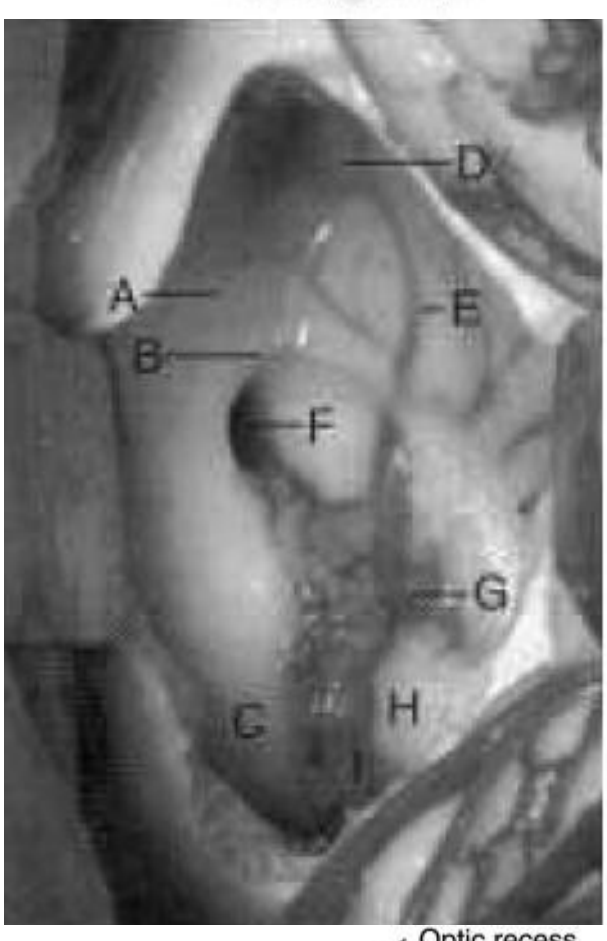
Chance of an ETV lasting 6 months without failure:

Table 25.1 ETV Success Score

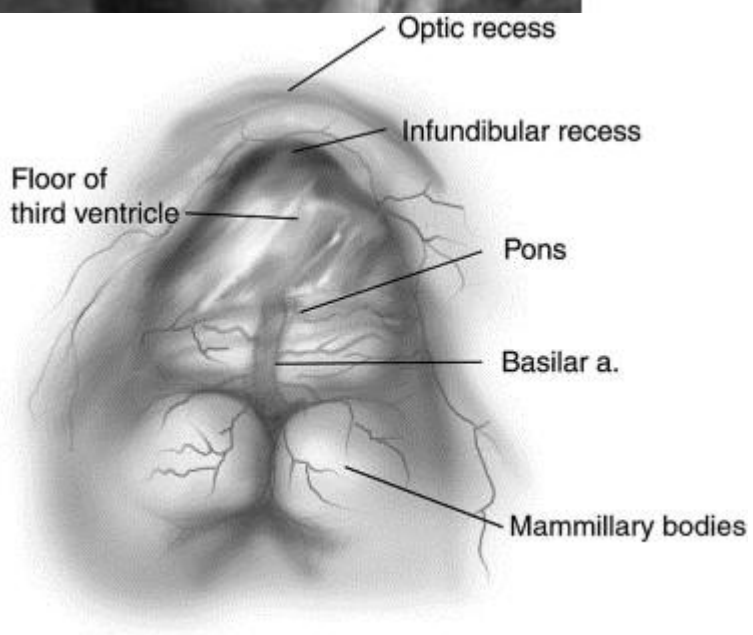
Category	Description	Value	Score
Age	<1 month	0%	___%
	1 to<6 months	10%	
	6 months to<1 year	30%	
	1 to>10 years	40%	
	≥10 years	50%	
Etiology	• post-infectious	0%	___%
	• myelomeningocele • post IVH • non-tectal brain tumor	20%	
	• aqueductal stenosis • tectal tumor • other	30%	
Shunt history	• previous shunt	0%	___%
	• no previous shunt	10%	
		Total (range 0–90%)	___%

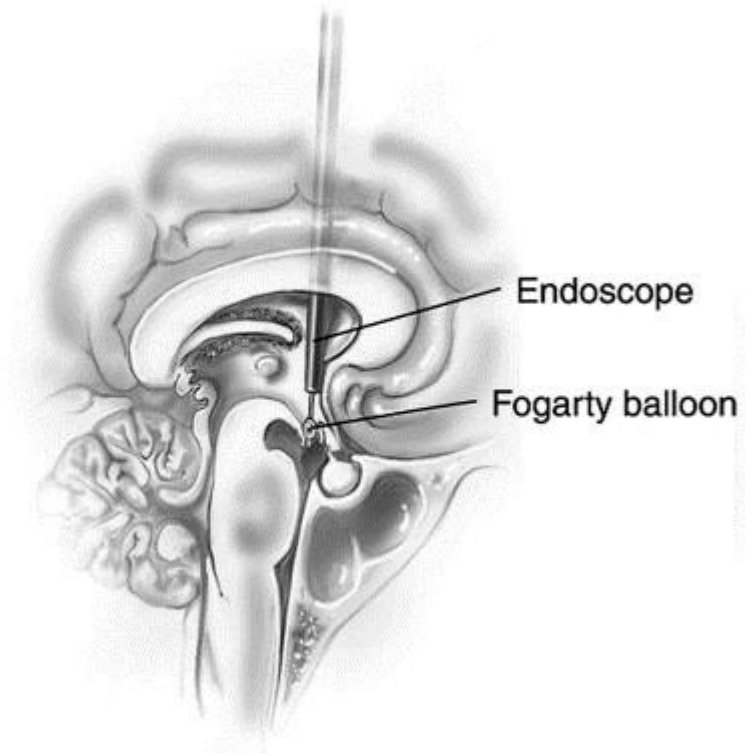
ANATOMY

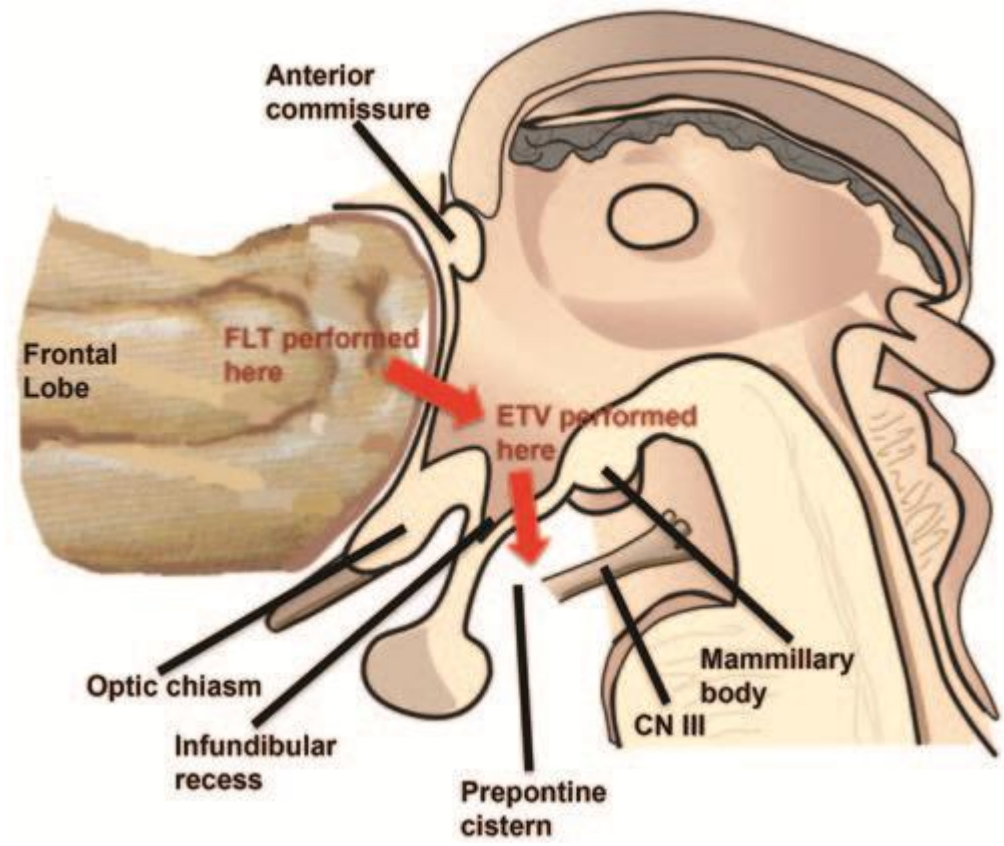


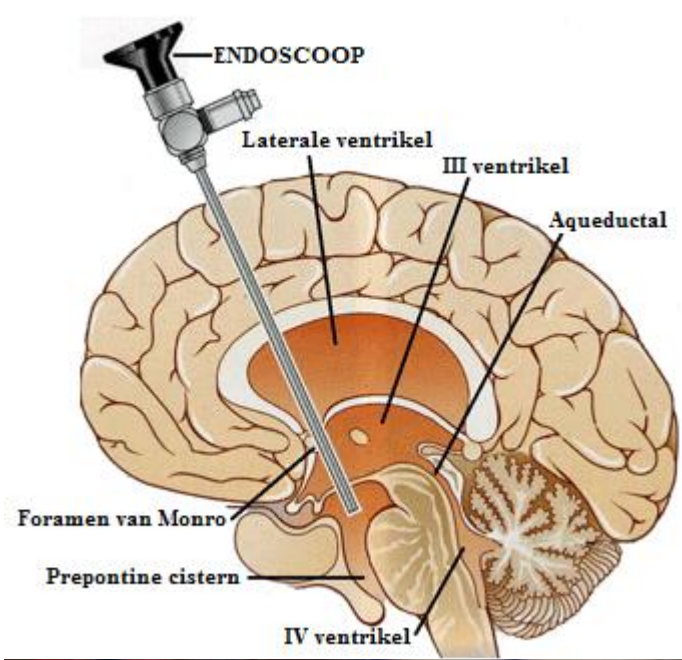


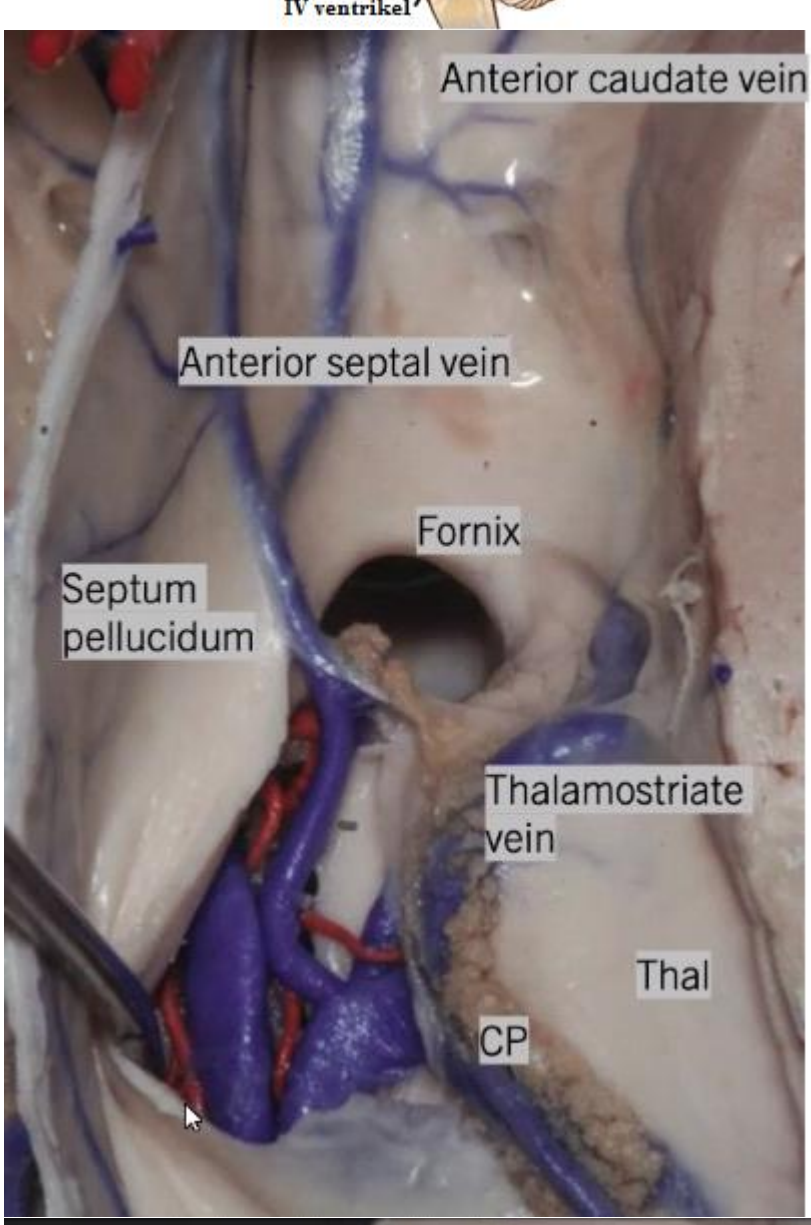
A. Septum pellucidum
B. Column of fornix
C. Body of fornix
D. Caudate nucleus
E. Anterior caudate vein
F. Foramen of Monro
G. Thalamostriate vein
H. Thalamus
I. Choroid plexus

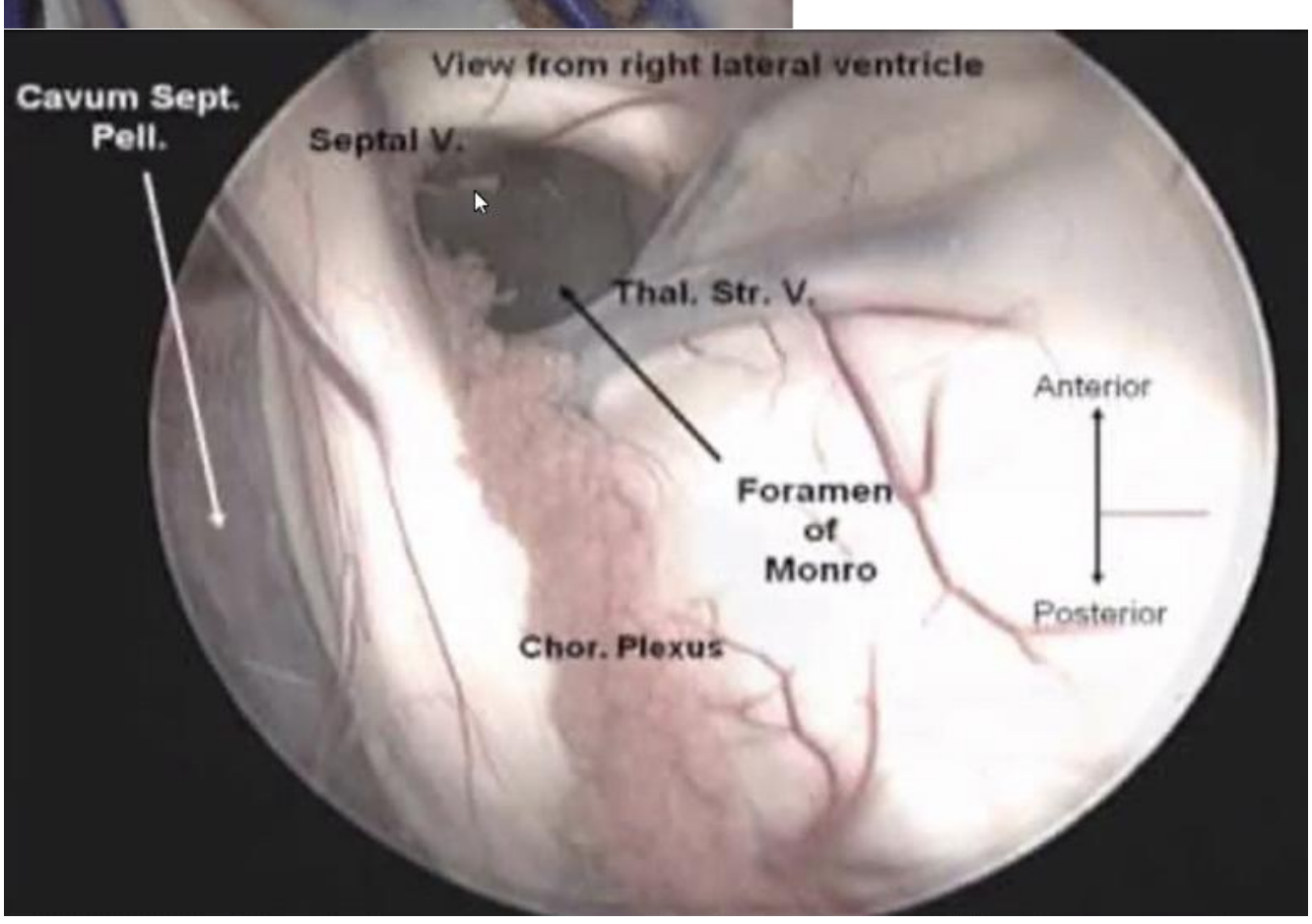


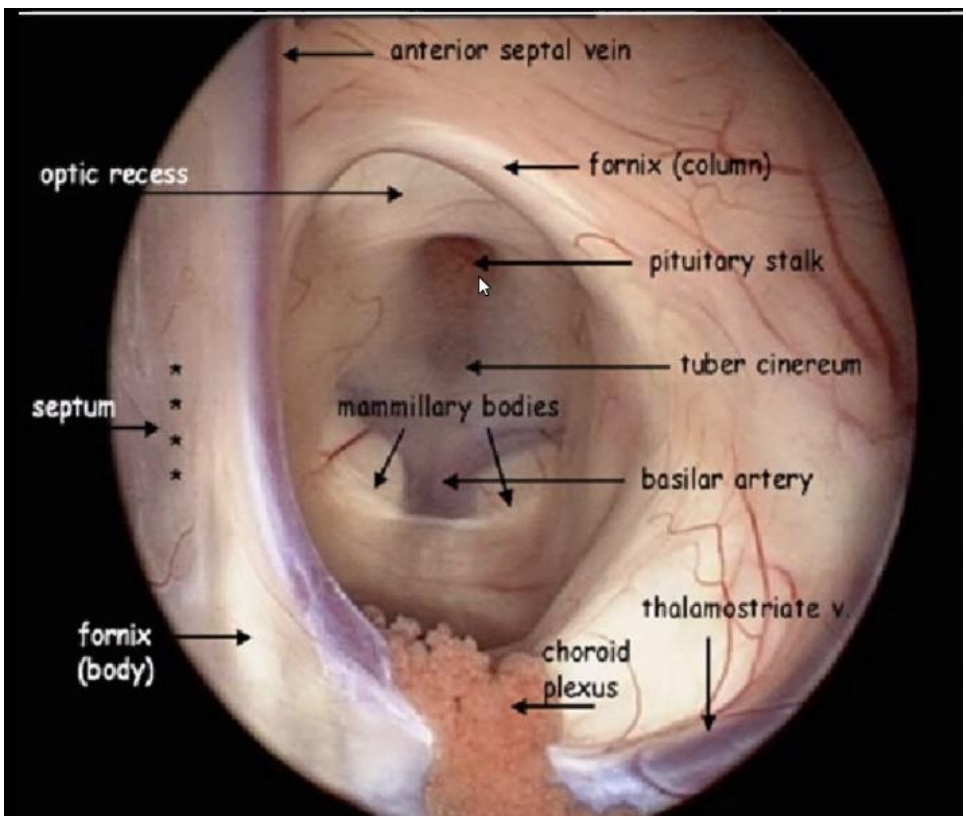



Anterior commissure
Frontal Lobe
FLT performed here
ETV performed here
Optic chiasm
Infundibular recess
Prepontine cistern
Mammillary body
CN III


ENDOSCOOP
Laterale ventrikel
III ventrikel
Aqueductal
Foramen van Monro
Prepontine cistern
IV ventrikel

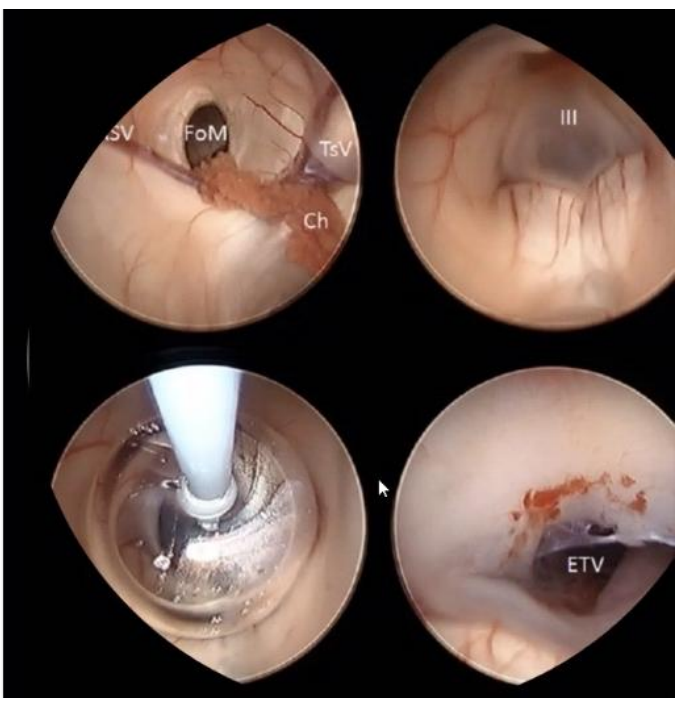

Anterior caudate vein
Anterior septal vein
Fornix
Septum pellucidum
Thalamostriate vein
Thal
CP


View from right lateral ventricle
Cavum Sept. Pell.
Septal V.
Thal. Str. V.
Foramen of Monro
Chor. Plexus
Anterior
Posterior



STEPS CONTINUED

- Enter the foramen of Monro to approach the floor of the 3rd ventricle
- Puncture through the tuber cinereum and membrane of Liliequist
  - Can be accomplished with electrocautery, blunt dissection, or balloon dilation



SEPTOSTOMY

Need more lateral bur hole than for Kocher approach (classically – **lateral eye canthus**); use endoscope and Fogarty balloon.

Dr. Collins:

- uses navigation for better orientation (e.g. to avoid injury to fornices) – chose entry and target points so trajectory spans frontal horn (important if ventricles are slit).
- uses SureTrak attached to "Dr. Collins shunt passer" secured in Mitaka robotic arm.
- measure the distance (on Stealth) from Dr. Collins shunt passer tip to target; insert Becker catheter through shunt passer so that exact length exits, then mark Becker at proximal end flush to shunt passer hub; align shunt passer to trajectory and pass Becker; remove shunt passer; advance 10F peel-away sheath (aka introducer) on the Becker catheter; staple peel-away sheath hands to the skin; insert endoscope through sheath.
- locate septum and poke with sharp monopolar tip (use coagulation intermittently) or just mechanically with blunt Bugbee tip; hemostasis with monopolar Bugbee; then insert 2F Fogarty ballon and dilate the opening with balloon (also helps with hemostasis).

LUMBO-PERITONEAL (LP) SHUNT

INDICATION

NPH

Pseudotumor cerebri (IIH, idiopathic intracranial hypertension)

N.B. LPS may induce secondary (iatrogenic) cerebellar tonsillar ectopia ("Chiari") in IIH!

HARDWARE

N.B. to prevent overdrainage, it is highly advisable to use **programmable valve** (siphon control is probably not important as there is no height difference between lumbar spine and abdomen)

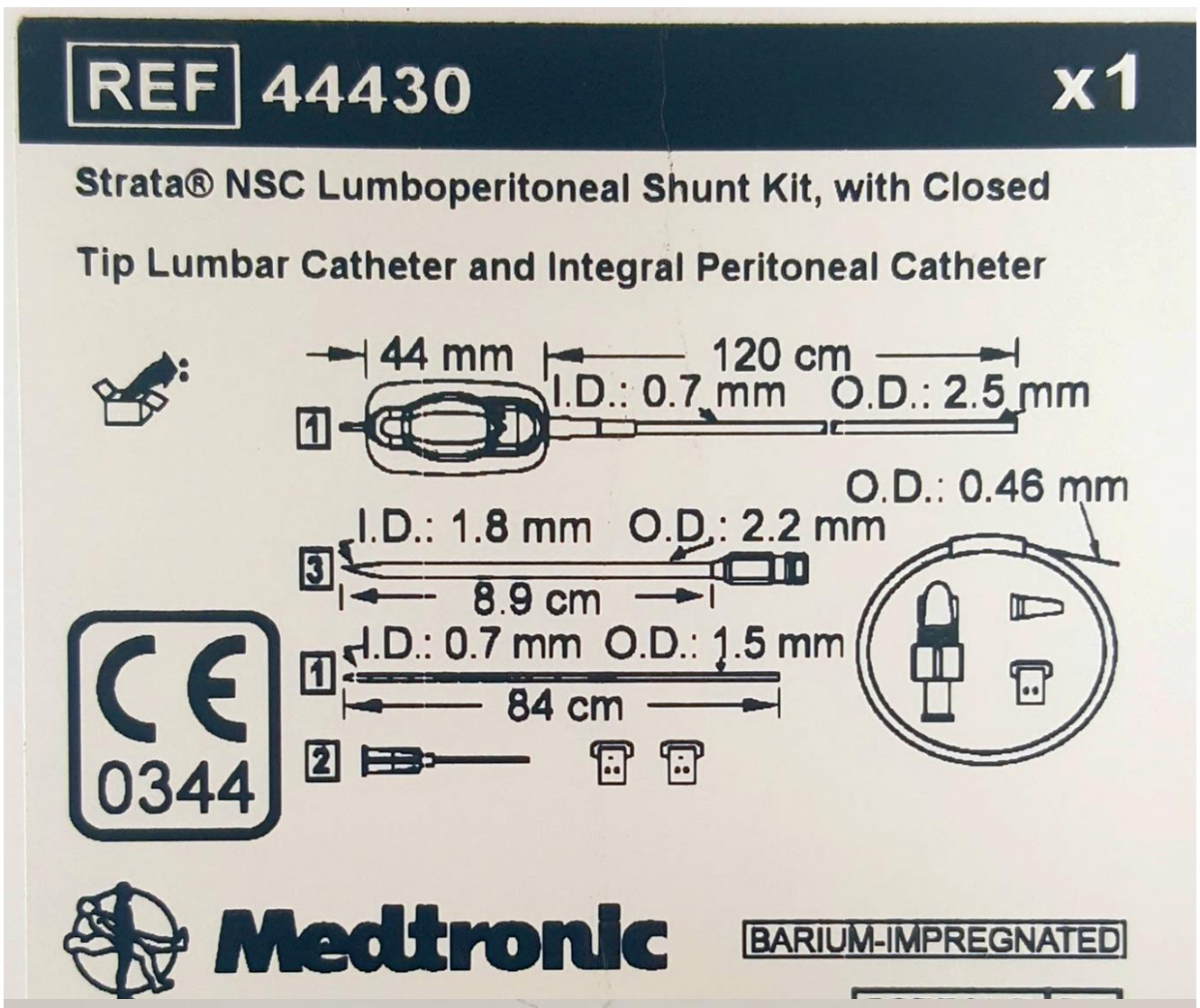
SPETZLER CATHETER

(Integra™ Spetzler™ Lumbar-Peritoneal Shunt) >>

Pressure control is achieved through combination of *double slit valve* at peritoneal end and smal*l inner diameter* catheter:

MEDTRONIC 44430 KIT (WITH NO-SIPHON-CONTROL NSC VALVE AND BOTH CATHETERS)

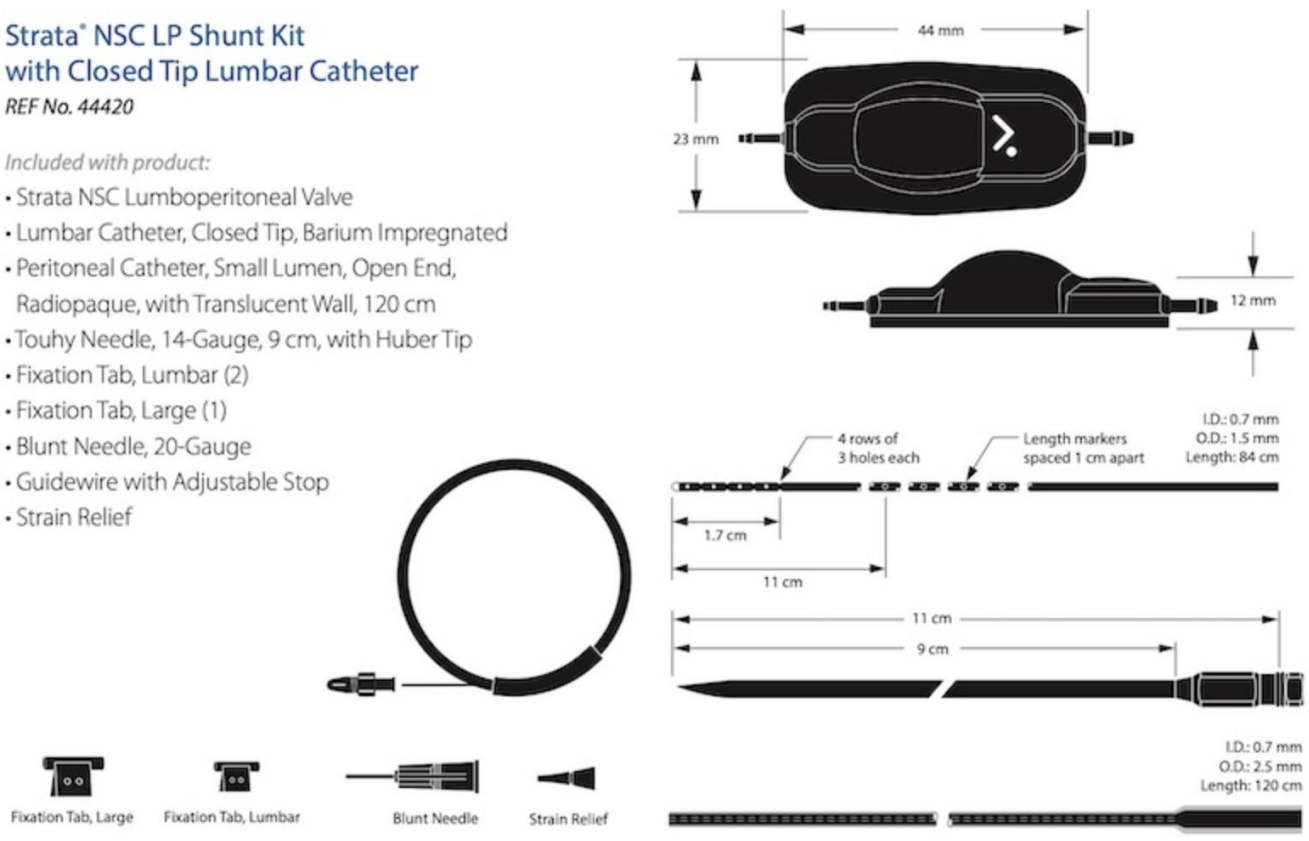
Box comes with two separate packages:



Valve has small diameter intake nipple (to match proximal lumbar catheter) and big flanges for easy suture to tissues. *see above >>*

Catheter has distal slits so need to cut off that end!

MEDTRONIC 44420 KIT (WITH SIPHON-CONTROL VALVE)



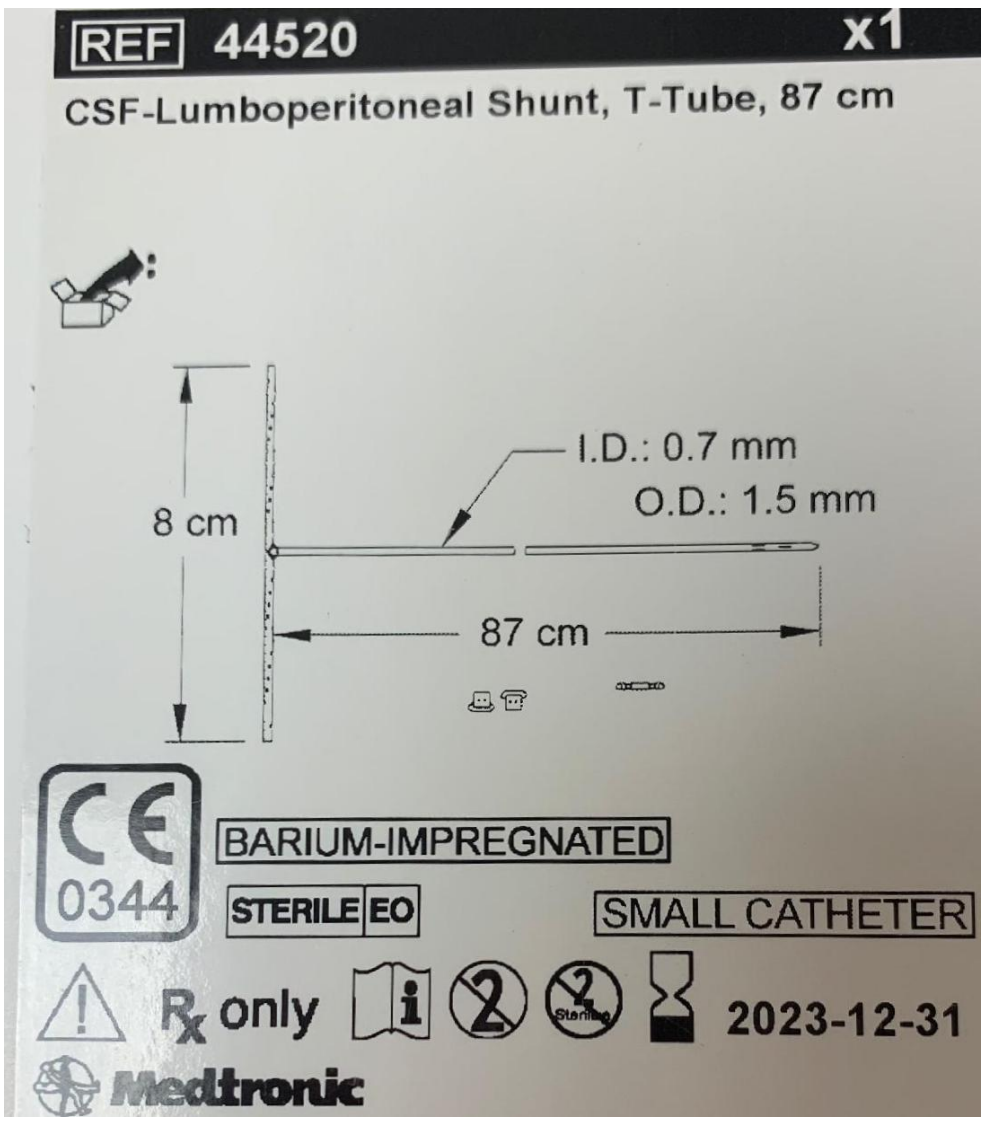
MEDTRONIC 44410 KIT (WITHOUT VALVE)

Flow control is by **peritoneal catheter slits**;

- if using with stand-alone valve (e.g. Strata II), there is diameter difference between regular valve intake nipple and this catheter – may need to use **stepdown connector** although it is possible to put catheter on.

MEDTRONIC T-TUBE

- for open intradural placement.



PROCEDURE

- left lateral position on bean bag.
- prefer to use flat-top spine table – easy to use fluoroscopy if needed.
- use loupes and headlight (usually midline incision sags downward – need to look upwards and no OR light will help).
- sit on chair.
- incise skin in midline over L4 and L5 spinous processes.
- dissect down to fascia.
- 14G Tuohy needle is inserted at L4-5 interspace (under optional fluoroscopic guidance – usually don't need it).
- **lumbar catheter** is advanced to lumbar subarachnoid space (if have fluoro available, may inject contrast to verify myelographic effect); place 2-0 silk purse string on fascia around catheter (while needle is still in – protects catheter); suture 1-2 butterfly plastic anchors (around catheter) to fascia.
- good distal CSF egress must be verified (if needed, attach blunt needle and aspirate air bubbles)
- tunnel catheter from spine to abdomen using bent tunneler.
- place into peritoneal cavity (e.g. laparoscopically* or open).

*laparoscopy may be difficult in lateral position

- <u>if using valve</u> (often Spetzler is enough and no valve is needed but risk of overdrainage without ability to adjust drainage).

a) **valve at the same lumbar incision** (in obese patient valve may end up too deep for postop programming) – create generous pocket, position **valve** vertically along spine and suture to fascia; suture several **tie-down anchors** on both catheters to make sure they make nice round curves (otherwise, high tendency to kink!).

b) **valve in flank area** (not recommended – much more difficult to interrogate and program as valve has no firm base and just floats in fatty tissue)

— create a generous pocket for valve in flank subcutaneous fat with big Kelly clamp.
— tunnel distal **Bactiseal catheter** from spinal incision to lateral abdominal incision
— connect **valve** to Bactiseal
— connect short segment of Bactiseal to proximal valve inlet, then **stepdown connector** (as Spetzler lumbar catheter is of smaller diameter).
— trim Spetzler lumbar catheter short and connect to stepdown connector.
— pull Bactiseal catheter to abdomen while situating valve in pocket.