Supplementary material

Supplementary Figure 1A: Traffic light plot for the risk of bias assessment for the included studies

Risk of bias domains

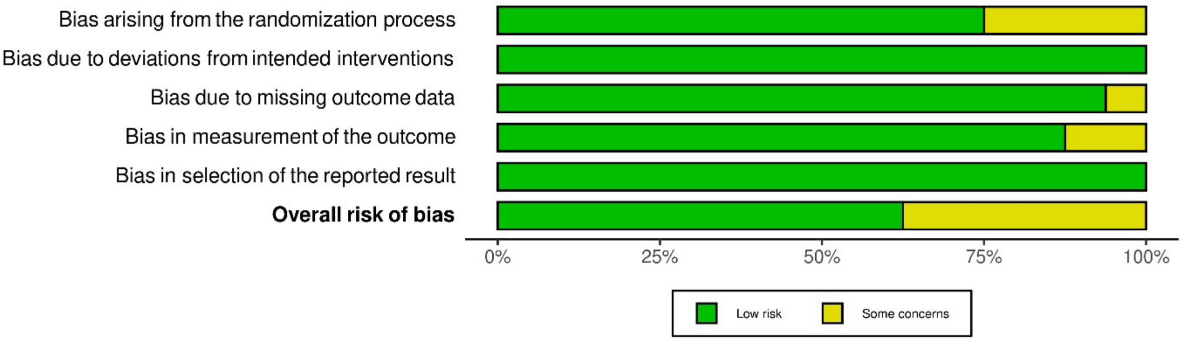
Study	D1	D2	D3	D4	D5	Overall
Attam 2015	+	+	+	+	+	+
Bansal 2017	+	+	+	+	+	+
Weston 2017	+	+	+	+	+	+
Bang 2018	+	+	+	+	+	+
Saxena 2018	-	+	+	+	+	-
Lee 2018	-	+	+	+	+	-
Cheng 2019	+	+	+	+	+	+
Di Mitri 2019	+	+	+	+	+	+
Moreira 2020	+	+	+	+	+	+
Tong 2020	-	+	+	-	+	-
Wang 2020	+	+	+	+	+	+
Bang 2020	+	+	+	+	+	+
Takasumi 2021	+	+	+	-	+	-
Ladd 2021	+	+	-	+	+	-
Zhou 2021	-	+	+	+	+	-
Paik 2021	+	+	+	+	+	+

Domains:
D1: Bias arising from the randomization process.
D2: Bias due to deviations from intended intervention.
D3: Bias due to missing outcome data.
D4: Bias in measurement of the outcome.
D5: Bias in selection of the reported result.

Judgement
- Some concerns
+ Low

Supplementary material

Supplementary Figure 1B: Summary plot for the risk of bias assessment for the included studies



Supplementary table 1: Definition of outcomes used in the included studies

Authors	Adequacy	Cellularity	Bloodiness
Attam 2015[18]	0 = inadequate aspirate for the cytopathologist to make a diagnosis; 1 = adequate aspirate	0 = no cells; 1 = sparsely cellular; 2 = moderately cellular; 3 = highly cellular	0 = free of blood; 1 = contaminated with red blood cells; 2 = blood clots present
Bansal 2017[19]	0 = inadequate aspirate for the cytopathologist to make a diagnosis; 1 = adequate aspirate	0 = no cells; 1 = sparsely cellular; 2 = moderately cellular 3 = highly cellular	0 = no blood; 1 = contaminated with red blood cells; 2 = blood clots present
Weston 2017[20]	Cellularity score < 2 = inadequate; Cellularity score 2 – 3 = adequate	2 = estimated cell count > 500 cells; 3 = estimated cell count > 1000 cells	
Bang 2018[21]	Adequacy defined as FNA sample being of sufficient quality to render a preliminary diagnosis		mild < 33%; moderate 33-66%; severe > 66%
Lee 2018[22]	Adequacy defined as FNA sample being of sufficient quality to render a preliminary diagnosis	fair, <10 cell nests; good, 10 to 20 cell nests; excellent, >20 cell nests	3 or fewer blood clots (<25% of the slide) 4 – 6 blood clots (25–50% of the slide) 7 or more blood clots (> 50% of the slide)
Saxena 2018[23]	Adequacy defined as FNA sample being of sufficient quality to render a preliminary diagnosis		
Cheng 2019[24]		0 (absence or < 10% of cell groups); 1+ (10–50% of cell groups); 2+ (50–70% of cell groups); 3+ (70–90% of cell groups)	1+ (red blood cells 10–50%); 2+ (red blood cells 50–70%); 3+ (red blood cells 70–90%)

Di Mitri 2019[25]			high-moderate contamination (≥33%: interference with the pathological diagnosis); none-mild contamination (≤33%: non-interference with the pathological diagnosis)
Moreira 2020[26]	Adequacy defined as sample containing adequate cellular material for a conclusive histological diagnosis	0 = no cells; 1 = sparsely cellular; 2 = moderately cellular 3 = highly cellular	'none', absent blood cells; 'low', a few blood cells without affecting histological diagnosis; 'moderate', partially obscured by blood cells but possible histological diagnosis; 'high', hidden by blood cells leading to inadequate interpretation
Tong 2020[27]	0=no valid specimen; 1=insufficient tissue to diagnose; 2=moderate tissue but still diagnosable; 3=sufficient tissue for diagnosis		0=no blood contamination; 1=slight blood contamination, sparseness of RBCs; 2=moderate blood contamination, monolayer of RBCs; 3=significant blood contamination, cell clustering or stratification
Wang 2020[28]	score 0 = sample with no material; score 1 = samples did not provide histological information; score 2 = limited histological assessment; score 3 = architecturally intact piece of tissue with a length of at least 550μm Score of 2 or 3 = adequate	Score 2 = moderate Score 3 = high	score 3 = < 25%; score 2 = 25%– 50 %; score 1 = >50%; score 0 = no material
Bang 2020[29]		Low Intermediate High	
Takasumi 2021[30]	Adequacy defined as FNA sample being of sufficient quality to render a preliminary diagnosis	0 = no cells; 1 = sparsely cellular; 2 = moderately cellular; 3 = highly cellular	
Ladd 2021[31]	Adequacy defined as FNA sample being of sufficient quality to render a preliminary diagnosis	0—insufficient material for interpretation; 1—sufficient material for limited cytological	1—blood present; 2—blood clots present

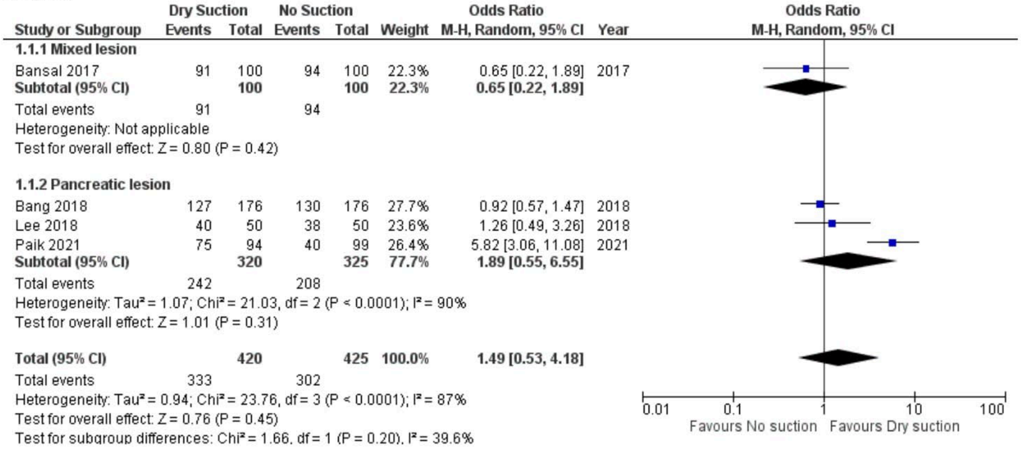
Supplementary material

		interpretation, but may not be representative of the entire lesion; 2—sufficient material for adequate cytological interpretation	
Zhou 2021[32]	Grade A – existing core tissue (defined as an architecturally intact piece of tissue with a long axis measuring at least 550 μm) Grade B – existing core fragments, which does not meet the criteria for architecturally intact histology, but can still yield a diagnosis based on cell morphology; Grade C – no lesion tissue found, and a diagnosis cannot be made based on the sample	Grade A, > 4 clusters, with a minimum of 10 cells in each cluster; Grade B, approximately 2–4 clusters, with a minimum of 10 cells in each cluster; Grade C, < 2 clusters or no cellular smear	
Paik 2021[33]	Poor—no cellular material or inconspicuous whitish core mixed with blood; Fair—presence of whitish core; Good—whitish core with the presence of a wormlike tissue architecture		

Supplementary material

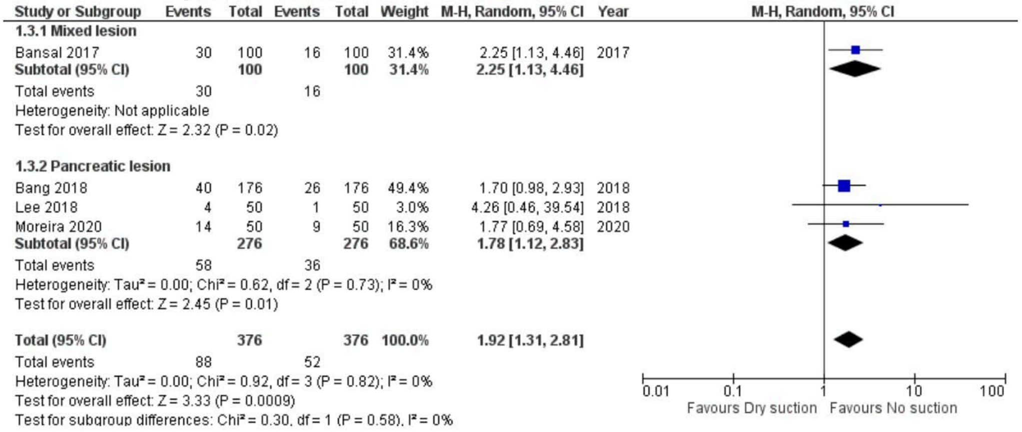
Supplementary Figure 2A: Pair-wise meta-analysis for dry suction vs. no suction based on lesion type

(A) Adequacy



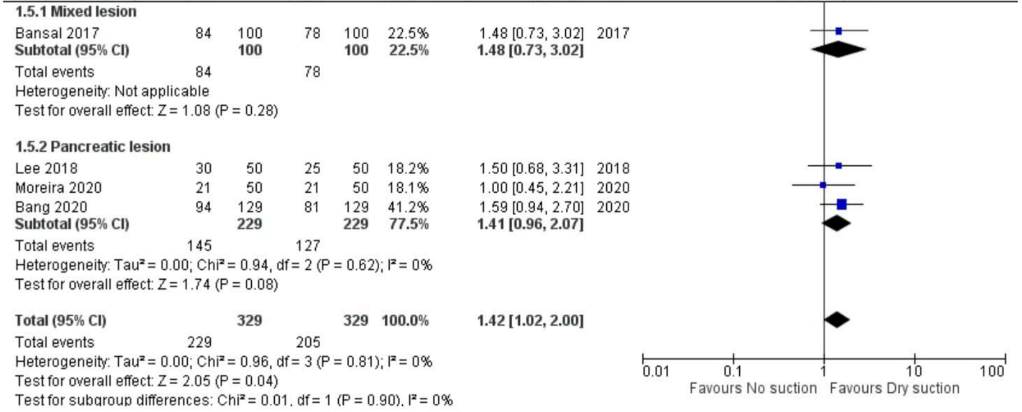
Study or Subgroup	Dry Suction Events	Dry Suction Total	No Suction Events	No Suction Total	Weight	Odds Ratio M-H, Random, 95% CI	Year
1.1.1 Mixed lesion							
Bansal 2017	91	100	94	100	22.3%	0.65 [0.22, 1.89]	2017
Subtotal (95% CI)		**100**		**100**	**22.3%**	**0.65 [0.22, 1.89]**	
Total events	91		94				
Heterogeneity: Not applicable							
Test for overall effect: Z = 0.80 (P = 0.42)							
1.1.2 Pancreatic lesion							
Bang 2018	127	176	130	176	27.7%	0.92 [0.57, 1.47]	2018
Lee 2018	40	50	38	50	23.6%	1.26 [0.49, 3.26]	2018
Paik 2021	75	94	40	99	26.4%	5.82 [3.06, 11.08]	2021
Subtotal (95% CI)		**320**		**325**	**77.7%**	**1.89 [0.55, 6.55]**	
Total events	242		208				
Heterogeneity: Tau² = 1.07; Chi² = 21.03, df = 2 (P < 0.0001); I² = 90%							
Test for overall effect: Z = 1.01 (P = 0.31)							
Total (95% CI)		**420**		**425**	**100.0%**	**1.49 [0.53, 4.18]**	
Total events	333		302				
Heterogeneity: Tau² = 0.94; Chi² = 23.76, df = 3 (P < 0.0001); I² = 87%							
Test for overall effect: Z = 0.76 (P = 0.45)							
Test for subgroup differences: Chi² = 1.66, df = 1 (P = 0.20), I² = 39.6%							

(B) Bloodiness



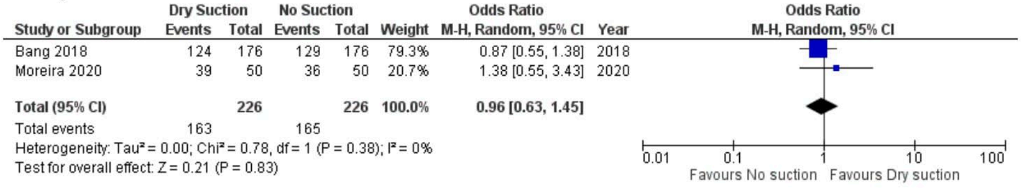
Study or Subgroup	Dry Suction Events	Dry Suction Total	No Suction Events	No Suction Total	Weight	Odds Ratio M-H, Random, 95% CI	Year
1.3.1 Mixed lesion							
Bansal 2017	30	100	16	100	31.4%	2.25 [1.13, 4.46]	2017
Subtotal (95% CI)		**100**		**100**	**31.4%**	**2.25 [1.13, 4.46]**	
Total events	30		16				
Heterogeneity: Not applicable							
Test for overall effect: Z = 2.32 (P = 0.02)							
1.3.2 Pancreatic lesion							
Bang 2018	40	176	26	176	49.4%	1.70 [0.98, 2.93]	2018
Lee 2018	4	50	1	50	3.0%	4.26 [0.46, 39.54]	2018
Moreira 2020	14	50	9	50	16.3%	1.77 [0.69, 4.58]	2020
Subtotal (95% CI)		**276**		**276**	**68.6%**	**1.78 [1.12, 2.83]**	
Total events	58		36				
Heterogeneity: Tau² = 0.00; Chi² = 0.62, df = 2 (P = 0.73); I² = 0%							
Test for overall effect: Z = 2.45 (P = 0.01)							
Total (95% CI)		**376**		**376**	**100.0%**	**1.92 [1.31, 2.81]**	
Total events	88		52				
Heterogeneity: Tau² = 0.00; Chi² = 0.92, df = 3 (P = 0.82); I² = 0%							
Test for overall effect: Z = 3.33 (P = 0.0009)							
Test for subgroup differences: Chi² = 0.30, df = 1 (P = 0.58), I² = 0%							

(C) Cellularity



Study or Subgroup	Dry Suction Events	Dry Suction Total	No Suction Events	No Suction Total	Weight	Odds Ratio M-H, Random, 95% CI	Year
1.5.1 Mixed lesion							
Bansal 2017	84	100	78	100	22.5%	1.48 [0.73, 3.02]	2017
Subtotal (95% CI)		**100**		**100**	**22.5%**	**1.48 [0.73, 3.02]**	
Total events	84		78				
Heterogeneity: Not applicable							
Test for overall effect: Z = 1.08 (P = 0.28)							
1.5.2 Pancreatic lesion							
Lee 2018	30	50	25	50	18.2%	1.50 [0.68, 3.31]	2018
Moreira 2020	21	50	21	50	18.1%	1.00 [0.45, 2.21]	2020
Bang 2020	94	129	81	129	41.2%	1.59 [0.94, 2.70]	2020
Subtotal (95% CI)		**229**		**229**	**77.5%**	**1.41 [0.96, 2.07]**	
Total events	145		127				
Heterogeneity: Tau² = 0.00; Chi² = 0.94, df = 2 (P = 0.62); I² = 0%							
Test for overall effect: Z = 1.74 (P = 0.08)							
Total (95% CI)		**329**		**329**	**100.0%**	**1.42 [1.02, 2.00]**	
Total events	229		205				
Heterogeneity: Tau² = 0.00; Chi² = 0.96, df = 3 (P = 0.81); I² = 0%							
Test for overall effect: Z = 2.05 (P = 0.04)							
Test for subgroup differences: Chi² = 0.01, df = 1 (P = 0.90), I² = 0%							

(D) Accuracy

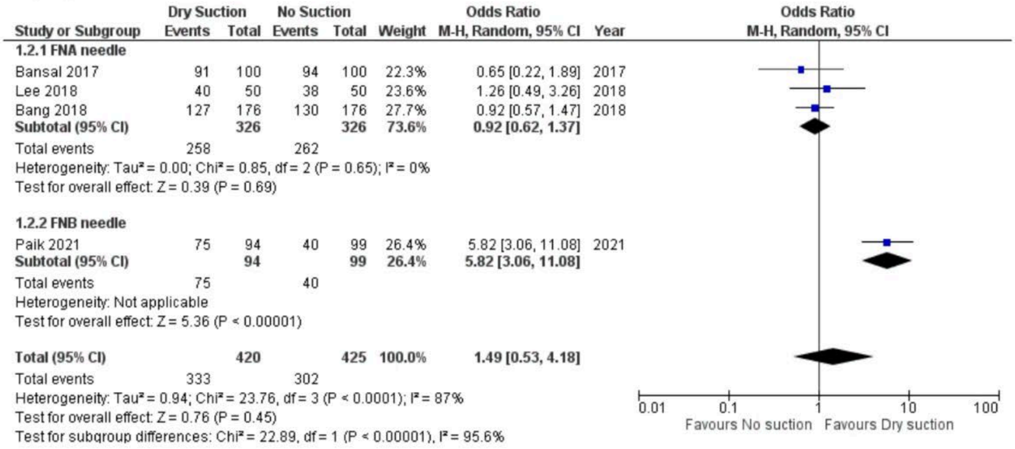


Study or Subgroup	Dry Suction Events	Dry Suction Total	No Suction Events	No Suction Total	Weight	Odds Ratio M-H, Random, 95% CI	Year
Bang 2018	124	176	129	176	79.3%	0.87 [0.55, 1.38]	2018
Moreira 2020	39	50	36	50	20.7%	1.38 [0.55, 3.43]	2020
Total (95% CI)		**226**		**226**	**100.0%**	**0.96 [0.63, 1.45]**	
Total events	163		165				
Heterogeneity: Tau² = 0.00; Chi² = 0.78, df = 1 (P = 0.38); I² = 0%							
Test for overall effect: Z = 0.21 (P = 0.83)							

Supplementary material

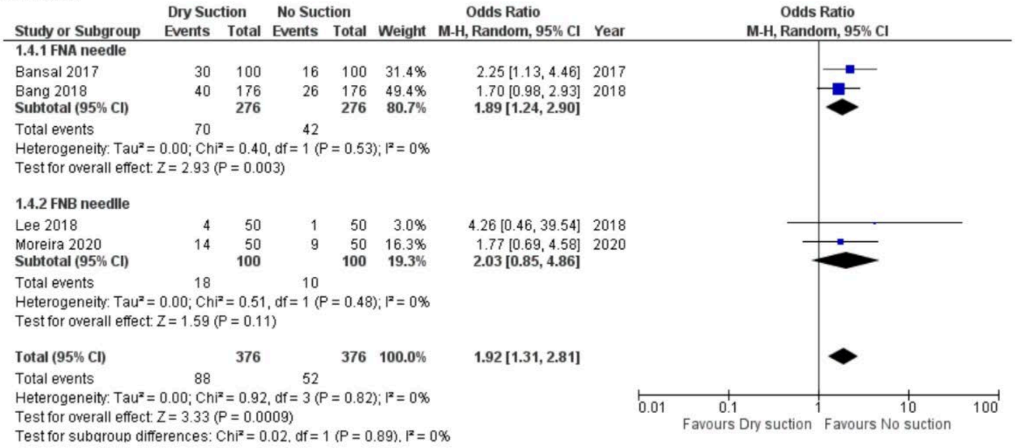
Supplementary Figure 2B: Pair-wise meta-analysis for dry suction vs. no suction based on needle type

(A) Adequacy



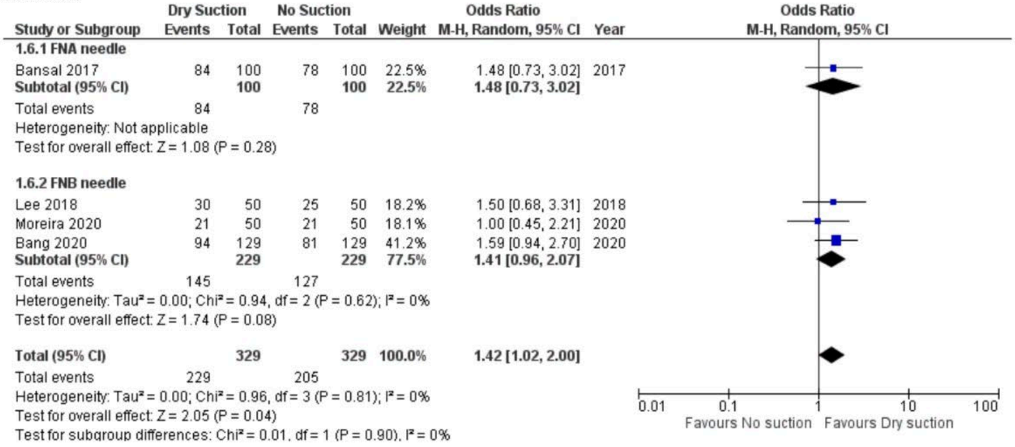
	Dry Suction		No Suction			Odds Ratio	
Study or Subgroup	**Events**	**Total**	**Events**	**Total**	**Weight**	**M-H, Random, 95% CI**	**Year**
1.2.1 FNA needle							
Bansal 2017	91	100	94	100	22.3%	0.65 [0.22, 1.89]	2017
Lee 2018	40	50	38	50	23.6%	1.26 [0.49, 3.26]	2018
Bang 2018	127	176	130	176	27.7%	0.92 [0.57, 1.47]	2018
Subtotal (95% CI)		**326**		**326**	**73.6%**	**0.92 [0.62, 1.37]**	
Total events	258		262				
Heterogeneity: Tau^2 = 0.00; Chi^2 = 0.85, df = 2 (P = 0.65); I^2 = 0%							
Test for overall effect: Z = 0.39 (P = 0.69)							
1.2.2 FNB needle							
Paik 2021	75	94	40	99	26.4%	5.82 [3.06, 11.08]	2021
Subtotal (95% CI)		**94**		**99**	**26.4%**	**5.82 [3.06, 11.08]**	
Total events	75		40				
Heterogeneity: Not applicable							
Test for overall effect: Z = 5.36 (P < 0.00001)							
Total (95% CI)		**420**		**425**	**100.0%**	**1.49 [0.53, 4.18]**	
Total events	333		302				
Heterogeneity: Tau^2 = 0.94; Chi^2 = 23.76, df = 3 (P < 0.0001); I^2 = 87%							
Test for overall effect: Z = 0.76 (P = 0.45)							
Test for subgroup differences: Chi^2 = 22.89, df = 1 (P < 0.00001), I^2 = 95.6%							

(B) Bloodiness



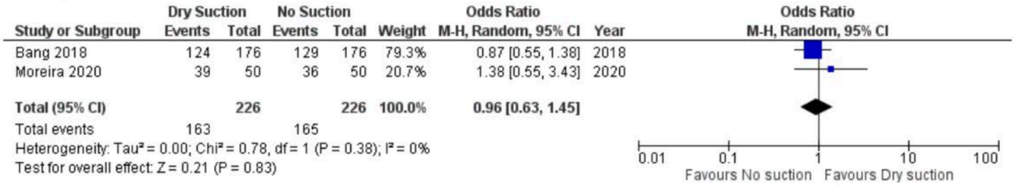
	Dry Suction		No Suction			Odds Ratio	
Study or Subgroup	**Events**	**Total**	**Events**	**Total**	**Weight**	**M-H, Random, 95% CI**	**Year**
1.4.1 FNA needle							
Bansal 2017	30	100	16	100	31.4%	2.25 [1.13, 4.46]	2017
Bang 2018	40	176	26	176	49.4%	1.70 [0.98, 2.93]	2018
Subtotal (95% CI)		**276**		**276**	**80.7%**	**1.89 [1.24, 2.90]**	
Total events	70		42				
Heterogeneity: Tau^2 = 0.00; Chi^2 = 0.40, df = 1 (P = 0.53); I^2 = 0%							
Test for overall effect: Z = 2.93 (P = 0.003)							
1.4.2 FNB needlle							
Lee 2018	4	50	1	50	3.0%	4.26 [0.46, 39.54]	2018
Moreira 2020	14	50	9	50	16.3%	1.77 [0.69, 4.58]	2020
Subtotal (95% CI)		**100**		**100**	**19.3%**	**2.03 [0.85, 4.86]**	
Total events	18		10				
Heterogeneity: Tau^2 = 0.00; Chi^2 = 0.51, df = 1 (P = 0.48); I^2 = 0%							
Test for overall effect: Z = 1.59 (P = 0.11)							
Total (95% CI)		**376**		**376**	**100.0%**	**1.92 [1.31, 2.81]**	
Total events	88		52				
Heterogeneity: Tau^2 = 0.00; Chi^2 = 0.92, df = 3 (P = 0.82); I^2 = 0%							
Test for overall effect: Z = 3.33 (P = 0.0009)							
Test for subgroup differences: Chi^2 = 0.02, df = 1 (P = 0.89), I^2 = 0%							

(C) Cellularity



	Dry Suction		No Suction			Odds Ratio	
Study or Subgroup	**Events**	**Total**	**Events**	**Total**	**Weight**	**M-H, Random, 95% CI**	**Year**
1.6.1 FNA needle							
Bansal 2017	84	100	78	100	22.5%	1.48 [0.73, 3.02]	2017
Subtotal (95% CI)		**100**		**100**	**22.5%**	**1.48 [0.73, 3.02]**	
Total events	84		78				
Heterogeneity: Not applicable							
Test for overall effect: Z = 1.08 (P = 0.28)							
1.6.2 FNB needle							
Lee 2018	30	50	25	50	18.2%	1.50 [0.68, 3.31]	2018
Moreira 2020	21	50	21	50	18.1%	1.00 [0.45, 2.21]	2020
Bang 2020	94	129	81	129	41.2%	1.59 [0.94, 2.70]	2020
Subtotal (95% CI)		**229**		**229**	**77.5%**	**1.41 [0.96, 2.07]**	
Total events	145		127				
Heterogeneity: Tau^2 = 0.00; Chi^2 = 0.94, df = 2 (P = 0.62); I^2 = 0%							
Test for overall effect: Z = 1.74 (P = 0.08)							
Total (95% CI)		**329**		**329**	**100.0%**	**1.42 [1.02, 2.00]**	
Total events	229		205				
Heterogeneity: Tau^2 = 0.00; Chi^2 = 0.96, df = 3 (P = 0.81); I^2 = 0%							
Test for overall effect: Z = 2.05 (P = 0.04)							
Test for subgroup differences: Chi^2 = 0.01, df = 1 (P = 0.90), I^2 = 0%							

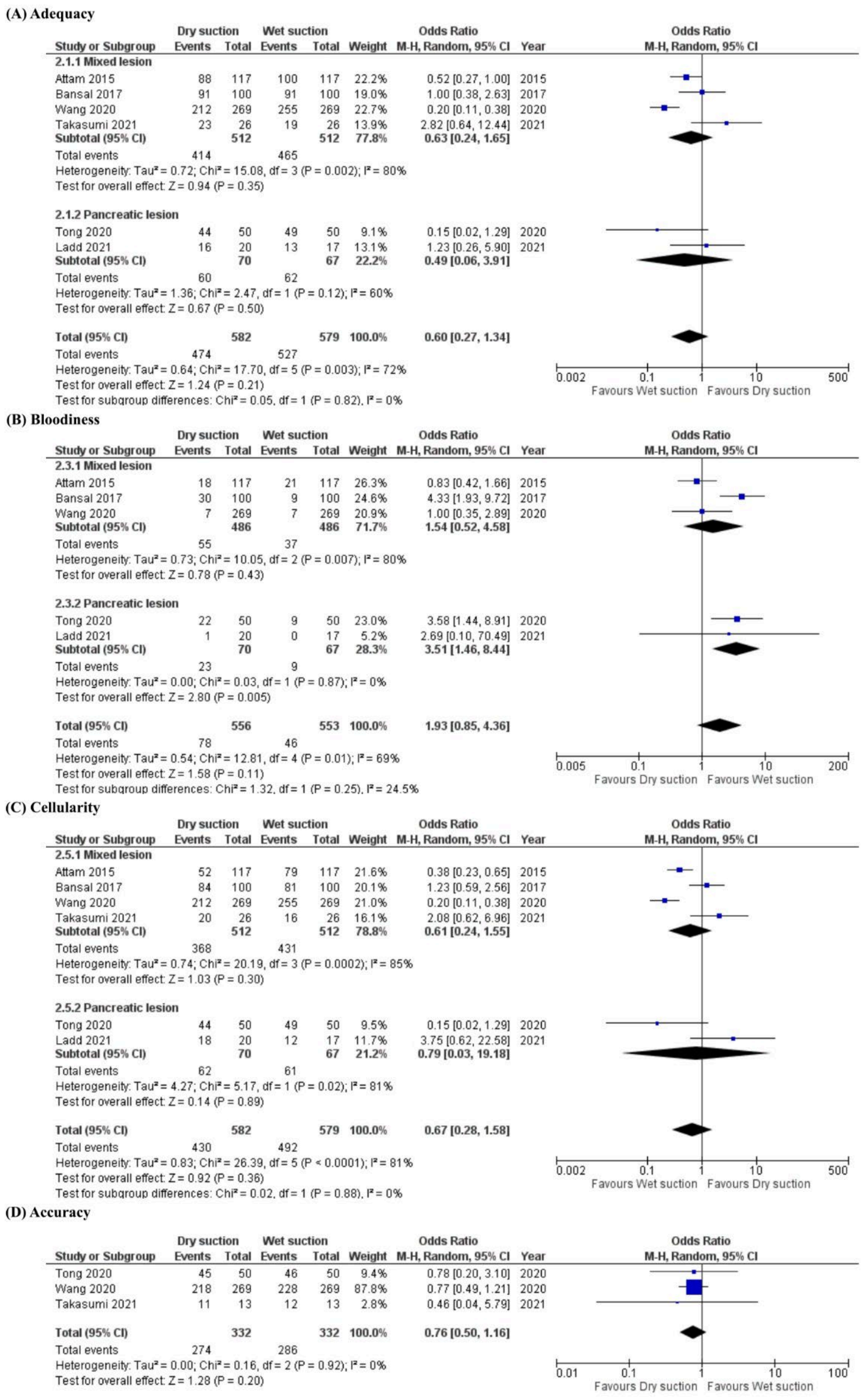
(D) Accuracy



	Dry Suction		No Suction			Odds Ratio	
Study or Subgroup	**Events**	**Total**	**Events**	**Total**	**Weight**	**M-H, Random, 95% CI**	**Year**
Bang 2018	124	176	129	176	79.3%	0.87 [0.55, 1.38]	2018
Moreira 2020	39	50	36	50	20.7%	1.38 [0.55, 3.43]	2020
Total (95% CI)		**226**		**226**	**100.0%**	**0.96 [0.63, 1.45]**	
Total events	163		165				
Heterogeneity: Tau^2 = 0.00; Chi^2 = 0.78, df = 1 (P = 0.38); I^2 = 0%							
Test for overall effect: Z = 0.21 (P = 0.83)							

Supplementary material

Supplementary Figure 3A: Pair-wise meta-analysis for dry suction vs. wet suction based on lesion type



(A) Adequacy

	Dry suction		Wet suction			Odds Ratio	
Study or Subgroup	**Events**	**Total**	**Events**	**Total**	**Weight**	**M-H, Random, 95% CI**	**Year**
2.1.1 Mixed lesion							
Attam 2015	88	117	100	117	22.2%	0.52 [0.27, 1.00]	2015
Bansal 2017	91	100	91	100	19.0%	1.00 [0.38, 2.63]	2017
Wang 2020	212	269	255	269	22.7%	0.20 [0.11, 0.38]	2020
Takasumi 2021	23	26	19	26	13.9%	2.82 [0.64, 12.44]	2021
Subtotal (95% CI)		**512**		**512**	**77.8%**	**0.63 [0.24, 1.65]**	
Total events	414		465				
Heterogeneity: Tau^2 = 0.72; Chi^2 = 15.08, df = 3 (P = 0.002); I^2 = 80%							
Test for overall effect: Z = 0.94 (P = 0.35)							
2.1.2 Pancreatic lesion							
Tong 2020	44	50	49	50	9.1%	0.15 [0.02, 1.29]	2020
Ladd 2021	16	20	13	17	13.1%	1.23 [0.26, 5.90]	2021
Subtotal (95% CI)		**70**		**67**	**22.2%**	**0.49 [0.06, 3.91]**	
Total events	60		62				
Heterogeneity: Tau^2 = 1.36; Chi^2 = 2.47, df = 1 (P = 0.12); I^2 = 60%							
Test for overall effect: Z = 0.67 (P = 0.50)							
Total (95% CI)		**582**		**579**	**100.0%**	**0.60 [0.27, 1.34]**	
Total events	474		527				
Heterogeneity: Tau^2 = 0.64; Chi^2 = 17.70, df = 5 (P = 0.003); I^2 = 72%							
Test for overall effect: Z = 1.24 (P = 0.21)							
Test for subgroup differences: Chi^2 = 0.05, df = 1 (P = 0.82), I^2 = 0%							

(B) Bloodiness

	Dry suction		Wet suction			Odds Ratio	
Study or Subgroup	**Events**	**Total**	**Events**	**Total**	**Weight**	**M-H, Random, 95% CI**	**Year**
2.3.1 Mixed lesion							
Attam 2015	18	117	21	117	26.3%	0.83 [0.42, 1.66]	2015
Bansal 2017	30	100	9	100	24.6%	4.33 [1.93, 9.72]	2017
Wang 2020	7	269	7	269	20.9%	1.00 [0.35, 2.89]	2020
Subtotal (95% CI)		**486**		**486**	**71.7%**	**1.54 [0.52, 4.58]**	
Total events	55		37				
Heterogeneity: Tau^2 = 0.73; Chi^2 = 10.05, df = 2 (P = 0.007); I^2 = 80%							
Test for overall effect: Z = 0.78 (P = 0.43)							
2.3.2 Pancreatic lesion							
Tong 2020	22	50	9	50	23.0%	3.58 [1.44, 8.91]	2020
Ladd 2021	1	20	0	17	5.2%	2.69 [0.10, 70.49]	2021
Subtotal (95% CI)		**70**		**67**	**28.3%**	**3.51 [1.46, 8.44]**	
Total events	23		9				
Heterogeneity: Tau^2 = 0.00; Chi^2 = 0.03, df = 1 (P = 0.87); I^2 = 0%							
Test for overall effect: Z = 2.80 (P = 0.005)							
Total (95% CI)		**556**		**553**	**100.0%**	**1.93 [0.85, 4.36]**	
Total events	78		46				
Heterogeneity: Tau^2 = 0.54; Chi^2 = 12.81, df = 4 (P = 0.01); I^2 = 69%							
Test for overall effect: Z = 1.58 (P = 0.11)							
Test for subgroup differences: Chi^2 = 1.32, df = 1 (P = 0.25), I^2 = 24.5%							

(C) Cellularity

	Dry suction		Wet suction			Odds Ratio	
Study or Subgroup	**Events**	**Total**	**Events**	**Total**	**Weight**	**M-H, Random, 95% CI**	**Year**
2.5.1 Mixed lesion							
Attam 2015	52	117	79	117	21.6%	0.38 [0.23, 0.65]	2015
Bansal 2017	84	100	81	100	20.1%	1.23 [0.59, 2.56]	2017
Wang 2020	212	269	255	269	21.0%	0.20 [0.11, 0.38]	2020
Takasumi 2021	20	26	16	26	16.1%	2.08 [0.62, 6.96]	2021
Subtotal (95% CI)		**512**		**512**	**78.8%**	**0.61 [0.24, 1.55]**	
Total events	368		431				
Heterogeneity: Tau^2 = 0.74; Chi^2 = 20.19, df = 3 (P = 0.0002); I^2 = 85%							
Test for overall effect: Z = 1.03 (P = 0.30)							
2.5.2 Pancreatic lesion							
Tong 2020	44	50	49	50	9.5%	0.15 [0.02, 1.29]	2020
Ladd 2021	18	20	12	17	11.7%	3.75 [0.62, 22.58]	2021
Subtotal (95% CI)		**70**		**67**	**21.2%**	**0.79 [0.03, 19.18]**	
Total events	62		61				
Heterogeneity: Tau^2 = 4.27; Chi^2 = 5.17, df = 1 (P = 0.02); I^2 = 81%							
Test for overall effect: Z = 0.14 (P = 0.89)							
Total (95% CI)		**582**		**579**	**100.0%**	**0.67 [0.28, 1.58]**	
Total events	430		492				
Heterogeneity: Tau^2 = 0.83; Chi^2 = 26.39, df = 5 (P < 0.0001); I^2 = 81%							
Test for overall effect: Z = 0.92 (P = 0.36)							
Test for subgroup differences: Chi^2 = 0.02, df = 1 (P = 0.88), I^2 = 0%							

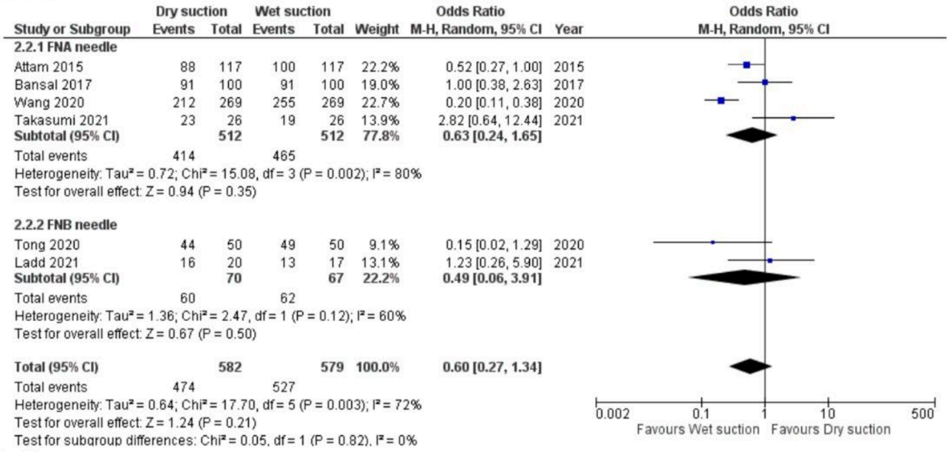
(D) Accuracy

	Dry suction		Wet suction			Odds Ratio	
Study or Subgroup	**Events**	**Total**	**Events**	**Total**	**Weight**	**M-H, Random, 95% CI**	**Year**
Tong 2020	45	50	46	50	9.4%	0.78 [0.20, 3.10]	2020
Wang 2020	218	269	228	269	87.8%	0.77 [0.49, 1.21]	2020
Takasumi 2021	11	13	12	13	2.8%	0.46 [0.04, 5.79]	2021
Total (95% CI)		**332**		**332**	**100.0%**	**0.76 [0.50, 1.16]**	
Total events	274		286				
Heterogeneity: Tau^2 = 0.00; Chi^2 = 0.16, df = 2 (P = 0.92); I^2 = 0%							
Test for overall effect: Z = 1.28 (P = 0.20)							

Supplementary material

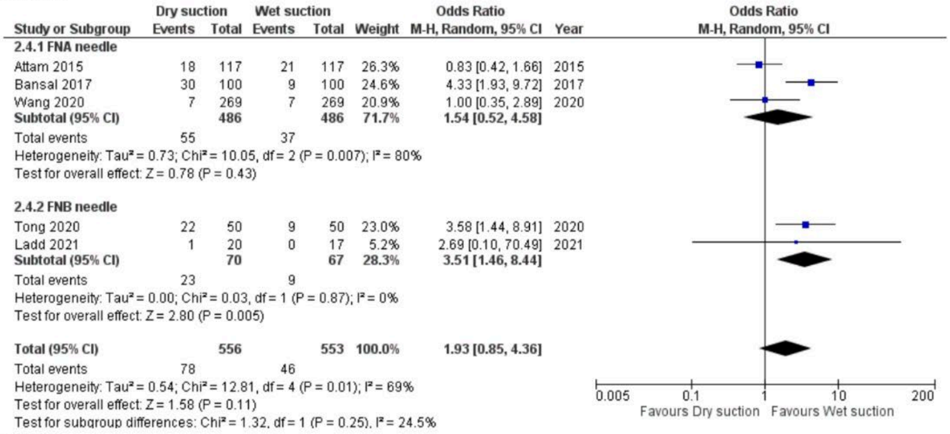
Supplementary Figure 3B: Pair-wise meta-analysis for dry suction vs. wet suction based on needle type

(A) Adequacy



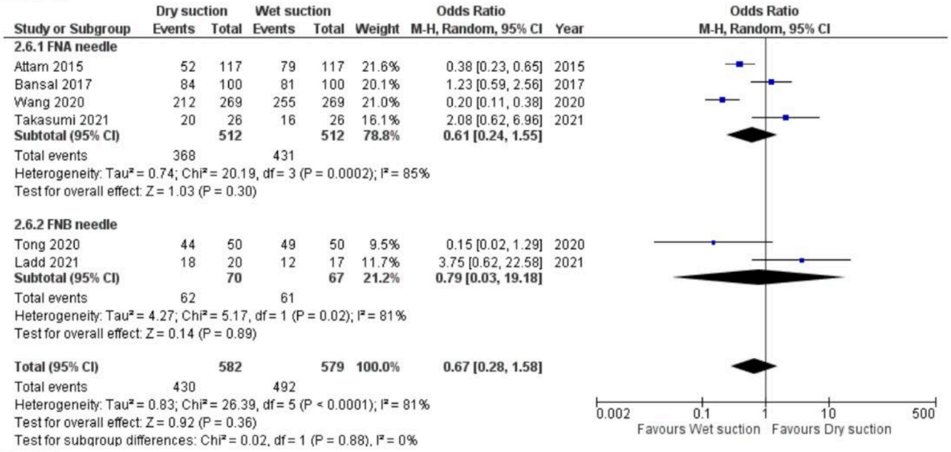
	Dry suction		Wet suction			Odds Ratio	
Study or Subgroup	**Events**	**Total**	**Events**	**Total**	**Weight**	**M-H, Random, 95% CI**	**Year**
2.2.1 FNA needle							
Attam 2015	88	117	100	117	22.2%	0.52 [0.27, 1.00]	2015
Bansal 2017	91	100	91	100	19.0%	1.00 [0.38, 2.63]	2017
Wang 2020	212	269	255	269	22.7%	0.20 [0.11, 0.38]	2020
Takasumi 2021	23	26	19	26	13.9%	2.82 [0.64, 12.44]	2021
Subtotal (95% CI)		**512**		**512**	**77.8%**	**0.63 [0.24, 1.65]**	
Total events	414		465				
Heterogeneity: Tau^2 = 0.72; Chi^2 = 15.08, df = 3 (P = 0.002); I^2 = 80%							
Test for overall effect: Z = 0.94 (P = 0.35)							
2.2.2 FNB needle							
Tong 2020	44	50	49	50	9.1%	0.15 [0.02, 1.29]	2020
Ladd 2021	16	20	13	17	13.1%	1.23 [0.26, 5.90]	2021
Subtotal (95% CI)		**70**		**67**	**22.2%**	**0.49 [0.06, 3.91]**	
Total events	60		62				
Heterogeneity: Tau^2 = 1.36; Chi^2 = 2.47, df = 1 (P = 0.12); I^2 = 60%							
Test for overall effect: Z = 0.67 (P = 0.50)							
Total (95% CI)		**582**		**579**	**100.0%**	**0.60 [0.27, 1.34]**	
Total events	474		527				
Heterogeneity: Tau^2 = 0.64; Chi^2 = 17.70, df = 5 (P = 0.003); I^2 = 72%							
Test for overall effect: Z = 1.24 (P = 0.21)							
Test for subgroup differences: Chi^2 = 0.05, df = 1 (P = 0.82), I^2 = 0%							

(B) Bloodiness



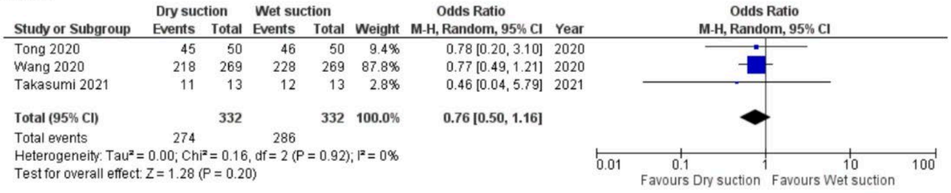
	Dry suction		Wet suction			Odds Ratio	
Study or Subgroup	**Events**	**Total**	**Events**	**Total**	**Weight**	**M-H, Random, 95% CI**	**Year**
2.4.1 FNA needle							
Attam 2015	18	117	21	117	26.3%	0.83 [0.42, 1.66]	2015
Bansal 2017	30	100	9	100	24.6%	4.33 [1.93, 9.72]	2017
Wang 2020	7	269	7	269	20.9%	1.00 [0.35, 2.89]	2020
Subtotal (95% CI)		**486**		**486**	**71.7%**	**1.54 [0.52, 4.58]**	
Total events	55		37				
Heterogeneity: Tau^2 = 0.73; Chi^2 = 10.05, df = 2 (P = 0.007); I^2 = 80%							
Test for overall effect: Z = 0.78 (P = 0.43)							
2.4.2 FNB needle							
Tong 2020	22	50	9	50	23.0%	3.58 [1.44, 8.91]	2020
Ladd 2021	1	20	0	17	5.2%	2.69 [0.10, 70.49]	2021
Subtotal (95% CI)		**70**		**67**	**28.3%**	**3.51 [1.46, 8.44]**	
Total events	23		9				
Heterogeneity: Tau^2 = 0.00; Chi^2 = 0.03, df = 1 (P = 0.87); I^2 = 0%							
Test for overall effect: Z = 2.80 (P = 0.005)							
Total (95% CI)		**556**		**553**	**100.0%**	**1.93 [0.85, 4.36]**	
Total events	78		46				
Heterogeneity: Tau^2 = 0.54; Chi^2 = 12.81, df = 4 (P = 0.01); I^2 = 69%							
Test for overall effect: Z = 1.58 (P = 0.11)							
Test for subgroup differences: Chi^2 = 1.32, df = 1 (P = 0.25), I^2 = 24.5%							

(C) Cellularity



	Dry suction		Wet suction			Odds Ratio	
Study or Subgroup	**Events**	**Total**	**Events**	**Total**	**Weight**	**M-H, Random, 95% CI**	**Year**
2.6.1 FNA needle							
Attam 2015	52	117	79	117	21.6%	0.38 [0.23, 0.65]	2015
Bansal 2017	84	100	81	100	20.1%	1.23 [0.59, 2.56]	2017
Wang 2020	212	269	255	269	21.0%	0.20 [0.11, 0.38]	2020
Takasumi 2021	20	26	16	26	16.1%	2.08 [0.62, 6.96]	2021
Subtotal (95% CI)		**512**		**512**	**78.8%**	**0.61 [0.24, 1.55]**	
Total events	368		431				
Heterogeneity: Tau^2 = 0.74; Chi^2 = 20.19, df = 3 (P = 0.0002); I^2 = 85%							
Test for overall effect: Z = 1.03 (P = 0.30)							
2.6.2 FNB needle							
Tong 2020	44	50	49	50	9.5%	0.15 [0.02, 1.29]	2020
Ladd 2021	18	20	12	17	11.7%	3.75 [0.62, 22.58]	2021
Subtotal (95% CI)		**70**		**67**	**21.2%**	**0.79 [0.03, 19.18]**	
Total events	62		61				
Heterogeneity: Tau^2 = 4.27; Chi^2 = 5.17, df = 1 (P = 0.02); I^2 = 81%							
Test for overall effect: Z = 0.14 (P = 0.89)							
Total (95% CI)		**582**		**579**	**100.0%**	**0.67 [0.28, 1.58]**	
Total events	430		492				
Heterogeneity: Tau^2 = 0.83; Chi^2 = 26.39, df = 5 (P < 0.0001); I^2 = 81%							
Test for overall effect: Z = 0.92 (P = 0.36)							
Test for subgroup differences: Chi^2 = 0.02, df = 1 (P = 0.88), I^2 = 0%							

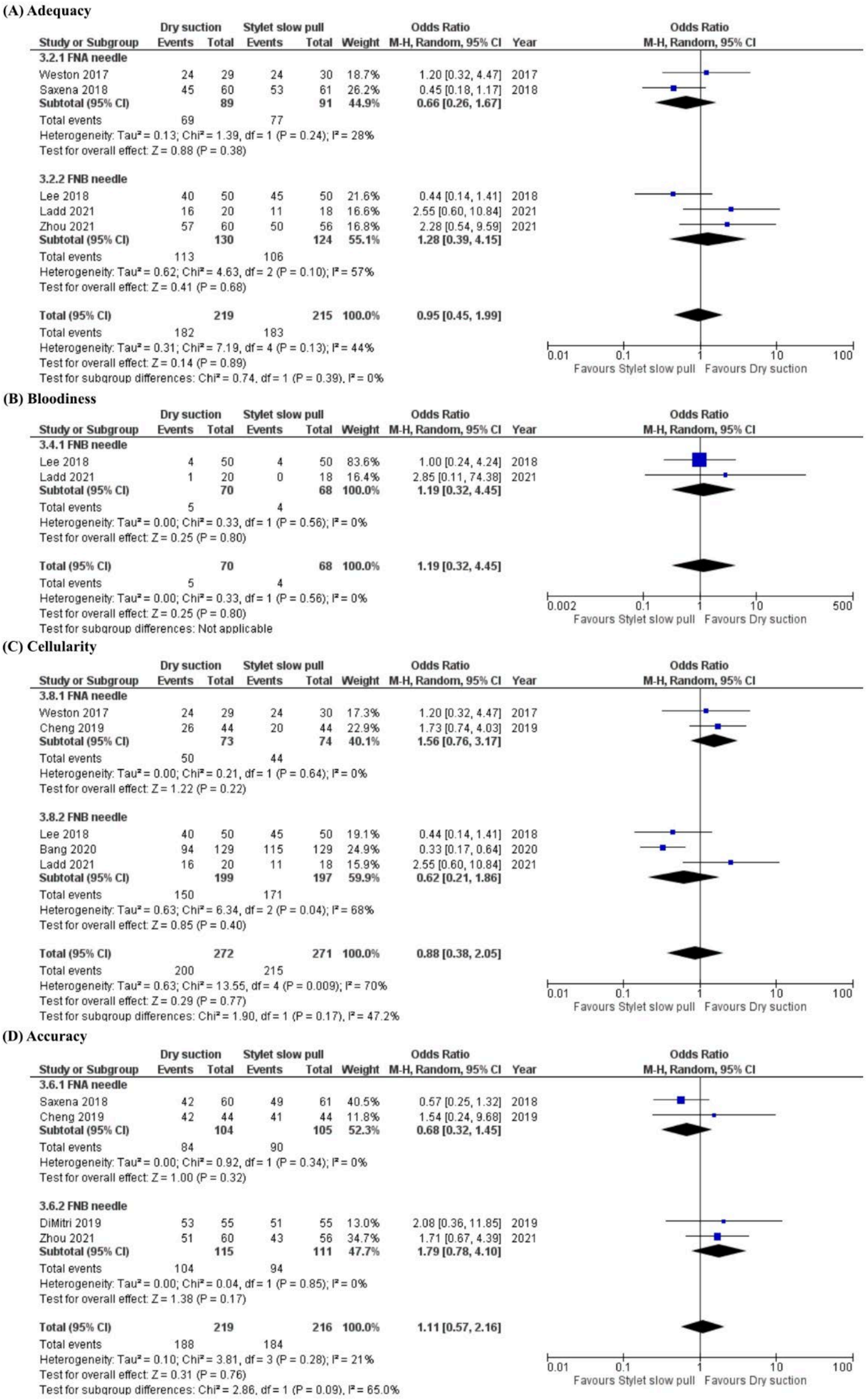
(D) Accuracy



	Dry suction		Wet suction			Odds Ratio	
Study or Subgroup	**Events**	**Total**	**Events**	**Total**	**Weight**	**M-H, Random, 95% CI**	**Year**
Tong 2020	45	50	46	50	9.4%	0.78 [0.20, 3.10]	2020
Wang 2020	218	269	228	269	87.8%	0.77 [0.49, 1.21]	2020
Takasumi 2021	11	13	12	13	2.8%	0.46 [0.04, 5.79]	2021
Total (95% CI)		**332**		**332**	**100.0%**	**0.76 [0.50, 1.16]**	
Total events	274		286				
Heterogeneity: Tau^2 = 0.00; Chi^2 = 0.16, df = 2 (P = 0.92); I^2 = 0%							
Test for overall effect: Z = 1.28 (P = 0.20)							

Supplementary material

Supplementary Figure 4: Pair-wise meta-analysis for dry suction vs. stylet slow pull based on needle type



(A) Adequacy

	Dry suction		Stylet slow pull			Odds Ratio		Odds Ratio
Study or Subgroup	**Events**	**Total**	**Events**	**Total**	**Weight**	**M-H, Random, 95% CI**	**Year**	**M-H, Random, 95% CI**
3.2.1 FNA needle								
Weston 2017	24	29	24	30	18.7%	1.20 [0.32, 4.47]	2017	
Saxena 2018	45	60	53	61	26.2%	0.45 [0.18, 1.17]	2018	
Subtotal (95% CI)		**89**		**91**	**44.9%**	**0.66 [0.26, 1.67]**		
Total events	69		77					
Heterogeneity: Tau² = 0.13; Chi² = 1.39, df = 1 (P = 0.24); I² = 28%								
Test for overall effect: Z = 0.88 (P = 0.38)								
3.2.2 FNB needle								
Lee 2018	40	50	45	50	21.6%	0.44 [0.14, 1.41]	2018	
Ladd 2021	16	20	11	18	16.6%	2.55 [0.60, 10.84]	2021	
Zhou 2021	57	60	50	56	16.8%	2.28 [0.54, 9.59]	2021	
Subtotal (95% CI)		**130**		**124**	**55.1%**	**1.28 [0.39, 4.15]**		
Total events	113		106					
Heterogeneity: Tau² = 0.62; Chi² = 4.63, df = 2 (P = 0.10); I² = 57%								
Test for overall effect: Z = 0.41 (P = 0.68)								
Total (95% CI)		**219**		**215**	**100.0%**	**0.95 [0.45, 1.99]**		
Total events	182		183					
Heterogeneity: Tau² = 0.31; Chi² = 7.19, df = 4 (P = 0.13); I² = 44%								
Test for overall effect: Z = 0.14 (P = 0.89)								
Test for subgroup differences: Chi² = 0.74, df = 1 (P = 0.39), I² = 0%								

(B) Bloodiness

	Dry suction		Stylet slow pull			Odds Ratio		Odds Ratio
Study or Subgroup	**Events**	**Total**	**Events**	**Total**	**Weight**	**M-H, Random, 95% CI**	**Year**	**M-H, Random, 95% CI**
3.4.1 FNB needle								
Lee 2018	4	50	4	50	83.6%	1.00 [0.24, 4.24]	2018	
Ladd 2021	1	20	0	18	16.4%	2.85 [0.11, 74.38]	2021	
Subtotal (95% CI)		**70**		**68**	**100.0%**	**1.19 [0.32, 4.45]**		
Total events	5		4					
Heterogeneity: Tau² = 0.00; Chi² = 0.33, df = 1 (P = 0.56); I² = 0%								
Test for overall effect: Z = 0.25 (P = 0.80)								
Total (95% CI)		**70**		**68**	**100.0%**	**1.19 [0.32, 4.45]**		
Total events	5		4					
Heterogeneity: Tau² = 0.00; Chi² = 0.33, df = 1 (P = 0.56); I² = 0%								
Test for overall effect: Z = 0.25 (P = 0.80)								
Test for subgroup differences: Not applicable								

(C) Cellularity

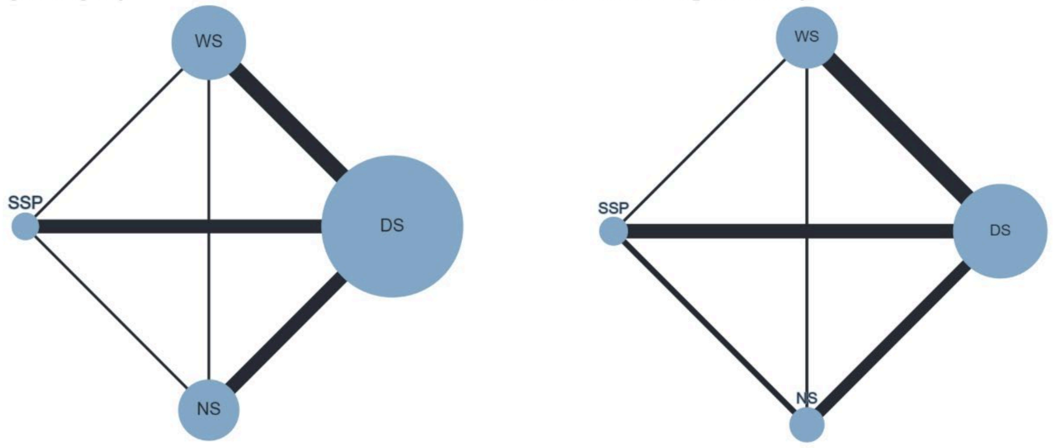
	Dry suction		Stylet slow pull			Odds Ratio		Odds Ratio
Study or Subgroup	**Events**	**Total**	**Events**	**Total**	**Weight**	**M-H, Random, 95% CI**	**Year**	**M-H, Random, 95% CI**
3.8.1 FNA needle								
Weston 2017	24	29	24	30	17.3%	1.20 [0.32, 4.47]	2017	
Cheng 2019	26	44	20	44	22.9%	1.73 [0.74, 4.03]	2019	
Subtotal (95% CI)		**73**		**74**	**40.1%**	**1.56 [0.76, 3.17]**		
Total events	50		44					
Heterogeneity: Tau² = 0.00; Chi² = 0.21, df = 1 (P = 0.64); I² = 0%								
Test for overall effect: Z = 1.22 (P = 0.22)								
3.8.2 FNB needle								
Lee 2018	40	50	45	50	19.1%	0.44 [0.14, 1.41]	2018	
Bang 2020	94	129	115	129	24.9%	0.33 [0.17, 0.64]	2020	
Ladd 2021	16	20	11	18	15.9%	2.55 [0.60, 10.84]	2021	
Subtotal (95% CI)		**199**		**197**	**59.9%**	**0.62 [0.21, 1.86]**		
Total events	150		171					
Heterogeneity: Tau² = 0.63; Chi² = 6.34, df = 2 (P = 0.04); I² = 68%								
Test for overall effect: Z = 0.85 (P = 0.40)								
Total (95% CI)		**272**		**271**	**100.0%**	**0.88 [0.38, 2.05]**		
Total events	200		215					
Heterogeneity: Tau² = 0.63; Chi² = 13.55, df = 4 (P = 0.009); I² = 70%								
Test for overall effect: Z = 0.29 (P = 0.77)								
Test for subgroup differences: Chi² = 1.90, df = 1 (P = 0.17), I² = 47.2%								

(D) Accuracy

	Dry suction		Stylet slow pull			Odds Ratio		Odds Ratio
Study or Subgroup	**Events**	**Total**	**Events**	**Total**	**Weight**	**M-H, Random, 95% CI**	**Year**	**M-H, Random, 95% CI**
3.6.1 FNA needle								
Saxena 2018	42	60	49	61	40.5%	0.57 [0.25, 1.32]	2018	
Cheng 2019	42	44	41	44	11.8%	1.54 [0.24, 9.68]	2019	
Subtotal (95% CI)		**104**		**105**	**52.3%**	**0.68 [0.32, 1.45]**		
Total events	84		90					
Heterogeneity: Tau² = 0.00; Chi² = 0.92, df = 1 (P = 0.34); I² = 0%								
Test for overall effect: Z = 1.00 (P = 0.32)								
3.6.2 FNB needle								
DiMitri 2019	53	55	51	55	13.0%	2.08 [0.36, 11.85]	2019	
Zhou 2021	51	60	43	56	34.7%	1.71 [0.67, 4.39]	2021	
Subtotal (95% CI)		**115**		**111**	**47.7%**	**1.79 [0.78, 4.10]**		
Total events	104		94					
Heterogeneity: Tau² = 0.00; Chi² = 0.04, df = 1 (P = 0.85); I² = 0%								
Test for overall effect: Z = 1.38 (P = 0.17)								
Total (95% CI)		**219**		**216**	**100.0%**	**1.11 [0.57, 2.16]**		
Total events	188		184					
Heterogeneity: Tau² = 0.10; Chi² = 3.81, df = 3 (P = 0.28); I² = 21%								
Test for overall effect: Z = 0.31 (P = 0.76)								
Test for subgroup differences: Chi² = 2.86, df = 1 (P = 0.09), I² = 65.0%								

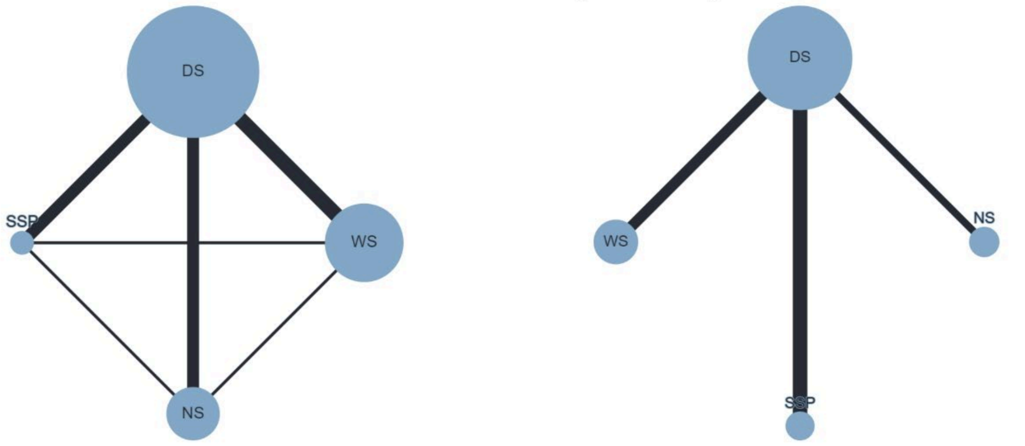
Supplementary material

Supplementary Figure 5: Network plots for the outcomes (5A) Sample adequacy, (5B) Moderate to high cellularity, (5C) Gross bloodiness, (5D) Diagnostic accuracy



5A: Sample adequacy

5B: Moderate to high cellularity



5C: Gross bloodiness

5D: Diagnostic accuracy

Supplementary material

Supplementary table 2: League table for the treatment estimates from the Bayesian network meta-analysis for sample adequacy

Dry suction			
1.45 (0.60, 3.49)	**No suction**		
0.94 (0.36, 2.52)	0.64 (0.19, 2.23)	**Stylet slow pull**	
0.61 (0.26, 1.49)	0.42 (0.13, 1.38)	0.65 (0.19, 2.24)	**Wet suction**

Supplementary table 3: League table for the treatment estimates from the Bayesian network meta-analysis for cellularity

Dry suction			
1.47 (0.63, 3.52)	**No suction**		
0.67 (0.29, 1.60)	0.46 (0.17, 1.31)	**Slow stylet pull**	
0.65 (0.31, 1.48)	0.45 (0.16, 1.33)	0.97 (0.33, 2.91)	**Wet suction**

Supplementary table 4: League table for the treatment estimates from the Bayesian network meta-analysis for gross bloodiness

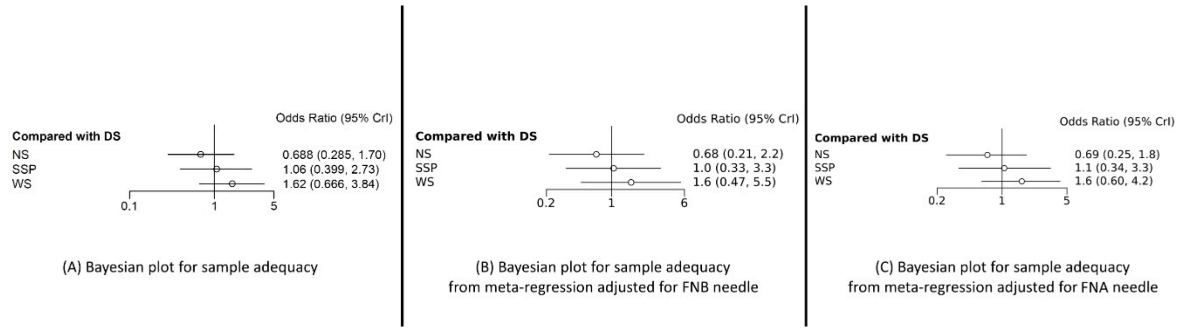
Dry suction			
1.84 (0.94, 3.79)	**No suction**		
1.00 (0.44, 2.25)	0.54 (0.19, 1.47)	**Stylet slow pull**	
2.00 **(1.03, 4.14)**	1.02 (0.41, 2.44)	1.88 (0.68, 5.34)	**Wet suction**

Supplementary material

Supplementary table 5: League table for the treatment estimates from the Bayesian network meta-analysis for diagnostic accuracy

Dry suction			
0.99 (0.53, 1.97)	**No Suction**		
1.08 (0.57, 2.20)	1.10 (0.43, 2.89)	**Stylet slow pull**	
0.75 (0.37, 1.46)	0.76 (0.28, 1.86)	0.69 (0.25, 1.73)	**Wet suction**

Supplementary Figure 6: Bayesian Forest plot for adequacy

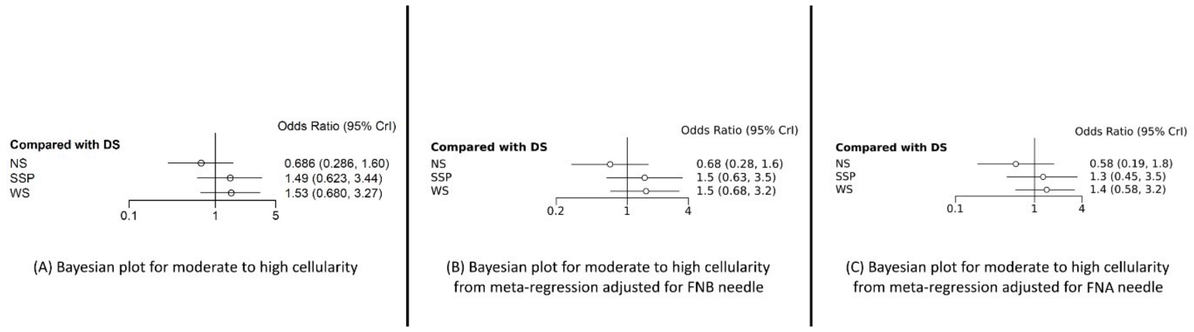


(A) Bayesian plot for sample adequacy

(B) Bayesian plot for sample adequacy from meta-regression adjusted for FNB needle

(C) Bayesian plot for sample adequacy from meta-regression adjusted for FNA needle

Supplementary Figure 7: Bayesian Forest plot for moderate to high cellularity



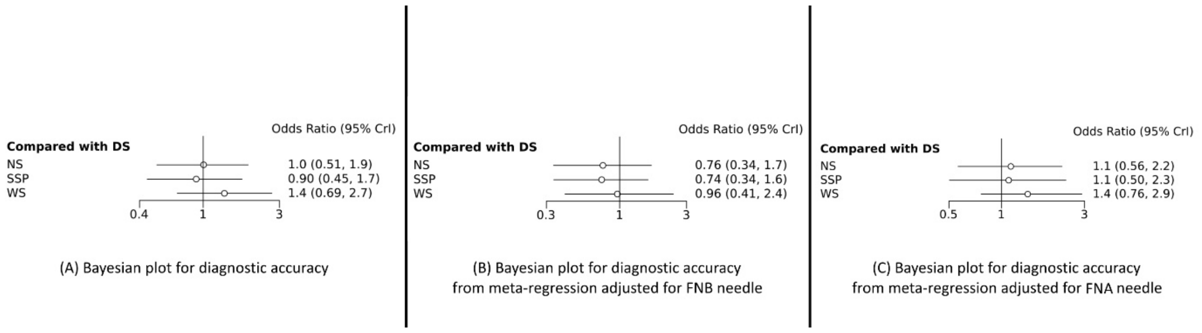
(A) Bayesian plot for moderate to high cellularity

(B) Bayesian plot for moderate to high cellularity from meta-regression adjusted for FNB needle

(C) Bayesian plot for moderate to high cellularity from meta-regression adjusted for FNA needle

Supplementary material

Supplementary Figure 8: Bayesian Forest plot for diagnostic accuracy

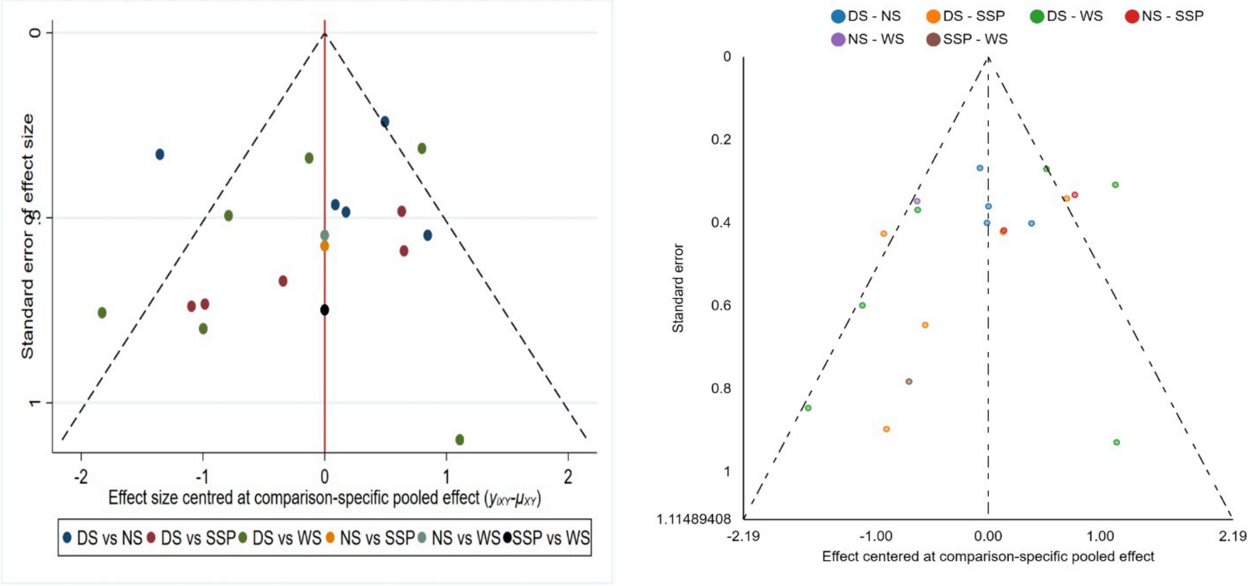


(A) Bayesian plot for diagnostic accuracy

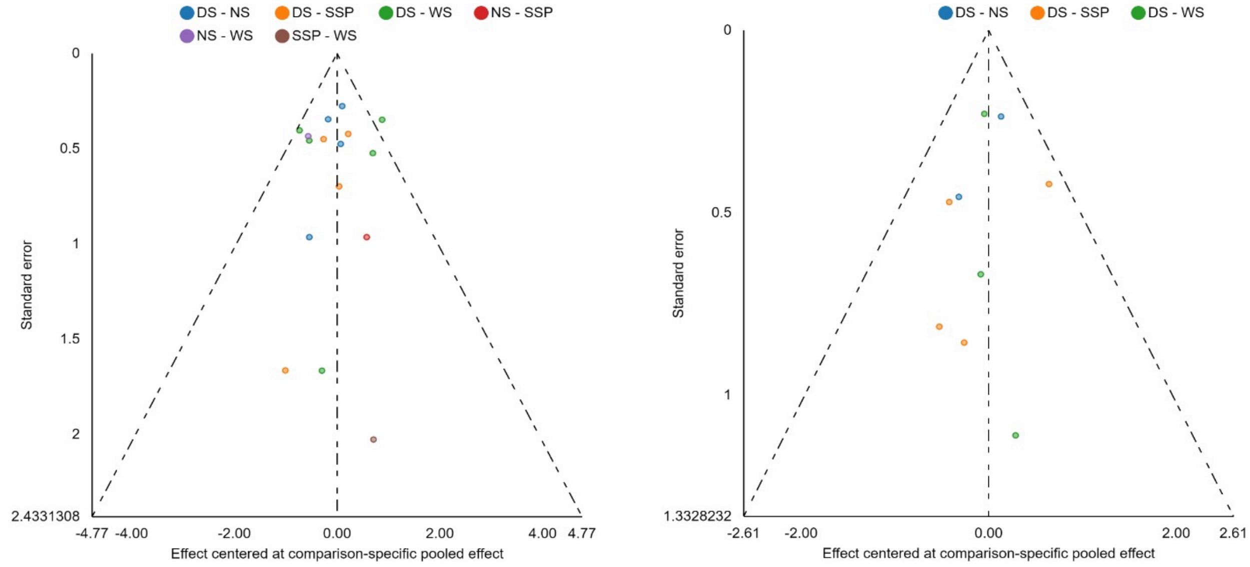
(B) Bayesian plot for diagnostic accuracy from meta-regression adjusted for FNB needle

(C) Bayesian plot for diagnostic accuracy from meta-regression adjusted for FNA needle

Supplementary Figure 9: Funnel plot for assessment of small study effect for various outcomes (9A) Sample adequacy, (9B) Moderate to high cellularity, (9C) Gross bloodiness, (9D) Diagnostic accuracy


9A: Sample adequacy

9B: Moderate to high cellularity


9C: Gross bloodiness

9D: Diagnostic accuracy

Supplementary material

Supplementary Table 6: Wald test for estimation of global inconsistency in networks of outcomes

Outcomes	Chi-square with degrees of freedom	P-value
Sample adequacy	chi^2 (6) = 3.48	0.747
Moderate to high cellularity	chi^2 (6) = 10.29	0.113
Gross bloodiness	chi^2 (6) = 4.01	0.674
Diagnostic accuracy	chi^2 (0) = 0.00	-

Supplementary Table 7: Summary of findings table with quality of evidence

	Direct OR	Confidence	Indirect OR	Confidence	NMA OR	Confidence
Sample adequacy						
DS – NS	1.48 (0.66 – 3.29)	Low[¶, §]	1.13 (0.07 – 18.91)	Low[¶, §]	1.45 (0.67 – 3.13)	Low[¶, Δ]
DS – SSP	0.99 (0.40 – 2.44)	Moderate[¶]	0.61 (0.03 – 10.71)	Low[¶, §]	0.94 (0.40 – 2.24)	Low[¶, Δ]
DS – WS	0.60 (0.27 – 1.35)	Low[¶, §]	1.29 (0.07 – 22.50)	Low[¶, §]	0.64 (0.29 – 1.39)	Low[¶, Δ]
NS – SSP	0.35 (0.05 – 2.48)	Low[¶, §]	0.86 (0.23 – 3.16)	Low[¶, §]	0.65 (0.22 – 1.93)	Low[¶, Δ]
NS – WS	1.55 (0.23 – 10.57)	Low[¶, §]	**0.26 (0.07 – 0.90)**	Low[¶, §]	0.44 (0.16 – 1.23)	Low[¶, Δ]
SSP – WS	0.48 (0.05 – 4.22)	Low[¶, §]	0.76 (0.21 – 7.88)	Low[¶, §]	0.67 (0.22 – 2.03)	Low[¶, Δ]
Moderate to high cellularity						
DS – NS	1.38 (0.66 – 2.89)	Moderate[¶]	2.10 (0.28 – 15.88)	Low[¶, §]	1.45 (0.73 – 2.90)	Low[¶, Δ]
DS – SSP	0.82 (0.39 – 1.73)	Low[¶, §]	0.11 (0.01 – 1.02)	Low[¶, §]	0.67 (0.33 – 1.72)	Low[¶, Δ]
DS – WS	0.64 (0.32 – 1.26)	Low[¶, §]	1.14 (0.11 – 11.36)	Low[¶, §]	0.67 (0.35 – 1.29)	Low[¶, Δ]
NS – SSP	0.28 (0.10 – 0.80)	Low[¶, §]	1.13 (0.28 – 4.57)	Low[¶, §]	0.46 (0.20 – 1.07)	Low[¶, Δ]
NS – WS	0.83 (0.19 – 3.60)	Low[¶, §]	0.33 (0.11 – 0.98)	Low[¶, §]	0.46 (0.19 – 1.03)	Low[¶, Δ]
SSP – WS	2.08 (0.26 – 16.56)	Low[¶, §]	0.84 (0.30 – 2.30)	Low[¶, §]	1.00 (0.40 – 2.47)	Low[¶, Δ]
Gross bloodiness						
DS – NS	1.97 (1.15 – 3.38)	Moderate[¶]	0.26 (0.02 – 2.90)	Low[¶, §]	**1.79 (1.06 – 3.03)**	Low[¶, §]
DS – SSP	1.09 (0.55 – 2.13)	Moderate[¶]	0.19 (0.00 – 12.98)	Low[¶, §]	1.04 (0.53 – 2.03)	Low[¶, Δ]
DS – WS	1.88 (1.11 – 3.20)	Low[¶, §]	2.12 (0.12 – 37.52)	Low[¶, §]	**1.89 (1.12 – 3.18)**	Low[¶, §]
NS – SSP	0.23 (0.02 – 2.39)	Low[¶, §]	0.66 (0.27 – 1.62)	Moderate[¶]	0.58(0.25 – 1.34)	Low[¶, Δ]
NS – WS	1.93 (0.65 – 5.70)	Low[¶, §]	0.70 (0.29 – 1.71)	Low[¶, §]	1.05 (0.53 – 2.10)	Low[¶, Δ]
SSP – WS	0.95 (0.02 – 53.06)	Low[¶, §]	1.87 (0.79 – 4.41)	Low[¶, §]	1.81 (0.78 – 4.20)	Low[¶, Δ]
Diagnostic accuracy						
DS – NS	0.96 (0.63 – 1.45)	Moderate[¶]	-	-	0.96 (0.63 – 1.45)	Very low[¶, Δ, ¥]
DS – SSP	1.06 (0.60 – 1.85)	Moderate[¶]	-	-	1.06 (0.60 – 1.85)	Very low[¶, Δ, ¥]
DS – WS	0.76 (0.50 – 1.16)	Moderate[¶]	-	-	0.76 (0.50 – 1.16)	Very low[¶, Δ, ¥]
NS – SSP	-	-	1.11 (0.55 – 2.22)	Moderate[¶]	1.11 (0.55 – 2.22)	Very low[¶, Δ, ¥]
NS – WS	-	-	0.79 (0.44 – 1.43)	Moderate[¶]	0.79 (0.44 – 1.43)	Very low[¶, Δ, ¥]
SSP – WS	-	-	0.72 (0.35 – 1.45)	Moderate[¶]	0.72 (0.35 – 1.45)	Very low[¶, Δ, ¥]

¶ risk of bias; Δ Imprecision; § Heterogeneity; ¥ Incoherence