Supplemental materials

Search methods (supplemental)

OVID: MEDLINE + EMBASE
((subdural hematoma or subdural haematoma or SDH or CSDH).af. AND (embolization or middle meningeal artery or MMA).af.

Web of Science: subdural hematoma OR subdural haematoma OR SDH OR CSDH (All Fields) AND embolization OR middle meningeal artery OR MMA (All Fields)

Cochrane Library: (subdural hematoma OR subdural haematoma OR SDH OR CSDH) AND (embolization OR middle meningeal artery OR MMA) (All Text)

Supplemental Table 1: Details of included studies.

Study (*et al*), year	Design	Size	Country	Embolization agent	PVA particle size, PVA +/- coils	Complications	Follow-up (mean, month)
Hashimoto, 2013[12]	R	5	Japan	n-BCA (4), n-BCA+PVA (1)	200 um	none	3.5
Tempaku, 2015[25]	R	5	Japan	PVA (4), PVA+coil (1)	180-300 um	none	17.6
Kim, 2017[15]	R	20	Korea	PVA (20)	150-250 um	2 surgical, 3 medical (not further specified)	3.5
Ban, 2018[7]	R	72	Korea	PVA (72)	150-250 um	none	6
Link, 2018[16]	R	45	USA	PVA (45)	150-250 um	none	At least 1.5 month
Nakagawa, 2019[18]	R	20	Japan	n-BCA (20)	n/a	none	6
Ng, 2020[19]	P	21	France	PVA (21)	150-250 um	none	3
Okuma, 2019[20]	R	17	Japan	n-BCA (11), embosphere (3), n-BCA+embosphere (2), coil (1)	300-500 um microsphere	none	26.3
Waqas, 2019[26]	R	8	USA	Onyx (n=8)	n/a	none	3.3
Catapano, 2021[9]	R	35	USA	Onyx (29), particles (7), n-BCA (5)	ns, 7 patients "particles and/or coils"	1 CVA in type 3 aortic arch	4
Fan, 2020[11]	R	7	China	Absolute alcohol (7)	n/a	none	N/A
Joyce, 2020[13]	R	135	USA	Coil (6), liquid (30), particles (38), liquid +coil (2), particles+coils (72), particles+liquid (1)	100-300 or 300-500 um microsphere, 150-250 or 250-355 PVA	1 seizure, 1 delayed infarct, 1 intermittent aphasia	6

Kan, 2021[14]	R	138	USA	Coils (5), liquid (37), liquid+coil (2), particles (38), particles+coil (70)	ns, 5 coil alone (imaging findings - dangerous anastomotic vessels)	1 asymptomatic intra-procedure MMA rupture, 1 seizure, 1 facial droop	3.2
Mureb, 2020[17]	R	8	USA	PVA + coil (8)	45-150 um, PVA then coils	none	3
Rajah, 2020[22]	R	46	USA	Onyx 18 (36), onyx 34 (7), n-BCA (1)	na	1 bradycardia during lidocaine injection intra-op	2
Shotar, 2020[24]	R	89	France	Microsphere (81), n-BCA (5), coil (5)	300-500 um microspheres	1 seizure, 1 headache, 2 diplopia, 1 meningomeningeal fistula, 1 femoral artery occlusion	N/A
Yajima, 2020[27]	R	18	Japan	n-BCA (18)	na	none	8
Al-Mufti 2021[6]	P	16	USA	n-BCA	na	none	3
Carpenter 2021[8]	R	44	USA	PVA	45-150 um	7 Seizures, 3 UTI, 4 AKI, 1 stroke, 1 pneumonia, 1 DVT/PE (complications in 15 total patients as more than 1 complication may occur in 1 patient)	3
Enriquez-Marulanda 2021[10]	R	45	USA	PVA + coils (43), coils (2) - Most MMA embolization procedures were	ns	1 complication not specified	2

				performed with a combination of distal penetration with polyvinyl particles of 150 to 250 microns followed by coil embolization for permanent trunk occlusion of the MMA (95.6%) while remaining cases (n = 2) were treated with coils only (due to an anastomosis of the MMA with the ophthalmic artery conferring a higher risk of blindness after particulate embolization migration)			
Onyinzo 2021[21]	R	50	Germany	PVA and/or coils	45-150 um	none	3.4
Schwarz 2021[23]	R	44	USA	PVA	250-350 um	none	12

Abbreviations: AKI, acute kidney injury; DVT, deep venous thrombosis; NA, not available; NS, not specified; P, prospective; PE, pulmonary embolism; R, retrospective; UTI, urinary tract infection.

RISK OF BIAS (ROB)

Newcastle-Ottawa Quality Assessment Scale for Case-Control Studies tool was after modification to assess the risk of bias in our included studies. This modification is focusing on four questions which included: 1) did the study include all patients or consecutive patients versus a selected sample?; 2) was the study retrospective or prospective?; 3) was angiographic and clinical follow-up satisfactory, thus allowing for ascertainment of all outcomes?; and, 4) were outcomes clearly reported?

Cohort Studies (Newcastle Ottawa Scale)

- For non-comparative cohort studies: he maximum cumulative value: 4, the maximum values were as follows: Selection: 3, Outcome: 2.
  (4-5: Low, 3: Moderate, 0-2: High ROB).
- For comparative cohort studies: the maximum cumulative value: 7, the maximum values are as follows: Selection: 4, Comparability:2, Outcome: 2.
  (7-8: Low, 3-6: Moderate, 0-2: High ROB)

- **Selection**
  1. Representativeness of the exposed cohort
  2. Selection of the non-exposed cohort (Comparative studies)
  3. Ascertainment of exposure.
  4. Study design (Prospective or Retrospective)

- **Comparability (Comparative studies)**
  1. Evaluation of the most important outcome.
  2. Evaluation of additional outcomes.

- **Outcome**
  1. Assessment of outcome.
  2. Sufficient follow-up ($\geq$ 3 months)

Supplemental Table 2: Risk of bias assessment.

Study (et al), Year	Design	ROB	Selection	Comparability	Outcome
Hashimoto, 2013[12]	R	3 (Mod)	1	None	2
Tempaku, 2015[25]	R	3 (Mod)	1	None	2
Kim, 2017[15]	R	7 (Low)	3	2	2
Ban, 2018[7]	R	3 (Mod)	1	None	2
Link, 2018[16]	R	3 (Mod)	2	None	1
Nakagawa, 2019[18]	R	3 (Mod)	1	None	2
Ng, 2020[19]	P	7 (Low)	4	1	2

Okuma, 2019[20]	R	3 (Mod)	1	None	2
Waqas, 2019[26]	R	3 (Mod)	1	None	2
Catapano, 2021[9]	R	4 (Low)	2	None	2
Fan, 2020[11]	R	2 (High)	1	None	1
Joyce, 2020[13]	R	3 (Mod)	1	None	2
Kan, 2021[14]	R	4 (Low)	2	None	2
Mureb, 2020[17]	R	4 (Low)	2	None	2
Rajah, 2020[22]	R	3 (Mod)	1	None	2
Shotar, 2020[24]	R	3 (Mod)	2	None	1
Yajima, 2020[27]	R	4 (Low)	2	None	2
Al-Mufti 2021[6]	P	4 (Low)	3	None	2
Carpenter 2021[8]	R	4 (Mod)	1	1	2
Enriquez-Marulanda 2021[10]	R	6 (Mod)	2	2	2
Onyinzo 2021[21]	R	6 (Mod)	2	2	2
Schwarz 2021[23]	R	3 (Mod)	1	None	2

Supplemental Table 3: Subgroup meta-analysis outcomes.

Outcome	**Subgroup meta-analysis results**			
	Rates following embolization alone (%, 95% CI)	**Rates following embolization + surgery (%, 95% CI)**	P value	I^2 **(%)**
SDH recurrence	6.3 (3.3–9.3)	5.3 (2.7–7.9)	0.976	0.000
SDH recurrence (Person-Time)	1.7 (0.7–2.6)/month	0.3 (0.0–0.6)/month	**0.035**	11.91
nBCA	3.5 (0.0, 8.1)			0.000
nBCA (Person-Time)	0.5 (0.0, 1.2)/month			0.000
Onyx	2.0 (0.0, 6.4)			0.000
Onyx (Person-Time)	0.7 (0.0, 2.2)/month			0.000
PVA	4.7 (1.5, 8.0)			27.49
PVA (Person-Time)	0.5 (0.0, 1.2)/month			27.86
PVA +/- coils	2.2 (0.0, 5.1)			0.000
PVA +/- coils (Person-Time)	0.7 (0.0, 1.7)/month			0.000
Overall	2.9 (1.3, 4.4)			0.000
Overall (Person-Time)	0.5 (0.0, 1.2)/month			0.000
SDH re-operation	5.4 (2.6–8.2)	4.6 (2.0–7.2)	0.912	0.000
nBCA	3.7 (0.0, 8.2)			0.000
Onyx	2.0 (0.0, 6.4)			0.000
PVA	4.2 (1.2, 7.3)			26.83
PVA +/- coils	4.1 (1.0, 7.3)			12.94
Overall	3.3 (1.8, 4.8)			0.000
Complication	2.2 (0.6–4.0)	5.5 (1.5–9.5)	**0.025**	43.18
nBCA	3.0 (0.0, 6.9)			0.000
Onyx	2.0 (0.0, 6.4)			0.000
PVA	5.6 (1.1, 10.1)			**79.28**

PVA +/- coils	1.4 (0.0, 3.7)			0.000
Overall	2.8 (0.0, 4.8)			47.96
Good radiologic outcome	94.1 (84.8–100)	92.1 (85.8–98.5)	0.187	0.000
Onyx	82.0 (57.0, 100)			**79.65**
PVA +/- coils	84.4 (63.9, 100)			**87.37**
Overall	83.6 (69.5, 97.6)			**81.55**
Good clinical outcome	81.2 (66.7–95.6)	75.3 (36–100)	0.569	**71.81**
nBCA	78.5 (55.9, 100)			51.06
Onyx	75.7 (63.8, 87.5)			17.99
PVA +/- coils	85.2 (68.1, 100)			**82.6**
Overall	81.0 (71.4, 90.6)			**64.98**

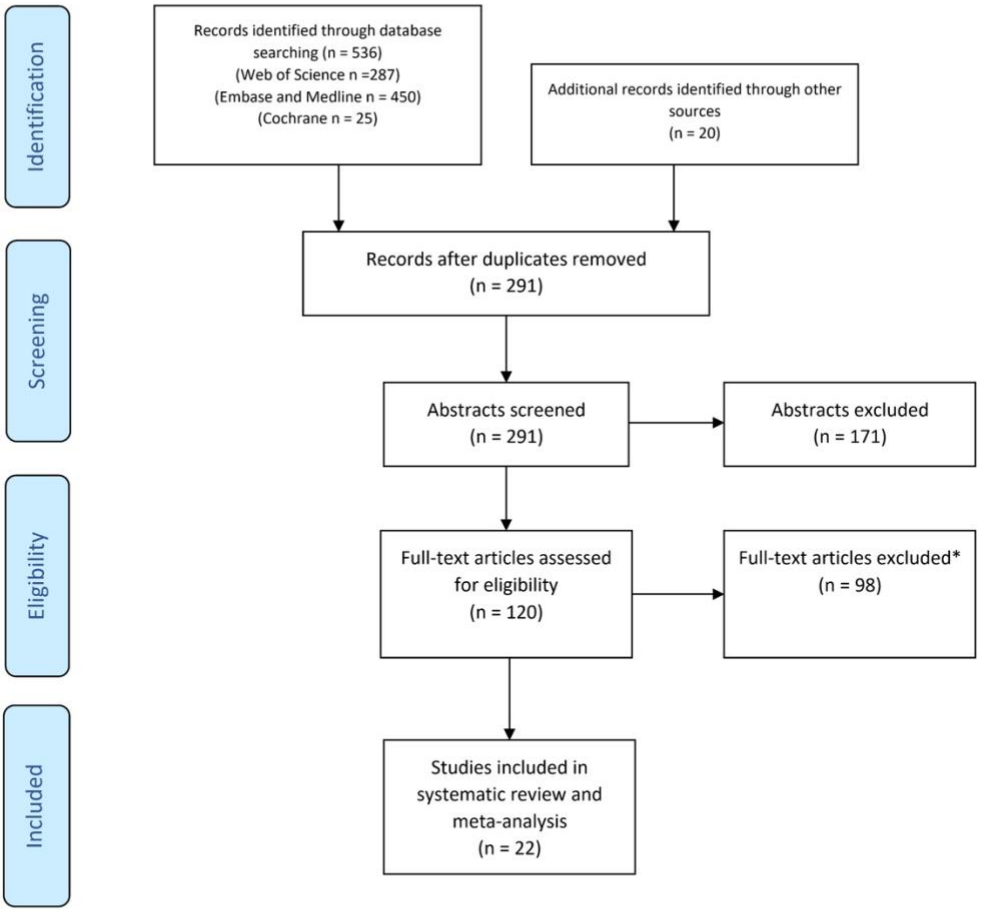
Abbreviations: CI, confidence interval, n, nominator; nBCA, N-butyl-2-cyanoacrylate; PVA, polyvinyl alcohol, SDH, subdural hematoma;

Supplemental Table 4: Pairwise meta-analysis outcomes.

Outcome	No. of Studies	Sample Size		Random Effect		Heterogeneity		
		MMA	Combined treatment	OR (95% CI)	*P* value	Tau^2	*P*	I^2 (%)
SDH recurrence	5	180	674	0.36 (0.12–1.09)	0.071	0.640	0.144	41.63
PVA	3	85	235	0.53 (0.13–2.15)	0.372		0.176	42.39
PVA +/- coils	2	77	439	0.17 (0.04–0.77)	**0.021**		0.324	0.000
Overall					0.071			
SDH re-operation	8	382	1373	0.48 (23.4–99.1)	**0.047**	0.364	0.130	37.49
PVA	4	157	637	0.39 (0.10–1.49)	0.168		0.136	45.96
PVA +/- coils	3	184	613	0.40 (0.17–0.94)	**0.035**		0.240	30.01
Overall					**0.013**			
Complication	7	341	1250	0.81 (0.49–1.33)	0.407	0.000	0.522	0.000
PVA	3	113	450	1.03 (0.23–4.59)	0.967		0.236	0.000
PVA +/- coils	2	95	439	0.37 (0.07–1.96)	0.241		0.342	0.000
Overall					0.568			
Good radiologic outcome	3	108	530	1.72 (0.16–18.7)	0.657	4.005	<.001	**94.51**
Good clinical outcome	3	96	462	0.88 (0.31–2.49)	0.308	0.446	0.130	**51.01**
Outcome	**No. of Studies**	**MMA**	**Conservative**	**OR (95% CI)**	***P* value**	**Tau^2**	***P***	**I^2 (%)**
SDH re-operation	2	113	226	0.02 (0.00–1.67)	0.085	8.251	0.004	**88.16**
Outcome	**No. of Studies**	**Surgery**	**Conservative**	**OR (95% CI)**	***P* value**	**Tau^2**	***P***	**I^2 (%)**
SDH re-operation	2	525	226	0.02 (0.00–45.78)	0.334	28.95	0.130	37.49

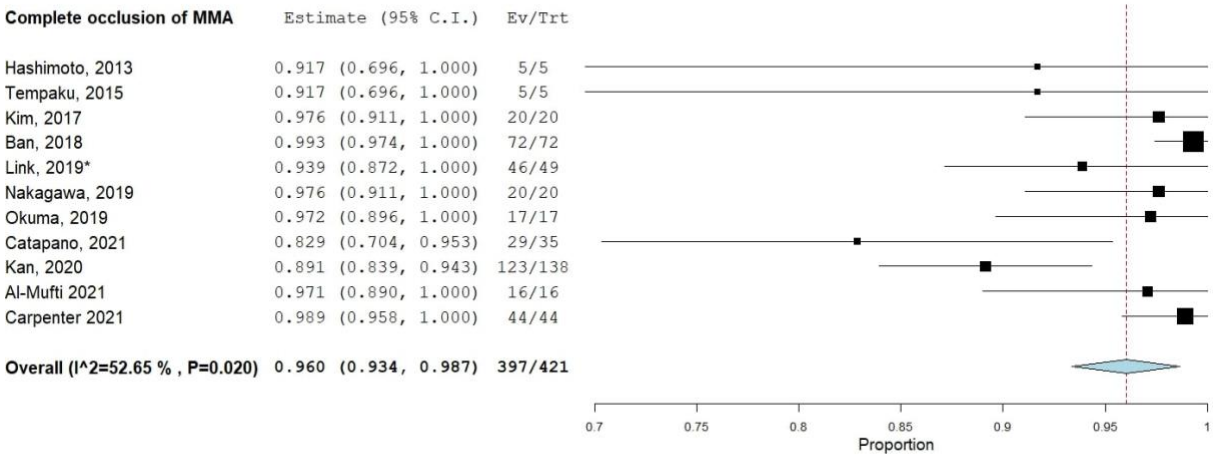
Abbreviations: CI, confidence interval, n, nominator; nBCA, N-butyl-2-cyanoacrylate; PVA, polyvinyl alcohol, SDH, subdural hematoma;

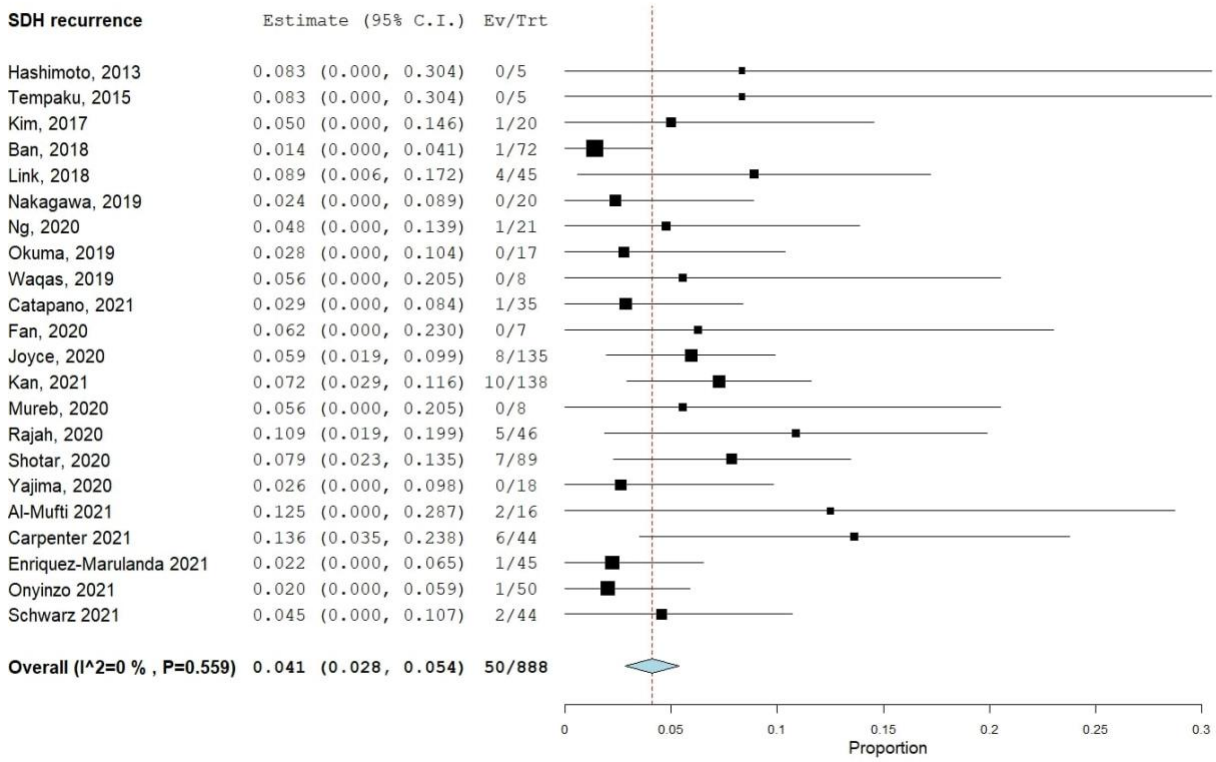
Supplemental figure 1: Flow diagram of study selection process.

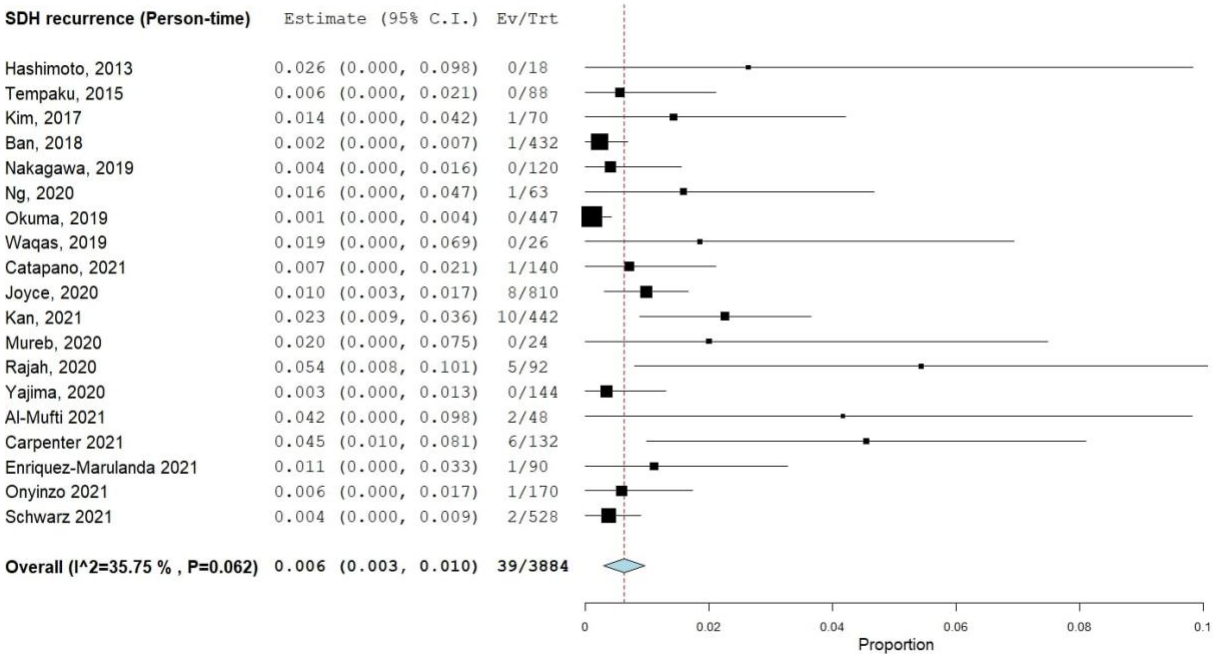


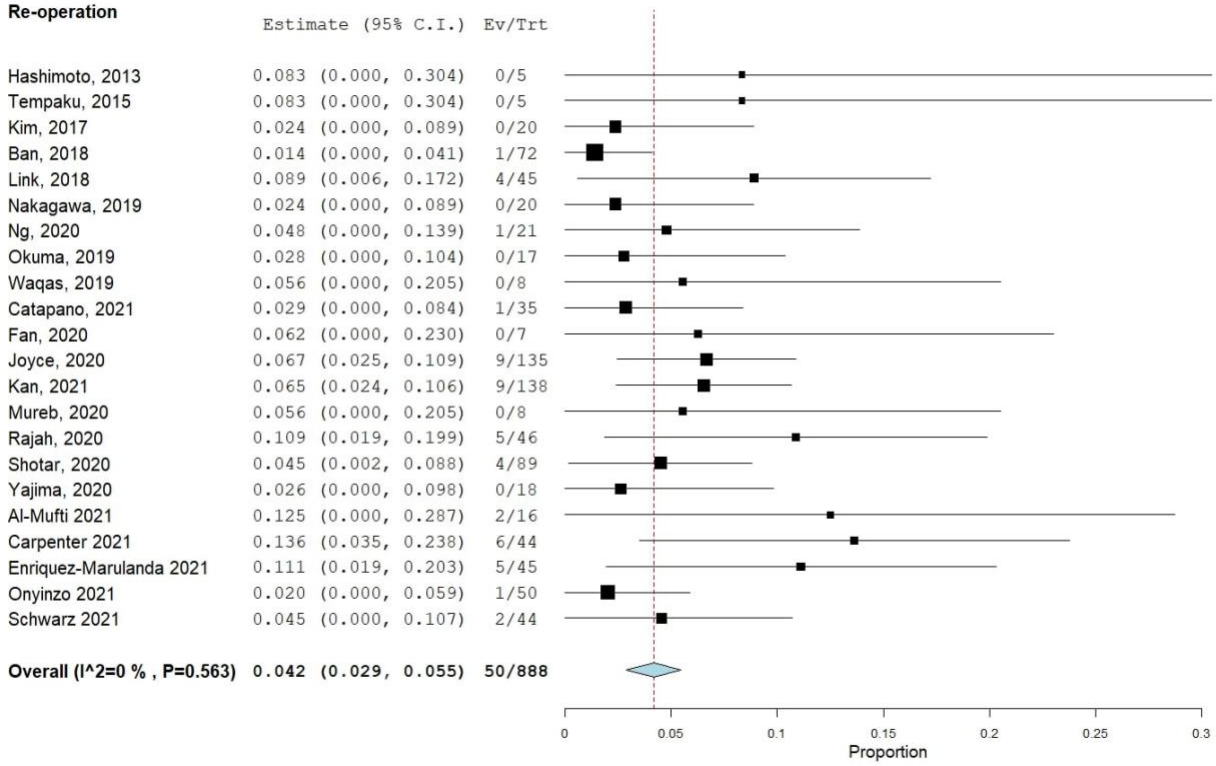
* Reasons for exclusion include: articles not written in English, less than 5 patients in each treatment group, larger cohort of the same population reported elsewhere, conference abstracts, review articles, studies of acute subdural hematoma.

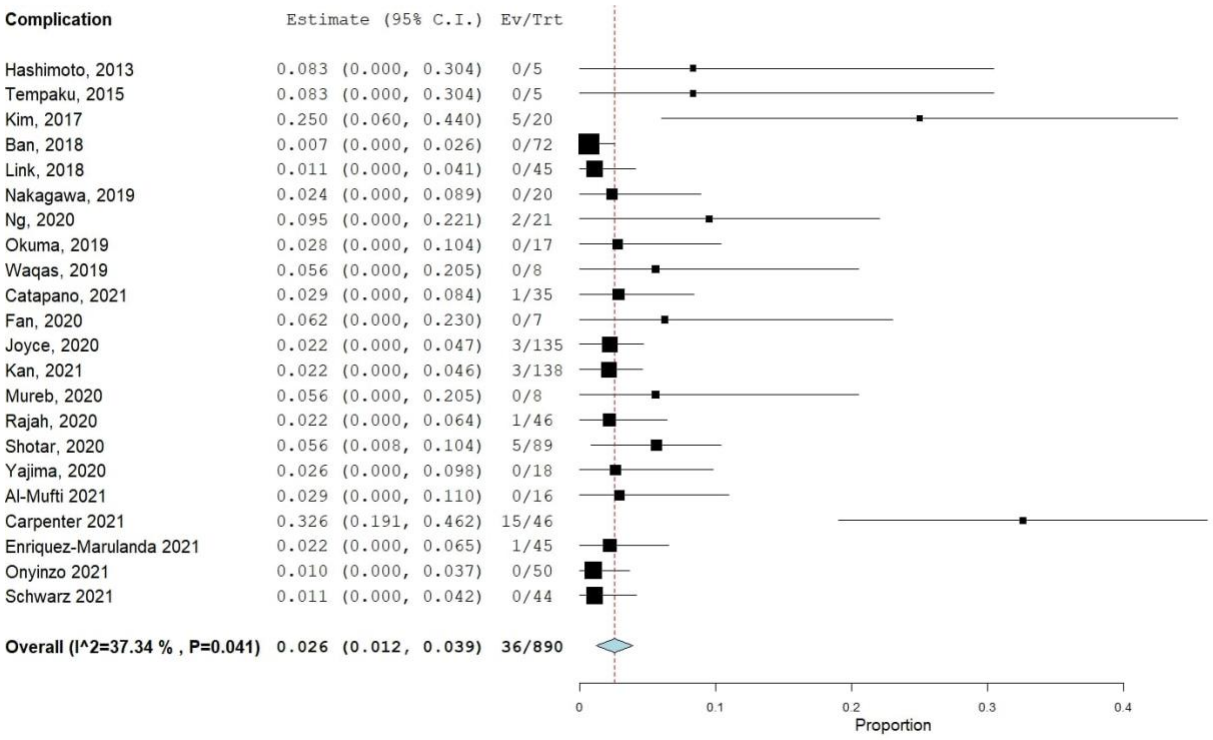
Supplemental figure 2: Forest plots of the outcomes; **A)** Intraprocedural complete occlusion of MMA, **B)** Subdural hematoma recurrence, **C)** Subdural hematoma recurrence per month (Person-Time analysis), **D)** Re-operation, **E)** Complication rate, **F)** Good radiologic outcomes, **G)** Good clinical outcomes, **H)** Rate of decrease in postoperative decrease SDH volume, and **I)** Rate of decrease in postoperative decrease SDH width.

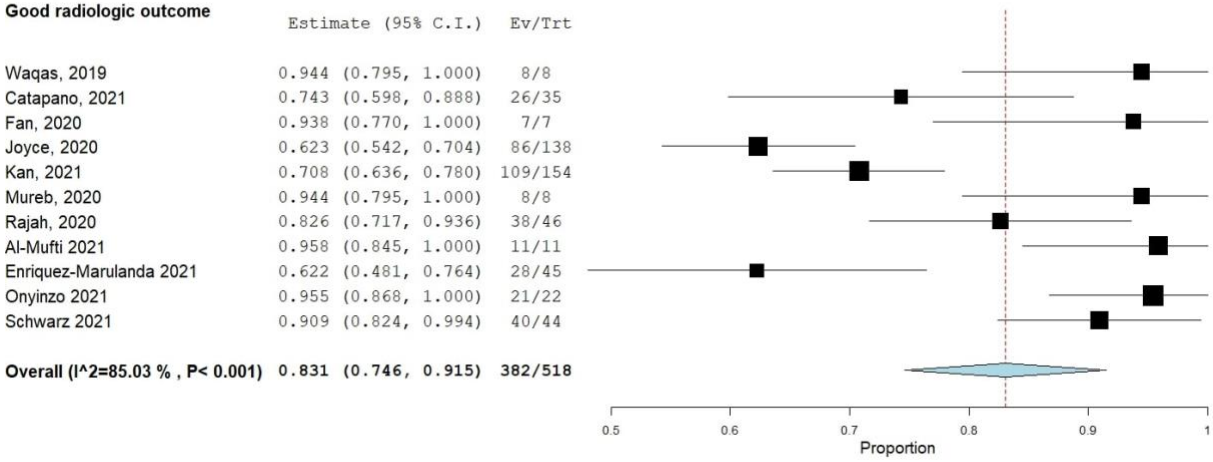


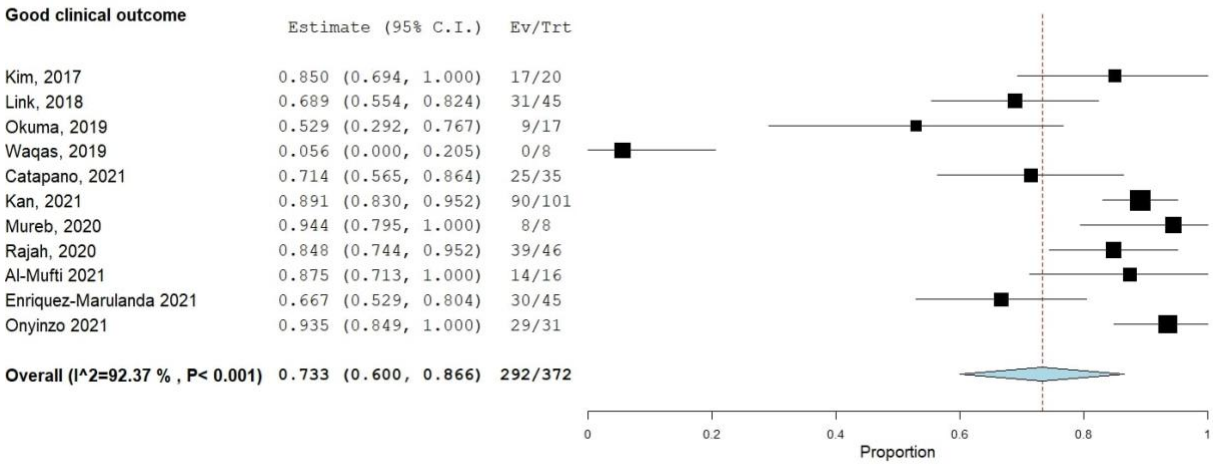

SDH recurrence
Estimate (95% C.I.)
Ev/Trt
Hashimoto, 2013 0.083 (0.000, 0.304) 0/5
Tempaku, 2015 0.083 (0.000, 0.304) 0/5
Kim, 2017 0.050 (0.000, 0.146) 1/20
Ban, 2018 0.014 (0.000, 0.041) 1/72
Link, 2018 0.089 (0.006, 0.172) 4/45
Nakagawa, 2019 0.024 (0.000, 0.089) 0/20
Ng, 2020 0.048 (0.000, 0.139) 1/21
Okuma, 2019 0.028 (0.000, 0.104) 0/17
Waqas, 2019 0.056 (0.000, 0.205) 0/8
Catapano, 2021 0.029 (0.000, 0.084) 1/35
Fan, 2020 0.062 (0.000, 0.230) 0/7
Joyce, 2020 0.059 (0.019, 0.099) 8/135
Kan, 2021 0.072 (0.029, 0.116) 10/138
Mureb, 2020 0.056 (0.000, 0.205) 0/8
Rajah, 2020 0.109 (0.019, 0.199) 5/46
Shotar, 2020 0.079 (0.023, 0.135) 7/89
Yajima, 2020 0.026 (0.000, 0.098) 0/18
Al-Mufti 2021 0.125 (0.000, 0.287) 2/16
Carpenter 2021 0.136 (0.035, 0.238) 6/44
Enriquez-Marulanda 2021 0.022 (0.000, 0.065) 1/45
Onyinzo 2021 0.020 (0.000, 0.059) 1/50
Schwarz 2021 0.045 (0.000, 0.107) 2/44
Overall (I^2=0 % , P=0.559) 0.041 (0.028, 0.054) 50/888
0
0.05
0.1
0.15
0.2
0.25
0.3
Proportion

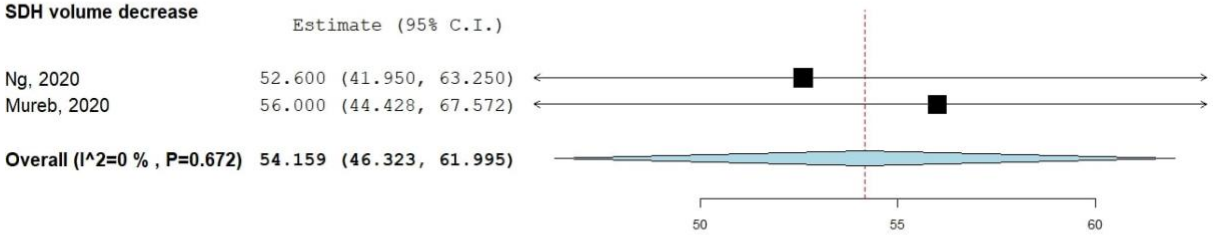

SDH recurrence (Person-time)
Estimate (95% C.I.)
Ev/Trt
Hashimoto, 2013 0.026 (0.000, 0.098) 0/18
Tempaku, 2015 0.006 (0.000, 0.021) 0/88
Kim, 2017 0.014 (0.000, 0.042) 1/70
Ban, 2018 0.002 (0.000, 0.007) 1/432
Nakagawa, 2019 0.004 (0.000, 0.016) 0/120
Ng, 2020 0.016 (0.000, 0.047) 1/63
Okuma, 2019 0.001 (0.000, 0.004) 0/447
Waqas, 2019 0.019 (0.000, 0.069) 0/26
Catapano, 2021 0.007 (0.000, 0.021) 1/140
Joyce, 2020 0.010 (0.003, 0.017) 8/810
Kan, 2021 0.023 (0.009, 0.036) 10/442
Mureb, 2020 0.020 (0.000, 0.075) 0/24
Rajah, 2020 0.054 (0.008, 0.101) 5/92
Yajima, 2020 0.003 (0.000, 0.013) 0/144
Al-Mufti 2021 0.042 (0.000, 0.098) 2/48
Carpenter 2021 0.045 (0.010, 0.081) 6/132
Enriquez-Marulanda 2021 0.011 (0.000, 0.033) 1/90
Onyinzo 2021 0.006 (0.000, 0.017) 1/170
Schwarz 2021 0.004 (0.000, 0.009) 2/528
Overall (I^2=35.75 % , P=0.062) 0.006 (0.003, 0.010) 39/3884
0
0.02
0.04
0.06
0.08
0.1
Proportion


Re-operation
Estimate (95% C.I.) Ev/Trt
Hashimoto, 2013 0.083 (0.000, 0.304) 0/5
Tempaku, 2015 0.083 (0.000, 0.304) 0/5
Kim, 2017 0.024 (0.000, 0.089) 0/20
Ban, 2018 0.014 (0.000, 0.041) 1/72
Link, 2018 0.089 (0.006, 0.172) 4/45
Nakagawa, 2019 0.024 (0.000, 0.089) 0/20
Ng, 2020 0.048 (0.000, 0.139) 1/21
Okuma, 2019 0.028 (0.000, 0.104) 0/17
Waqas, 2019 0.056 (0.000, 0.205) 0/8
Catapano, 2021 0.029 (0.000, 0.084) 1/35
Fan, 2020 0.062 (0.000, 0.230) 0/7
Joyce, 2020 0.067 (0.025, 0.109) 9/135
Kan, 2021 0.065 (0.024, 0.106) 9/138
Mureb, 2020 0.056 (0.000, 0.205) 0/8
Rajah, 2020 0.109 (0.019, 0.199) 5/46
Shotar, 2020 0.045 (0.002, 0.088) 4/89
Yajima, 2020 0.026 (0.000, 0.098) 0/18
Al-Mufti 2021 0.125 (0.000, 0.287) 2/16
Carpenter 2021 0.136 (0.035, 0.238) 6/44
Enriquez-Marulanda 2021 0.111 (0.019, 0.203) 5/45
Onyinzo 2021 0.020 (0.000, 0.059) 1/50
Schwarz 2021 0.045 (0.000, 0.107) 2/44
Overall (I^2=0 % , P=0.563) 0.042 (0.029, 0.055) 50/888
0
0.05
0.1
0.15
0.2
0.25
0.3
Proportion


Complication
Estimate (95% C.I.)
Ev/Trt
Hashimoto, 2013 0.083 (0.000, 0.304) 0/5
Tempaku, 2015 0.083 (0.000, 0.304) 0/5
Kim, 2017 0.250 (0.060, 0.440) 5/20
Ban, 2018 0.007 (0.000, 0.026) 0/72
Link, 2018 0.011 (0.000, 0.041) 0/45
Nakagawa, 2019 0.024 (0.000, 0.089) 0/20
Ng, 2020 0.095 (0.000, 0.221) 2/21
Okuma, 2019 0.028 (0.000, 0.104) 0/17
Waqas, 2019 0.056 (0.000, 0.205) 0/8
Catapano, 2021 0.029 (0.000, 0.084) 1/35
Fan, 2020 0.062 (0.000, 0.230) 0/7
Joyce, 2020 0.022 (0.000, 0.047) 3/135
Kan, 2021 0.022 (0.000, 0.046) 3/138
Mureb, 2020 0.056 (0.000, 0.205) 0/8
Rajah, 2020 0.022 (0.000, 0.064) 1/46
Shotar, 2020 0.056 (0.008, 0.104) 5/89
Yajima, 2020 0.026 (0.000, 0.098) 0/18
Al-Mufti 2021 0.029 (0.000, 0.110) 0/16
Carpenter 2021 0.326 (0.191, 0.462) 15/46
Enriquez-Marulanda 2021 0.022 (0.000, 0.065) 1/45
Onyinzo 2021 0.010 (0.000, 0.037) 0/50
Schwarz 2021 0.011 (0.000, 0.042) 0/44
Overall (I^2=37.34 % , P=0.041) 0.026 (0.012, 0.039) 36/890
0
0.1
0.2
0.3
0.4
Proportion


Good radiologic outcome
Estimate (95% C.I.)
Ev/Trt
Waqas, 2019 0.944 (0.795, 1.000) 8/8
Catapano, 2021 0.743 (0.598, 0.888) 26/35
Fan, 2020 0.938 (0.770, 1.000) 7/7
Joyce, 2020 0.623 (0.542, 0.704) 86/138
Kan, 2021 0.708 (0.636, 0.780) 109/154
Mureb, 2020 0.944 (0.795, 1.000) 8/8
Rajah, 2020 0.826 (0.717, 0.936) 38/46
Al-Mufti 2021 0.958 (0.845, 1.000) 11/11
Enriquez-Marulanda 2021 0.622 (0.481, 0.764) 28/45
Onyinzo 2021 0.955 (0.868, 1.000) 21/22
Schwarz 2021 0.909 (0.824, 0.994) 40/44
Overall (I^2=85.03 % , P< 0.001) 0.831 (0.746, 0.915) 382/518
0.5
0.6
0.7
0.8
0.9
1
Proportion


Good clinical outcome
Estimate (95% C.I.)
Ev/Trt
Kim, 2017 0.850 (0.694, 1.000) 17/20
Link, 2018 0.689 (0.554, 0.824) 31/45
Okuma, 2019 0.529 (0.292, 0.767) 9/17
Waqas, 2019 0.056 (0.000, 0.205) 0/8
Catapano, 2021 0.714 (0.565, 0.864) 25/35
Kan, 2021 0.891 (0.830, 0.952) 90/101
Mureb, 2020 0.944 (0.795, 1.000) 8/8
Rajah, 2020 0.848 (0.744, 0.952) 39/46
Al-Mufti 2021 0.875 (0.713, 1.000) 14/16
Enriquez-Marulanda 2021 0.667 (0.529, 0.804) 30/45
Onyinzo 2021 0.935 (0.849, 1.000) 29/31
Overall (I^2=92.37 % , P< 0.001) 0.733 (0.600, 0.866) 292/372
0
0.2
0.4
0.6
0.8
1
Proportion


SDH volume decrease
Estimate (95% C.I.)
Ng, 2020 52.600 (41.950, 63.250)
Mureb, 2020 56.000 (44.428, 67.572)
Overall (I^2=0 % , P=0.672) 54.159 (46.323, 61.995)
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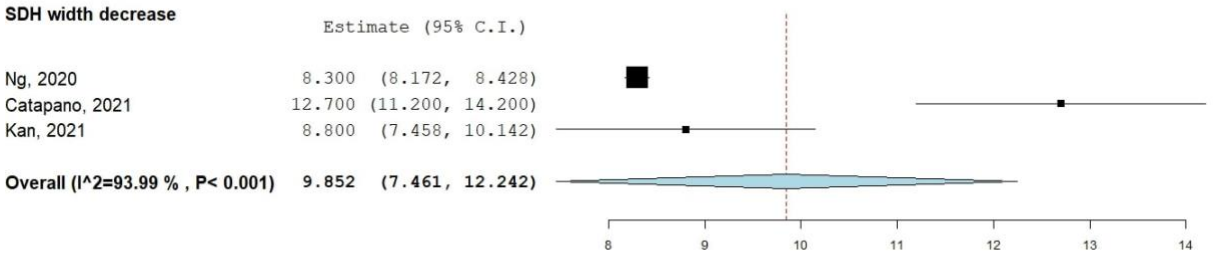
55
60


SDH width decrease
Estimate (95% C.I.)
Ng, 2020 8.300 (8.172, 8.428)
Catapano, 2021 12.700 (11.200, 14.200)
Kan, 2021 8.800 (7.458, 10.142)
Overall (I^2=93.99 % , P< 0.001) 9.852 (7.461, 12.242)
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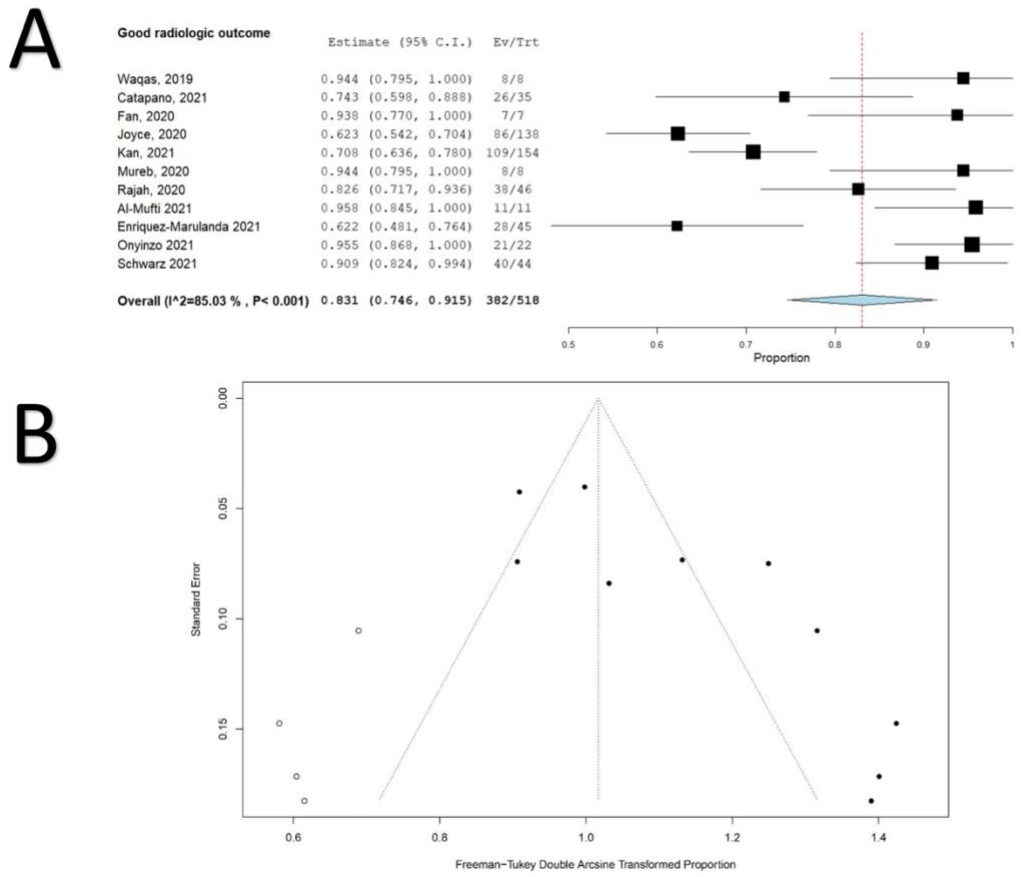
Supplemental figure 3: Forest plot (A) and funnel plot trim and fill approach (B) of good radiologic outcome.