Le infezioni post-neurochirurgiche: come affrontarle

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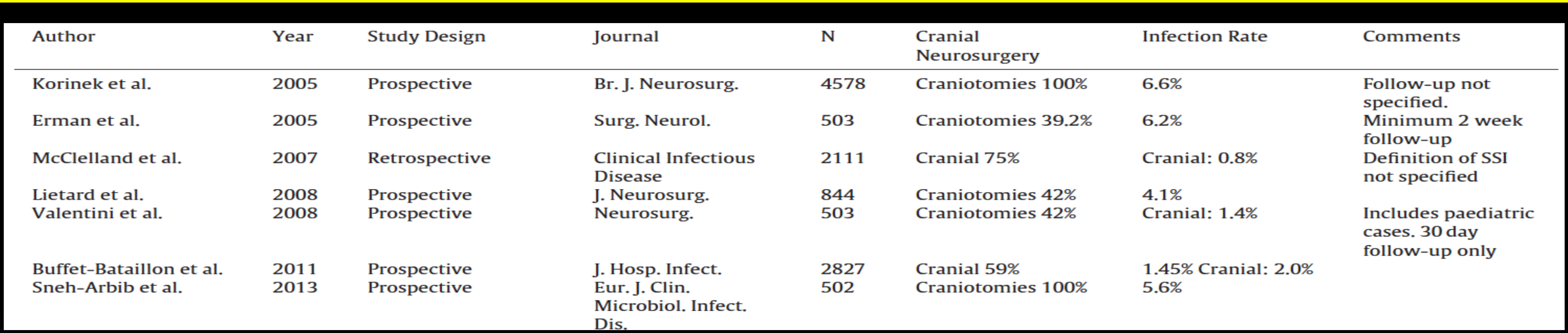
Convegno Nazionale
La Gestione Appropriata
delle Infezioni in Riabilitazione:
indicazioni strategiche

Cona (Fe) 20 Giugno 2019
Aula Congressuale
Nuovo Arcispedale S. Anna, Via A. Moro n. 8

Infezioni in Neurochirurgia

- **Infezioni ferita chirurgica - Surgical Site Infection (SSI)**
- **Infezioni sistemi di derivazione liquorale**
  - derivazione liquorale esterna (DVE, DLE)
  - derivazione ventricolo-atriale (DVA)
  - derivazione ventricolo-peritoneale (DVP)
- **Infezioni materiale protesico**
  - cranioplastiche (autologhe/eterologhe)
  - sistema di fissazione spinale
  - sistemi di neuromodulazione
    - Intrathecal Baclofen (ITB) pump – Spinal Cord Stimulator (SCS)
    - Vagus Nerve Stimulation (VNS)
    - Stereo-EEG e Deep Brain Stimulation (DBS)

Surgical Site Infections (SSI)



Author	Year	Study Design	Journal	N	Cranial Neurosurgery	Infection Rate	Comments
Korinek et al.	2005	Prospective	Br. J. Neurosurg.	4578	Craniotomies 100%	6.6%	Follow-up not specified.
Erman et al.	2005	Prospective	Surg. Neurol.	503	Craniotomies 39.2%	6.2%	Minimum 2 week follow-up
McClelland et al.	2007	Retrospective	Clinical Infectious Disease	2111	Cranial 75%	Cranial: 0.8%	Definition of SSI not specified
Lietard et al.	2008	Prospective	J. Neurosurg.	844	Craniotomies 42%	4.1%	
Valentini et al.	2008	Prospective	Neurosurg.	503	Craniotomies 42%	Cranial: 1.4%	Includes paediatric cases. 30 day follow-up only
Buffet-Bataillon et al.	2011	Prospective	J. Hosp. Infect.	2827	Cranial 59%	1.45% Cranial: 2.0%	
Sneh-Arbib et al.	2013	Prospective	Eur. J. Clin. Microbiol. Infect. Dis.	502	Craniotomies 100%	5.6%	

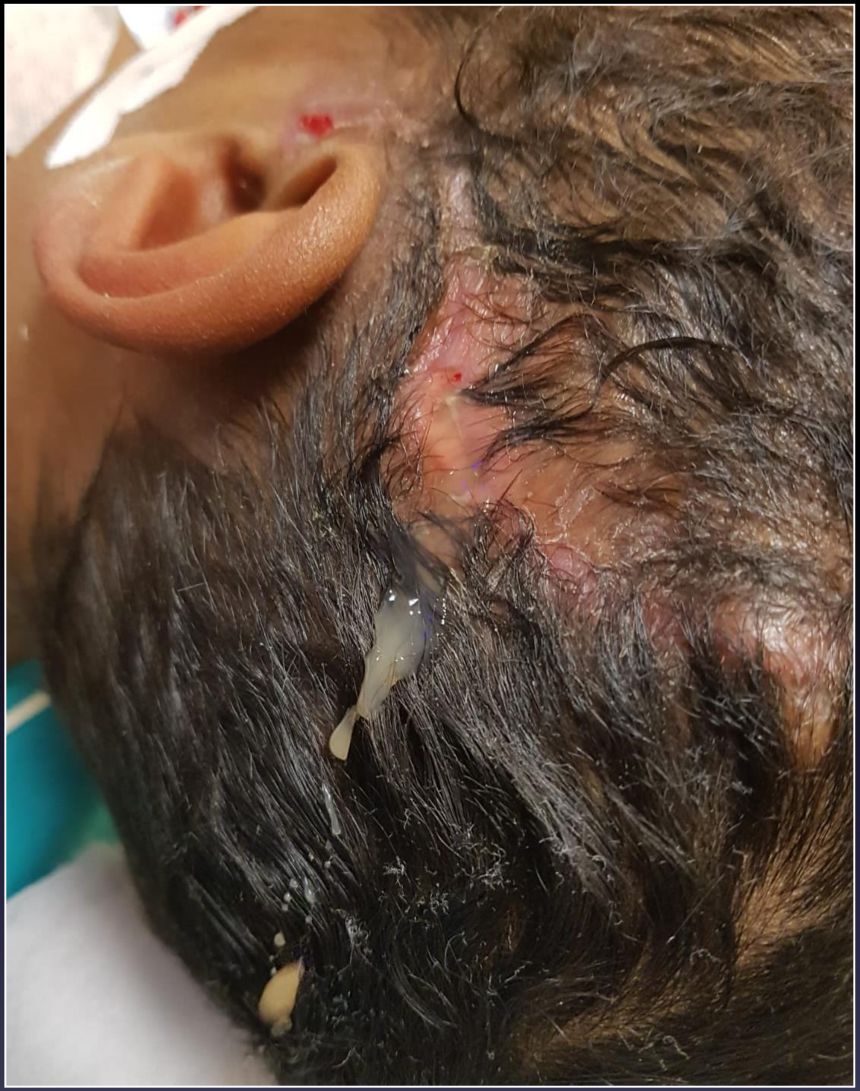
Incidenza 0,8-7% (0,5-7% craniotomia - 0,5-18% spinale)

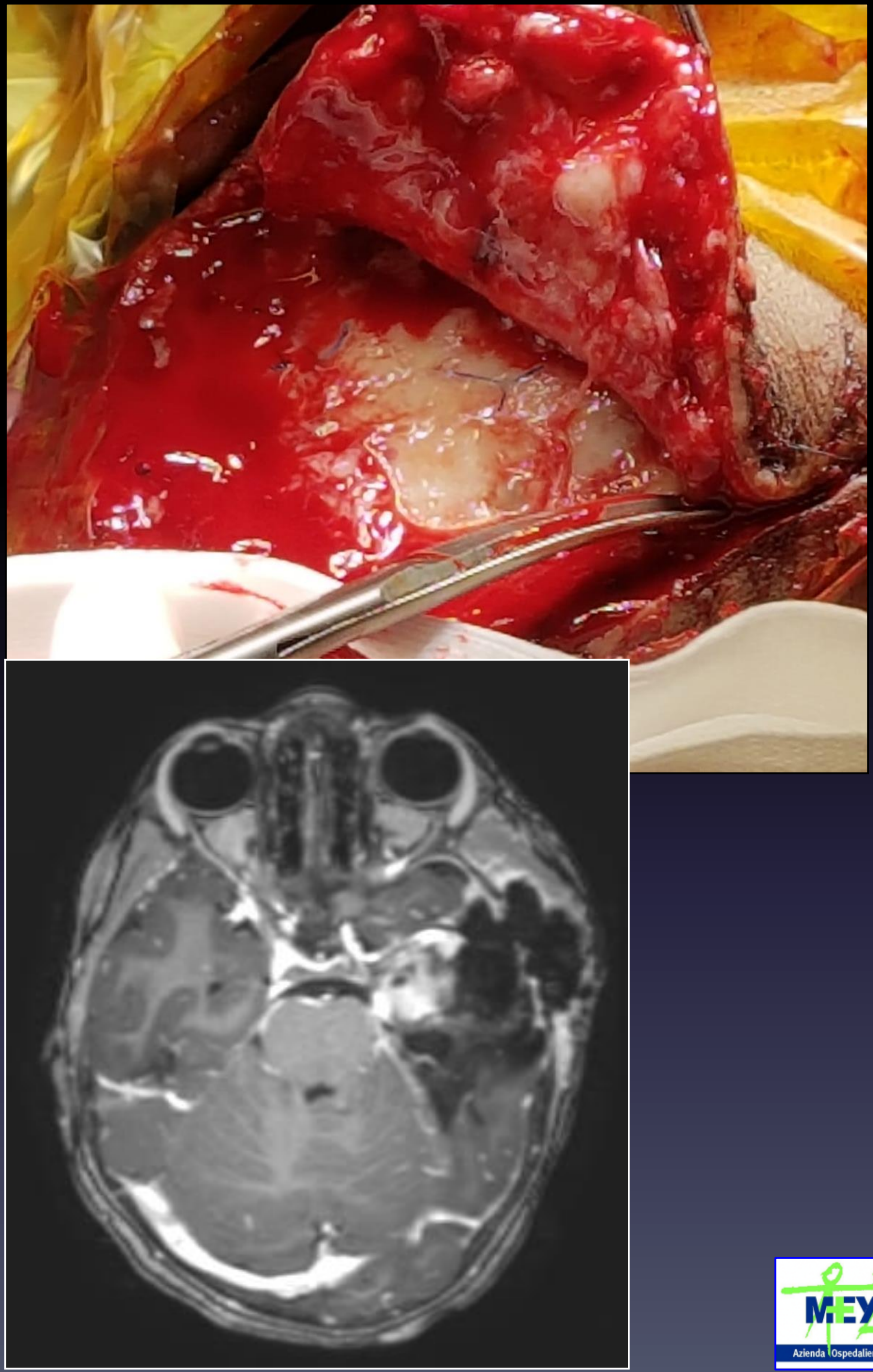
Unplanned return to OR (URTOR) 4,2%

Fattori di rischio

- fistola e distrofia di ferita (RR 27,41)
- chirurgia d’urgenza e traumatologia (RR 2,01)
- terapia steroidea prolungata (RR 3,55)
- protesi, corpi estranei (RR 2,74)
- invasività, complessità e durata procedura > 3h (RR 1,85)
- infezioni precedenti e riapertura
- età > 50 anni, ASA elevato
- obesità (RR 3,1)

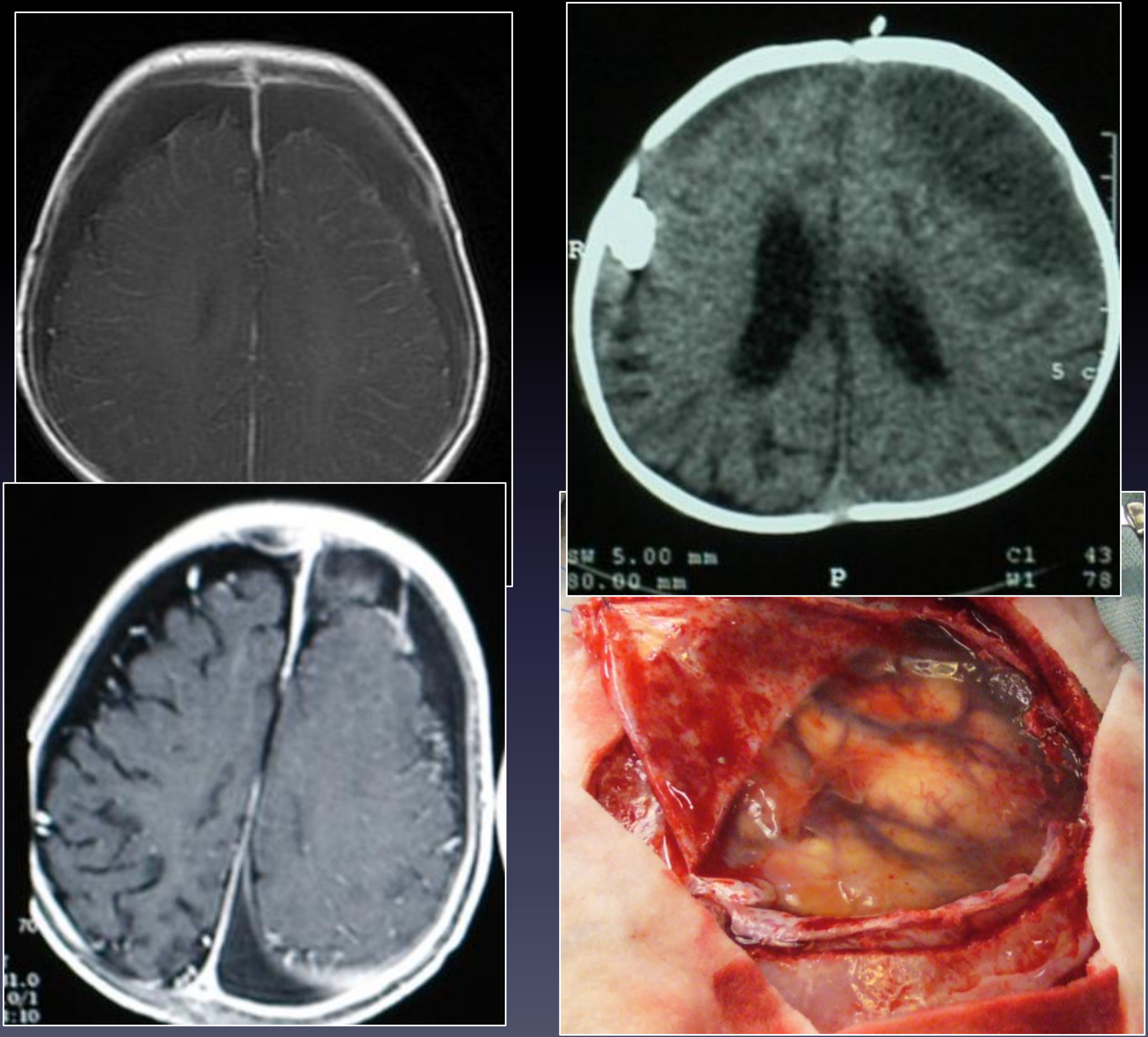
Davies BM Clinical Neurology Neurosurgery 2016
Pereira PL Br J Neurosurgery 2017
Wang J World Neurosurgery 2018





Lobectomia temporale
Infezione ferita chirurgica

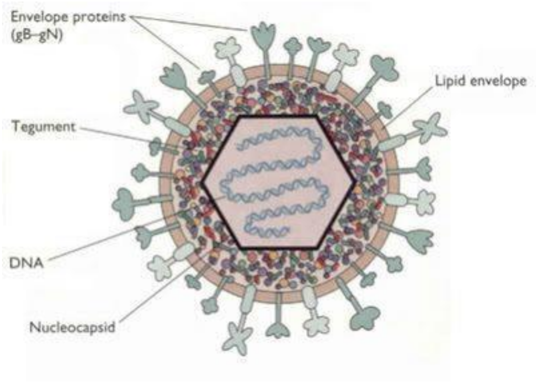
Empiema Subdurale


R
5 c
SW 5.00 mm
80.00 mm
P
C1 43
W1 78
70
1.0
0/1
:10

Drenaggio subdurale esterno

Craniotomia
Membranectomia

Encefalite Erpetica (HSV-I, HSV-II)


Envelope proteins
(gB–gN)
Lipid envelope
Tegument
DNA
Nucleocapsid

- HSV1 encefalite
- HSV2 meningite asettica
- Riattivazione HSV1
- Lobo frontale e temporale (++)
- TC: Ipodensità tardiva (5 g dopo chirurgia)
- ICP, antiedema, craniotomia decompressiva (81,2% casi)
- GOS 4/5 92,3%
- Mortalità 19-38%

Kuhnt D J Neurol Surg 2012; 73: 116-22
Safan MG Clinical Neurology Neurosurgery 2015; 128: 10-6
Jaques DA Virology Journal 2016; 13: 83

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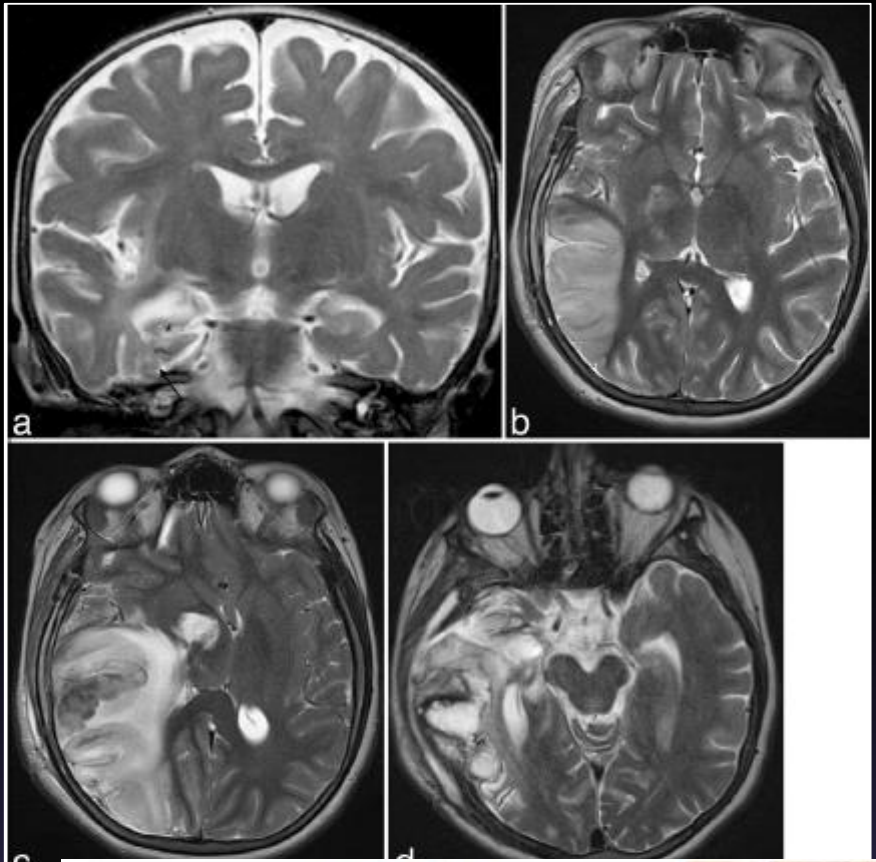


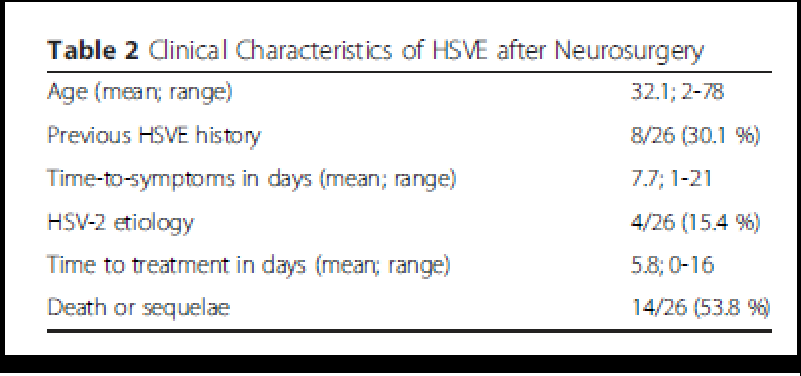


Table 2 Clinical Characteristics of HSVE after Neurosurgery

Age (mean; range)	32.1; 2-78
Previous HSVE history	8/26 (30.1 %)
Time-to-symptoms in days (mean; range)	7.7; 1-21
HSV-2 etiology	4/26 (15.4 %)
Time to treatment in days (mean; range)	5.8; 0-16
Death or sequelae	14/26 (53.8 %)

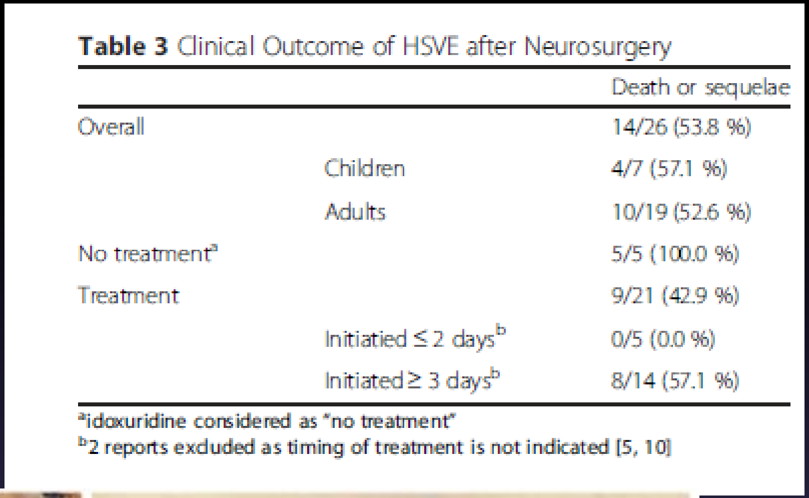
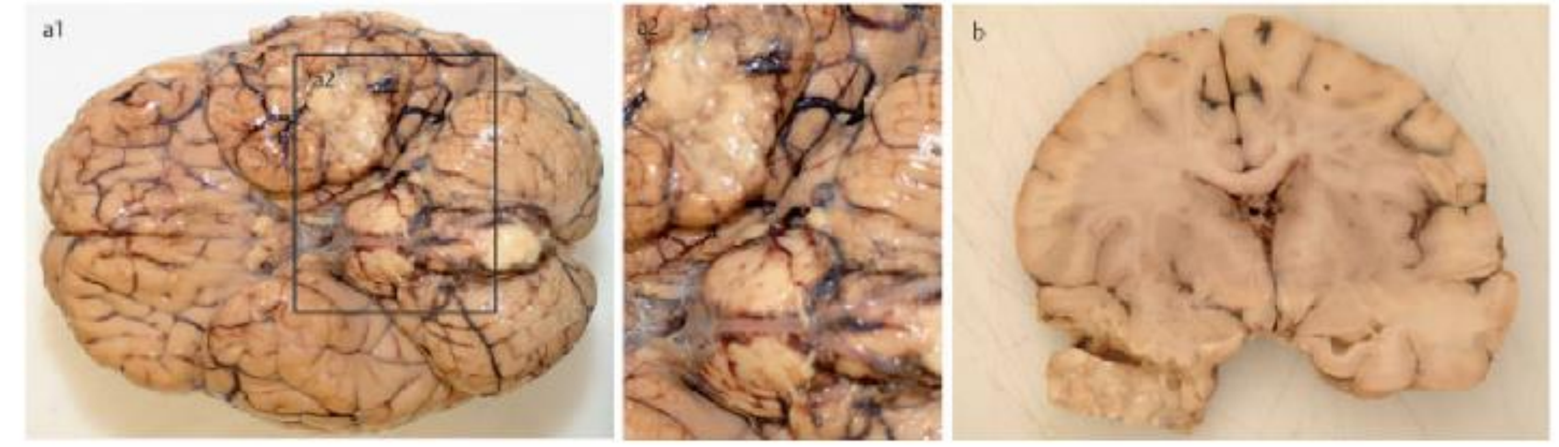


Table 3 Clinical Outcome of HSVE after Neurosurgery

		Death or sequelae
Overall		14/26 (53.8 %)
	Children	4/7 (57.1 %)
	Adults	10/19 (52.6 %)
No treatment[a]		5/5 (100.0 %)
Treatment		9/21 (42.9 %)
	Initiated ≤ 2 days[b]	0/5 (0.0 %)
	Initiated ≥ 3 days[b]	8/14 (57.1 %)

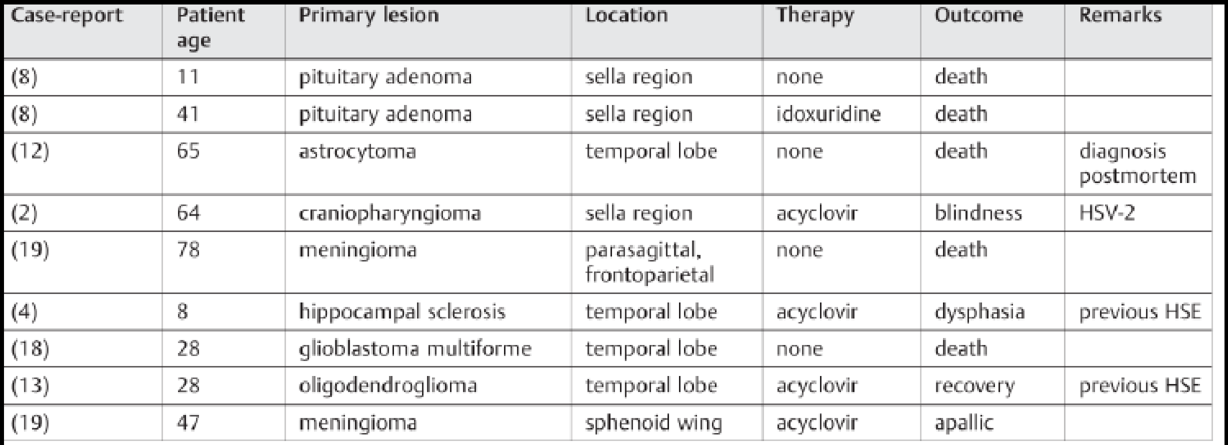
[a] idoxuridine considered as "no treatment"

[b] 2 reports excluded as timing of treatment is not indicated [5, 10]

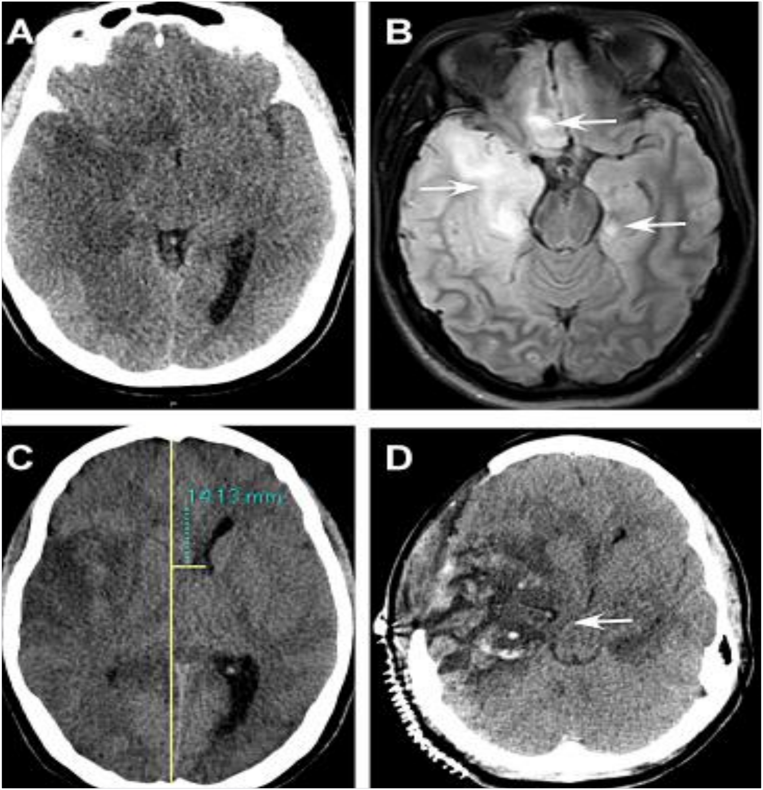


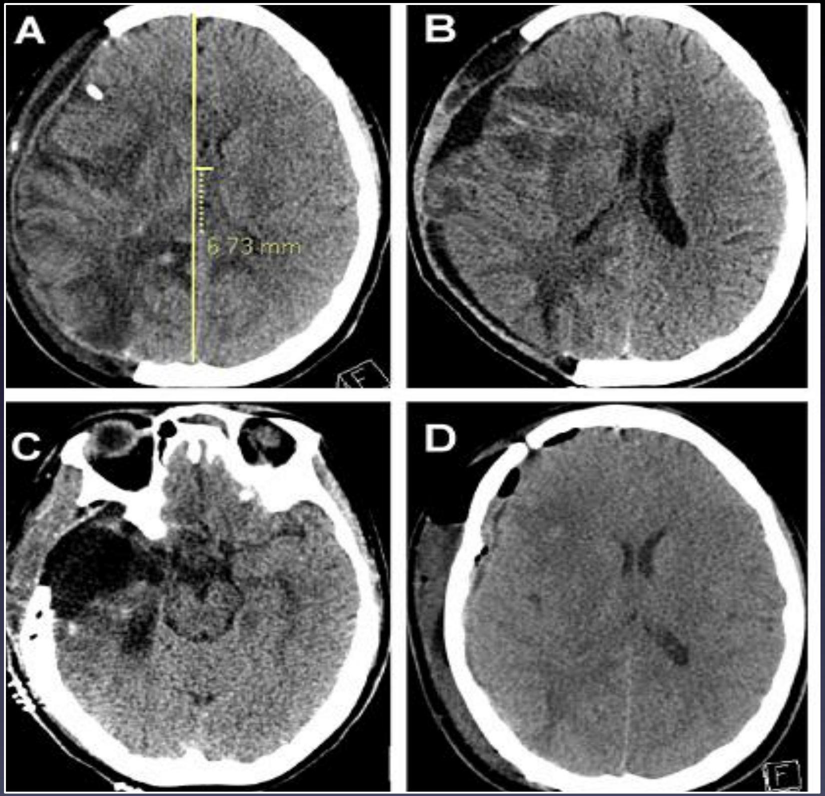
Jaques DA Virology Journal 2016; 13: 83

Riattivazione HSV1 dopo interventi neurochirurgici



Case-report	Patient age	Primary lesion	Location	Therapy	Outcome	Remarks
(8)	11	pituitary adenoma	sella region	none	death	
(8)	41	pituitary adenoma	sella region	idoxuridine	death	
(12)	65	astrocytoma	temporal lobe	none	death	diagnosis postmortem
(2)	64	craniopharyngioma	sella region	acyclovir	blindness	HSV-2
(19)	78	meningioma	parasagittal, frontoparietal	none	death	
(4)	8	hippocampal sclerosis	temporal lobe	acyclovir	dysphasia	previous HSE
(18)	28	glioblastoma multiforme	temporal lobe	none	death	
(13)	28	oligodendroglioma	temporal lobe	acyclovir	recovery	previous HSE
(19)	47	meningioma	sphenoid wing	acyclovir	apallic	



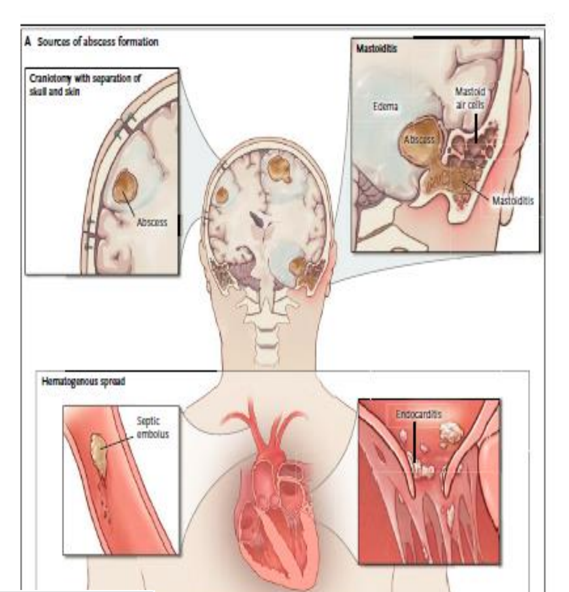


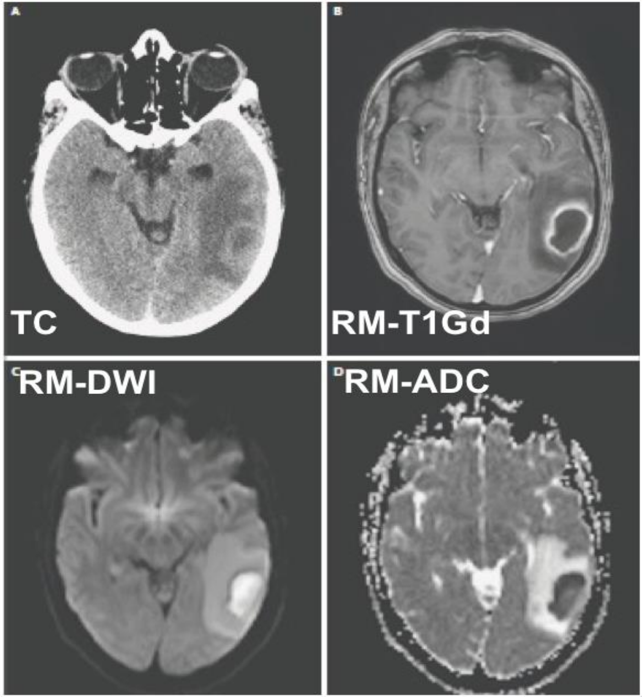
Kuhnt D J Neurol Surg 2012; 73: 116-22
Safain MG Clinical Neurology and Neurosurgery 2015; 128: 10-6

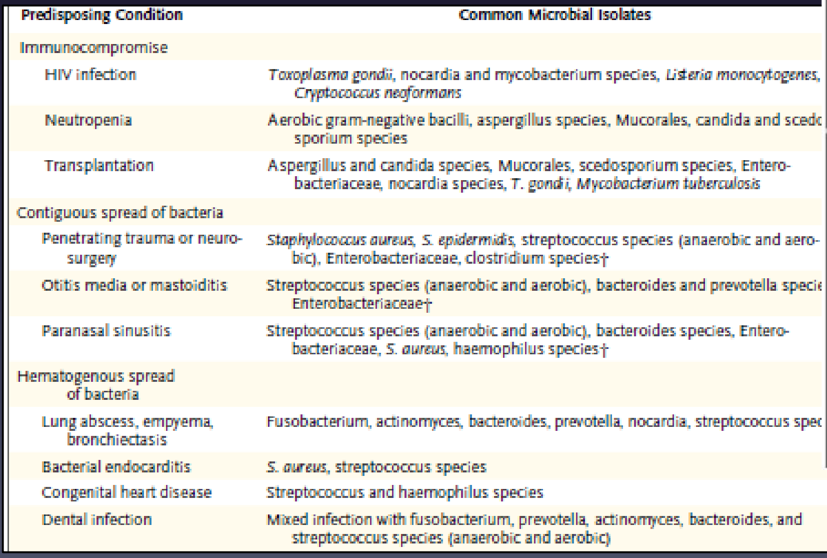
Ascesso Cerebrale

- Post-traumatico 14%
- Post-chirurgico 9%

- Tx antibiotica 6-8 sett
- Chirurgia ≥ 2,5 cm
  - Puntura stereotassica 90%
  - Asportazione diretta 8-10%

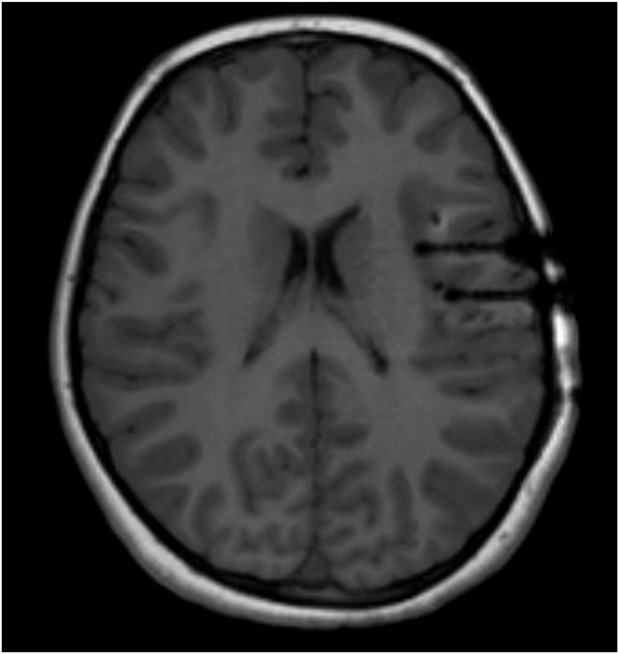

A Sources of abscess formation
Craniotomy with separation of skull and skin
Abscess
Mastoiditis
Edema
Mastoid air cells
Abscess
Mastoiditis
Hematogenous spread
Septic embolus
Endocarditis
cortical abscess
Abscess cavity
Abscess capsule

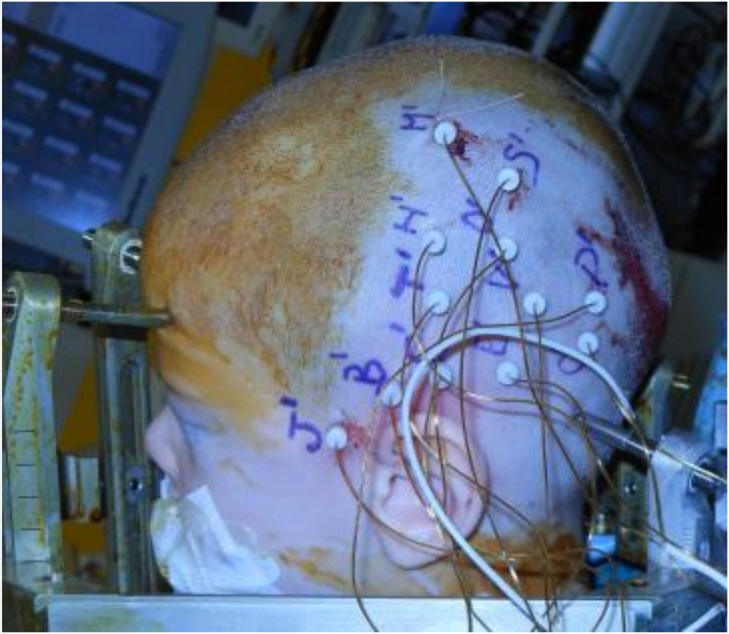

A
B
TC
RM-T1Gd
C
RM-DWI
D
RM-ADC

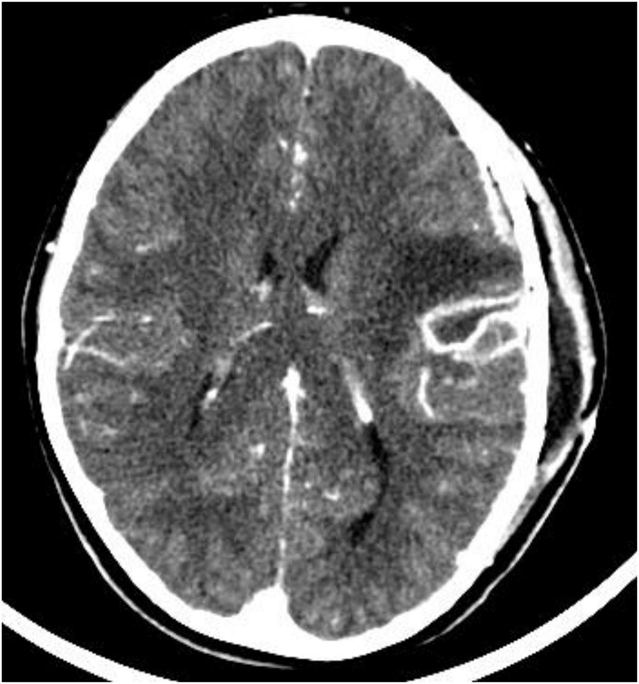


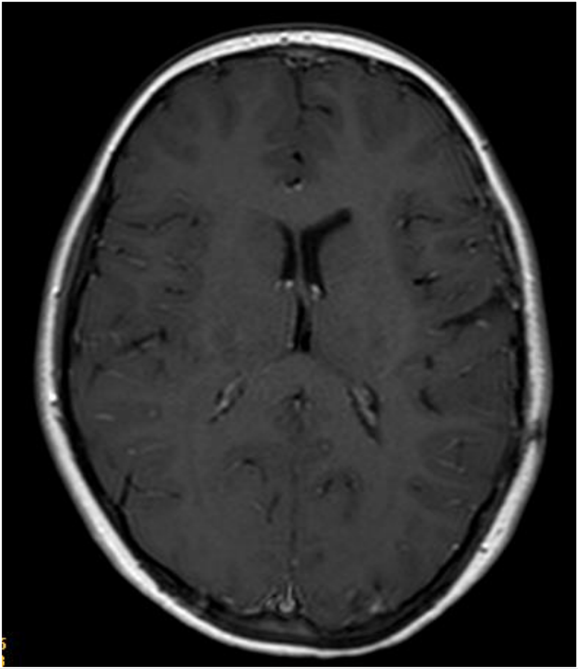
Predisposing Condition	Common Microbial Isolates
Immunocompromise	
HIV infection	*Toxoplasma gondii*, nocardia and mycobacterium species, *Listeria monocytogenes*, *Cryptococcus neoformans*
Neutropenia	Aerobic gram-negative bacilli, aspergillus species, Mucorales, candida and scedosporium species
Transplantation	Aspergillus and candida species, Mucorales, scedosporium species, Enterobacteriaceae, nocardia species, *T. gondii*, *Mycobacterium tuberculosis*
Contiguous spread of bacteria	
Penetrating trauma or neurosurgery	*Staphylococcus aureus*, *S. epidermidis*, streptococcus species (anaerobic and aerobic), Enterobacteriaceae, clostridium species†
Otitis media or mastoiditis	Streptococcus species (anaerobic and aerobic), bacteroides and prevotella specie Enterobacteriaceae†
Paranasal sinusitis	Streptococcus species (anaerobic and aerobic), bacteroides species, Enterobacteriaceae, *S. aureus*, haemophilus species†
Hematogenous spread of bacteria	
Lung abscess, empyema, bronchiectasis	Fusobacterium, actinomyces, bacteroides, prevotella, nocardia, streptococcus spec
Bacterial endocarditis	*S. aureus*, streptococcus species
Congenital heart disease	Streptococcus and haemophilus species
Dental infection	Mixed infection with fusobacterium, prevotella, actinomyces, bacteroides, and streptococcus species (anaerobic and aerobic)

da Brouwer MC et al. N Engl J Med 2014; 371: 447-56









Ascesso cerebrale
da infezione
elettrodo SEEG

Trattamento medico
esclusivo

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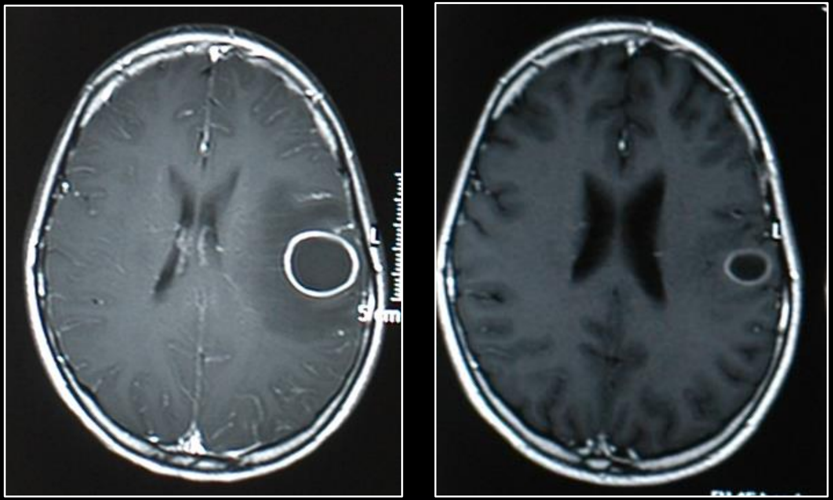
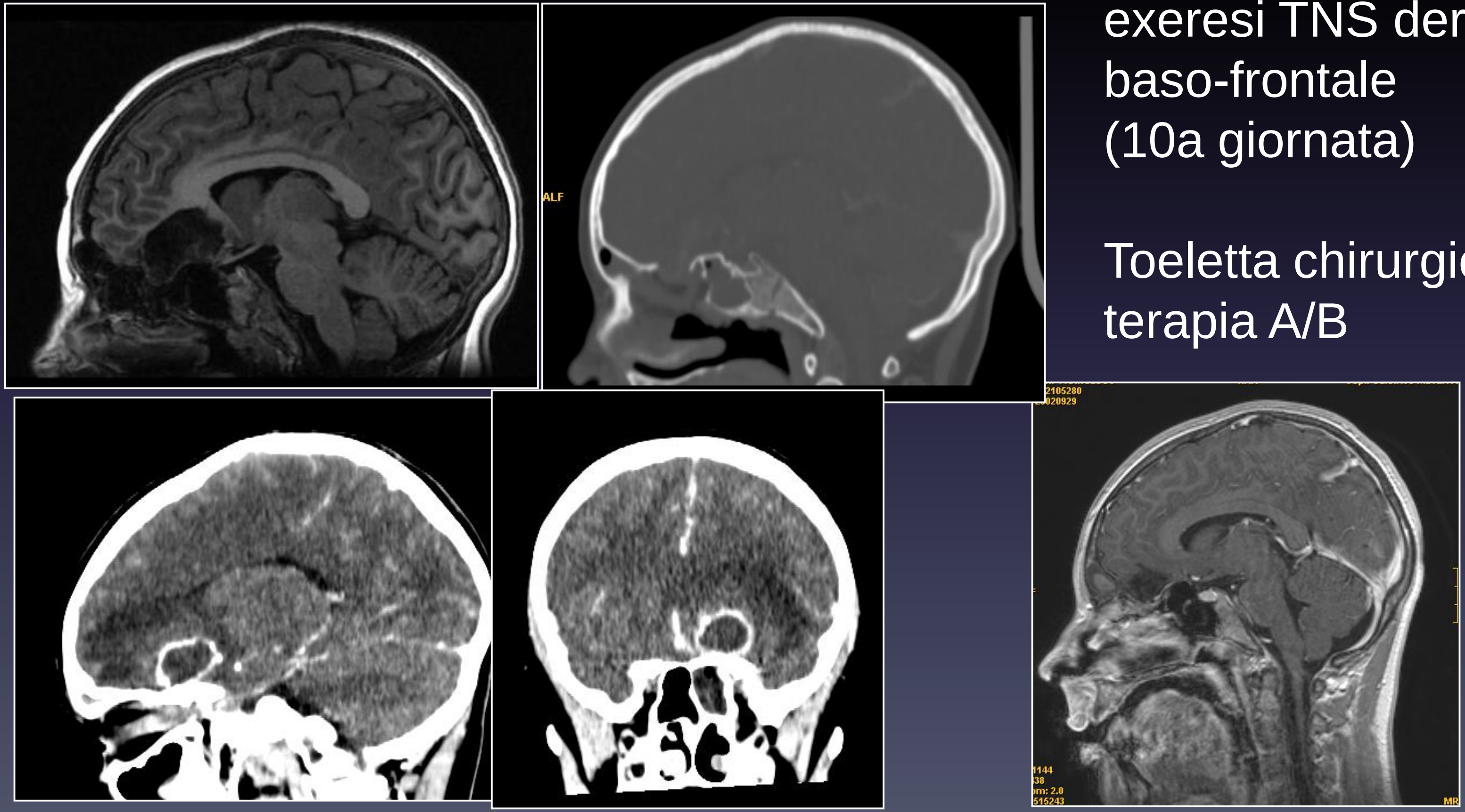


Ascesso cerebrale da infezione sito chirurgico (20a giornata)

Puntura stereotassica + terapia A/B

Ascesso cerebrale dopo exeresi TNS dermoide baso-frontale
(10a giornata)

Toeletta chirurgica + terapia A/B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38
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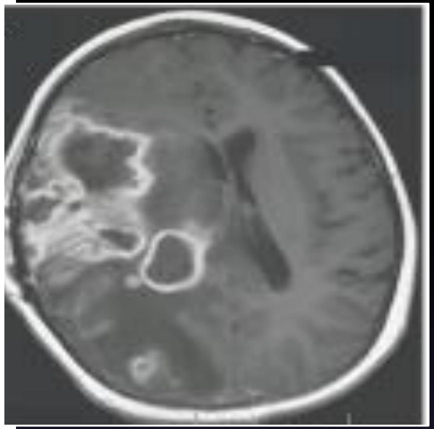
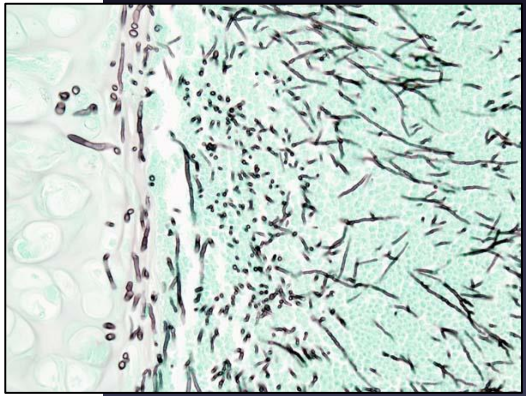
Infezioni fungine in Neurochirurgia

- Contaminazione diretta post-chirurgica
- Via ematogena
- Continuità/contiguità (seni nasali/paranasali)

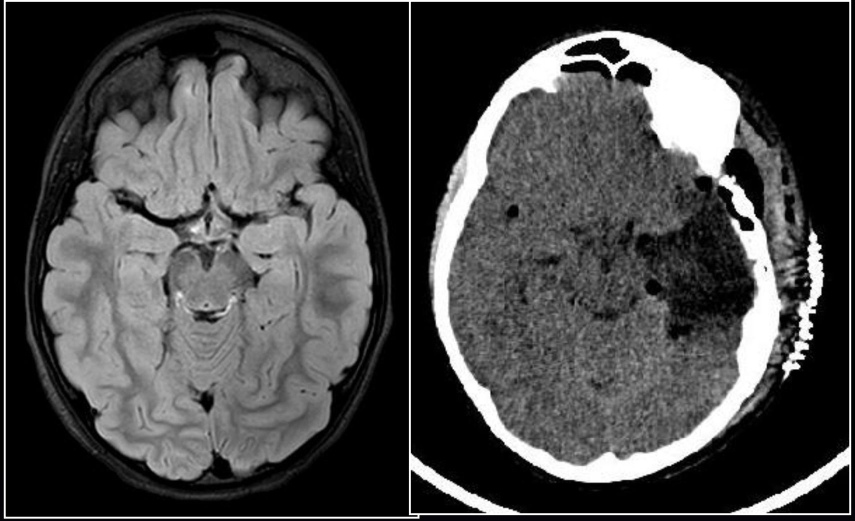
- Angioinvasità (Aspergillus Flavus, Fumigatus)
  - Stroke
  - Aneurismi micotici

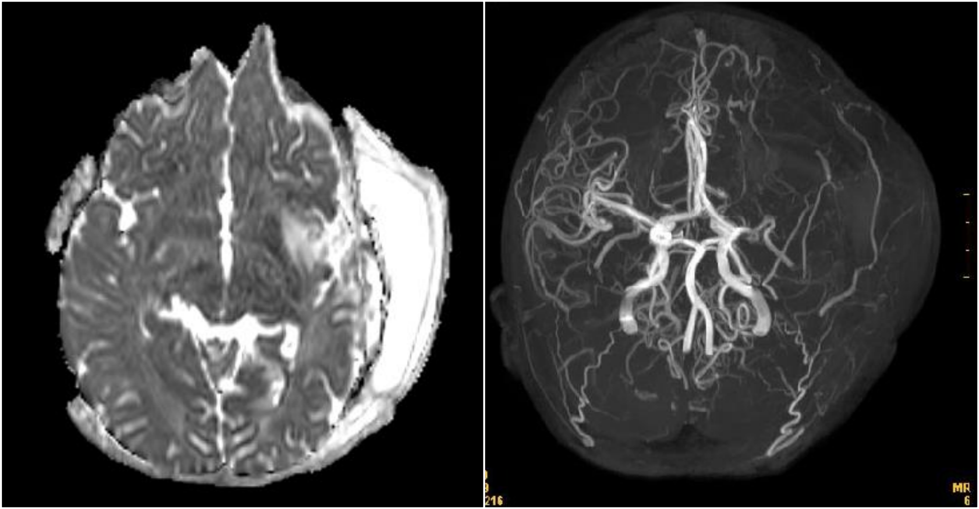
- Bonifica focolaio centrale + Tx A/B
- Asportazione diretta micetoma

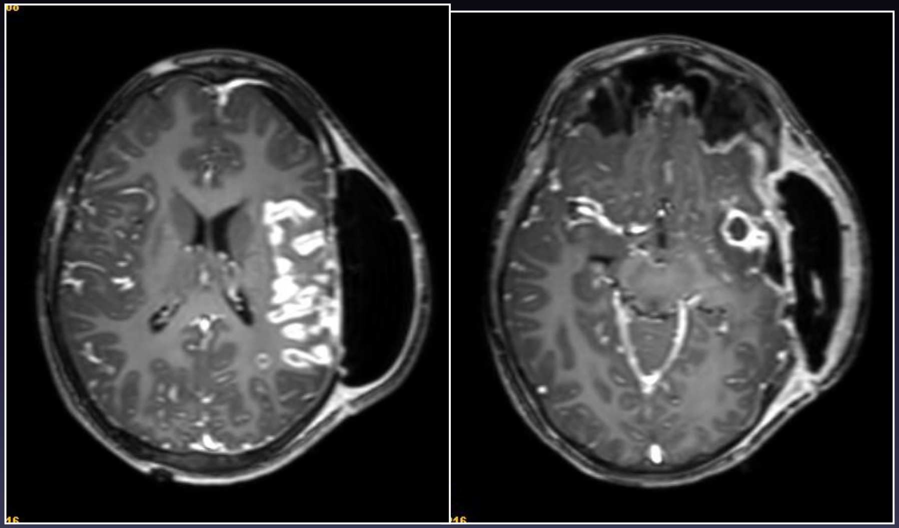




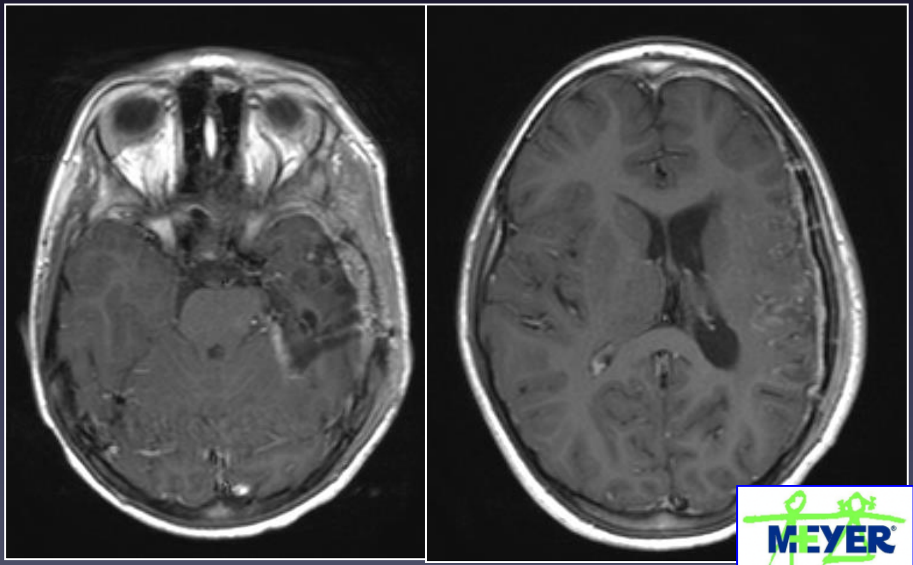
Lahoti S Curr Neurol Neurosci Rep 2013; 13: 399
McCarthy M N Engl J Med 2014; 10; 371 (2): 150-60
Kouberti IS Expert Rev Anti Infect Ther 2014; 12 (2): 265-73

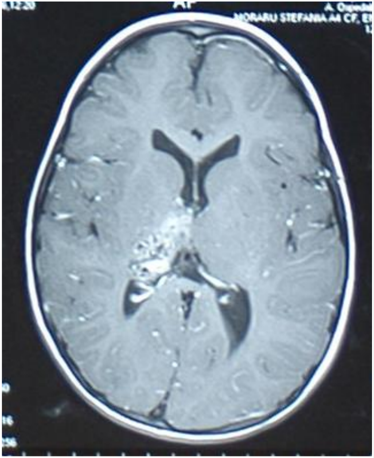


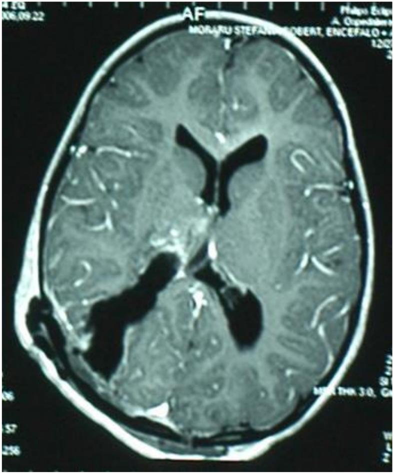


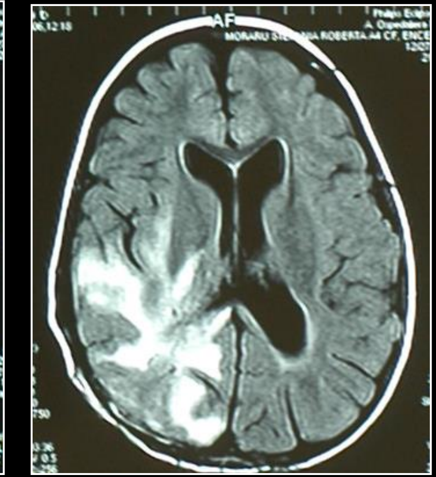


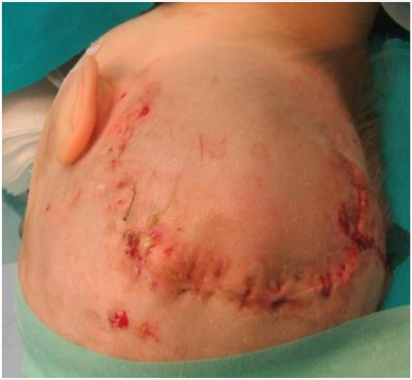
Febbre in 25a giornata
Stroke

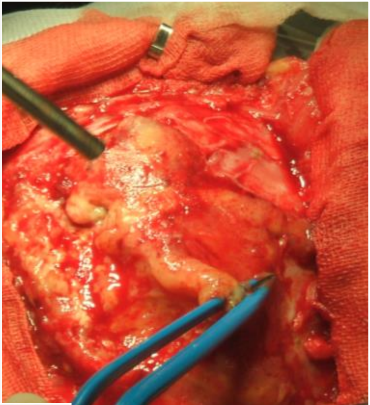


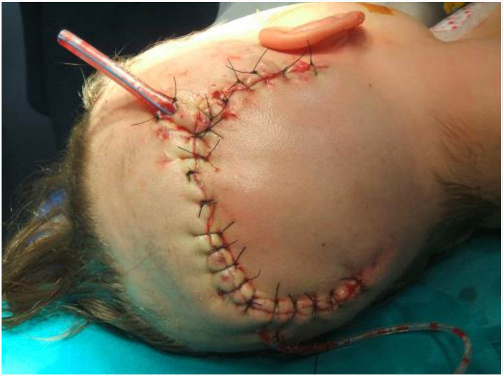


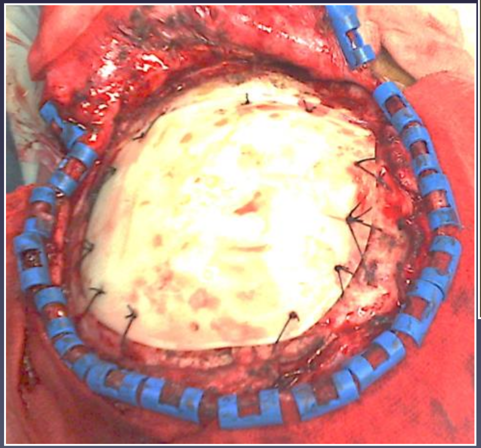


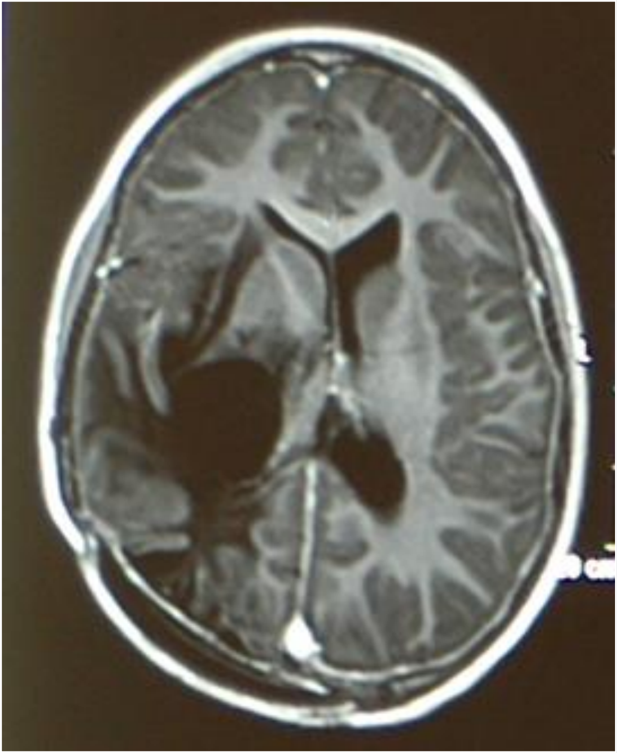












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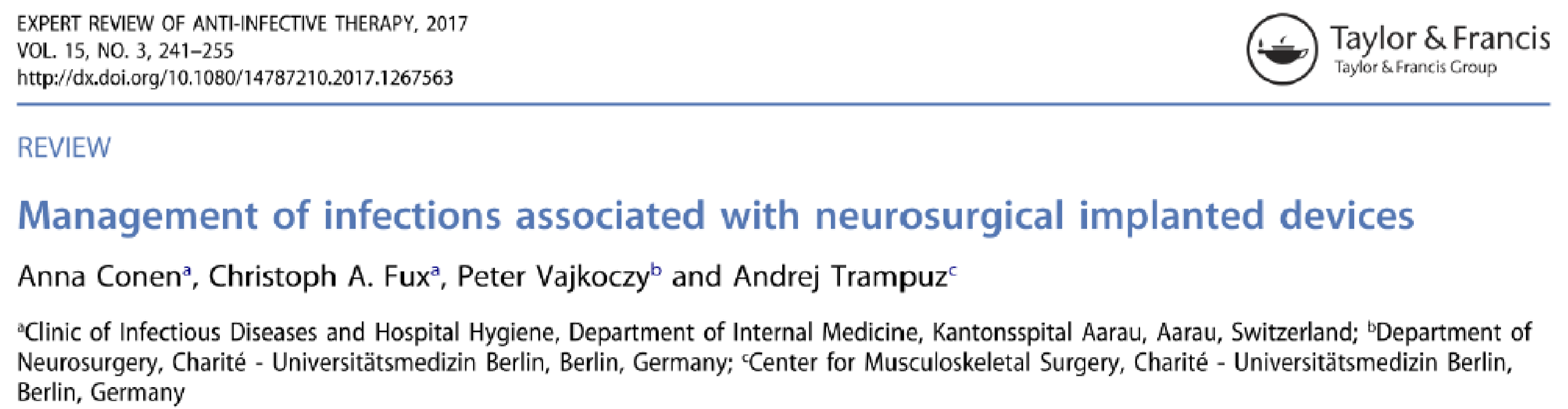

EXPERT REVIEW OF ANTI-INFECTIVE THERAPY, 2017
VOL. 15, NO. 3, 241–255
http://dx.doi.org/10.1080/14787210.2017.1267563

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REVIEW

Management of infections associated with neurosurgical implanted devices

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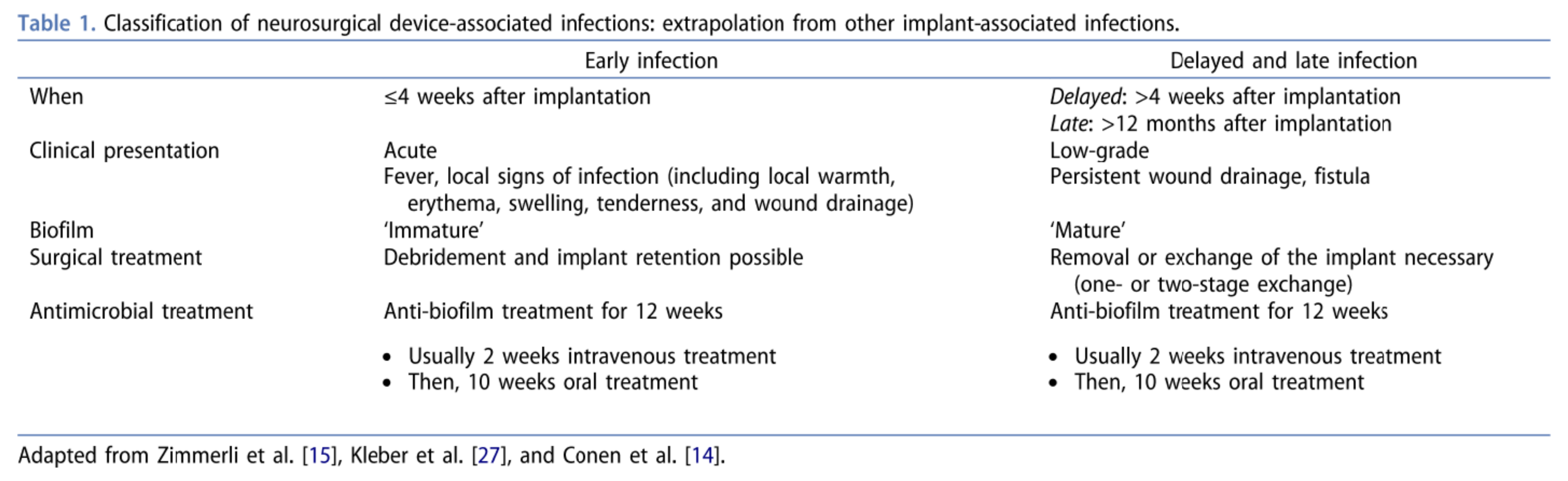


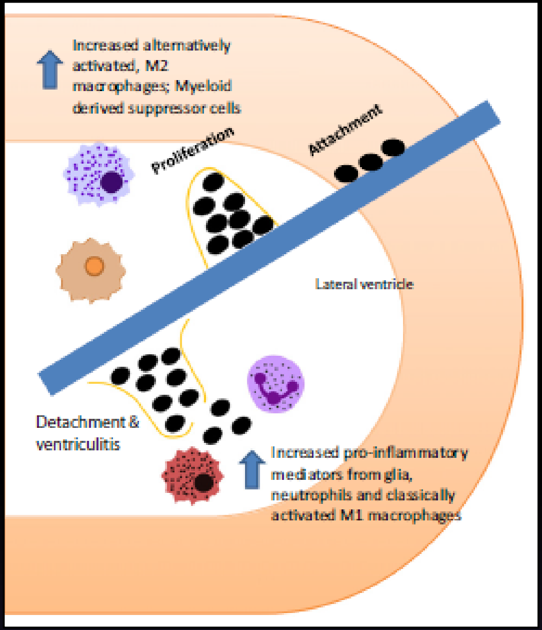
Table 1. Classification of neurosurgical device-associated infections: extrapolation from other implant-associated infections.

	Early infection	Delayed and late infection
When	≤4 weeks after implantation	*Delayed*: >4 weeks after implantation *Late*: >12 months after implantation
Clinical presentation	Acute Fever, local signs of infection (including local warmth, erythema, swelling, tenderness, and wound drainage)	Low-grade Persistent wound drainage, fistula
Biofilm	'Immature'	'Mature'
Surgical treatment	Debridement and implant retention possible	Removal or exchange of the implant necessary (one- or two-stage exchange)
Antimicrobial treatment	Anti-biofilm treatment for 12 weeks • Usually 2 weeks intravenous treatment • Then, 10 weeks oral treatment	Anti-biofilm treatment for 12 weeks • Usually 2 weeks intravenous treatment • Then, 10 weeks oral treatment

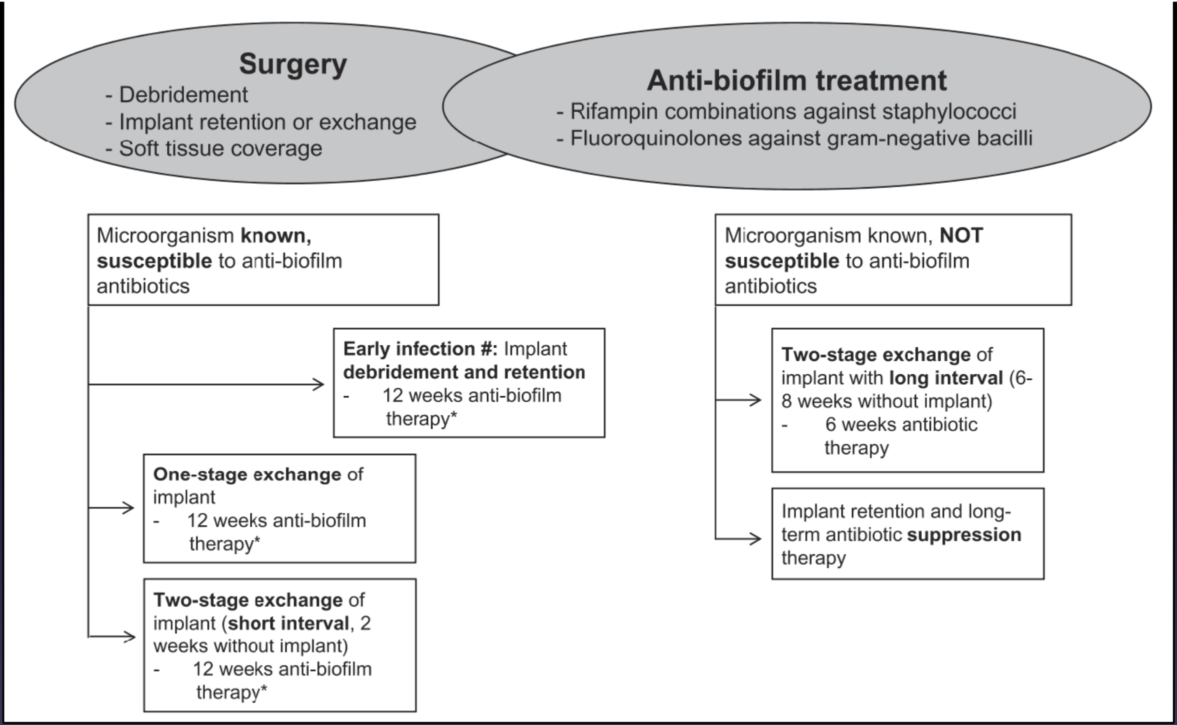
Adapted from Zimmerli et al. [15], Kleber et al. [27], and Conen et al. [14].

BIOFILM: matrice di sostanze polimeriche extracellulari (EPS)

- protezione da azione antibiotici e sistema immunitario
- annidamento batteri quiescienti non responsivi a beta-lattamici e vancocina
- «fagocitosi frustrata»



Increased alternatively activated, M2 macrophages; Myeloid derived suppressor cells
Proliferation
Attachment
Lateral ventricle
Detachment & ventriculitis
Increased pro-inflammatory mediators from glia, neutrophils and classically activated M1 macrophages



Surgery
- Debridement
- Implant retention or exchange
- Soft tissue coverage

Anti-biofilm treatment
- Rifampin combinations against staphylococci
- Fluoroquinolones against gram-negative bacilli

Microorganism **known, susceptible** to anti-biofilm antibiotics

Early infection #: Implant debridement and retention
- 12 weeks anti-biofilm therapy*

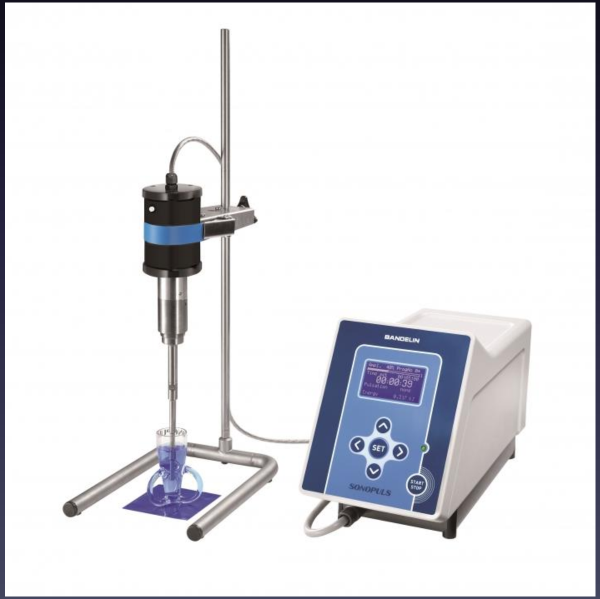
One-stage exchange of implant
- 12 weeks anti-biofilm therapy*

Two-stage exchange of implant (**short interval**, 2 weeks without implant)
- 12 weeks anti-biofilm therapy*

Microorganism known, **NOT susceptible** to anti-biofilm antibiotics

Two-stage exchange of implant with **long interval** (6-8 weeks without implant)
- 6 weeks antibiotic therapy

Implant retention and long-term antibiotic **suppression** therapy



BANDELIN
SONOPULS
SET
START STOP

Sonicazione essudato e protesi: incubazione prolungata ed estrazioni agenti patogeni dal biofilm (sensibilità 90%; specificità 99%)

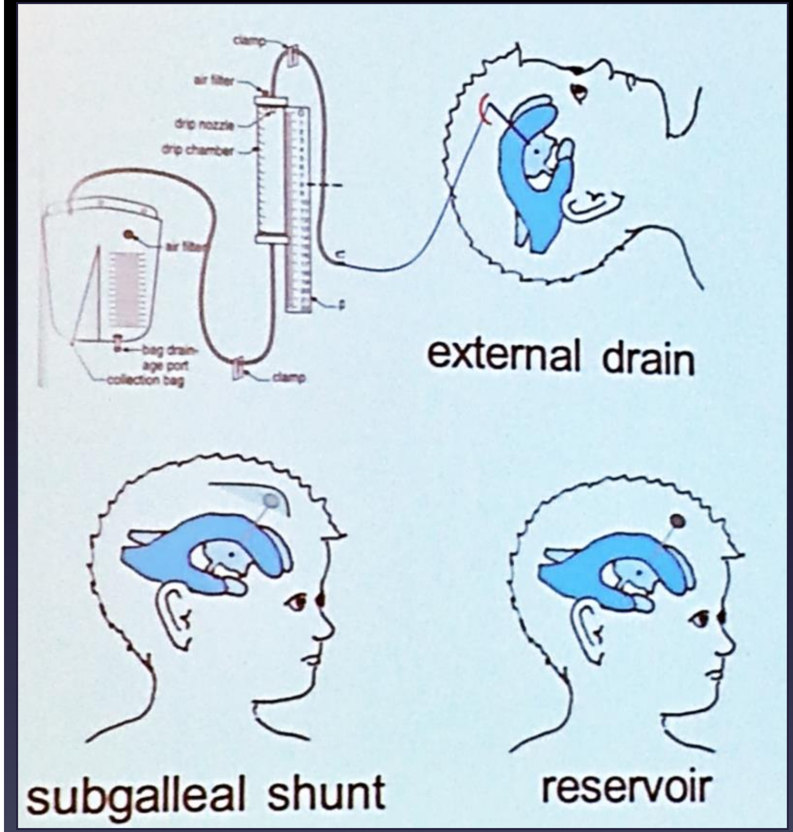
Conen A Expert review of antiinfective therapy 2017

Infezione Derivazione Ventricolare Esterna (DVE)

- Incidenza 1-28%
- Aumento rischio 8.8% dopo 5 gg
- Flora batterica cutanea (*Staf. Epidermidis, Staf. Aureus, P. Acnes, gram neg*)

Diagnosi differenziale

- Contaminazione (colturale *pos*, chimico-fisico *neg*)
- Infezione vera (colturale *pos*, chimico-fisico *pos*)


clamp
air filter
drip nozzle
drip chamber
air filter
bag drainage port
collection bag
clamp
external drain
subgalleal shunt
reservoir

von Sprackelsen N Acta Neurochir 2018

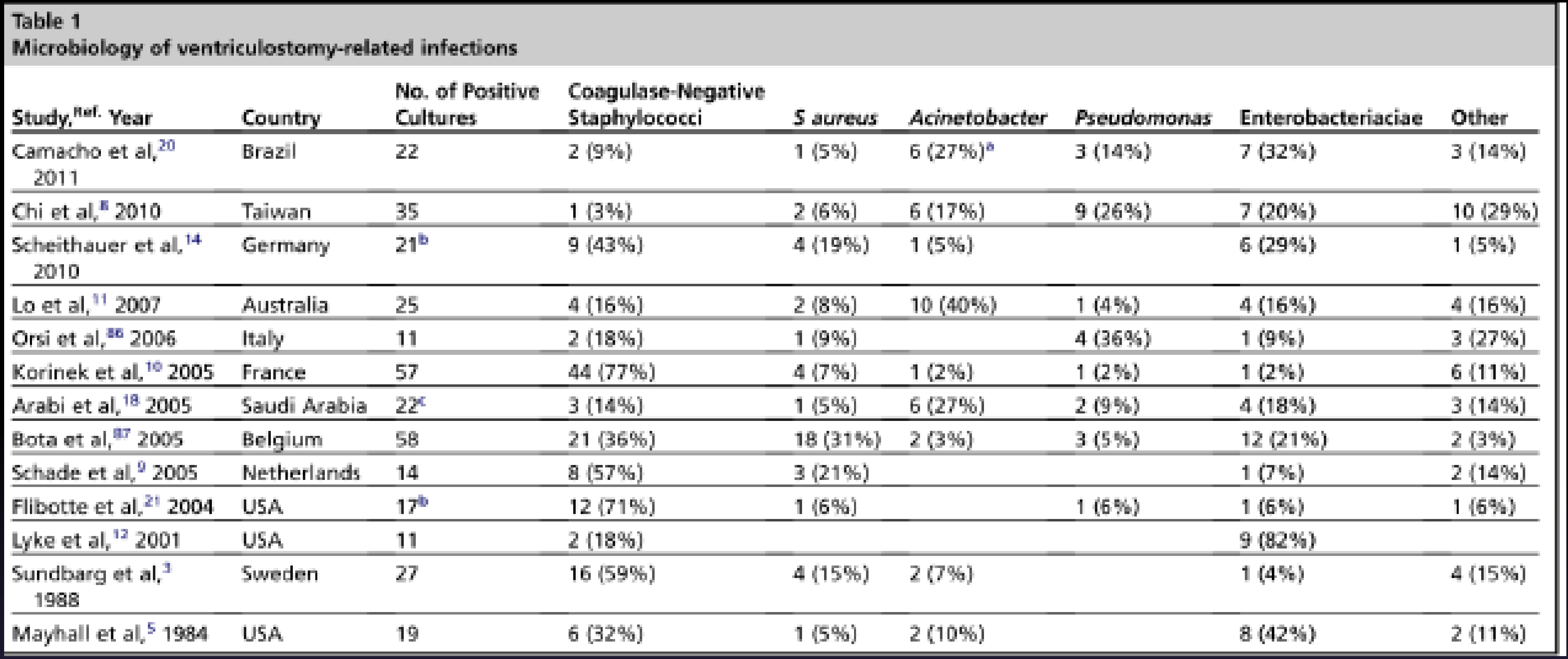


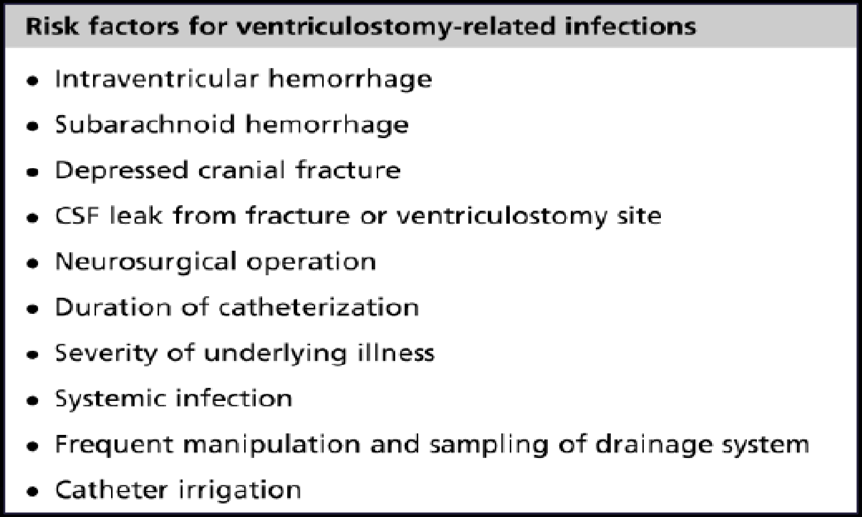
Table 1
Microbiology of ventriculostomy-related infections

Study,^Ref. Year	Country	No. of Positive Cultures	Coagulase-Negative Staphylococci	*S aureus*	*Acinetobacter*	*Pseudomonas*	Enterobacteriaciae	Other
Camacho et al,[20] 2011	Brazil	22	2 (9%)	1 (5%)	6 (27%)[a]	3 (14%)	7 (32%)	3 (14%)
Chi et al,[8] 2010	Taiwan	35	1 (3%)	2 (6%)	6 (17%)	9 (26%)	7 (20%)	10 (29%)
Scheithauer et al,[14] 2010	Germany	21[b]	9 (43%)	4 (19%)	1 (5%)		6 (29%)	1 (5%)
Lo et al,[11] 2007	Australia	25	4 (16%)	2 (8%)	10 (40%)	1 (4%)	4 (16%)	4 (16%)
Orsi et al,[86] 2006	Italy	11	2 (18%)	1 (9%)		4 (36%)	1 (9%)	3 (27%)
Korinek et al,[10] 2005	France	57	44 (77%)	4 (7%)	1 (2%)	1 (2%)	1 (2%)	6 (11%)
Arabi et al,[18] 2005	Saudi Arabia	22[c]	3 (14%)	1 (5%)	6 (27%)	2 (9%)	4 (18%)	3 (14%)
Bota et al,[87] 2005	Belgium	58	21 (36%)	18 (31%)	2 (3%)	3 (5%)	12 (21%)	2 (3%)
Schade et al,[9] 2005	Netherlands	14	8 (57%)	3 (21%)			1 (7%)	2 (14%)
Flibotte et al,[21] 2004	USA	17[b]	12 (71%)	1 (6%)		1 (6%)	1 (6%)	1 (6%)
Lyke et al,[12] 2001	USA	11	2 (18%)				9 (82%)	
Sundbarg et al,[3] 1988	Sweden	27	16 (59%)	4 (15%)	2 (7%)		1 (4%)	4 (15%)
Mayhall et al,[5] 1984	USA	19	6 (32%)	1 (5%)	2 (10%)		8 (42%)	2 (11%)

Fattori di rischio infezione drenaggio liquorale esterno:

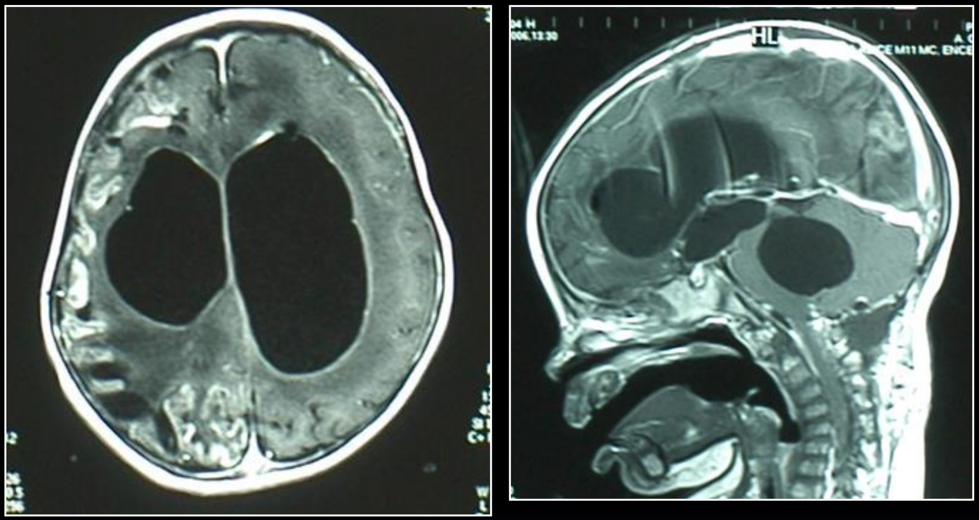
- mantenimento prolungato (> 15 gg)
- fistola liquorale
- terapia steroidea
- durata ricovero (> 7 gg)
- terapia intensiva

Stenehjem E Dis Clin N Am 2012; 26: 89-110



Risk factors for ventriculostomy-related infections

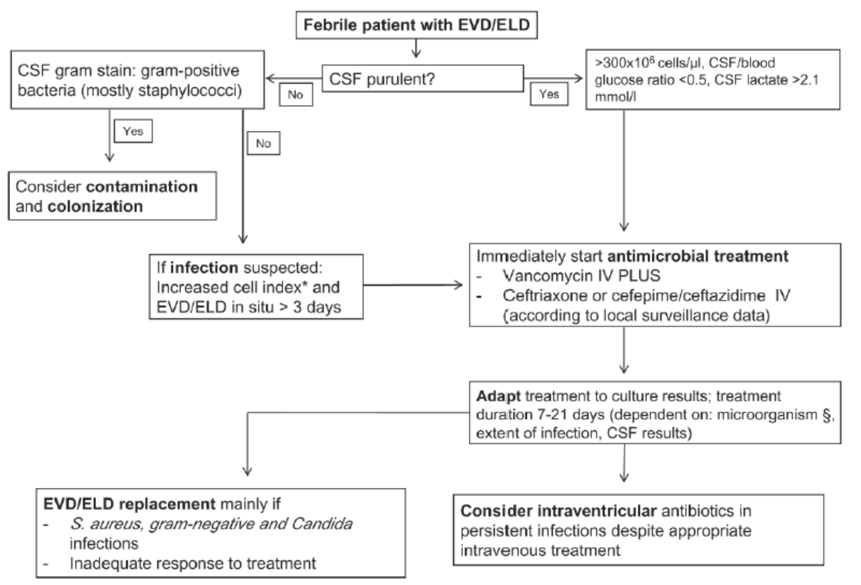
- Intraventricular hemorrhage
- Subarachnoid hemorrhage
- Depressed cranial fracture
- CSF leak from fracture or ventriculostomy site
- Neurosurgical operation
- Duration of catheterization
- Severity of underlying illness
- Systemic infection
- Frequent manipulation and sampling of drainage system
- Catheter irrigation



- Rischio evoluzione piocefalia/ventriculite, idrocefalo complesso (5-20%)

- Sostituzione DVE terapia intratecale dose 10 x MIC (*non consenso, effetti collaterali 28%*)
  - Vancocina — Staf. spp, MRSA
  - Gentamicina — Gram neg
  - Colistina — KFC, Acinetobacter
  - Amfotericina B — Aspergillus spp, Candida (tossicità SNC, ventriculite, meningite)

Stenehjem E Dis Clin N Am 2012; 26: 89-110



Febrile patient with EVD/ELD

CSF purulent?

No

CSF gram stain: gram-positive bacteria (mostly staphylococci)

Yes

Consider **contamination** and **colonization**

No

If **infection** suspected: Increased cell index* and EVD/ELD in situ > 3 days

Yes

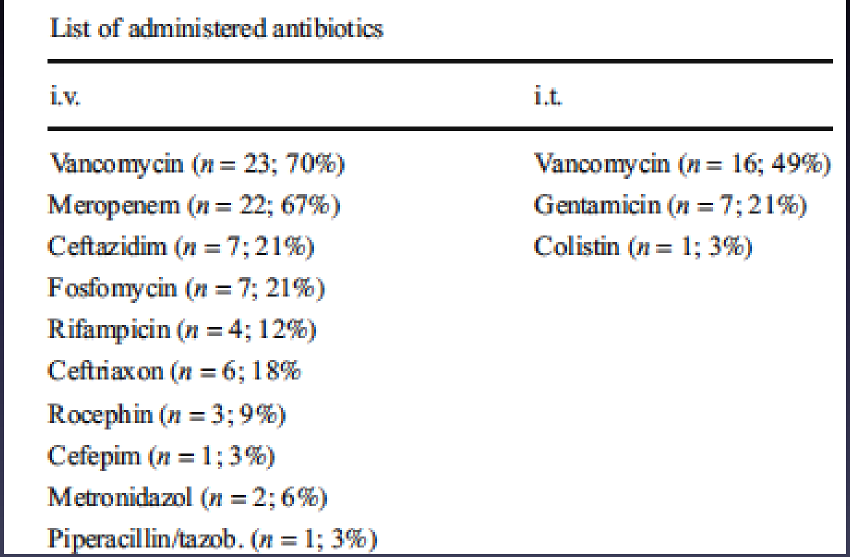
>300×10^6 cells/µl, CSF/blood glucose ratio <0.5, CSF lactate >2.1 mmol/l

Immediately start **antimicrobial treatment**
- Vancomycin IV PLUS
- Ceftriaxone or cefepime/ceftazidime IV (according to local surveillance data)

Adapt treatment to culture results; treatment duration 7-21 days (dependent on: microorganism §, extent of infection, CSF results)

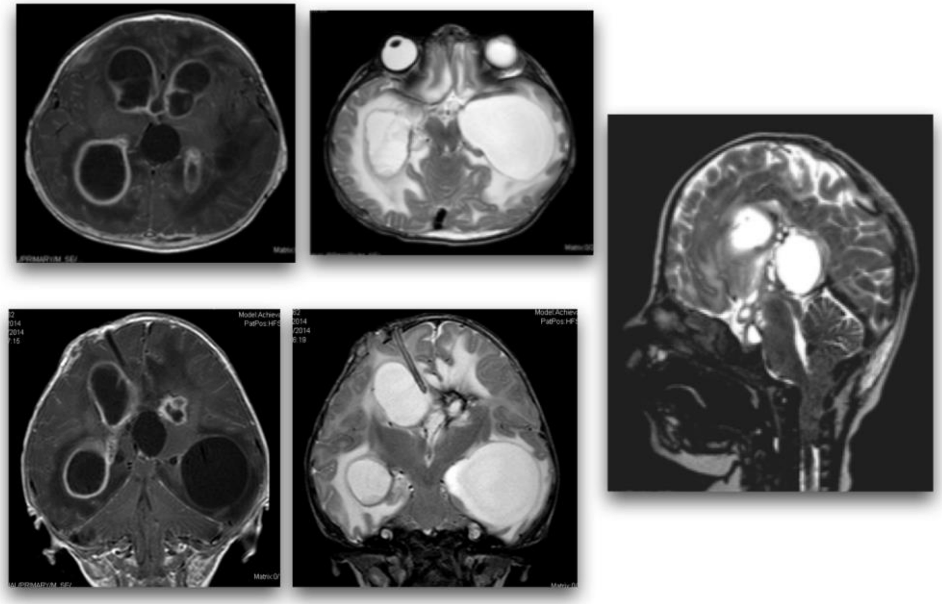
EVD/ELD replacement mainly if
- *S. aureus, gram-negative and Candida* infections
- Inadequate response to treatment

Consider intraventricular antibiotics in persistent infections despite appropriate intravenous treatment



List of administered antibiotics

i.v.	i.t.
Vancomycin (*n* = 23; 70%)	Vancomycin (*n* = 16; 49%)
Meropenem (*n* = 22; 67%)	Gentamicin (*n* = 7; 21%)
Ceftazidim (*n* = 7; 21%)	Colistin (*n* = 1; 3%)
Fosfomycin (*n* = 7; 21%)	
Rifampicin (*n* = 4; 12%)	
Ceftriaxon (*n* = 6; 18%	
Rocephin (*n* = 3; 9%)	
Cefepim (*n* = 1; 3%)	
Metronidazol (*n* = 2; 6%)	
Piperacillin/tazob. (*n* = 1; 3%)	



Evolution in multiloculated complex hydrocephalus
multicystic + trapped temporal horn

Ventriculite da gram negativi
(*Acinet.Baumanni, Klebsiella spp.*)

- mortalità 70%
- ruolo neuroendoscopia
- lavaggi ventricolari e terapia intratecale

Kumar A World Neurosurgery 2016
Conen A Expert review of antiinfective therapy 2017
von Sprackelsen N Acta Neurochir 2018
Chen FM Infection and Drug resistance 2019

Infezione Derivazione Ventricolare Interna

Tasso di incidenza 3-15%

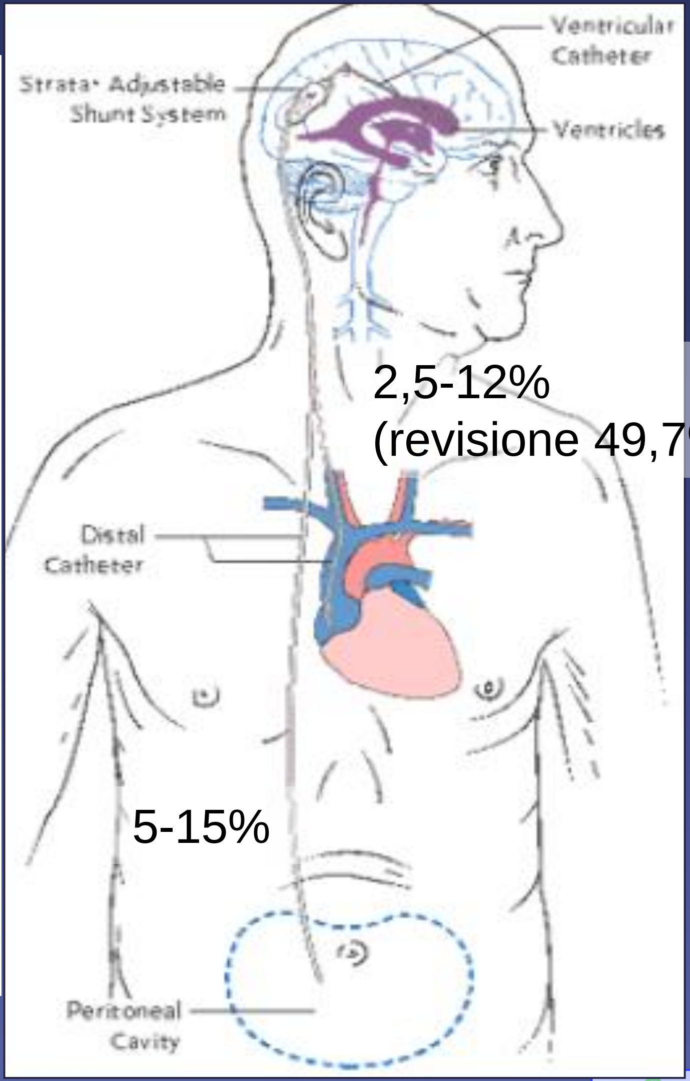
- 70% entro 2 mesi da impianto
- 80% entro 6 mesi da impianto
- 12% dopo 12 mesi (pb. addominali)

- Mortalità 10%

- Sequele cognitive, epilessia

- Segni Clinici

- segni/sintomi infezione (+)
- disfunzione di shunt (+++)


Ventricular Catheter
Strata· Adjustable Shunt System
Ventricles
Distal Catheter
Peritoneal Cavity

2,5-12%
(revisione 49,7%)

5-15%

Gramman B. Journal of Clinical Neuroscience 2014 21: 1819-21

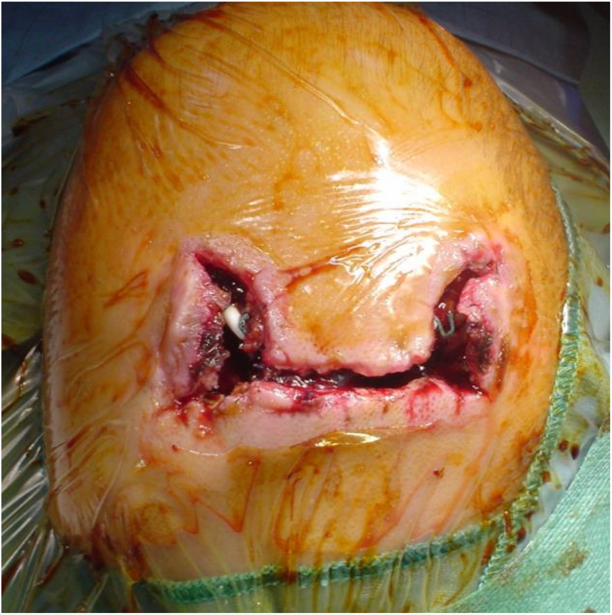
Infezione Shunt Liquorali

Eziologia

- contaminazione diretta precoce (72%)
- via ematogena (DVA)
- contaminazione diretta tardiva (27%, lesione intestino)

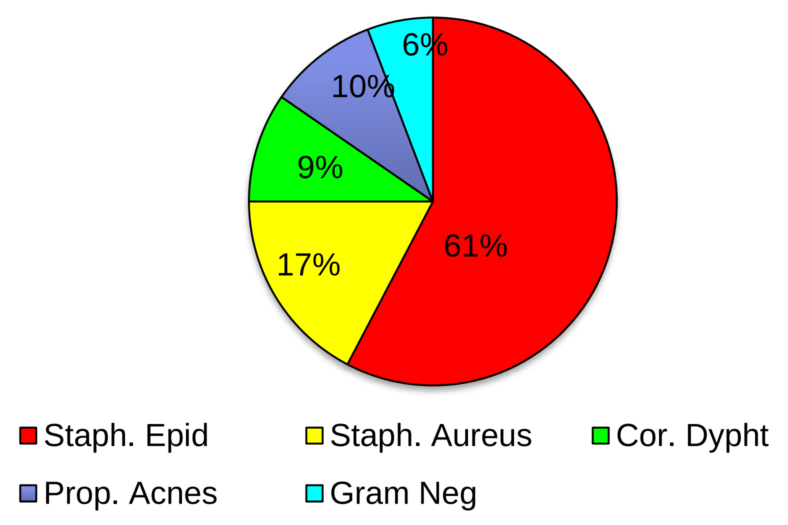
Fattori di Rischio

- prematurità, neonati, lattanti
- idrocefalo post-emorragico, mielomeningocele
- liquorrea, precedente infezione di ferita
- chirurgo
- fattori ambientali (sala operatoria)

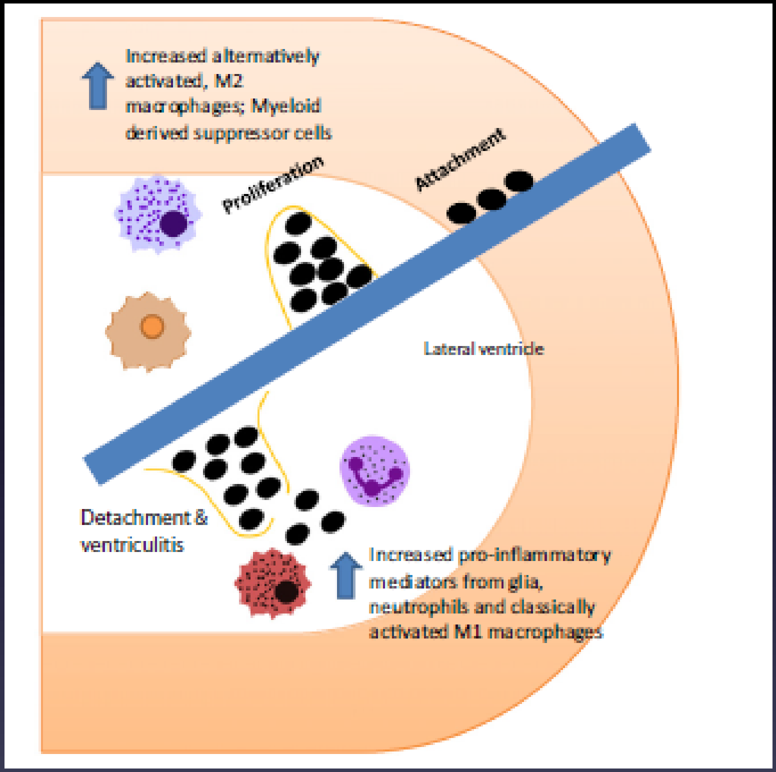


Kulkarni AV J Neurosurg 2001; 94: 195-201

Infezione Derivazione Ventricolare Interna (DVP/DVA)



Cateteri impregnati AB (Bactiseal®, Silver-EVD®)
Riduzione «bacterial coat»


Increased alternatively activated, M2 macrophages; Myeloid derived suppressor cells
Proliferation
Attachment
Lateral ventricle
Detachment & ventriculitis
Increased pro-inflammatory mediators from glia, neutrophils and classically activated M1 macrophages

- Infezioni CSF/DVP 9,4% → 1,3%
- Colonizzazione 36,7% → 17,9%

Possibili falsi negativi in esame liquor e antibiotico-resistenza !!

Thompson DNP. Hartley JC. Shunt Infections
In: Albright AL, Pollack IF, Adelson PD.
Principles and practice of Pediatric Neurosurgery
Thieme, New York 2015

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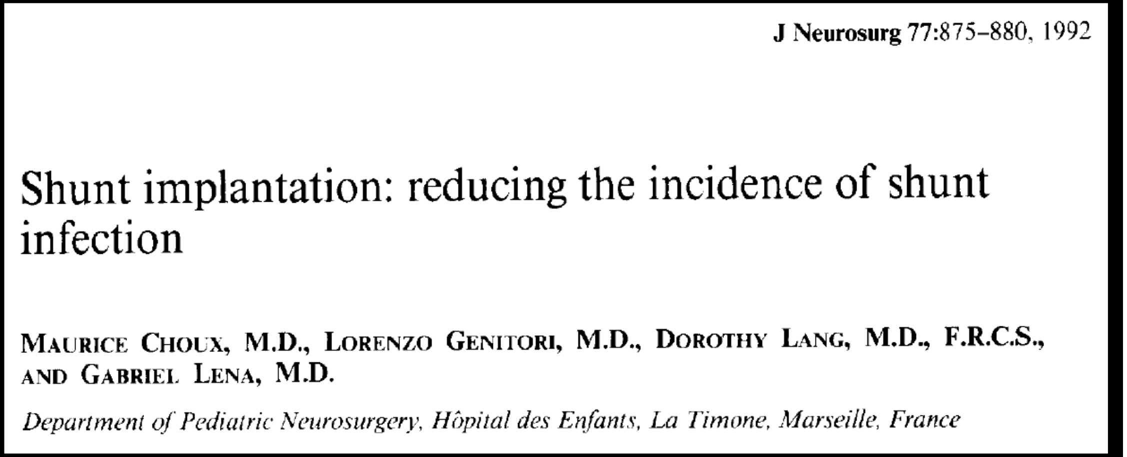


J Neurosurg 77:875–880, 1992

Shunt implantation: reducing the incidence of shunt infection

Maurice Choux, M.D., Lorenzo Genitori, M.D., Dorothy Lang, M.D., F.R.C.S., and Gabriel Lena, M.D.

Department of Pediatric Neurosurgery, Hôpital des Enfants, La Timone, Marseille, France

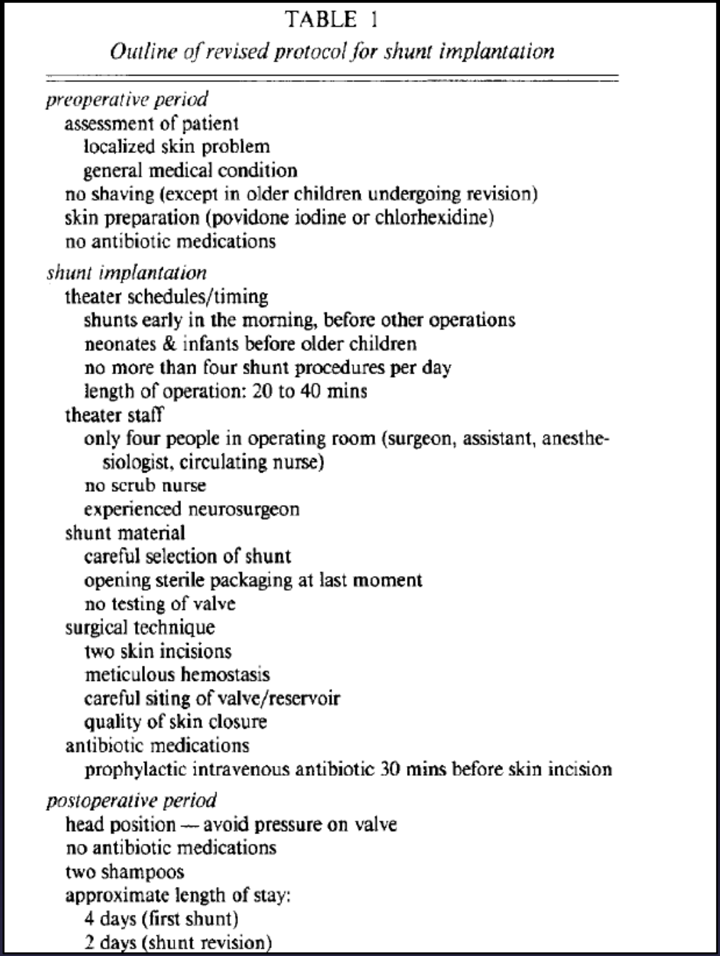


TABLE 1

Outline of revised protocol for shunt implantation

preoperative period
- assessment of patient
  - localized skin problem
  - general medical condition
- no shaving (except in older children undergoing revision)
- skin preparation (povidone iodine or chlorhexidine)
- no antibiotic medications

shunt implantation
- theater schedules/timing
  - shunts early in the morning, before other operations
  - neonates & infants before older children
  - no more than four shunt procedures per day
  - length of operation: 20 to 40 mins
- theater staff
  - only four people in operating room (surgeon, assistant, anesthesiologist, circulating nurse)
  - no scrub nurse
  - experienced neurosurgeon
- shunt material
  - careful selection of shunt
  - opening sterile packaging at last moment
  - no testing of valve
- surgical technique
  - two skin incisions
  - meticulous hemostasis
  - careful siting of valve/reservoir
  - quality of skin closure
- antibiotic medications
  - prophylactic intravenous antibiotic 30 mins before skin incision

postoperative period
- head position — avoid pressure on valve
- no antibiotic medications
- two shampoos
- approximate length of stay:
  - 4 days (first shunt)
  - 2 days (shunt revision)

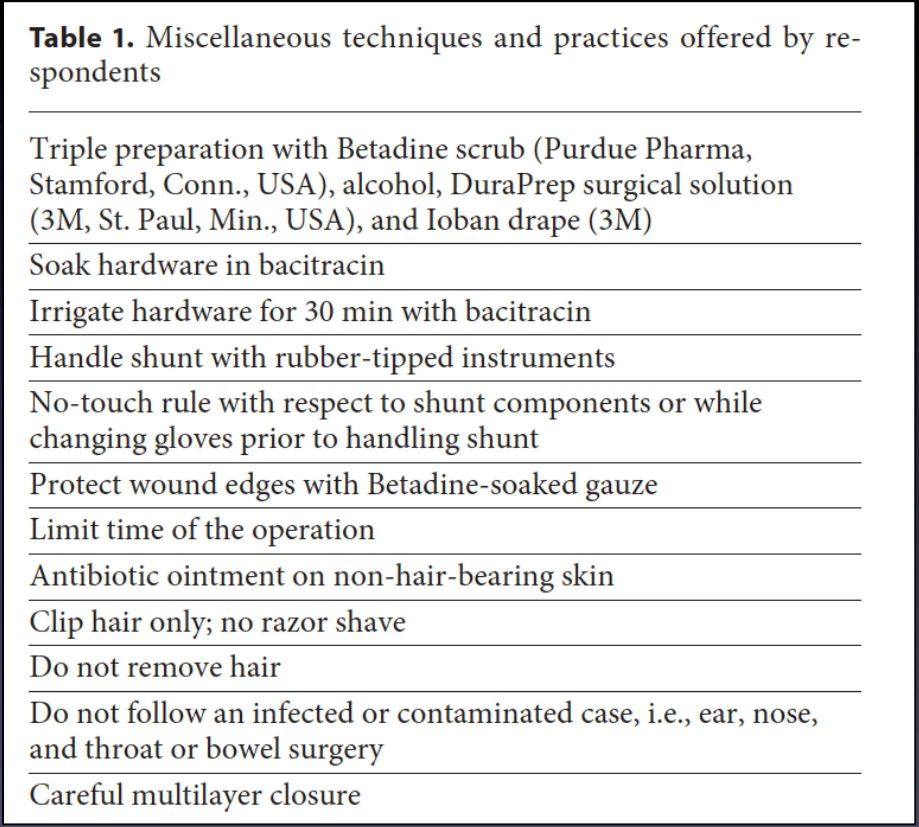
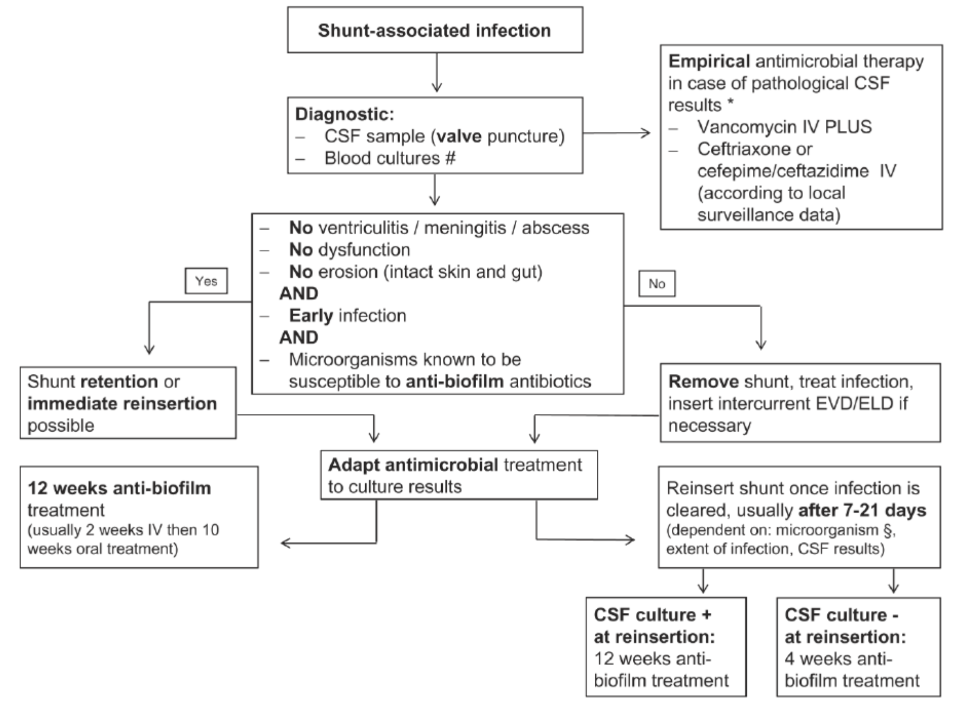


Table 1. Miscellaneous techniques and practices offered by respondents

Triple preparation with Betadine scrub (Purdue Pharma, Stamford, Conn., USA), alcohol, DuraPrep surgical solution (3M, St. Paul, Min., USA), and Ioban drape (3M)
Soak hardware in bacitracin
Irrigate hardware for 30 min with bacitracin
Handle shunt with rubber-tipped instruments
No-touch rule with respect to shunt components or while changing gloves prior to handling shunt
Protect wound edges with Betadine-soaked gauze
Limit time of the operation
Antibiotic ointment on non-hair-bearing skin
Clip hair only; no razor shave
Do not remove hair
Do not follow an infected or contaminated case, i.e., ear, nose, and throat or bowel surgery
Careful multilayer closure

Gruber TJ Pediatr Neurosurgery 2009

Ruolo ETV in infezioni di shunt



Shunt-associated infection

Diagnostic:
- CSF sample (**valve** puncture)
- Blood cultures #

Empirical antimicrobial therapy in case of pathological CSF results *
- Vancomycin IV PLUS
- Ceftriaxone or cefepime/ceftazidime IV (according to local surveillance data)

- **No** ventriculitis / meningitis / abscess
- **No** dysfunction
- **No** erosion (intact skin and gut)

AND
- **Early** infection

AND
- Microorganisms known to be susceptible to **anti-biofilm** antibiotics

Yes

Shunt **retention** or **immediate reinsertion** possible

No

Remove shunt, treat infection, insert intercurrent EVD/ELD if necessary

Adapt antimicrobial treatment to culture results

12 weeks anti-biofilm treatment (usually 2 weeks IV then 10 weeks oral treatment)

Reinsert shunt once infection is cleared, usually **after 7-21 days** (dependent on: microorganism §, extent of infection, CSF results)

CSF culture + at reinsertion: 12 weeks anti-biofilm treatment

CSF culture - at reinsertion: 4 weeks anti-biofilm treatment

Figure 2. Proposed management algorithm for shunt-associated infections. Adapted from Conen et al. [14].
Abbreviations: CSF: Cerebrospinal fluid; EVD: external ventricular drainage; ELD: external lumbar drainage; IV: intravenous
* Pathological CSF results: CSF leukocyte count $>5\times10^6$ cells/μl, with predominantly granulocytes, CSF lactate >1.9 mmol/l, CSF total protein >0.45 g/l, glucose CSF/blood ratio <0.5
# Blood cultures especially in ventriculo-atrial shunt infections recommended
§ For low-virulent microorganisms, including coagulase-negative staphylococci and *P. acnes*, re-implantation after 5–7 days; for *S. aureus*, *Streptococcus* spp., *Enterococcus* spp. and culture-negative infections 14 days; for Enterobacteriaceae and *P. aeruginosa* 21 days

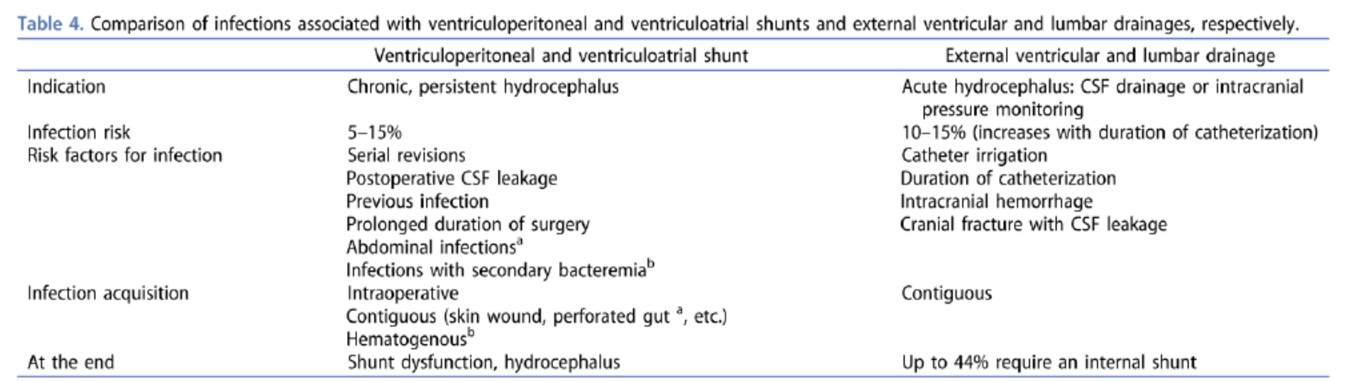
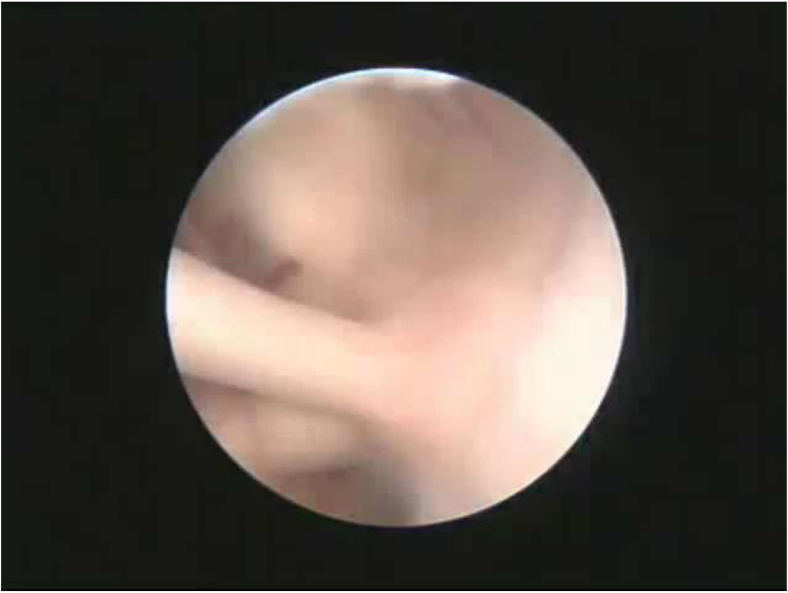
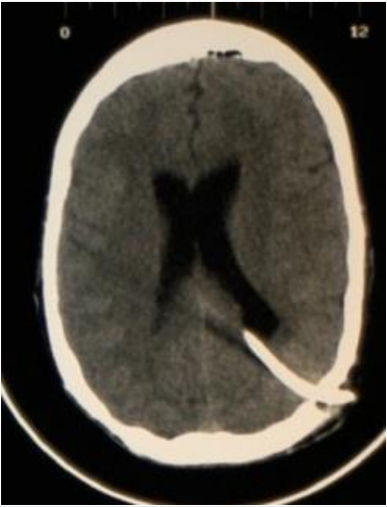


Table 4. Comparison of infections associated with ventriculoperitoneal and ventriculoatrial shunts and external ventricular and lumbar drainages, respectively.

	Ventriculoperitoneal and ventriculoatrial shunt	External ventricular and lumbar drainage
Indication	Chronic, persistent hydrocephalus	Acute hydrocephalus: CSF drainage or intracranial pressure monitoring
Infection risk	5–15%	10–15% (increases with duration of catheterization)
Risk factors for infection	Serial revisions Postoperative CSF leakage Previous infection Prolonged duration of surgery Abdominal infections[a] Infections with secondary bacteremia[b]	Catheter irrigation Duration of catheterization Intracranial hemorrhage Cranial fracture with CSF leakage
Infection acquisition	Intraoperative Contiguous (skin wound, perforated gut [a], etc.) Hematogenous[b]	Contiguous
At the end	Shunt dysfunction, hydrocephalus	Up to 44% require an internal shunt





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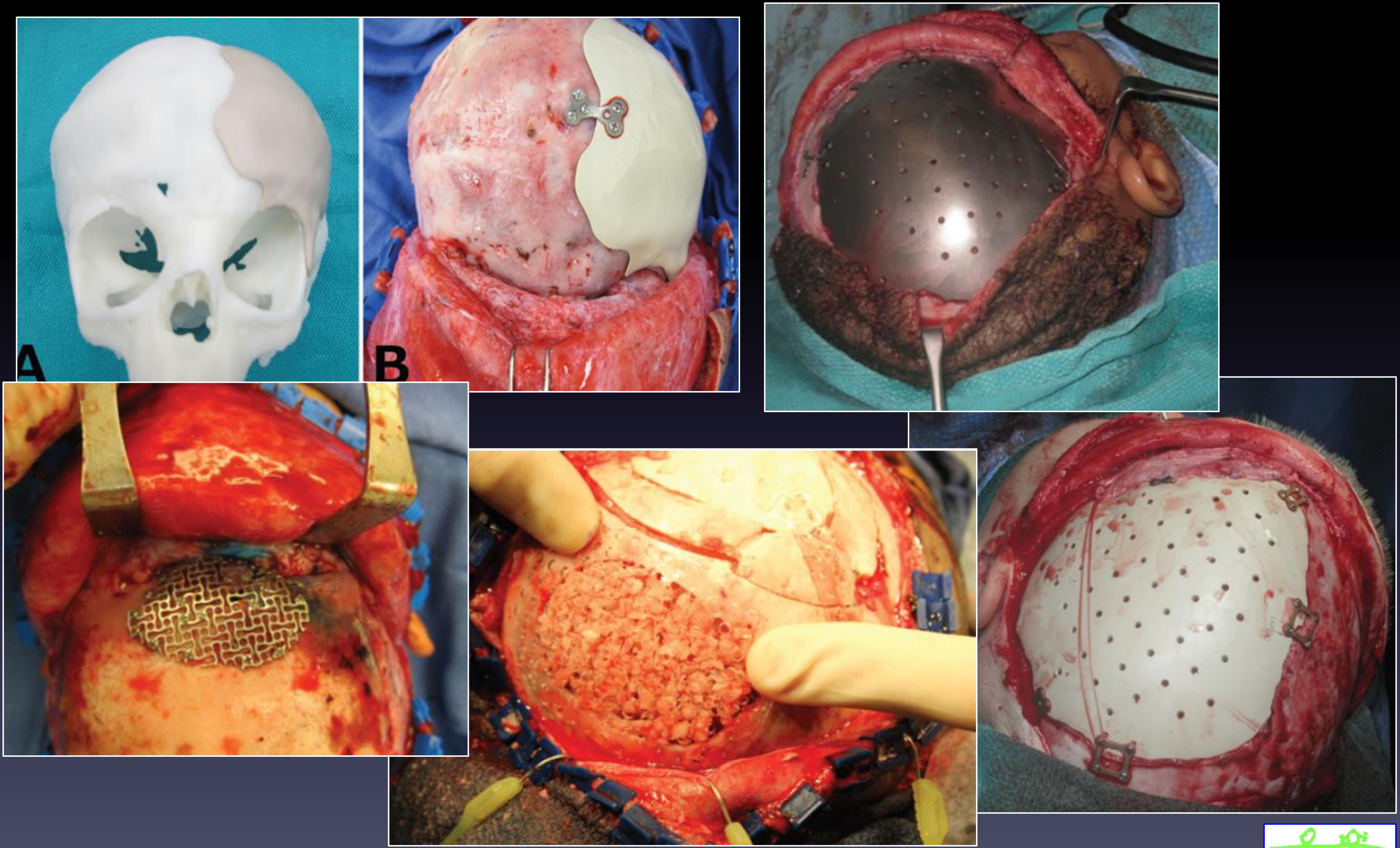
Conen A Expert review of antiinfective therapy 2017

Cranioplastica



Harris DA Neurosurg Focus 2014; 36 (4): E20

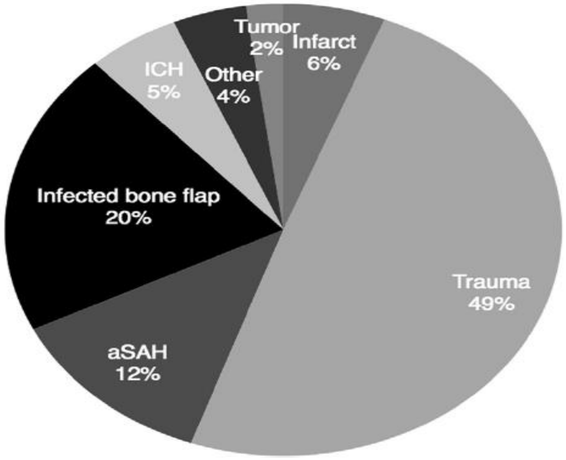


Figure 1. Reason for cranioplasty.

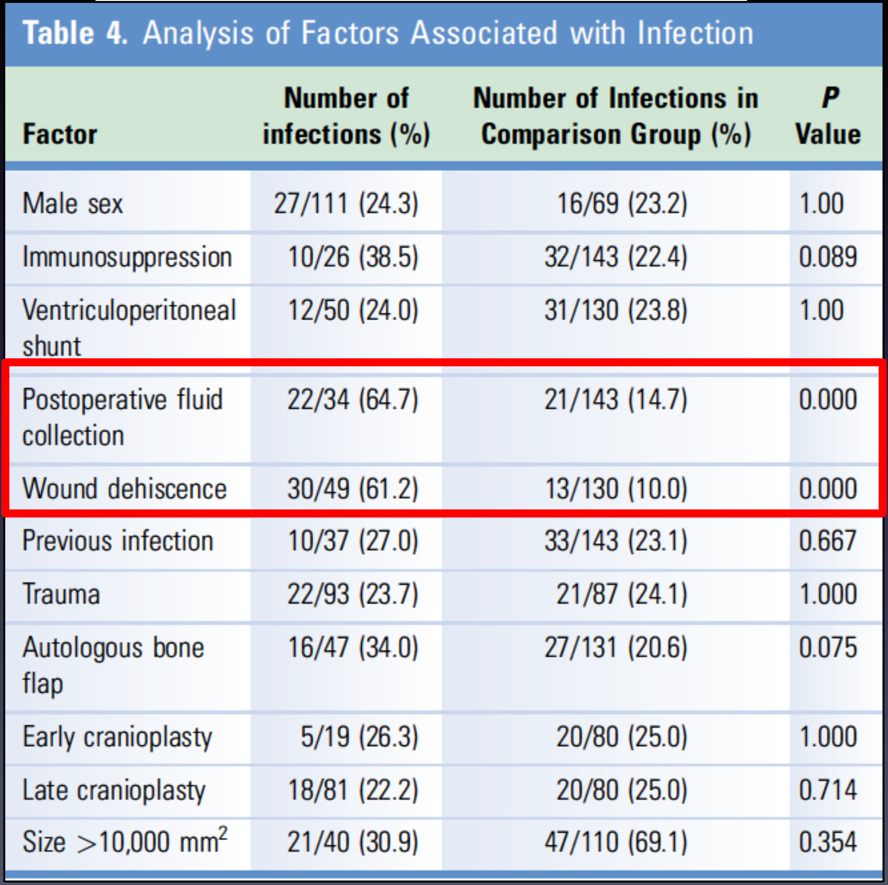


Table 4. Analysis of Factors Associated with Infection

Factor	Number of infections (%)	Number of Infections in Comparison Group (%)	*P* Value
Male sex	27/111 (24.3)	16/69 (23.2)	1.00
Immunosuppression	10/26 (38.5)	32/143 (22.4)	0.089
Ventriculoperitoneal shunt	12/50 (24.0)	31/130 (23.8)	1.00
Postoperative fluid collection	22/34 (64.7)	21/143 (14.7)	0.000
Wound dehiscence	30/49 (61.2)	13/130 (10.0)	0.000
Previous infection	10/37 (27.0)	33/143 (23.1)	0.667
Trauma	22/93 (23.7)	21/87 (24.1)	1.000
Autologous bone flap	16/47 (34.0)	27/131 (20.6)	0.075
Early cranioplasty	5/19 (26.3)	20/80 (25.0)	1.000
Late cranioplasty	18/81 (22.2)	20/80 (25.0)	0.714
Size >10,000 mm^2	21/40 (30.9)	47/110 (69.1)	0.354

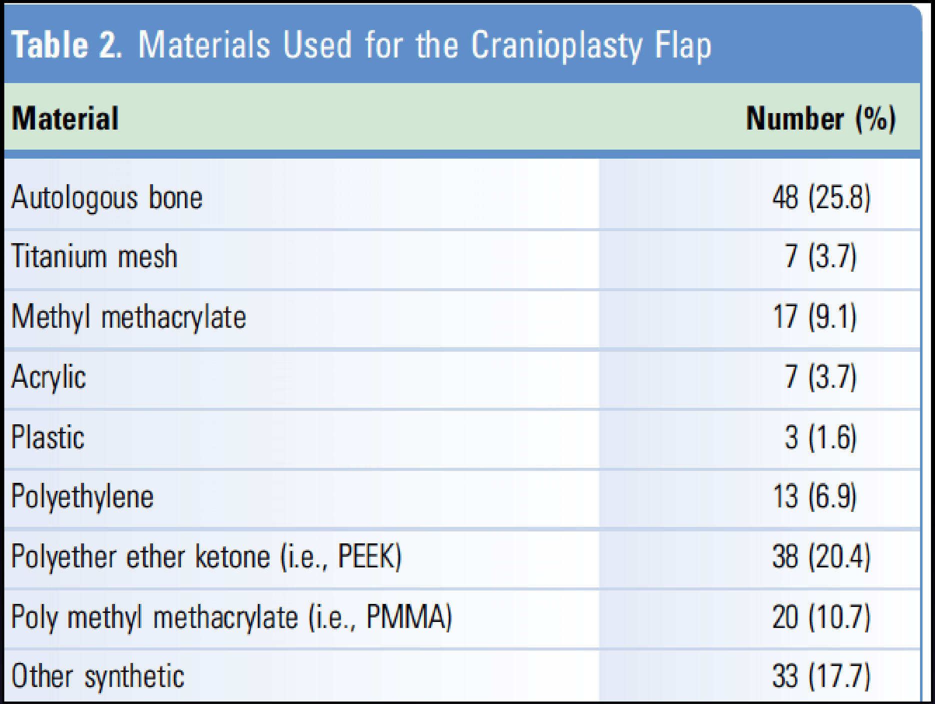


Table 2. Materials Used for the Cranioplasty Flap

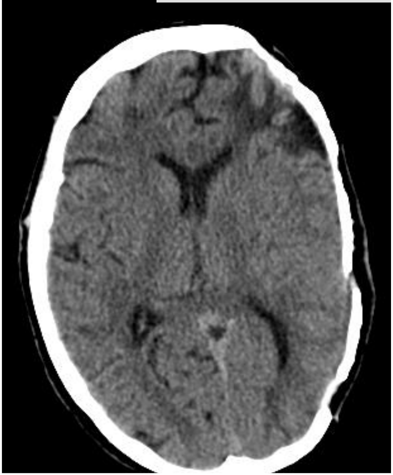
Material	Number (%)
Autologous bone	48 (25.8)
Titanium mesh	7 (3.7)
Methyl methacrylate	17 (9.1)
Acrylic	7 (3.7)
Plastic	3 (1.6)
Polyethylene	13 (6.9)
Polyether ether ketone (i.e., PEEK)	38 (20.4)
Poly methyl methacrylate (i.e., PMMA)	20 (10.7)
Other synthetic	33 (17.7)

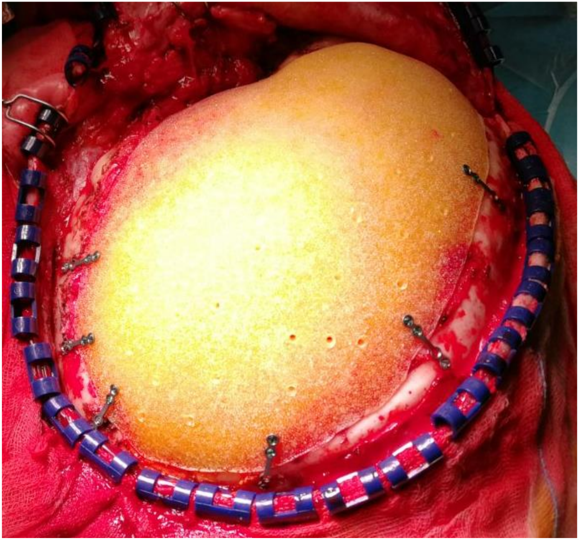
Eterologa
- infezioni 1-26%

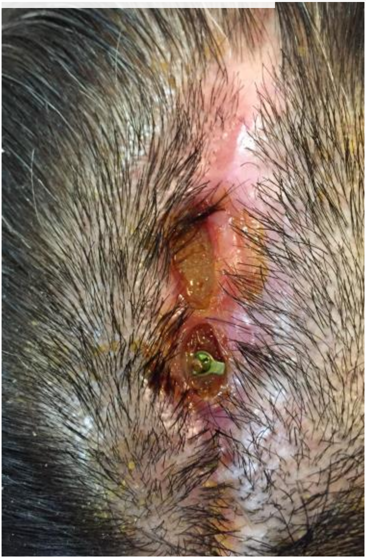
Autologa
- riassorbimento per necrosi asettica 2-32%

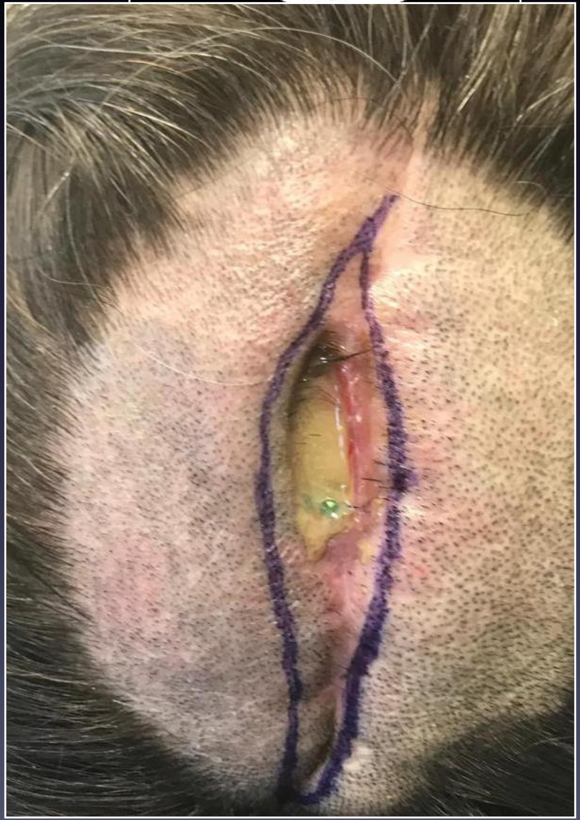
Riordan MA World Neurosurgery 2016

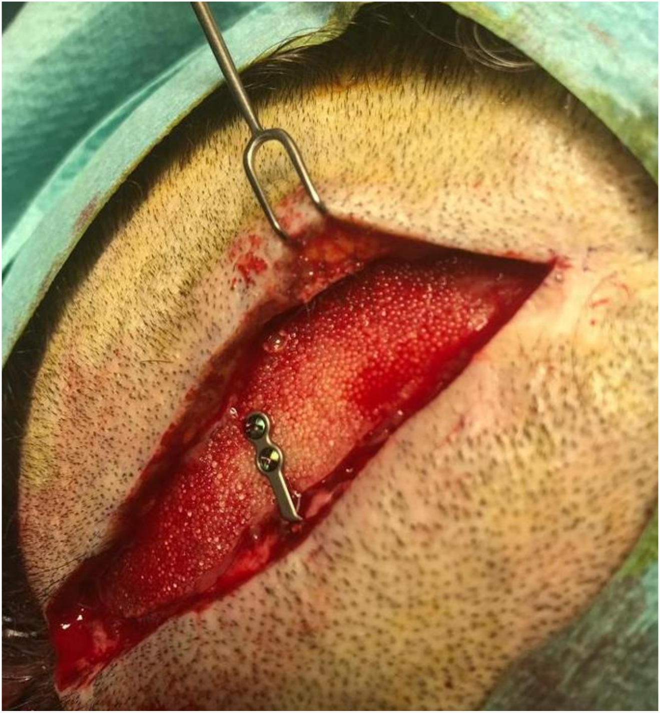
Salvataggio cranioplastica (revisione chirurgica + A/B)

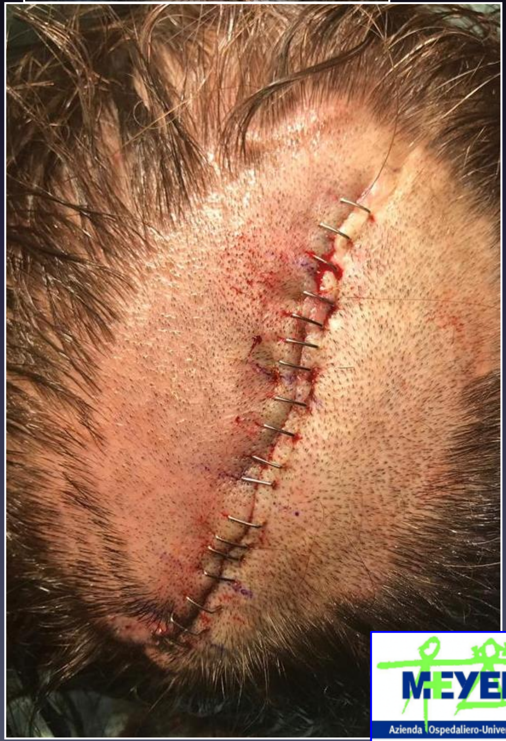












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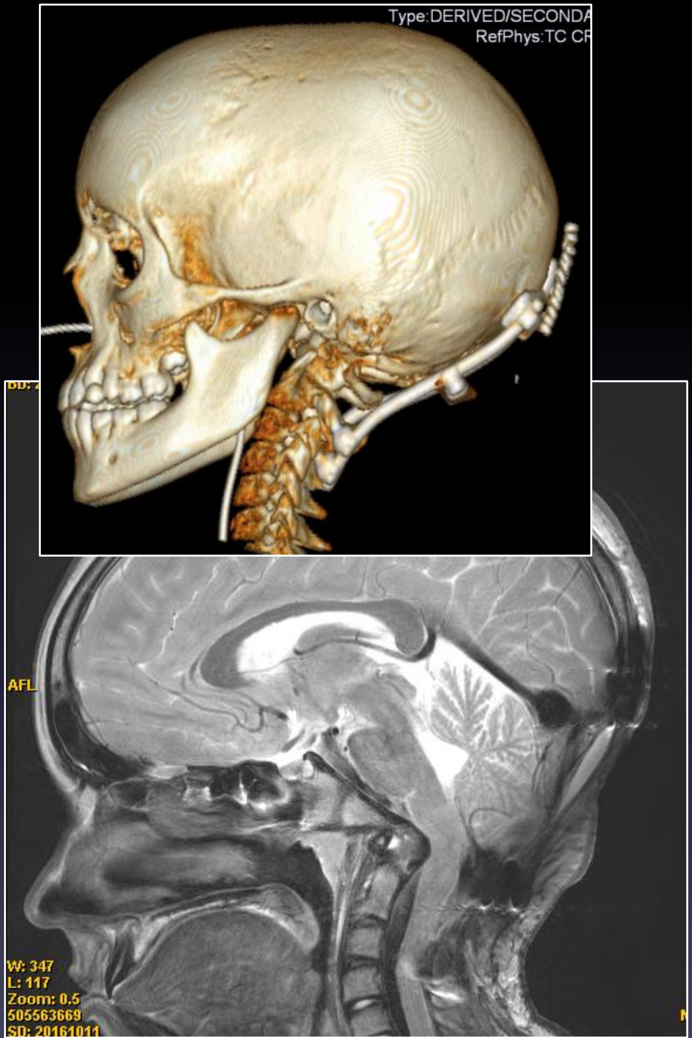
Sistemi di fissazione spinale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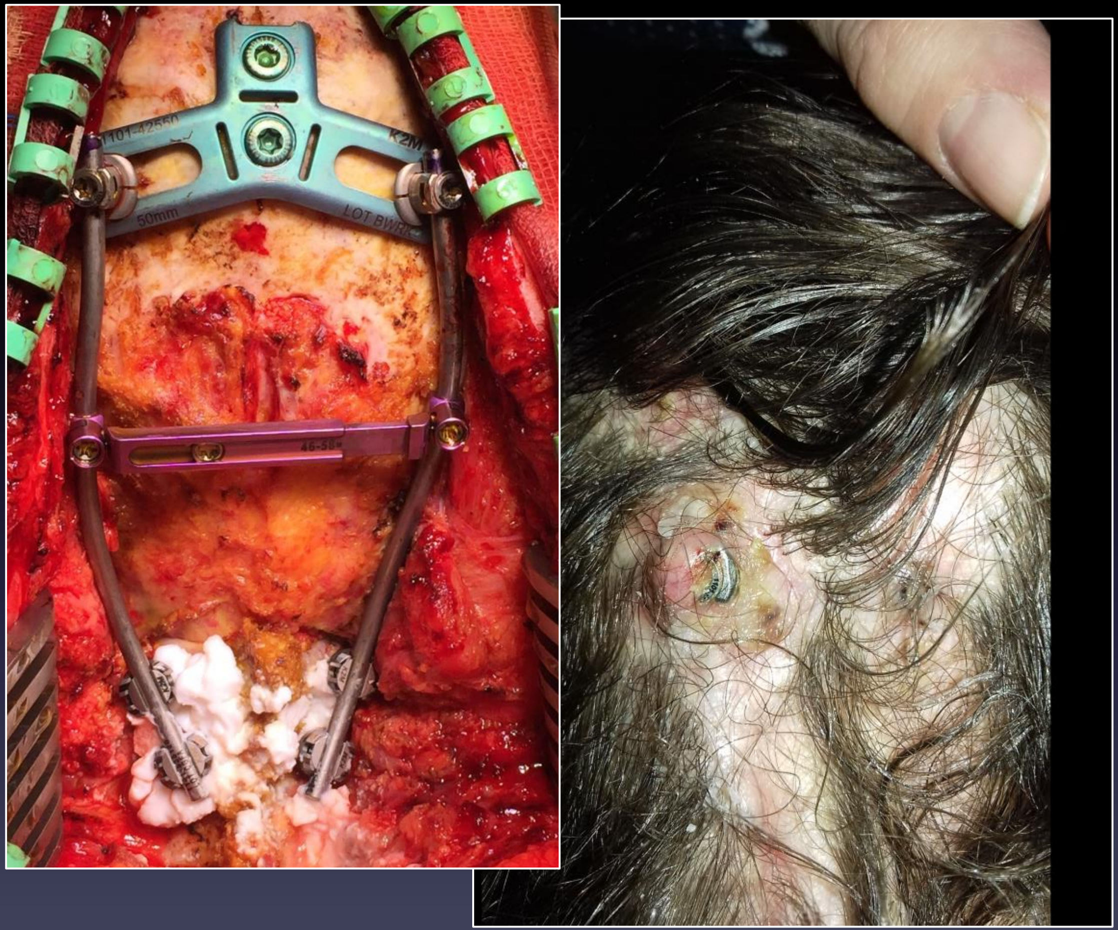
RefPhys:TC CR
AFL
W: 347
L: 117
Zoom: 0.5
505563669
SD: 20161011


K2M
50mm
LOT BWR
46-59

Infezione e distrofia cutanea
Salvataggio impianto con innesto libero di lembo peduncolato

Morbilità Intrathecal Baclofen (ITB) Pump

- **CHIRURGICHE**
- Procedura correlate (rare)
- Sistema correlate (++ infezioni, disfunzioni catetere, fistola LCR, decubio, dislocazioni pompa, sieroma,)
- Ricarica pompa (danneggiamento sistema, procedura errata)

- **FARMACOLOGICHE**
- Vertigini, sopore, arresto cardio-respiratorio,
- Disturbi SNV
- Stipsi, difficoltà minzione (reversibile)
- Sovradosaggio (a.d. fisostigmina)
- Ipertermia maligna
- Rabdomiolisi

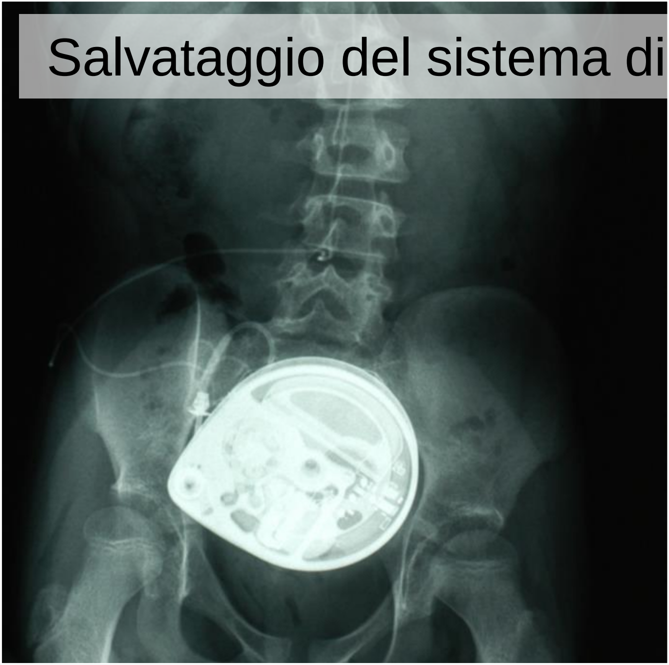
da sospensione

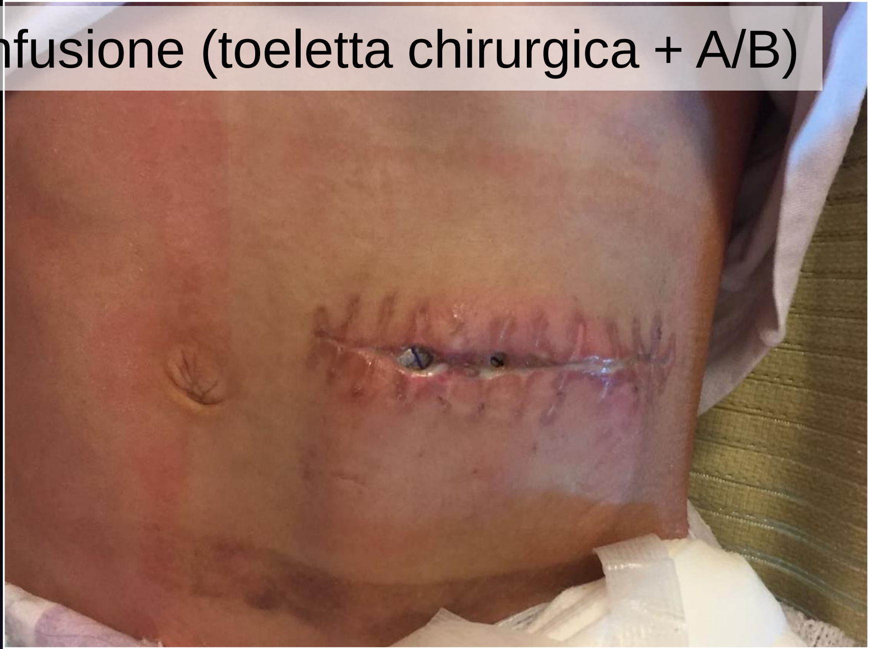
Complicazioni: 4-20% (+ bambini, + forme distono-discinetiche)

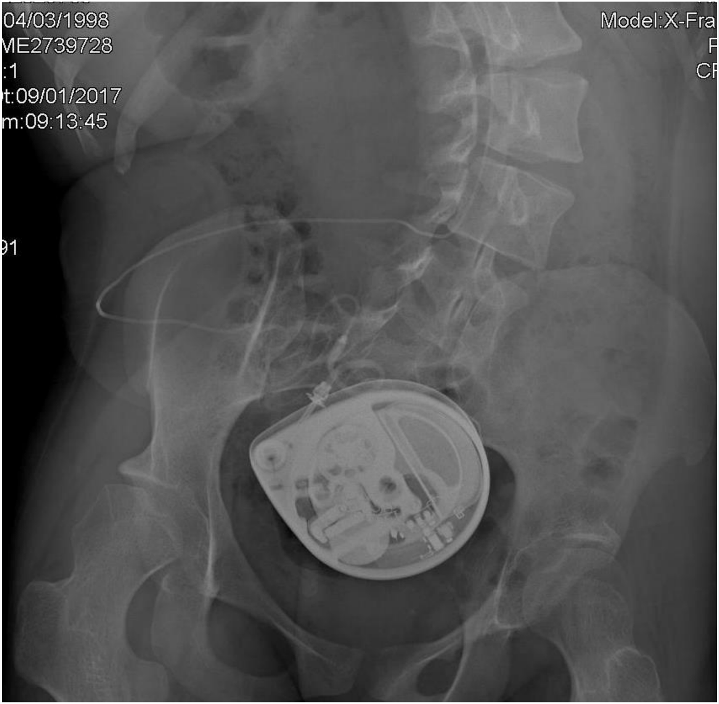
Infezioni 10-25%

Brennan PM Br J Neurosurg 2008; Aug (22): 508-19
Borrini L Arch Phys Med Rehabil 2014; Jan 6

Salvataggio del sistema di infusione (toeletta chirurgica + A/B)



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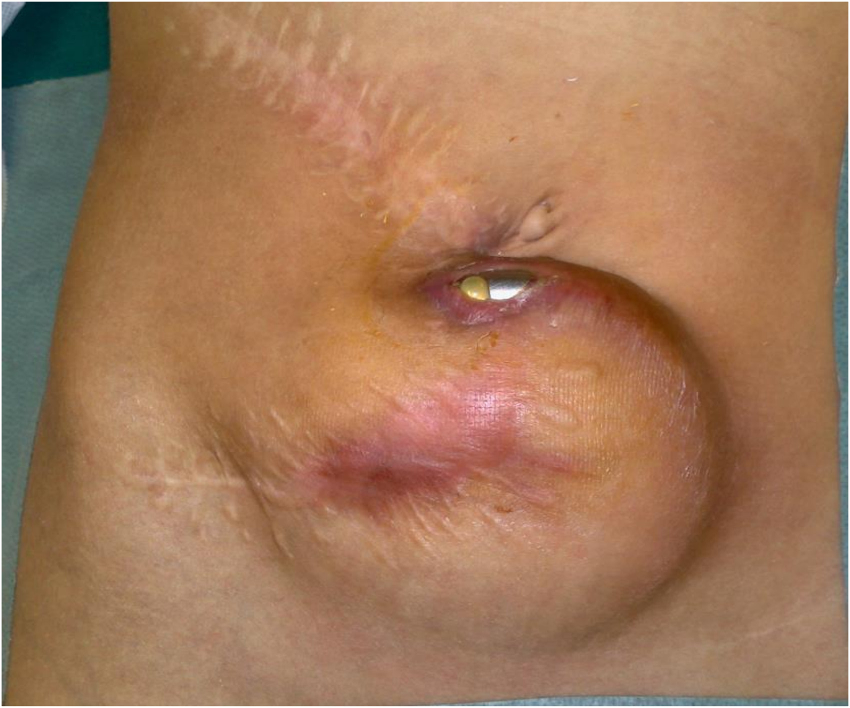
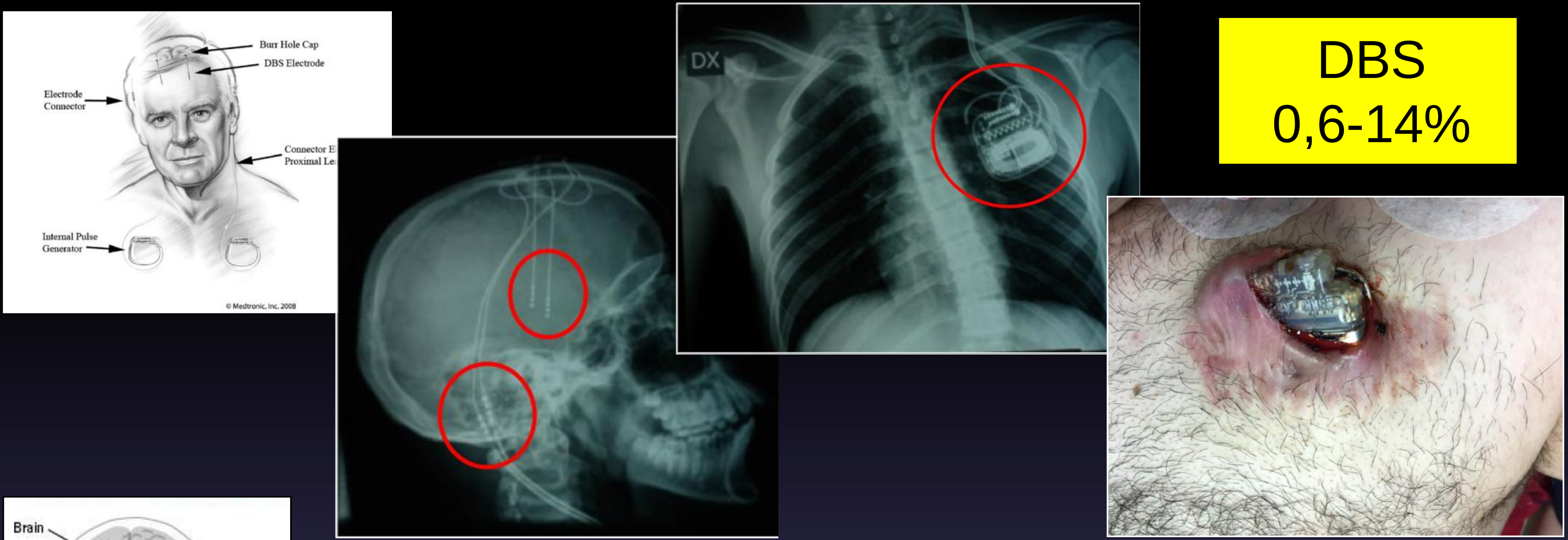
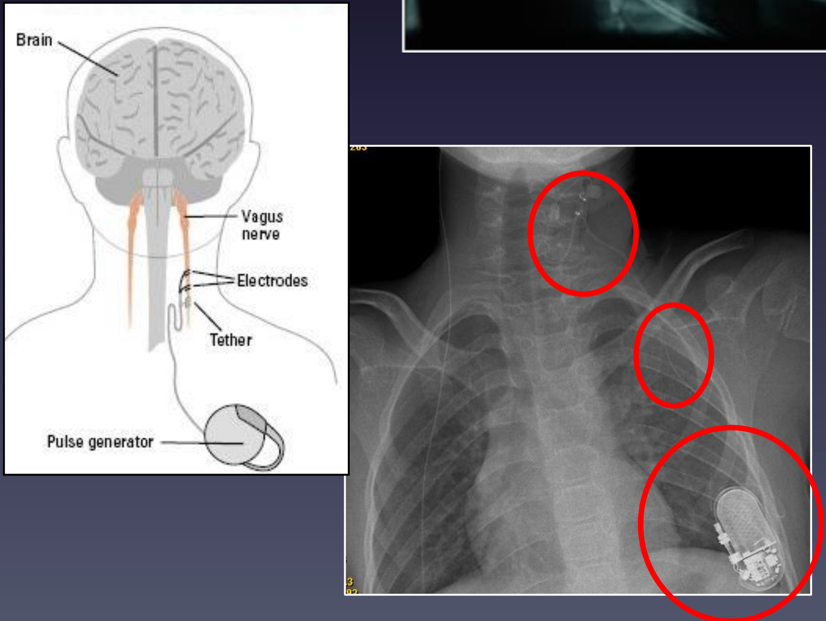
CF

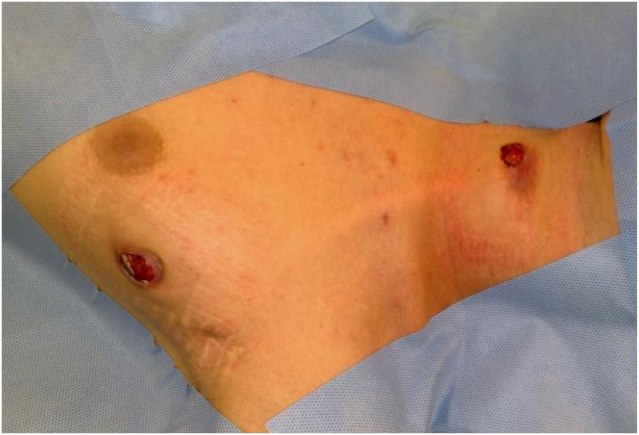


Infezioni materiale neuromodulazione


Burr Hole Cap
DBS Electrode
Electrode Connector
Connector E
Proximal Le
Internal Pulse Generator
© Medtronic, Inc. 2008
DX

DBS
0,6-14%


Brain
Vagus nerve
Electrodes
Tether
Pulse generator



VNS
1-6%

Stenehjem E Dis Clin N Am 2012; 26: 89-110

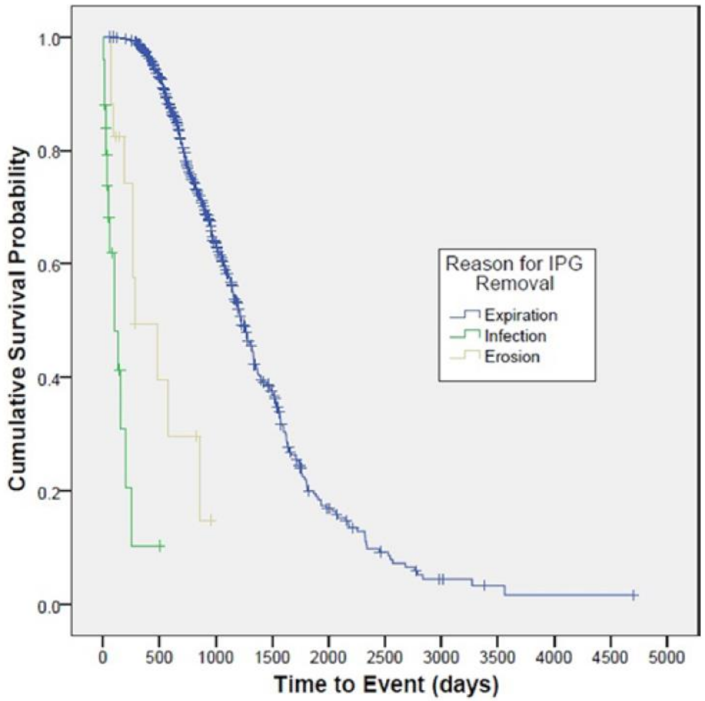


FIG. 2. IPG reoperation survival curves. Expiration refers to battery life. Figure is available in color online only.

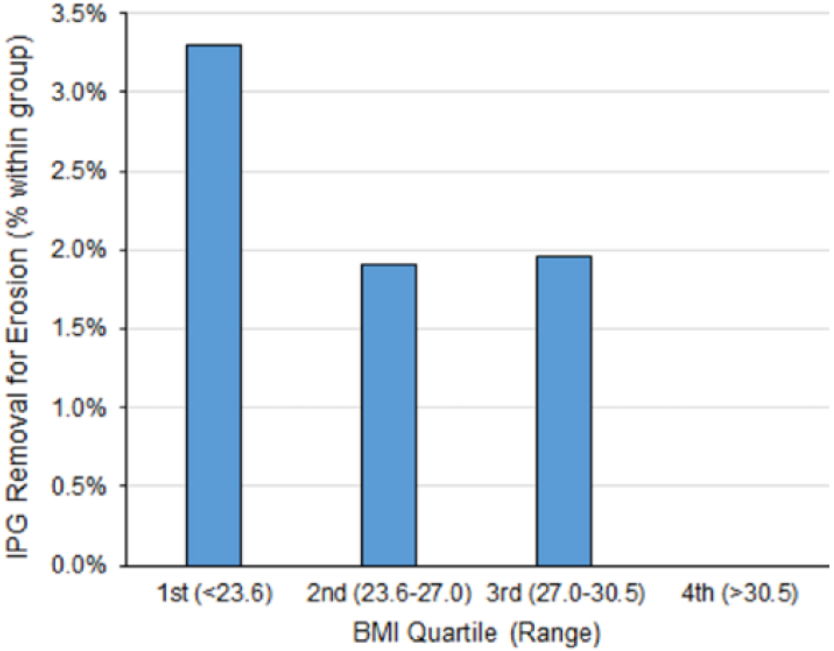


FIG. 3. IPG erosion frequency by BMI quartile. Figure is available in color online only.

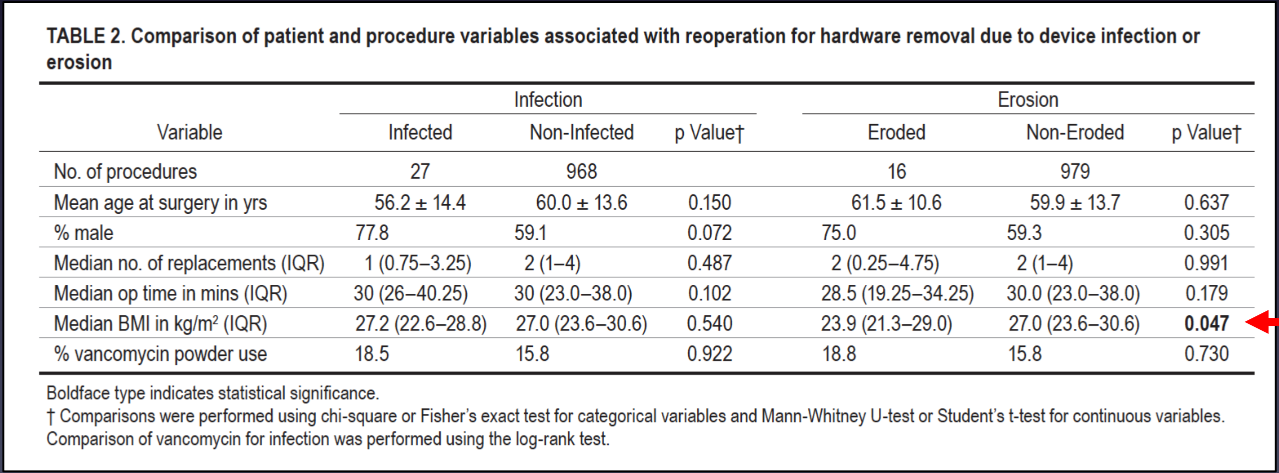


TABLE 2. Comparison of patient and procedure variables associated with reoperation for hardware removal due to device infection or erosion

Variable	Infection			Erosion		
	Infected	Non-Infected	p Value†	Eroded	Non-Eroded	p Value†
No. of procedures	27	968		16	979	
Mean age at surgery in yrs	56.2 ± 14.4	60.0 ± 13.6	0.150	61.5 ± 10.6	59.9 ± 13.7	0.637
% male	77.8	59.1	0.072	75.0	59.3	0.305
Median no. of replacements (IQR)	1 (0.75–3.25)	2 (1–4)	0.487	2 (0.25–4.75)	2 (1–4)	0.991
Median op time in mins (IQR)	30 (26–40.25)	30 (23.0–38.0)	0.102	28.5 (19.25–34.25)	30.0 (23.0–38.0)	0.179
Median BMI in kg/m² (IQR)	27.2 (22.6–28.8)	27.0 (23.6–30.6)	0.540	23.9 (21.3–29.0)	27.0 (23.6–30.6)	**0.047**
% vancomycin powder use	18.5	15.8	0.922	18.8	15.8	0.730

Boldface type indicates statistical significance.
† Comparisons were performed using chi-square or Fisher's exact test for categorical variables and Mann-Whitney U-test or Student's t-test for continuous variables. Comparison of vancomycin for infection was performed using the log-rank test.

Erosione/infezione
4,3%

Atchley T Journal of Neurosurgery 2019

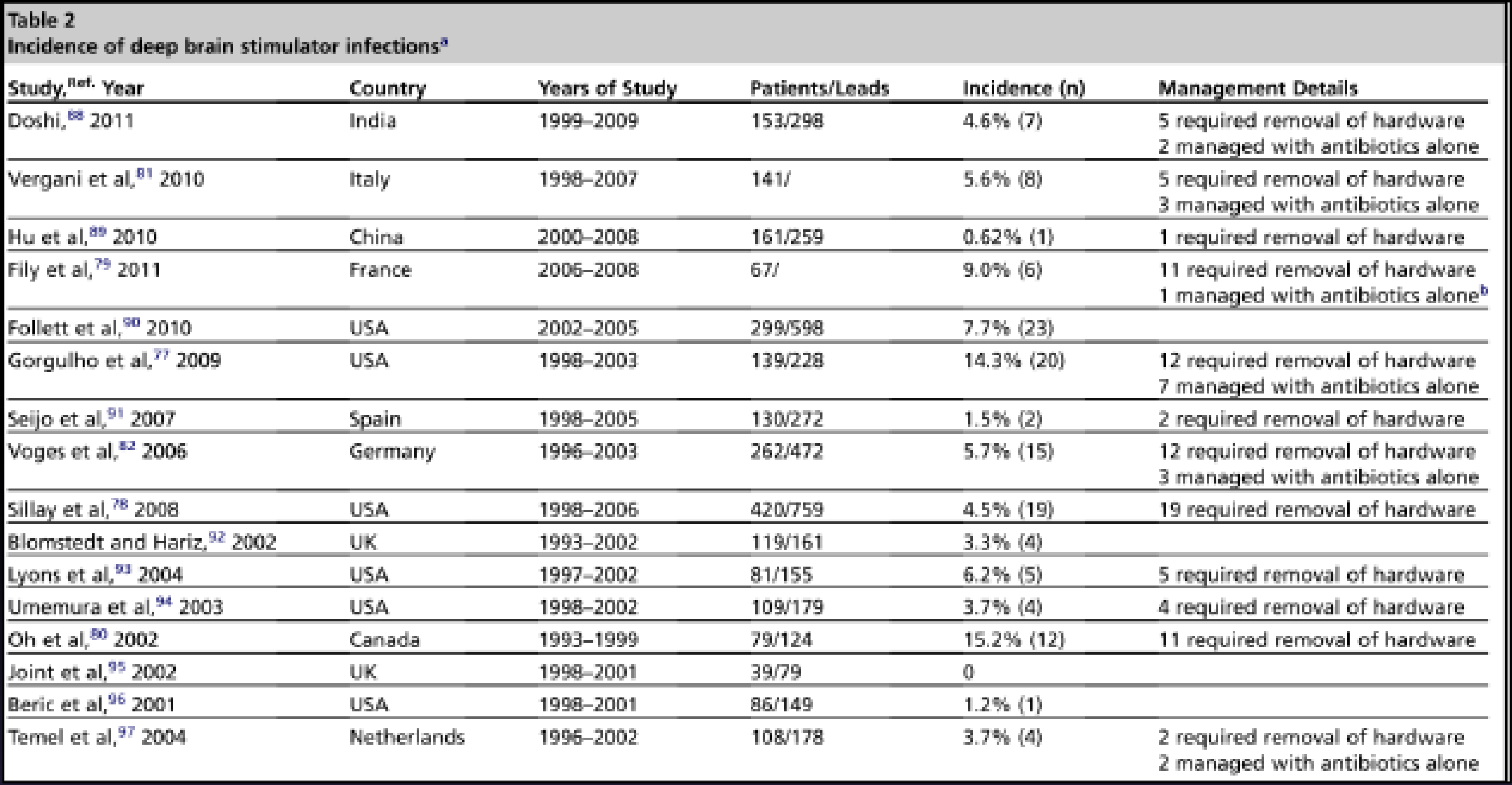


Table 2
Incidence of deep brain stimulator infections[a]

Study,[Ref.] Year	Country	Years of Study	Patients/Leads	Incidence (n)	Management Details
Doshi,[88] 2011	India	1999–2009	153/298	4.6% (7)	5 required removal of hardware 2 managed with antibiotics alone
Vergani et al,[81] 2010	Italy	1998–2007	141/	5.6% (8)	5 required removal of hardware 3 managed with antibiotics alone
Hu et al,[89] 2010	China	2000–2008	161/259	0.62% (1)	1 required removal of hardware
Fily et al,[79] 2011	France	2006–2008	67/	9.0% (6)	11 required removal of hardware 1 managed with antibiotics alone[b]
Follett et al,[90] 2010	USA	2002–2005	299/598	7.7% (23)	
Gorgulho et al,[77] 2009	USA	1998–2003	139/228	14.3% (20)	12 required removal of hardware 7 managed with antibiotics alone
Seijo et al,[91] 2007	Spain	1998–2005	130/272	1.5% (2)	2 required removal of hardware
Voges et al,[82] 2006	Germany	1996–2003	262/472	5.7% (15)	12 required removal of hardware 3 managed with antibiotics alone
Sillay et al,[78] 2008	USA	1998–2006	420/759	4.5% (19)	19 required removal of hardware
Blomstedt and Hariz,[92] 2002	UK	1993–2002	119/161	3.3% (4)	
Lyons et al,[93] 2004	USA	1997–2002	81/155	6.2% (5)	5 required removal of hardware
Umemura et al,[94] 2003	USA	1998–2002	109/179	3.7% (4)	4 required removal of hardware
Oh et al,[80] 2002	Canada	1993–1999	79/124	15.2% (12)	11 required removal of hardware
Joint et al,[95] 2002	UK	1998–2001	39/79	0	
Beric et al,[96] 2001	USA	1998–2001	86/149	1.2% (1)	
Temel et al,[97] 2004	Netherlands	1996–2002	108/178	3.7% (4)	2 required removal of hardware 2 managed with antibiotics alone

DBS - Incidenza 0,62-14,3 % (50% tasca sottocutanea)

Flora batterica della cute (Staf. Aureus, Staf. Epidermidis, Pr. Acnes)

- Rimozione completa
- Rimozione solo IPG + estensioni
- Debridment + A/B 6 settimane per salvataggio impianto

Stenehjem E Dis Clin N Am 2012; 26: 89-110

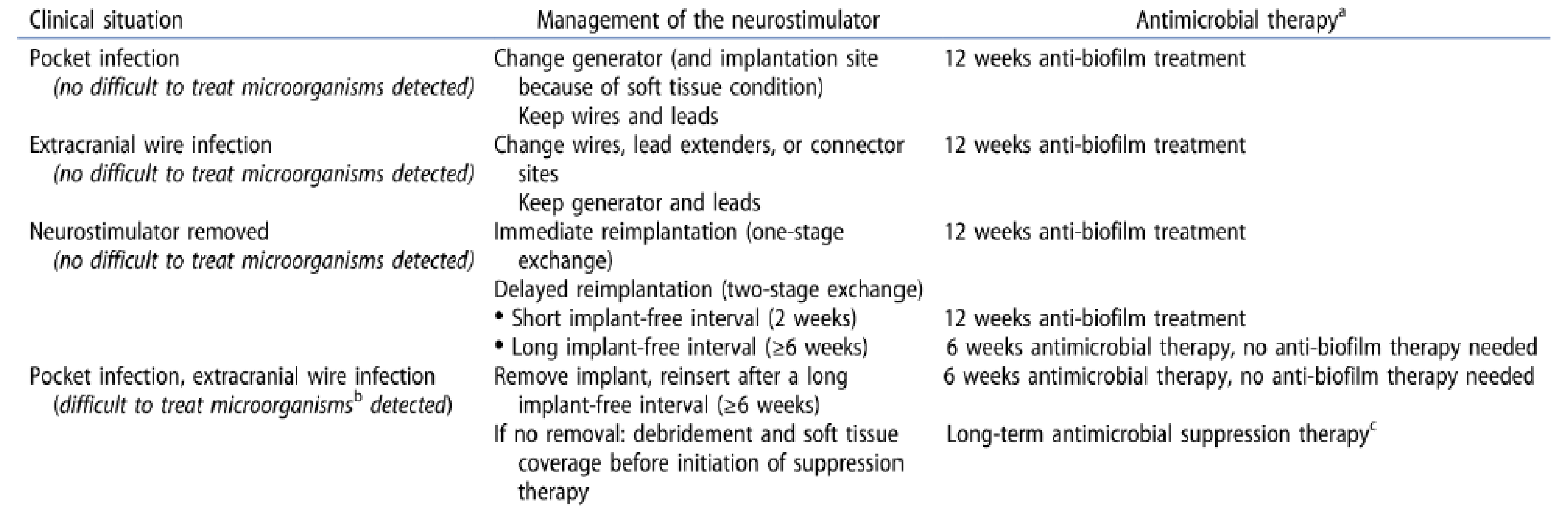


Table 6. Recommendations for the management of neurostimulator-associated infections according to the site of infection.

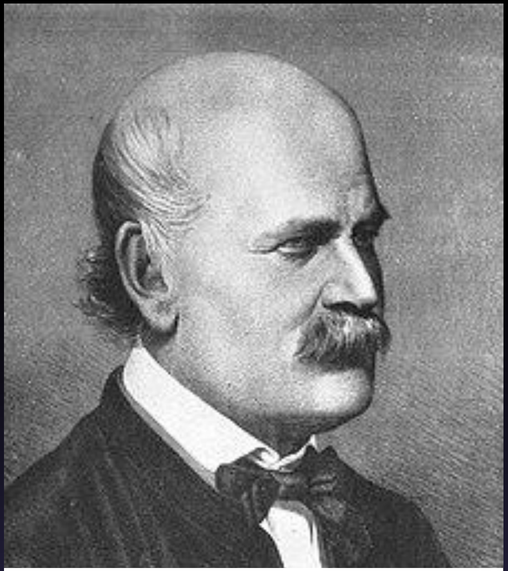
Clinical situation	Management of the neurostimulator	Antimicrobial therapy[a]
Pocket infection *(no difficult to treat microorganisms detected)*	Change generator (and implantation site because of soft tissue condition) Keep wires and leads	12 weeks anti-biofilm treatment
Extracranial wire infection *(no difficult to treat microorganisms detected)*	Change wires, lead extenders, or connector sites Keep generator and leads	12 weeks anti-biofilm treatment
Neurostimulator removed *(no difficult to treat microorganisms detected)*	Immediate reimplantation (one-stage exchange)	12 weeks anti-biofilm treatment
	Delayed reimplantation (two-stage exchange)	
	• Short implant-free interval (2 weeks)	12 weeks anti-biofilm treatment
	• Long implant-free interval (≥6 weeks)	6 weeks antimicrobial therapy, no anti-biofilm therapy needed
Pocket infection, extracranial wire infection *(difficult to treat microorganisms[b] detected)*	Remove implant, reinsert after a long implant-free interval (≥6 weeks)	6 weeks antimicrobial therapy, no anti-biofilm therapy needed
	If no removal: debridement and soft tissue coverage before initiation of suppression therapy	Long-term antimicrobial suppression therapy[c]

Tentativo di salvataggio device per possibile rischio di:

- tetano muscolare (ITB)
- peggioramento acuto/grave disturbo movimento e stato di male distonico (DBS)
- epilessia/depressione (VNS)

Conen A Expert review of antiinfective therapy 2017

Take Home Messages



Ignác Fülöp Semmelweis
(1818-1865)

- Asepsi chirurgica: primo fattore di prevenzione
- Infezioni liquorali: DVE spesso necessaria; ruolo neuroendoscopia
- Infezioni protesiche: possibile salvataggio se infezione acuta
- Infezioni neurostimolatori: tentativo di salvataggio per prevenire complicazioni neurologiche