Middle meningeal artery (MMA) embolization for chronic subdural hematoma

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Chronic Subdural Hematoma (CSDH)

Incidence

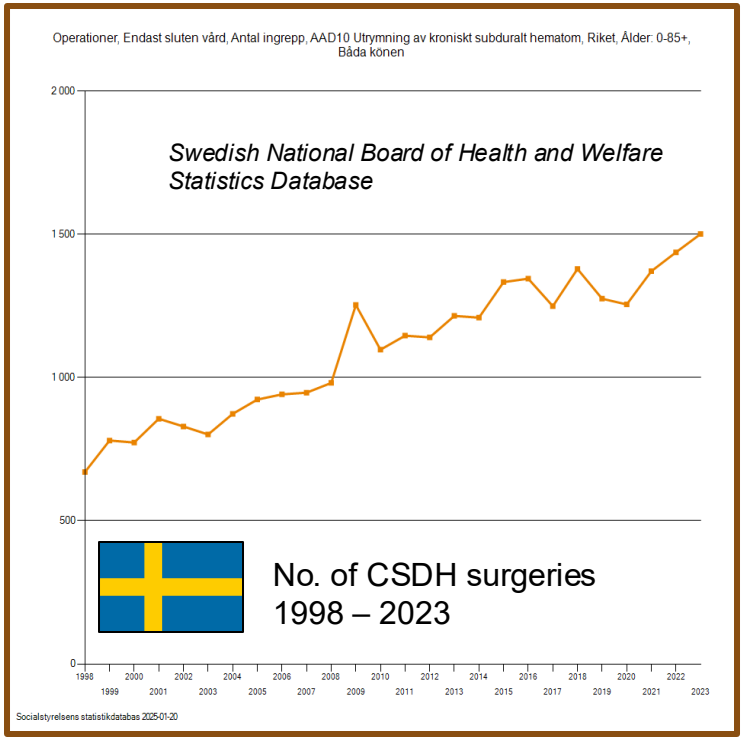
- 13,5 – 36.6[3] / 100’000 / year
- Increasing worldwide [1,2]

Risk factors

• ↑Age	Trauma
• Anticoagulation Tx	Alcoholism
• Antiplatelet Tx	Trombocytopenia
• Liver failure	Brain atrophy

Prognosis

- Persistant Morbidity: 4%
- Mortality: 8-11%
- Recurrence rates: 10-25%[4]



1. Balser, *J Neurosurg*. 2015, doi: 10.3171/2014.9.JNS141550
2. Tommiska, *J Neurosurg*. 2021 doi: 10.3171/2021.3.JNS21281
3. Rauhala, *Acta Neurochir* (2020), doi: 10.1007/s00701-020-04398-3
4. Feghali, *World Neurosurgery* (2020), doi.org/10.1016/j.wneu.2020.06.140

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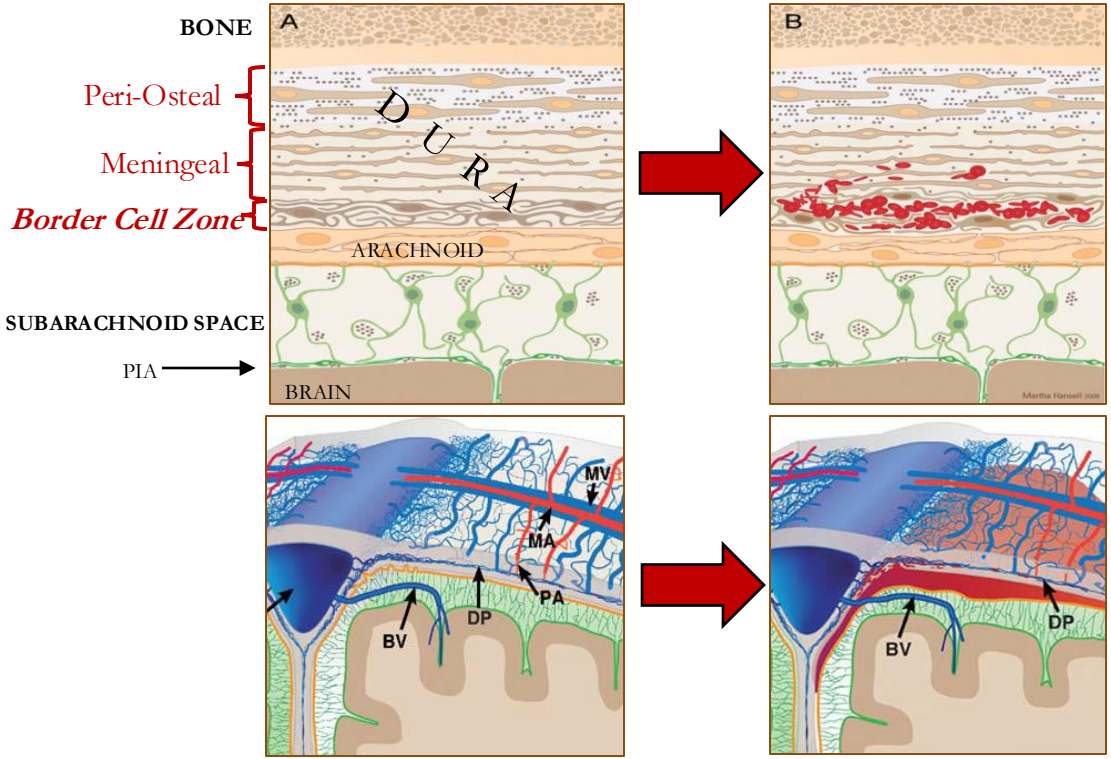
CSDH Pathophysiology



Mack et al, *Pediatr. Radiology* (2009) doi: 10.1007/s00247-008-1084-6

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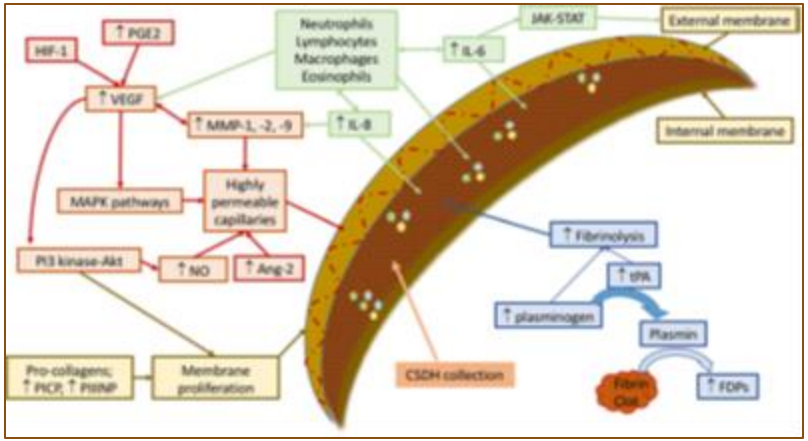
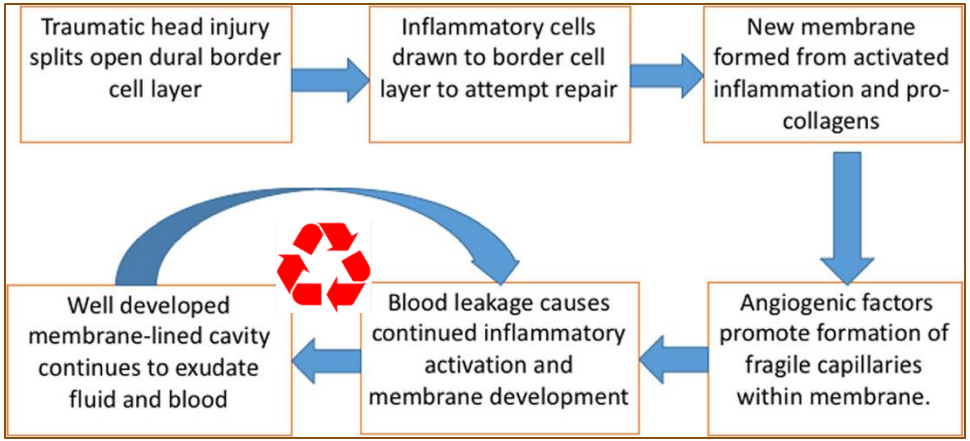
Pathophysiology continued





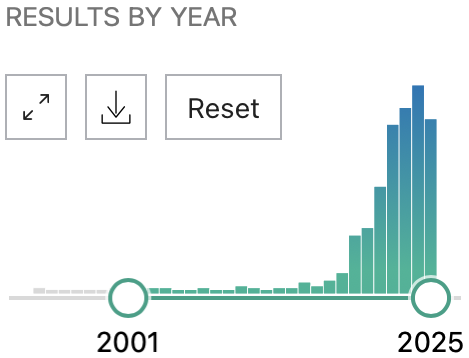
Surgery eleviates the compression but does not address the hematoma capsule

- Resulting in recurrence rates up to 25% following evacuation
- Resulting in at least 20% rescue operation rates following conservative treatment

Edlmann et al, *J. of Neuroinflammation* (2017), doi: 10.1186/s12974-017-0881-y

History in the making

- First case report 2000[1]
- More case reports…
- Case series…
- Prospective cohorts with historical control…
- Technical notes…
- Editorials…
- Meta analyses…
- RCTs…



"meningeal artery embolization chronic subdural hematoma"

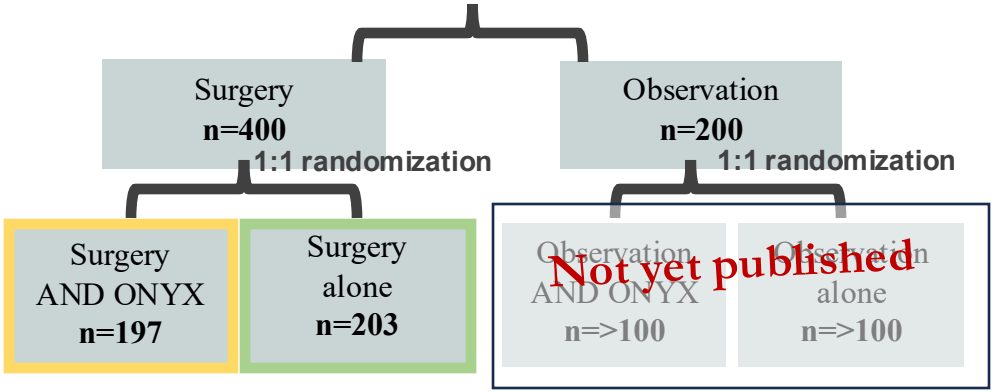
Mandai et al. *J Neurosurg* (2000), doi: 10.3171/jns.2000.93.4.0686.

2024 & 2025

Published and/or presented RCT-trials

- **EMBOLISE**
- **STEM**
- **MEMBRANE**
- **MAGIC-MT**
- **EMPROTECT**

EMBOLISE



Prospective RCT with two separate individually powered cohorts to compare safety and efficacy of

Surgery vs. **Surgery + ONYX embolization**

and

Observation vs. **Observation + ONYX MMAE**

Inclusion criteria

Age ≥18, mRS 0-3

CSDH

Treating neurosurgeon intended to operate

Primary Endpoint

Recurrent or progressing CSDH requiring surgery within 90 days

Davies JM et al. Adjunctive Middle Meningeal Artery Embolization for Subdural Hematoma. N Engl J Med. 2024 Nov 21;391(20):1890-1900.

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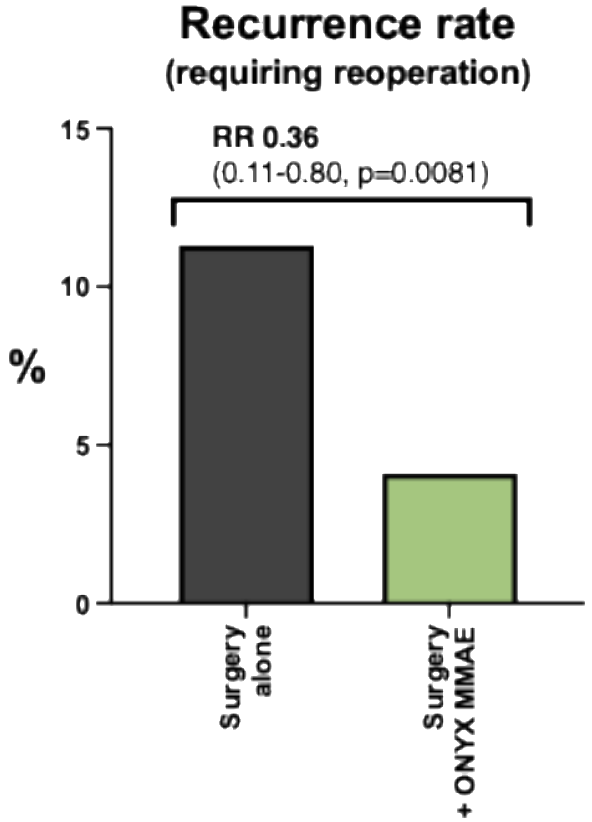
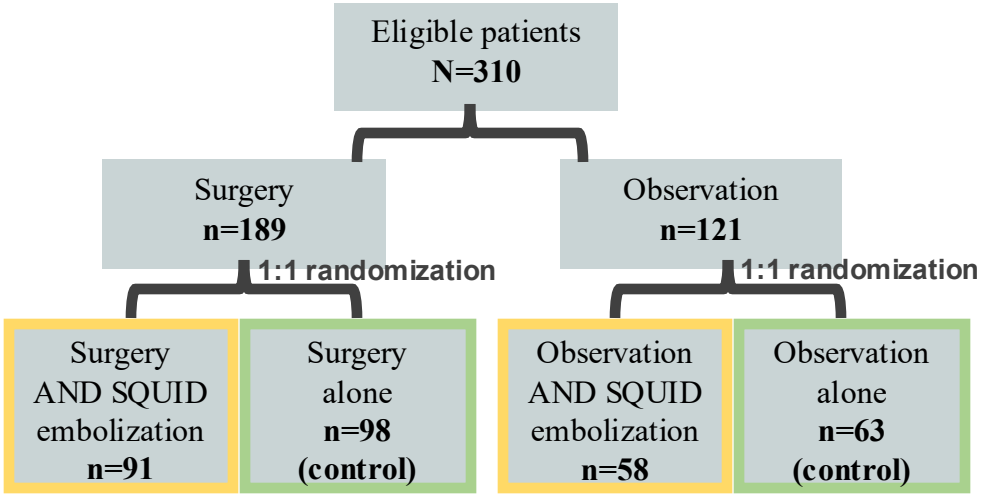
EMBOLISE – surgical arm



Conclusion:

Surgery + ONYX MMAE results in a statistically significant **3-fold reduction in reoperation of CSDH**, compared to surgery alone

STEM



Prospective RCT powered to compare safety and efficacy of

Standard Management vs.

Standard Management + SQUID MMA Embolization

Inclusion criteria

Age ≥ 30, mRS 0-1

CSDH (chronic) ≥10 mm

Mass effect & Neurological symptoms

Primary Endpoint

Failure at 180 days by either:

- Residual or recurrant CSDH
- Re- or Rescue-operation
- Stroke, MI or death

Fiorella D et al. Embolization of the Middle Meningeal Artery for Chronic Subdural Hematoma. N Engl J Med. 2025 Feb 27;392(9):855-864.

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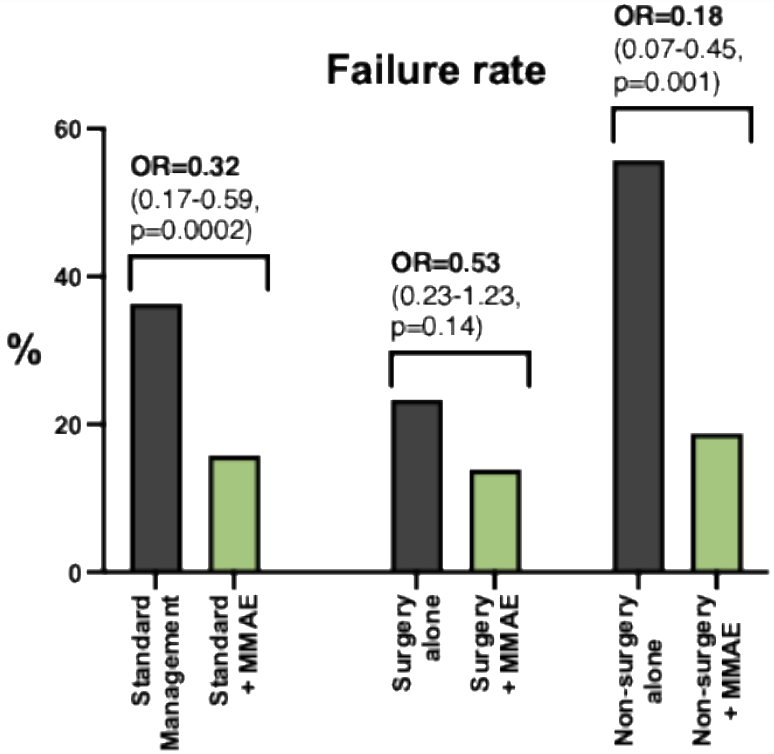
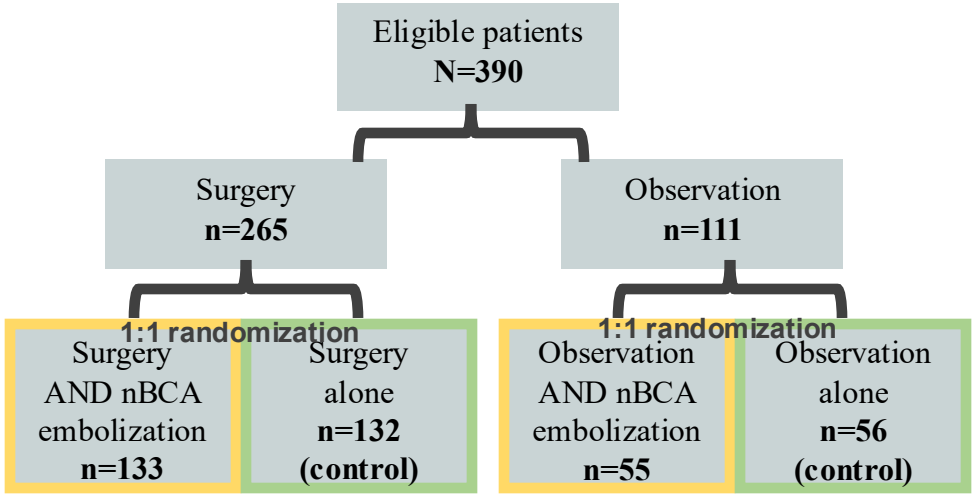
STEM



Conclusion

Adjunctive SQUID MMA embolization reduces the failure rate compared to standard management (**NNT=4.7**), as well as for non-surgical management (**NNT=2.6**) and the same trend is seen for surgical management(**NNT=10**)

MEMBRANE



Prospective RCT powered to compare safety and efficacy of **Standard Management** vs.

Standard Management + TRUFILL n-BCA MMA embolization

Inclusion criteria

Age ≥18, mRS 0-3

CSDH ≥10 mm

Mass effect, midline deviation ≤10 mm

Primary Endpoint

Recurrent or residual CSDH ≥10 mm at 6 months follow-up, OR

Re-operation within 6 months

Dr Ansaar Rai and Dr Christopher Kellner. Presentation at SVIN conference, San Diego 2024.

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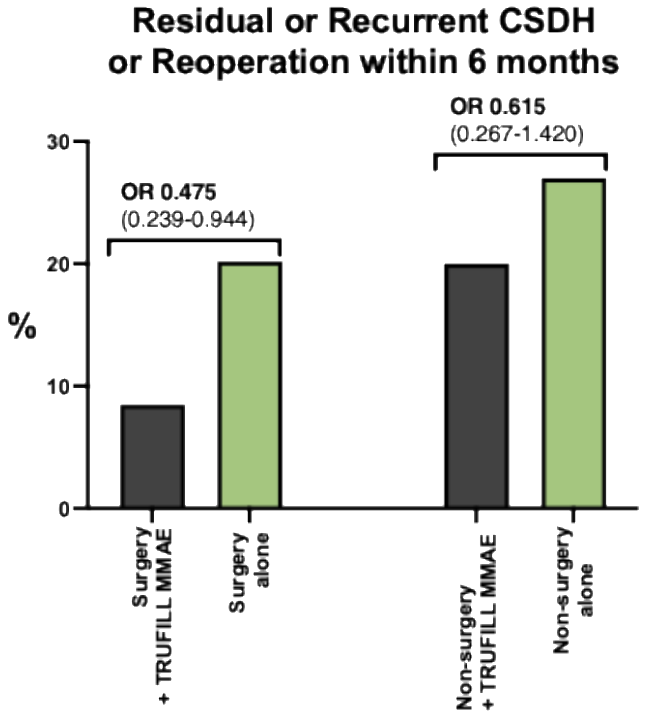
MEMBRANE



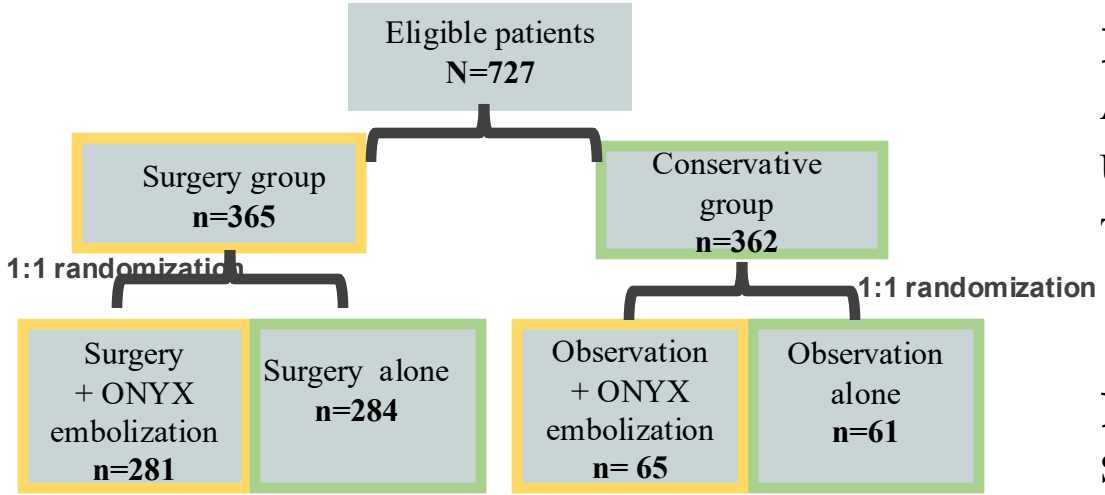
Conclusion

Adjunctive TRUFILL nBCA embolization reduces the overall failure rate with Odds Ratio 0.529

For surgical management OR= 0.475

For conservative management with OR= 0.615

MAGIC-MT



Prospective RCT, powered to compare safety and efficacy of **Standard Management** vs.

Standard Management + Onyx MMA embolization

Inclusion criteria

Age ≥18, mRS 0-2

Unilateral CSDH with mass effect

Treating neurosurgeon's intention to operate

Primary Endpoint

Symptomatic recurrent or progressing CSDH within 90 days (≥10 mm thickness, increase of ≥3mm, or reoperation)

Liu J et al. Middle Meningeal Artery Embolization for Nonacute Subdural Hematoma. N Engl J Med. 2024 Nov 21;391(20):1901-1912. doi: 10.1056/NEJMoa2401201. PMID: 39565989.

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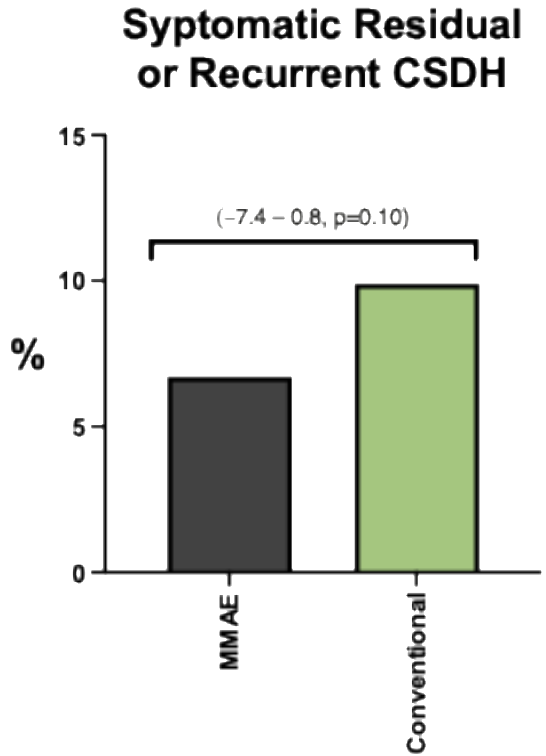
MAGIC-MT

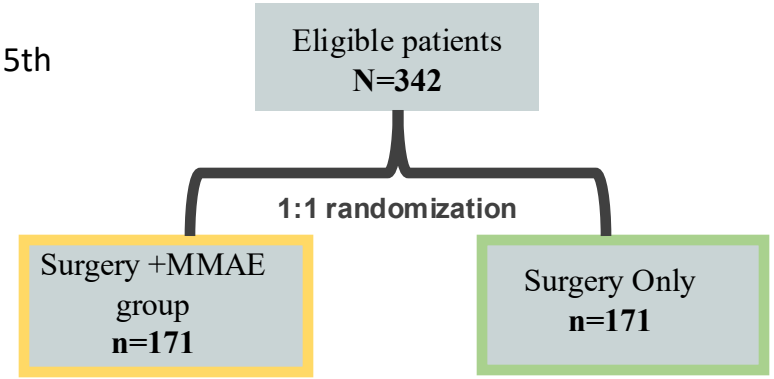


Conclusion:

Trend towards lower rate of residual/recurrent CSDH in the MMAE group (p=0.10)

EMPROTECT

June 5th



Prospective RCT powered to assess efficacy of **Surgery** vs. **Surgery + Particle MMA embolization**

Inclusion criteria

Age ≥18

Recurrent CSDH or *New CSDH with high risk of recurrance,* defined as:

- anticoagulant/antithrombotic treatment
- alcoholism
- liver failure
- thrombocytopenia
- 1st surgery w/o postoperative drain

Primary Endpoint

Recurrent or progressing CSDH (≥10 mm thickness), reoperation, hospital readmission within 180 days

Shotar et al, Meningeal Embolization for Preventing Chronic Subdural Hematoma Recurrence After Surgery: The EMPROTECT Randomized Clinical Trial. JAMA. 2025 Jun 5:e257583. doi: 10.1001/jama.2025.7583. Epub ahead of print. PMID: 40471557; PMCID: PMC12142473

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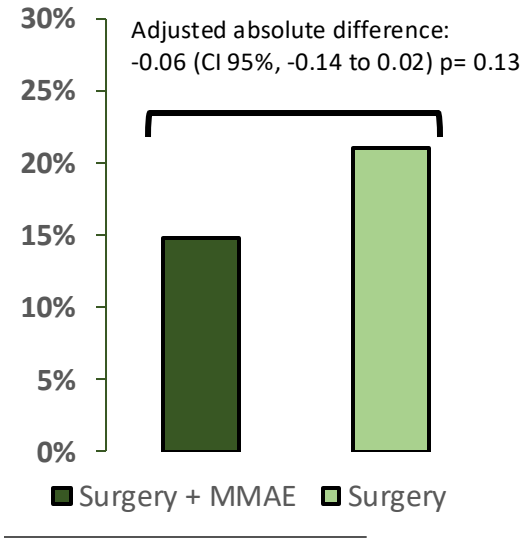
EMPROTECT

Recurrence, progression, reoperation or hospital admission



Conclusion:

Trend towards lower rate of recurrence, progression, reoperation or hospital admission for/of CSDH in the MMAE group (p=0.13)

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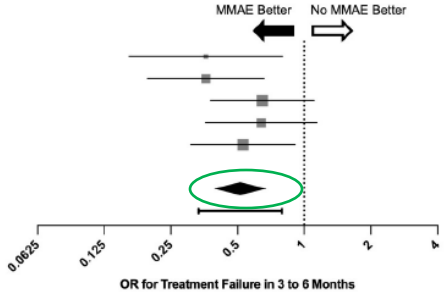
AJNR Meta-analysis

OVERALL

Study	OR [95%CI]	Weight
EMBOLISE	0.36 [0.16-0.80]	11.1%
STEM	0.36 [0.20-0.66]	19.2%
MAGIC-MT	0.65 [0.38-1.11]	24.4%
EMPROTECT	0.64 [0.36-1.14]	21.2%
MEMBRANE	0.53 [0.31-0.91]	24.1%
Overall [95%CI]	0.51 [0.39-0.67]	
Overall [95%PI]	0.51 [0.33-0.79]	

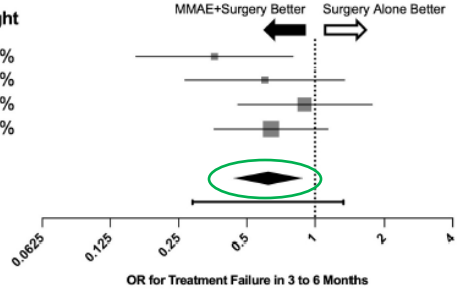
Heterogeneity: I-squared=0.00
Homogeneity: Q=3.35, df=4, p=0.50
Test for overall effect: Z=-4.896, p<0.001



A) Surgical SDH Patients

Study	OR [95%CI]	Weight
EMBOLISE	0.36 [0.16-0.80]	19.0%
STEM	0.60 [0.27-1.35]	18.4%
MAGIC-MT	0.90 [0.46-1.77]	26.5%
EMPROTECT	0.65 [0.37-1.17]	36.1%
Overall [95%CI]	0.63 [0.44-0.89]	
Overall [95%PI]	0.63 [0.29-1.34]	

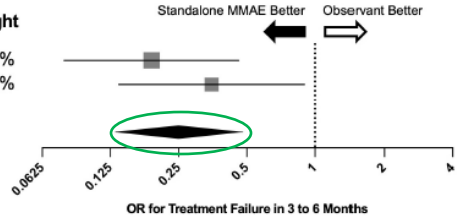
Heterogeneity: I-squared=0.00
Homogeneity: Q=2.98, df=3, p=0.40
Test for overall effect: Z=-2.65, p=0.008



B) Non-Surgical SDH Patients

Study	OR [95%CI]	Weight
STEM	0.19 [0.08-0.46]	53.3%
MAGIC-MT	0.35 [0.14-0.90]	46.7%
Overall [95%CI]	0.25 [0.13-0.48]	

Heterogeneity: I-squared=0.00
Homogeneity: Q=0.85, df=1, p=0.36
Test for overall effect: Z=-4.18, p<0.001



Conclusion

Adjuvant MMAE leads to significantly lower risk of treatment failure within 3-6 months for CSDH patients both with and without surgery, without any increased risk of death or stroke

Chen H et al. Middle meningeal artery embolization for non-acute subdural hematoma: a meta-analysis of large randomized controlled trials. AJNR Am J Neuroradiol. 2025 Apr 9:ajnr.A8781. doi: 10.3174/ajnr.A8781.

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AJNR Meta-analysis

OVERALL

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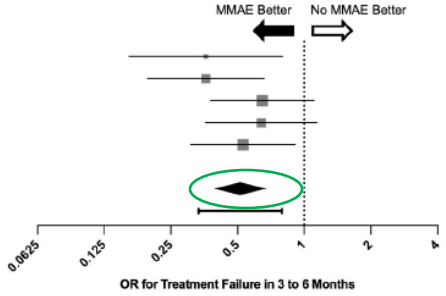
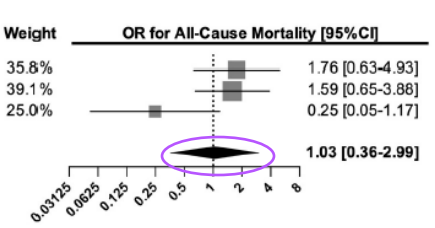
Overall [95%CI]	0.51 [0.39-0.67]	
Overall [95%PI]	0.51 [0.33-0.79]	

Heterogeneity: I-squared=0.00
Homogeneity: Q=3.35, df=4, p=0.50
Test for overall effect: Z=-4.896, p<0.001



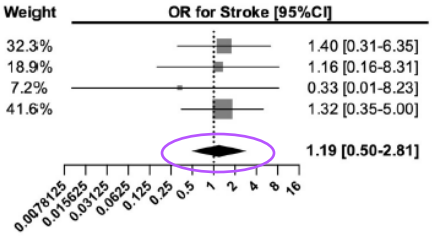
Study	MMAE Events	MMAE Total	No MMAE Events	No MMAE Total	Weight
EMBOLISE	10	197	6	203	35.8%
STEM	12	144	9	166	39.1%
MAGIC-MT	2	360	8	362	25.0%
Total [95%CI]	**24**	**701**	**23**	**731**	

Heterogeneity: I-squared=0.62
Homogeneity: Q=4.85, df=2, p=0.089
Test for overall effect: Z=0.06, p=0.95



Study	MMAE Events	MMAE Total	No MMAE Events	No MMAE Total	Weight
EMBOLISE	4	182	3	190	32.3%
STEM	2	144	2	166	18.9%
MAGIC-MT	0	360	1	362	7.2%
MEMBRANE	5	181	4	190	41.6%
Total [95%CI]	**11**	**867**	**10**	**908**	

Heterogeneity: I-squared=0.00
Homogeneity: Q=0.67, df=3, p=0.88
Test for overall effect: Z=0.396, p=0.69



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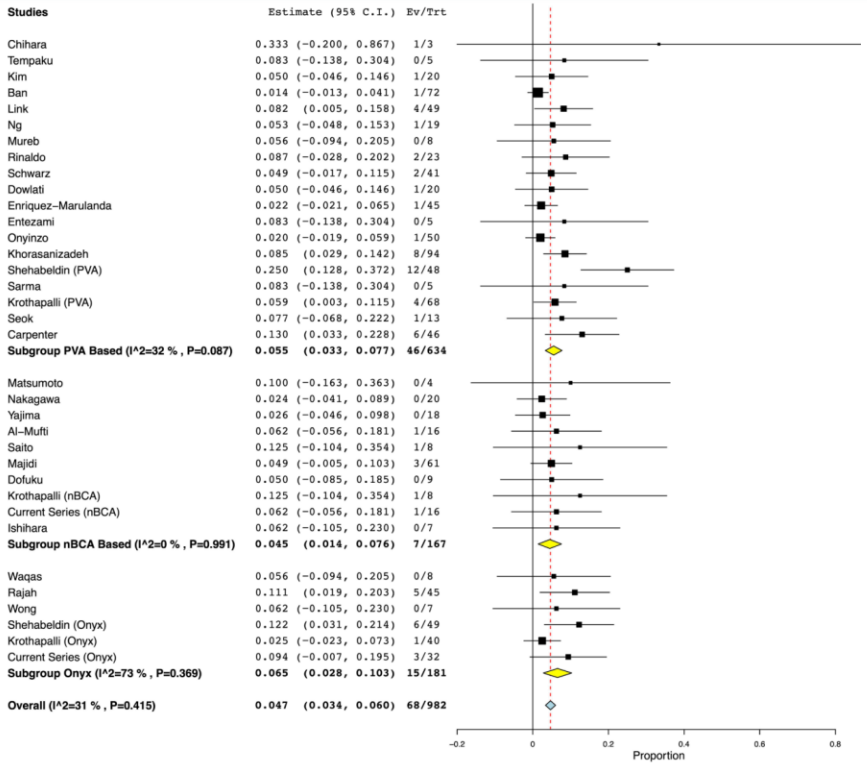
Embolization material



Conclusion

A recent meta-analysis did not result in any difference in recurrency, reoperation rates or safety between **PVA-particles**, **nBCA** or **ONYX** used in MMA embolization.

This will likely be further studied in ongoing and future trials and meta-analysis

Ellens et al. Safety and efficacy comparison of embolic agents for middle meningeal artery embolization for chronic subdural hematoma. J Cerebrovasc Endovasc Neurosurg. 2024 Mar;26(1):11-22. doi: 10.7461/jcen.2023.E2023.04.002. Epub 2023 Oct 13. PMID: 37828746; PMCID: PMC10995466.

Femoral or Radial Access?

Variable	Transfemoral access (n=150, 50%)	Transradial access (n=150, 50%)	P value
Age (years) (median (IQR))	72 (64–80)	72 (63–82)	0.67
Sex			
Women	41 (27.3)	33 (22)	0.61
Men	109 (72.7)	117 (78)	
Outcomes			
Hospital length of stay (days) (median (IQR))	6 (3–12)	5 (2–16)	0.64
Procedural technical success	146 (97.3)	147 (98.8)	0.41
Procedure duration (min) (median (IQR))	59 (42–84)	68.5 (43.1–95)	0.038
Access site complications	1 (0.6)	0 (0)	0.21
Overall complications	9 (6.5)	8 (5.4)	0.7
Decrease >50% of hematoma thickness on last follow-up (ie, radiographic success)	117 (87.3)	96 (77.4)	0.036
Undergoing rescue surgery (ie, clinical failure)	14 (9.3)	13 (8.7)	0.28
mRS on last follow-up*			
≤2	84 (73.7)	85 (69.1)	0.44
>2	30 (26.3)	38 (30.9)	

Values are number (%) unless indicated otherwise.
cSDH, chronic subdural hematoma; MMA, middle meningeal artery; mRS, modified Rankin Scale; n-BCA, n-butyl 2-cyanoacrylate.

Conclusion

A recent propensity score matched study did not find any differences in technical success-rate, recurrency, reoperation rates or safety between **Femoral access** and **Radial access** MMA embolization procedures.

This will likely be further studied in ongoing and future trials and meta-analysis

Salem MM et al. Femoral versus radial access for middle meningeal artery embolization for chronic subdural hematomas: multicenter propensity score matched study. J Neurointerv Surg. 2025 Jan 26:jnis-2024-021880. doi: 10.1136/jnis-2024-021880.

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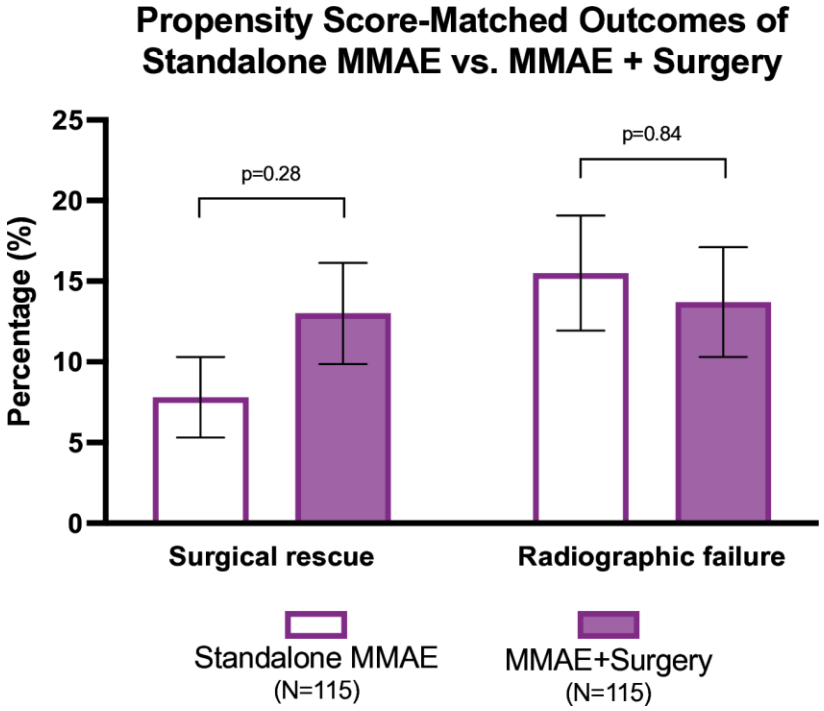
MMA Embolization alone



Conclusion

A recent propensity score matched study showed that **MMAE Alone** led to similar clinical and radiographic outcomes as **MMAE combined with surgery** in patients with moderately sized CSDH and mild symptoms.

Chen H et al. Standalone middle meningeal artery embolization versus middle meningeal artery embolization with concurrent surgical evacuation for chronic subdural hematomas: a multicenter propensity score matched analysis of clinical and radiographic outcomes. J Neurointerv Surg. 2024 Nov 22;16(12):1313-1319. doi: 10.1136/jnis-2023-020907. PMID: 37932033.

Simultaneous Embolization and Surgery?

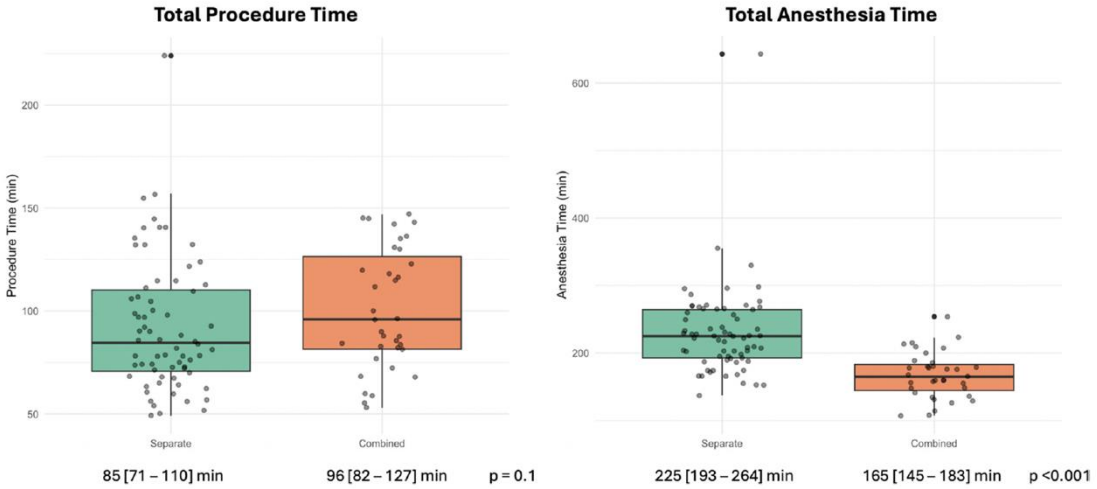


Figure 1 Box plots showing the distribution of cumulative procedure and anesthesia times for patients who underwent middle meningeal artery embolization and burr hole evacuation surgery under a single anesthesia session (Combined) or two separate sessions (Separate).

A recent observational study showed:

- reduced **Anethesia time**
- reduced **ICU time**
- similar total procedure time
- similar outcomes
- no safety concerns

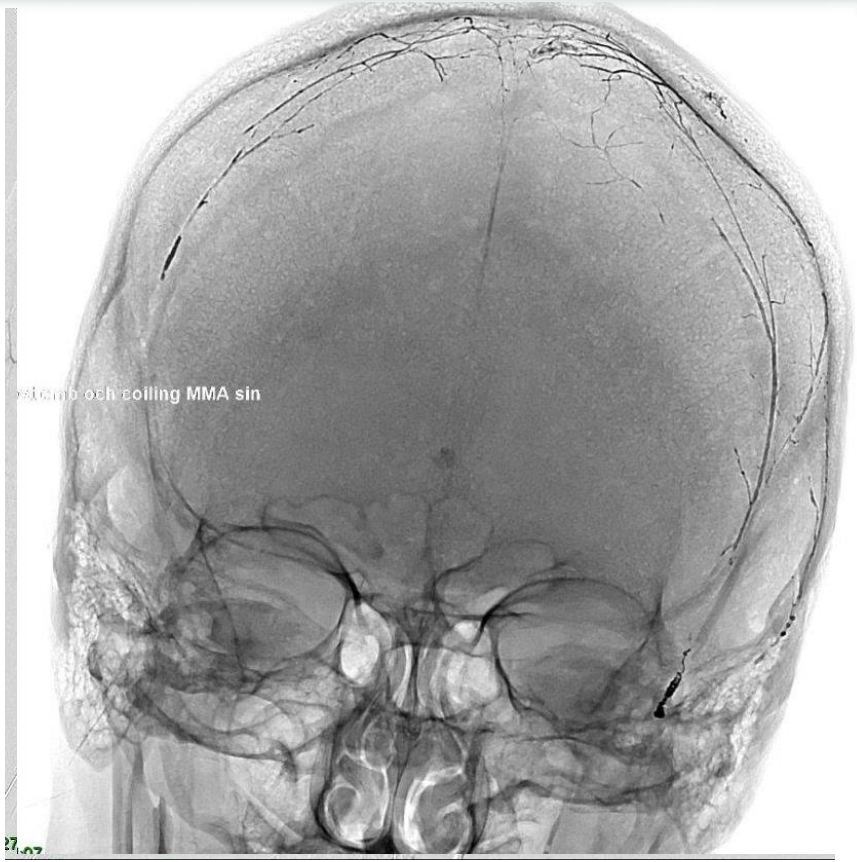
… for combined procedures, compared to separate procedures.

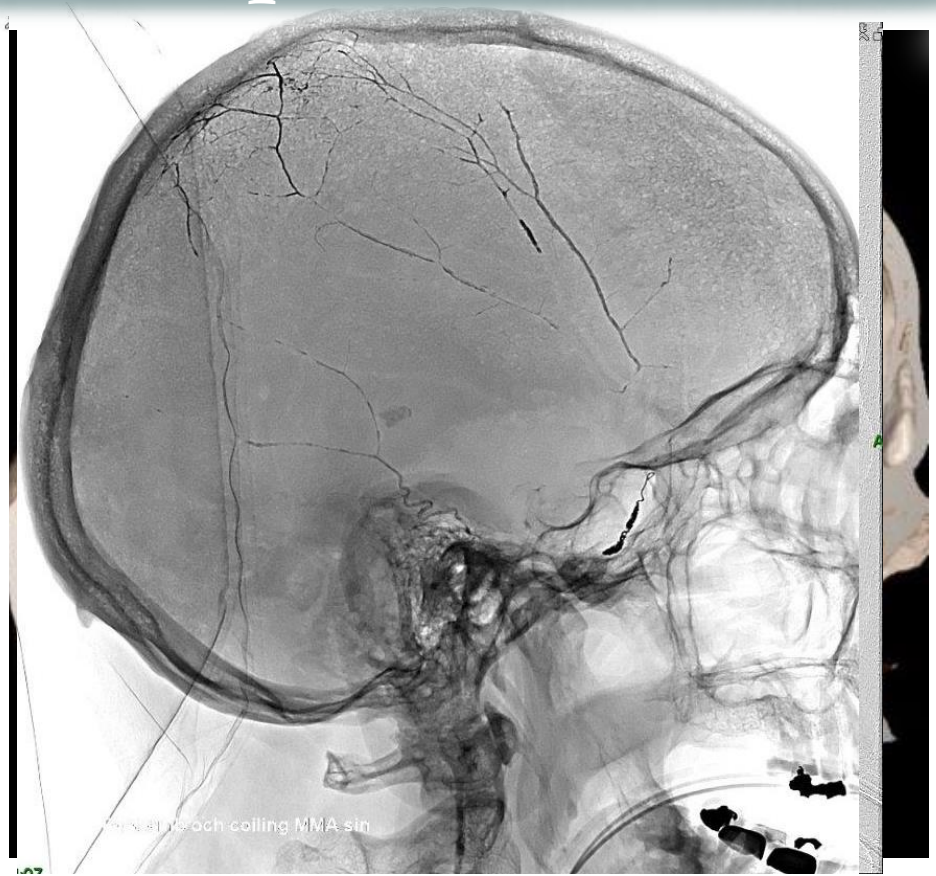
Koo AB et al. Single-session middle meningeal artery embolization and surgical evacuation for chronic subdural hematoma. J Neurointerv Surg. 2025 Mar 29:jnis-2025-023372. doi: 10.1136/jnis-2025-023372.

Our Setup

- Adjuvant to surgery or Standalone
- Uni- or Bilaterally
- GA / CS/ LA
- Femoral or Radial access, 5F sheath and guidecath
- .017 or .014 microcath (Headway 17, Duo, Marathon, Apollo, Sonic)
- Superselective vasodilation (verapamil)
- Superselective Lidocain (10-20 mg)
- Liquid embolics (Onyx or Squid)
- 2 hours postop observation

Our Technique





Consensus Statement Nov 24th 2024

World Federation of Neurosurgical Societies

European Society of Anaesthesiology and Intensive Care

EuGMS European Geriatric Medicine Society

The European Association of Neurosurgical Societies

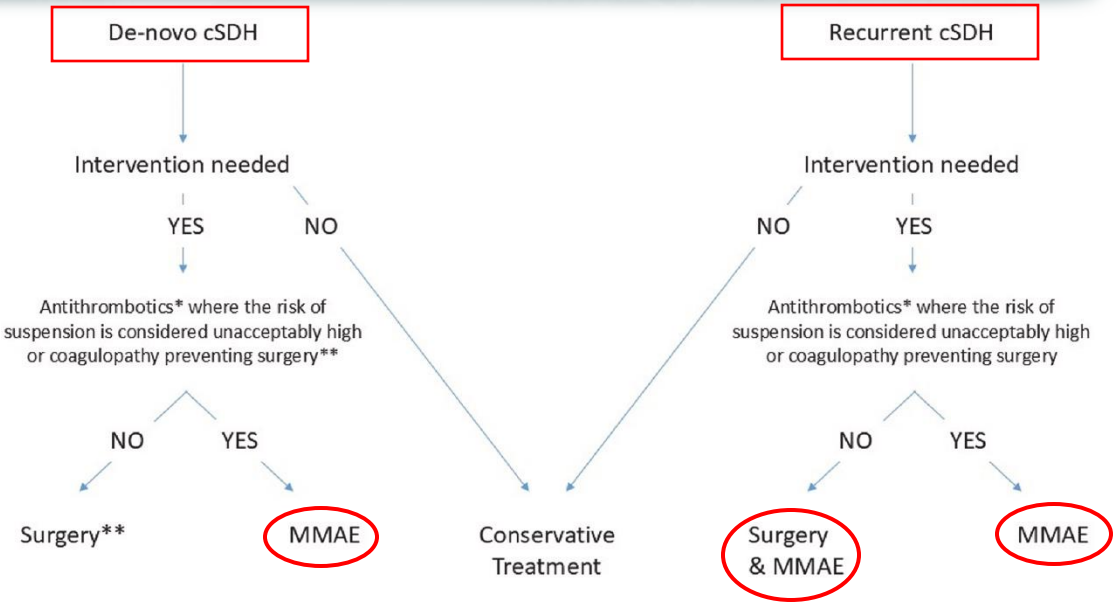
ESMINT

European Society of Neuroradiology Diagnostic and Interventional

WFITN

AINR Associazione Italiana di Neuroradiologia Diagnostica e Interventistica

SINCH Società Italiana Neurochirurgia



*Antithrombotics = anticoagulants and/or antiplatelet drugs
**In patients with substantial mass effect/neurological deficits, surgical intervention might be indicated even though these are on antithrombotics in whom the risk of suspension is very high. In these patients, MMAE as adjunct to surgery should be considered in order to allow for early resumption of antithrombotics.

Lund University Faculty of Medicine

Bartek et al. *Brain and Spine* (2024), doi: 10.1016/j.bas.2024.104143

THANK YOU!

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