ARTÍCULO ORIGINAL

Comparison between the different suction techniques for eus-guided tissue acquisition in pancreatic diseases and other gastrointestinal lesions: a systematic review and meta-analysis of randomized controlled trials

Comparación entre las diferentes técnicas de succión para la obtención ecoendoscópica de muestras en patología pancreática y otras lesiones gastrointestinales: una revisión sistemática y meta-análsis de estudios randomizados controlados

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ABSTRACT

Objectives: Endoscopic ultrasound–guided fine-needle aspiration/biopsy (EUS-FNA/B) is pivotal for diagnosing solid pancreatic lesions and other gastrointestinal (GI) masses. Multiple suction strategies are used to optimize tissue acquisition. Currently, their comparative performance remains uncertain. **Materials and methods:** We searched PubMed, Medline, Cochrane, and Ovid through July 2025 for English-language. RCTs comparing four suction methods during EUS-FNA/B of solid pancreatic or other GI lesions. Primary outcomes were specimen tissue adequacy and diagnostic accuracy. **Results:** Twenty-two RCTs encompassing 2,922 patients were included; pancreas was the sampled organ in 81% of cases, with the remainder primarily lymph nodes. Across 20 RCTs reporting adequacy, WS was associated with lower specimen adequacy than no suction (RR 0.88, 95% CI 0.77-0.99). WS likewise yielded lower diagnostic accuracy than no suction (RR 0.89, 95% CI 0.82-0.97). In head-to-head comparisons versus DS, differences among DS, SSP/capillarity, no suction, and WS were generally nonsignificant. Ranking analyses favoured no suction as the top performer and consistently placed WS lowest for both adequacy (p=0.92 vs 0.06, respectively) and accuracy (p=0.96 vs 0.04, respectively). In the needle-stratified analysis, results were concordant: with 22-G devices, WS showed lower adequacy (RR 0.86, 95% CI 0.74-0.99) and lower accuracy (RR 0.86, 95% CI 0.77-0.95) than with no suction. **Conclusions:** This meta-analysis suggests that wet suction may be associated with lower diagnostic yield and reduced tissue adequacy compared to no suction, especially with 22G needles. However, outside of these comparisons, no consistent differences were observed among the other techniques. Future comparative studies with standardized methodology and stricter control of confounding factors are needed.
Keywords: *Endoscopic Ultrasound-Guided Fine Needle Aspiration; Biopsy, Needle; Suction; Pancreatic Diseases; Gastrointestinal Diseases; Specimen Handling (source: MeSH NLM).*

RESUMEN

Objetivos: La biopsia por aspiración con aguja fina guiada por ultrasonido endoscópico constituye una herramienta fundamental para el diagnóstico de las lesiones sólidas pancreáticas y de otras masas del tracto gastrointestinal. Se han desarrollado diversas estrategias de succión con el objetivo de optimizar la obtención de tejido; sin embargo, su rendimiento comparativo aún no ha sido claramente establecido. **Materiales y métodos:** Se realizó una búsqueda sistemática en las bases de datos PubMed, MEDLINE, Cochrane Library y Ovid hasta julio de 2025, incluyendo ensayos clínicos aleatorizados (ECA) publicados en inglés que compararan cuatro técnicas de succión durante la biopsia por aspiración con aguja fina en lesiones sólidas pancreáticas u otras lesiones sólidas del tracto gastrointestinal. Los desenlaces primarios fueron la adecuación de la muestra tisular y el rendimiento diagnóstico. **Resultados:** Se incluyeron 22 ensayos controlados aleatorizados (ECA) que abarcaban a 2922 pacientes; el páncreas fue el órgano muestreado en el 81% de los casos, mientras que el resto correspondió principalmente a ganglios linfáticos. En los 20 estudios que informaron sobre la idoneidad, la técnica de succión húmeda (WS) se asoció con una menor idoneidad de la muestra en comparación con la ausencia de succión (RR: 0,88; IC del 95%: 0,77-0,99).

Asimismo, la succión húmeda arrojó una menor precisión diagnóstica que la ausencia de succión (RR: 0,89; IC del 95%: 0,82-0,97). En las comparaciones directas frente a la succión seca, las diferencias entre esta, la capilaridad, la ausencia de succión y la succión húmeda, fueron, por lo general, no significativas. Los análisis de clasificación situaron a la ausencia de succión como la técnica con mejor rendimiento y colocaron sistemáticamente a la succión húmeda en el último lugar, tanto en términos de idoneidad (p=0,92 frente a 0,06, respectivamente) como de precisión (p=0,96 frente a 0,04, respectivamente). En el análisis estratificado por tipo de aguja, los resultados fueron concordantes: con dispositivos de calibre 22G, la succión húmeda mostró una menor idoneidad (RR: 0,86; IC del 95%: 0,74-0,99) y una menor precisión (RR: 0,86; IC del 95%: 0,77-0,95) que la ausencia de succión. **Conclusiones:** Este metaanálisis sugiere que la aspiración húmeda podría asociarse con un menor rendimiento diagnóstico y una menor idoneidad de la muestra en comparación con la ausencia de aspiración, especialmente al utilizar agujas de calibre 22G. No obstante, al margen de estas comparaciones, no se observaron diferencias consistentes entre las demás técnicas. Se requieren futuros estudios comparativos con una metodología estandarizada y un control más riguroso de los factores de confusión.
Palabras clave: *Biopsia por Aspiración con Aguja Fina Guiada por Ultrasonido Endoscópico; Biopsia; Biopsia con Aguja; Succión; Enfermedades Pancreáticas; Enfermedades Gastrointestinales; Manejo de Especímenes (fuente: DeCS BIREME).*

INTRODUCTION

Endoscopic ultrasound-guided fine-needle aspiration (EUS-FNA) or biopsy (EUS-FNB) has become a fundamental part of the diagnostic process for solid pancreatic lesions and other intra-abdominal masses [1-3]. Nevertheless, the best aspiration technique remains debated, particularly in settings lacking rapid on-site cytopathological evaluation (ROSE) or when high-quality samples are required for molecular analyses [4,5]. A variety of aspiration methods, including dry suction (DS), wet suction (WS), stylet slow-pull (SSP), and modified versions such as heparinized WS, have been studied for their effects on tissue quality and diagnostic accuracy [6-8].

The choice of the technique can affect not only immediate diagnostic success but also the capacity to perform immunohistochemistry or genetic sequencing, which are vital in the era of personalized medicine [6,9]. Recent randomized trials have assessed these methods in various clinical contexts, using different needle types and procedural protocols, with or without ROSE [4,7,8]. However, heterogeneity in study designs and outcomes has resulted in inconsistent conclusions [2,5,7].

For these reasons, we performed a systematic review and meta-analyses of the different randomized controlled trials that include studies that compare the different EUS-guided suction techniques for tissue acquisition.

MATERIALS AND METHODS

Literature search and data selection criteria

We conducted a systematic review across various databases, such as PubMed, Cochrane, Medline, and OVID. A search was performed for all studies published up to July 2025. Only studies in English were considered. The following search terms were combined using Boolean operators: ("Endosonography"[Mesh] OR "endoscopic ultrasound" OR "EUS"), AND ("Biopsy, Fine-Needle"[Mesh] OR "fine needle aspiration" OR "FNA" OR "FNB"), AND ("Pancreatic Neoplasms"[Mesh] OR "solid pancreatic lesion" OR "pancreatic mass"), AND ("wet suction" OR "dry suction" OR "slow-pull" OR "heparinised suction" OR "stylet slow pull"), AND ("diagnostic accuracy" OR "sample adequacy" OR "cellularity" OR "blood contamination").

Those publications that reported the efficacy of only one technique or were not randomised controlled trials were excluded. Studies involving other techniques, review articles, meta-analyses, case reports, duplicates, redundant data, book chapters, editorials, commentaries, abstracts, non-relevant publications, or incomplete analyses were excluded from the present pooled data analysis (Figure 1). All reviewers fully agreed on the selection and analysis of the studies.

Statistic methods, ana data analysis and endpoints

The primary endpoints analyzed in this meta-analysis were specimen tissue adequacy and diagnostic accuracy based on the different suction techniques used during fine-needle aspiration or biopsy (FNA/FNB). The "specimen tissue adequacy" refers to the qualitative and quantitative sufficiency of the tissue obtained through EUS-FNA/B to allow for accurate cytological or histological interpretation, whereas the "diagnosis accuracy" represents the proportion of EUS-FNA/B procedures that achieve a correct diagnosis (benign or malignant).

Various suction methods were compared: dry suction, wet suction, capillary technique, and no suction. 1. Dry Suction (DS) involves applying negative pressure using a vacuum syringe (10-20 mL) in an air-filled needle lumen after removing the stylet. Wet Suction (WS) is a technique where the needle is flushed with saline or heparin to displace the air column before applying syringe suction, thereby improving vacuum transmission and tissue retrieval. The capillarity technique (or Slow-Pull) is a gentle aspiration method without syringe suction, where negative pressure is generated by slowly withdrawing the stylet while moving the needle within the lesion. The no suction technique entails puncturing without applying any negative pressure,

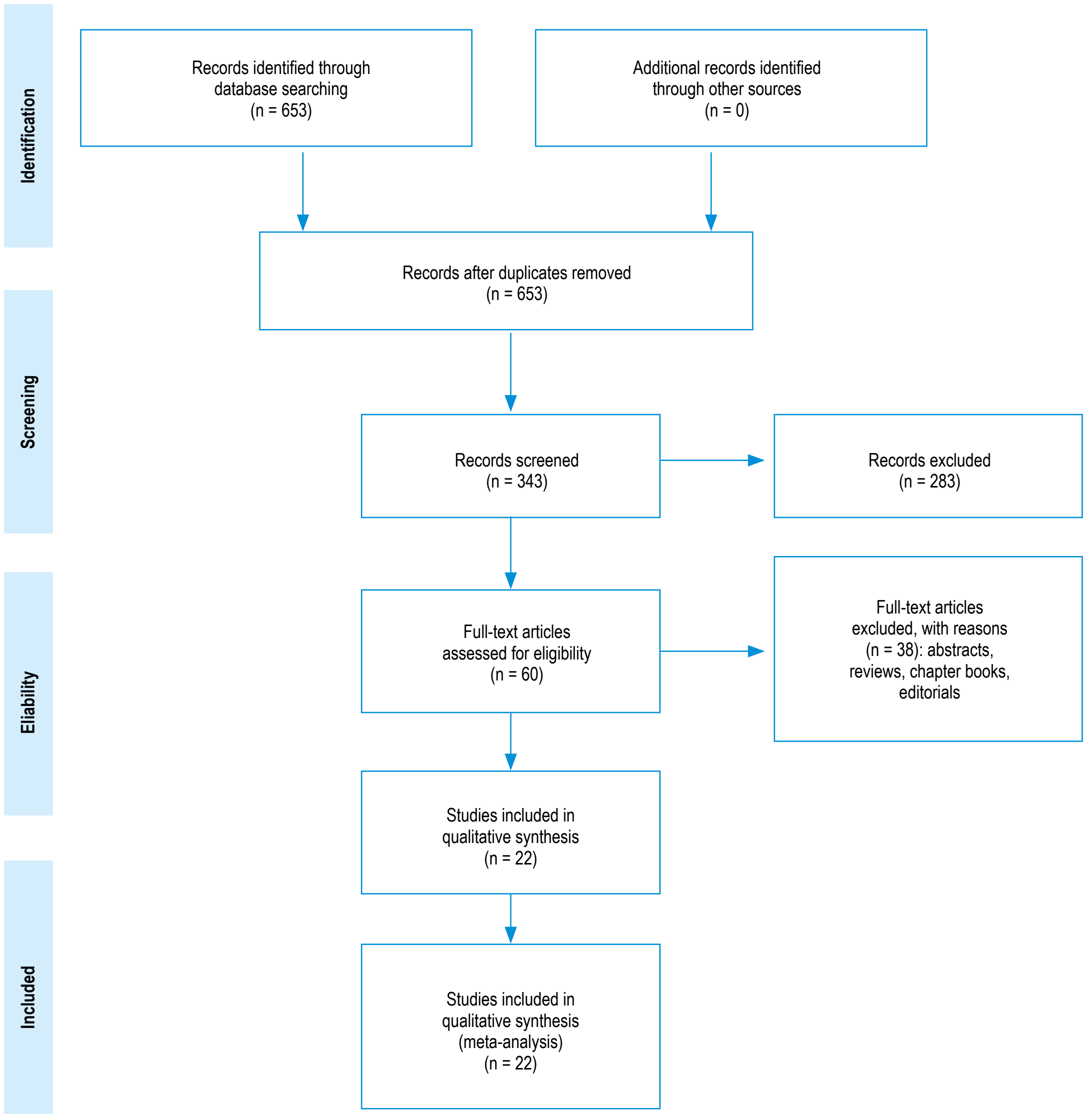

Figure 1. Flow diagram of study selection.

using only to-and-fro needle movements to allow tissue entry via capillary action, without removing the stylet or applying suction. Other factors such as needle type, number of passes, use of ROSE, and lesion location were also considered.

Data extraction

To confirm study eligibility, we reviewed the full texts of the 22 selected articles. To extract the chosen data, we designed a table for data extraction from each study. The main variables selected were: country, author, year of publication, study design, number of patients in each study, age and gender of the patients, localisation of the lesions, needle type used, presence of the ROSE, number of passes, the type of suction, the specimen tissue adequacy, and the accuracy of diagnosis.

Cinema assessment

We assessed the certainty of evidence for all outcomes using the CINeMA (Confidence in Network Meta-Analysis) framework, which is specifically designed for evaluating the credibility of findings from network meta-analyses. CINeMA considers six domains: within-study bias, reporting bias, indirectness, imprecision, heterogeneity, and incoherence. For each pairwise comparison within the network, we evaluated the contribution of direct and indirect evidence using the contribution matrix approach and then rated each domain accordingly. Risk of bias was judged at the study level using the Cochrane RoB approach and was incorporated into the within-study bias domain. The overall certainty of evidence for each comparison was classified as high, moderate, low, or very low.

Statistical analysis

We conducted a network meta-analysis using a frequentist framework to compare suction techniques: (i) dry suction, (ii) wet suction, (iii) capillarity, and (iv) no suction. We used a random-effects model with the inverse variance method for all meta-analyses. Effects on dichotomous outcomes were expressed as risk ratios (RR) with their 95% confidence intervals (CI). Transitivity was assessed by comparing characteristics of the study population and suction techniques between RCTs. Consistency between direct and indirect effects was assessed using the design-by-treatment interaction test for each overall network. Statistical heterogeneity was assessed using the I2 statistic and was defined as substantial if the I2 was greater than 60%. P-scores were used to assess the ranking between suction techniques for each outcome. In addition, we conducted a secondary analysis including the type of needle used in suction: (i) Capillarity 19g, (ii) Capillarity 22g, (iii) Dry suction 22g, (iv) Dry suction 25g, (v) No suction 22g, (vi) No suction 25g, and (vii) Wet suction 22g. The netmeta packages from R 4.4.2 (R Foundation for Statistical Computing, Vienna, Austria) was used for all meta-analyses. A two-tailed p-value < 0.05 was considered statistically significant.

RESULTS

Characteristics of included studies

In Figure 1, we described the search and selection process using a flow diagram. The initial search yielded a total of 653 articles, of which 22 studies [1-7,10-23] were selected and analysed. All the studies were randomised controlled trials. Six of the 22 studies were conducted in the USA [1,10,12,15,17,22], five in China [2,7,18,19,21], three in South Korea [4,13], two in Italy [5,16], one in India [11], one in Brazil [14], one in Portugal [20], one in Japan [3], one in Taiwan [6], and one in Mexico [23].

Characteristics of included studies

Table 1 lists the features and distribution of the twenty-two included studies [1-7,10-23]. All 22 studies included a total of 2922 patients. The studies were published from 2015 to 2025. All the studies were randomized controlled trials [1-7,10-23].

Demographic features

The mean age in all twenty-two studies was 62.1 ± 13,0 years. Of 2922 patients, 58.4% were male (1707 patients), and 41.6% were female (1215 patients). Pancreas was the most frequently punctured and studied organ (80.9%), followed by lymph node (14.6%), stomach (0.86%), liver (0.34%), and others (3.35%). The needle type most used in the different studies was the 22G-FNA (42.3%), followed by 22G-FNB (34.6%), 25G-FNA (11.54%), 20 G-FNB: 2 (7.69%) and 19 G-FNA: 1 (3.85%).

Specimen tissue adequacy

A total of 20 studies reported information on specimen tissue adequacy. The network structures for the different suction techniques are shown in Figure 2. The network meta-analysis showed that the specimen tissue adequacy was lower in wet suction group compared with no suction group (RR 0.88, 95% CI 0.77 - 0.99) (Table 2). Compared to the dry suction group, the effects of capillarity, no suction, and wet suction groups were similar (Figure 3). Treatment ranking analysis showed that no suction (p-score=0.92) and wet suction group (p-score=0.06) obtained the highest and lowest values in the analysis, respectively (Table 4).

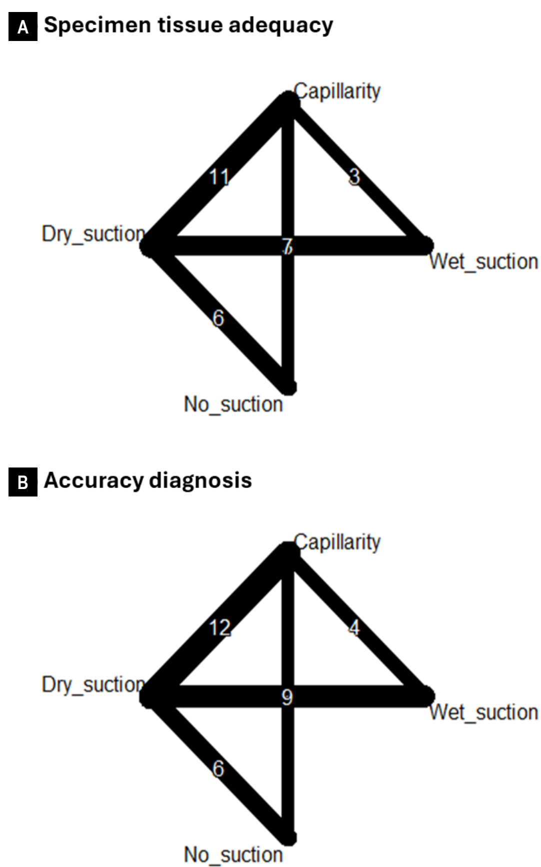

Figure 2. Network geometries for (A) specimen tissue adequacy and (B) accuracy diagnosis according to suction techniques.

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Table 1. Features of the different studies included.

	Country	Study design	Patients (n)	Sex M(%) /F(%)	Mean age (years) ± SD	Localization, n (%)	Needle Type	ROSE	Number of passes	Tyoe of suction (n)	Specimen tissue adequacy n (%)	Accuracy diagnosis
Attam et al 2015 (12)	USA	RCT Crossover	117	66 (56.4%) / 51 (43.6%)	60.5 ± 11.9	Pancreas, 63 (54%) Lymph node, 35 (30%) Liver, 10 (9%) Others, 9 (7%)	22G - FNA	Yes	2	Wet suction (117) Dry suction (117)	Wet suction, 100 (85.6%) Dry Suction, 88 (75.2%)	Wet suction, 100 (85.6%) Dry Suction, 88 (75.2%)
Bansal et al 2017 (13)	India	RCT Parallel	300	195 (65%) / 105 (35%)	52 ± 14	Pancreas, 65 (21.7%) Lymph node, 235 (78.3%)	19G - FNA 22G - FNA 25G - FNA	No	2	Capillarity (100) Dry suction (100) No suction (100)	Capillarity, 91 (91%) Dry suction, 91 (91%) No suction, 94 (94%)	Capillarity, 91 (91%) Dry suction, 91 (91%) No suction, 94 (94%)
Weston et al 2017 (14)	USA	RCT Parallel	60	35 (58.3%) / 25 (41.7%)	63 ± 13.6 (*)	Pancreas, 60 (100%)	22G - FNA 25G - FNA	Yes	4	Capillarity (30) Dry suction (30)	Capillarity, 19 (70.4%) Dry suction, 20 (69.0%)	Capillarity, 19 (70.4%) Dry suction, 20 (69.0%)
Saxena et al 2018 (1)	USA	RCT Parallel	121	70 (57.9%) / 51 (42.1%)	64.2 ± 13.8	Pancreas, 121 (100%)	22G - FNA	Yes	1 to 3	Capillarity (61) Dry suction (60)	Capillarity, 37 (60.6%) Dry suction, 28 (46.7%)	Capillarity, 49 (80.3%) Dry suction, 42 (70.0%)
Lee et al 2019 (15)	South Korea	RCT Crossover	50	27 (54%) / 23 (46%)	66.8 ± 12.6	Pancreas, 50 (100%)	22G - FNB	No	1	Capillarity (50) Dry suction (50) No suction (50)	Capillarity, 26 (52%) Dry suction, 17 (34%) No suction, 25 (50%)	Capillarity, 45 (90%) Dry suction, 40 (80%) No suction, 38 (76%)
Cheng et al 2019 (16)	Brazil	RCT Crossover	50	29 (58%) / 21 (42%)	63.9 ± 10.4	Pancreas, 50 (100%)	22G - FNA	No	2	Capillarity (50) Dry suction (50)	Capillarity, 40 (80.0%) Dry suction, 44 (88.0%)	Capillarity, 47 (93.0%) Dry suction, 48 (95.7%)
Bang et al 2018 (17)	USA	RCT Parallel	352	191 (54.3%) / 161 (45.7%)	68.3 ± 12.4	Pancreas, 352 (100%)	22G - FNA 25G - FNA	Yes	2.1	Dry suction 22G (88) No suction 22G (88) Dry suction 25G (88) No suction 25G (88)	Dry suction 22G, 63 (71.6%) No suction 22G, 71 (80.7%) Dry suction 25G, 64 (72.7%) No suction 25G, 59 (67.0%)	Dry suction 22G, 81 (92.0%) No suction 22G, 87 (98.9%) Dry suction 25G, 85 (96.6%) No suction 25G, 87 (98.9%)
Di Mitri et al 2020 (18)	Italy	RCT Parallel	110	49 (44.5%) / 61 (55.5%)	70.9 ± 11.3	Pancreas, 110 (100%)	20G - FNB	No	2 to 3	Capillarity (55) Dry suction (55)	Capillarity, 44 (80.0%) Dry suction, 41 (74.5%)	Capillarity, 53 (96.3%) Dry suction, 51 (92.7%)
Wang et al 2020 (2)	China	RCT Crossover	269	161 (59.9%), 108 (40.1%)	57.5 ± 11.1	Pancreas, 161 (59.9%) Lymph node, 108 (40.1%)	22G - FNA	No	2	Wet suction (269) Dry suction (269)	Wet suction, 255 (94.8%) Dry Suction, 212 (78.8%)	Wet suction, 228 (84.9%) Dry Suction, 197 (73.2%)
Bang et al 2021 (19)	USA	RCT Crossover	129	68 (56.6%) / 61 (43.4%)	68.4 ± 12.0	Pancreas, 129 (100%)	22G - FNB	No	1	Capillarity (129) Dry suction (129) No suction (129)	Capillarity, 119 (92.4%) Dry suction, 124 (96.2%) No suction, 102 (79.3%)	Capillarity, 111 (86.3%) Dry suction, 115 (89.4%) No suction, 94 (73.3%)
Tong et al 2021 (20)	China	RCT Crossover	50	34 (68%) / 16 (32%)	58.6±13.7	Pancreas, 50 (100%)	22G - FNB	No	2	Wet suction (108) Dry suction (108)	Wet suction, 80 (74.1%) Dry Suction, 61 (56.5%)	Wet suction, 90 (83.3%) Dry Suction, 84 (77.8%)
Zhou et al 2021 (21)	China	RCT Parallel	116	78 (67.2%), 38 (32.8%)	58.9±9.7	Pancreas, 116 (100%)	22G - FNB	No	5	Capillarity (56) Dry suction (60)	Capillarity, 44 (78.6%) Dry suction, 52 (86.7%)	Capillarity, 53 (94.6%) Dry suction, 57 (95.0%)
Costa Moreira et al 2021 (22)	Portugal	RCT Crossover	50	23 (46%) / 27 (54%)	65.5 ± 11.8	Pancreas, 50 (100%)	22G - FNB	No	2.3	Dry suction (50) No suction (50)	Dry suction, 39 (78%) No suction, 36 (72%)	Dry suction, 39 (78%) No suction, 36 (72%)
Takasumi et al 2021 (3)	Japan	RCT Crossover	26	16 (61.5%) / 10 (38.5%)	63.6±16.1	Esófago 1 (3.8%) Estómago 25 (96.2)	22G - FNA	No	2	Wet suction (26) Dry suction (26)	Wet suction, 16 (61.5%) Dry Suction, 20 (77.0%)	Wet suction, 12 (92.3%) Dry Suction, 11 (84.6%)
Paik et al (I) 2021 (4)	South Korea	RCT Parallel	193	124 (64.2%) / 69 (35.8%)	59.8±12.7	Pancreas, 193 (100%)	22G - FNA	No	3	Dry suction (94) No suction (99)	Dry suction, 199 (89.6%) No suction, 170 (71.7%)	Dry suction, 199 (89.6%) No suction, 170 (71.7%)
Paik et al (II) 2021 (4)	South Korea	RCT Parallel	48	21 (43.8%) / 27 (56.2%)	61.3 ± 10.2	Pancreas, 48 (100%)	22G - FNA	No	2	Capillarity (96) Dry suction (96)	Capillarity, 78 (81.3%) Dry suction, 89 (92.7%)	Capillarity, 50 (52.1%) Dry suction, 57 (59.4%)
Chen et al 2022 (23)	China	RCT Crossover	298	188 (63.1%) / 110 (36.9%)	60.6 ± 10.6	Pancreas, 226 (75.8%) Lymph node, 28 (9.4%) Others, 44 (14.8%)	22G - FNA	No	3	Capillarity (297) Wet suction (298) Dry suction (297)		Capillarity, 193 (65%) Wet suction, 222 (74.7%) Dry suction 192 (64.4%)
Mendoza Ladd et al 2022 (24)	USA	RCT Crossover	55	32 (58%) / 23 (42%)	66 ± 12.6	Pancreas, 55 (100%)	22G - FNB	No	3	Capillarity (52) Wet suction (46) Dry suction (49)	Capillarity, 15 (83.3%) Wet suction, 12 (70.6%) Dry suction 18 (90.0%)	Capillarity, 17 (94.4%) Wet suction, 16 (94.1%) Dry suction 19 (95.0%)
Lin et al 2023 (6)	Taiwan	RCT Crossover	50	32 (64%) / 18 (36%)	64.9 ± 9.7	Pancreas, 50 (100%)	20G - FNB	No	2	Wet suction (100) Dry suction (100)		Wet suction, 47 (94.0%) Dry Suction, 47 (94.0%)
Delgado et al 2023 (25)	México	RCT Crossover	75	39 (52.0%) / 36 (48.0%)	63 ± 4.3	Pancreas, 75 (100%)	22G - FNB	No	3	Capillarity (75) Wet suction (75) Dry suction (75)	Capillarity, 72 (96.0%) Wet suction, 65 (86.7%) Dry suction 68 (90.7%)	Capillarity, 72 (96.0%) Wet suction, 65 (86.7%) Dry suction 68 (90.7%)
Crino et al 2023 (5)	Italy	RCT Crossover	210	114 (54.3%) / 96 (45.7%)	65.9 ± 11.3	Pancreas, 146 (69.5%) Lymph node, 20 (9.5%) Others, 44 (21.0%)	22G - FNB	No	2	Capillarity (210) Wet suction (210)	Capillarity 129 (61.4%) Wet suction 150 (71.4%)	Capillarity, 183 (87.1%) Wet suction, 192 (91.4%)
Xu et al 2025 (7)	China	RCT Parallel	193	115 (59.6%) / 78 (40.4%)	61.52 ± 12.7	Pancreas, 193 (100%)	22G - FNB	No	3	Wet suction (97) Dry suction (96)	Wet suction, 96 (98.9%) Dry Suction, 95 (98.9%)	Wet suction, 94 (96.1%) Dry Suction, 94 (97.9%)

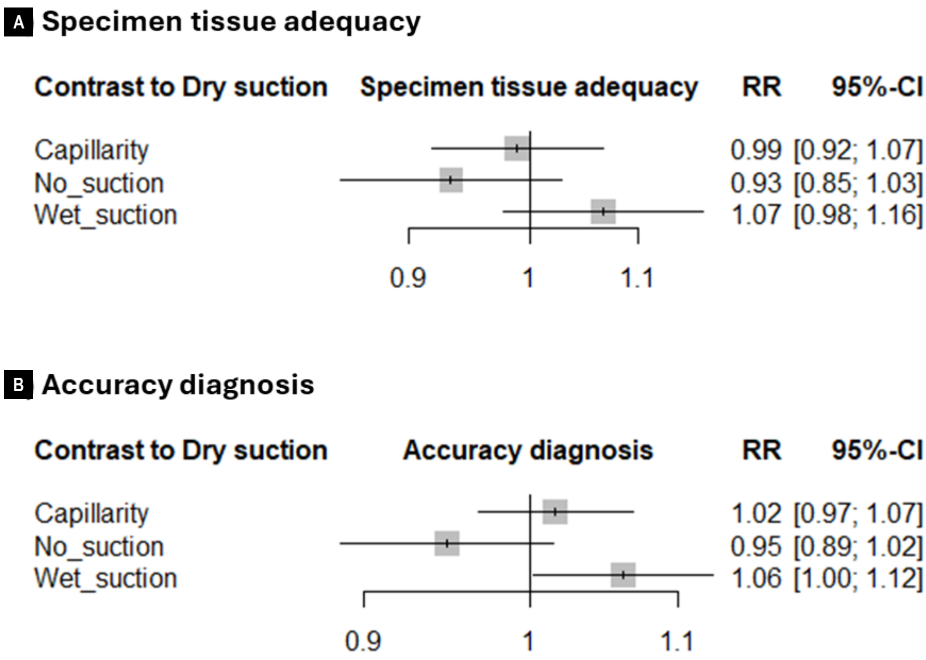

Figure 3. Effect of suction techniques on (**A**) specimen tissue adequacy and (**B**) accuracy diagnosis in comparison to dry suction. Abbreviations: RR, risk ratio; CI, confidence interval.

Accuracy diagnosis

A total of 22 studies reported information on accuracy diagnosis. The network meta-analysis showed that the accuracy diagnosis was significantly lower in wet suction group compared with no suction group (RR 0.89, 95% CI 0.82 - 0.97) (Table 3). Compared to the dry suction group, the effects of the other groups were similar (Figure 3). Treatment ranking analysis showed that no suction (p-score=0.96) and wet suction group (p-score=0.04) obtained the highest and lowest values in the analysis (Table 3). The network structures are shown in Figure 2.

Specimen tissue adequacy specifying the needle type

Twenty studies reported information on specimen tissue adequacy specifying the needle type. The network structures for the different suction techniques with the needle type are shown in Figure 4. The network meta-analysis showed that the specimen tissue adequacy was significantly lower in wet suction 22g group compared with no suction 22g group (RR 0.86, 95% CI 0.74 - 0.99) (Table 5). Compared to the dry suction group, the effects of capillarity, no suction, and wet suction groups were

Table 2. League table of the effects of suction techniques expressed as risk ratios with their 95% confidence intervals on specimen tissue adequacy.

Capillarity	0.99 (0.91 – 1.07)	1.06 (0.92 – 1.22)	0.99 (0.85 – 1.16)
0.99 (0.92 – 1.07)	Dry suction	1.07 (0.96 – 1.18)	0.94 (0.85 – 1.03)
1.06 (0.95 – 1.18)	1.07 (0.97 – 1.18)	No suction	-
0.93 (0.84 – 1.03)	0.94 (0.86 – 1.02)	0.88 (0.77 – 0.99)	Wet suction

Lower triangle: results from network meta-analysis (column vs row); Upper triangle: results from direct comparisons (row vs column). Effects in bold are statistically significant.

Table 3. League table of the effects of suction techniques expressed as risk ratios with their 95% confidence intervals on accuracy diagnosis.

Capillarity	1.01 (0.96 – 1.07)	1.08 (0.97 – 1.19)	0.97 (0.89 – 1.06)
1.02 (0.97 – 1.07)	Dry suction	1.06 (0.98 – 1.13)	0.94 (0.88 – 1.00)
1.07 (0.99 – 1.15)	1.05 (0.98 – 1.13)	No suction	-
0.96 (0.90 – 1.02)	0.94 (0.89 – 1.00)	0.89 (0.82 – 0.97)	Wet suction

Lower triangle: results from network meta-analysis (column vs row); Upper triangle: results from direct comparisons (row vs column). Effects in bold are statistically significant.

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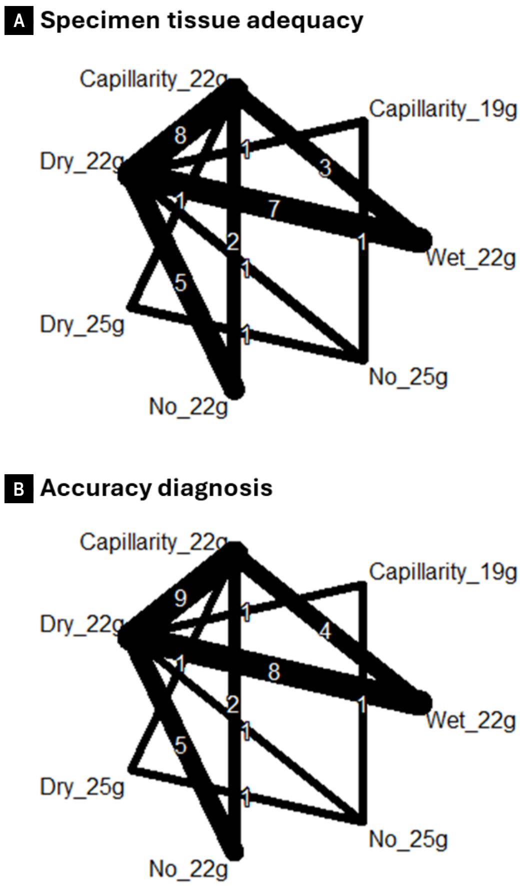

Figure 4. Network geometries for (**A**) specimen tissue adequacy and (**B**) accuracy diagnosis according to suction techniques specifying the needle type.

similar (Figure 5). Treatment ranking analysis showed that no suction 22g (p-score=0.87) and wet suction 22g (p-score=0.23) obtained the highest and lowest values in the analysis (Table 4).

Table 4. Raking of suction techniques per outcome according to p-scores.

Suction techniques	Specimen tissue adequacy	Accuracy diagnosis
No suction	0.92	0.96
Capillarity	0.56	0.40
Dry suction	0.46	0.59
Wet suction	0.06	0.04

Cells in green and red are the highest and lowest p-score values, respectively. A higher p-score means such a suction technique ranks better than others with lower p-scores for a given outcome.

Accuracy diagnosis specifying the needle type

Twenty-one studies reported information on accuracy diagnosis specifying the needle type. The network meta-analysis showed that the accuracy diagnosis was significantly lower in wet suction 22g group compared with no suction 22g group (RR 0.86, 95% CI 0.77 - 0.95) (Table 6). Compared to the dry suction 22g group, the effects of the other groups were similar (Figure 3). Treatment ranking analysis showed that no suction 22g (p-score=0.93) and wet suction 22g (p-score=0.19) obtained the highest and lowest values in the analysis, respectively (Table 3). The network structures are shown in Figure 2.

Figure 5 compares various suction and needle techniques against the reference standard of dry suction with a 22-gauge needle for two main outcomes: specimen tissue adequacy (Panel A) and diagnostic accuracy (Panel B). For specimen tissue adequacy, none of the alternative techniques demonstrated a statistically significant improvement over dry suction with a 22G needle. Relative risks (RR) ranged from 0.91 (95% CI: 0.81-1.03) for no suction with a 22G needle to 1.09 (95% CI: 0.83-1.43) for dry suction with a 25G needle.

For diagnostic accuracy, the results were similarly consistent across techniques, with RRs ranging from 0.91 (95% CI: 0.84-1.00) for no suction with a 22G needle to 1.07 (95% CI: 1.00-1.14) for wet suction with a 22G needle.

Table 5. League table of the effects of suction techniques specifying the needle type expressed as risk ratios with their 95% confidence intervals on specimen tissue adequacy.

Capillarity 19g	-	**1.00 (0.80 – 1.25)**	-	-	**0.97 (0.78 – 1.20)**	-
1.00 (0.80 – 1.26)	Capillarity 22g	0.98 (0.89 – 1.08)	0.95 (0.62 – 1.45)	1.14 (0.93 – 1.39)	-	0.99 (0.84 – 1.17)
0.99 (0.80 – 1.26)	0.99 (0.91 – 1.08)	Dry suction 22g	-	1.08 (0.96 – 1.22)	0.97 (0.78 – 1.20)	-
0.91 (0.67 – 1.24)	0.91 (0.69 – 1.20)	0.92 (0.70 – 1.21)	Dry suction 25g	-	1.08 (0.82 – 1.44)	-
1.09 (0.85 – 1.39)	1.09 (0.95 – 1.24)	1.09 (0.97 – 1.23)	1.19 (0.88 – 1.60)	No suction 22g	-	-
0.97 (0.79 – 1.21)	0.97 (0.78 – 1.20)	0.98 (0.80 – 1.20)	1.07 (0.84 – 1.36)	0.89 (0.71 – 1.13)	No suction 25g	-
0.93 (0.74 – 1.18)	0.93 (0.83 – 1.04)	0.94 (0.86 – 1.03)	1.02 (0.77 – 1.36)	0.86 (0.74 – 0.99)	0.96 (0.77 – 1.19)	Wet suction 22g

Lower triangle: results from network meta-analysis (column vs row); Upper triangle: results from direct comparisons (row vs column). Effects in bold are statistically significant.

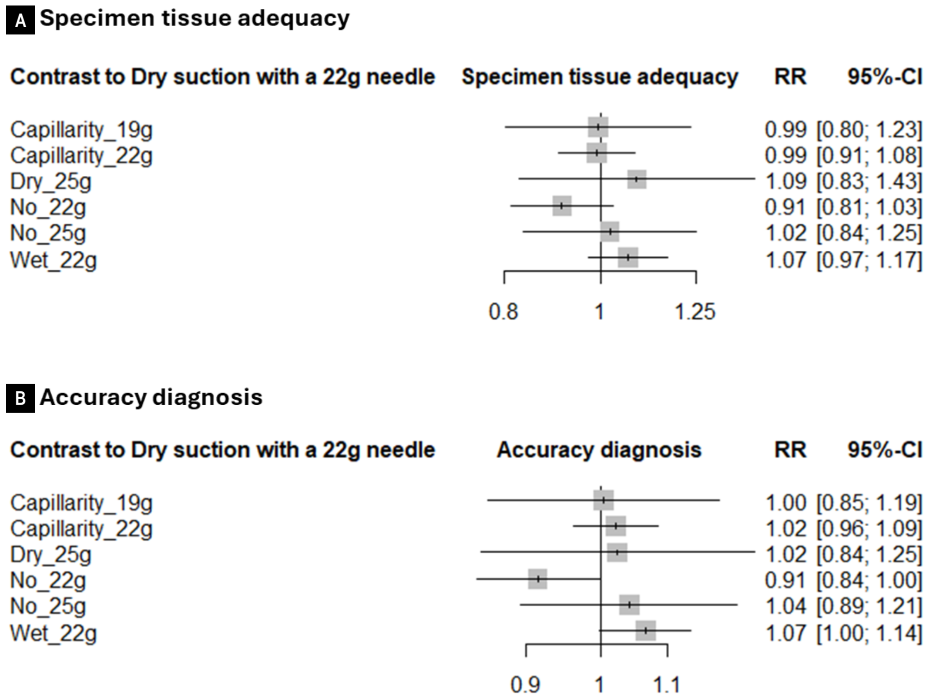

Figure 5. Effect of suction techniques specifying the needle type on (**A**) specimen tissue adequacy and (**B**) accuracy diagnosis in comparison to dry suction. Abbreviations: RR, risk ratio; CI, confidence interval.

While wet suction with a 22G needle approached statistical significance for higher diagnostic accuracy (lower bound of CI exactly at 1.00), the effect size remained modest, and the clinical relevance should be interpreted with caution.

When we analysed the ranking of suction techniques specifying the needle type per outcome according to p-scores, we observed that using a 22G needle without suction may optimise both tissue adequacy and diagnostic accuracy for EUS-guided sampling, while wet suction (22G) appears unfavourable. When suction is considered necessary, dry suction with 22G is a reasonable compromise, particularly if diagnostic accuracy is prioritized (Table 7).

Cinema assessment

Across all pairwise comparisons, the certainty of evidence was generally low to very low. For specimen tissue adequacy, certainty ranged from low to very low across comparisons, mainly driven by major concerns regarding heterogeneity, imprecision, and within-study bias. For diagnostic accuracy, the certainty of evidence was consistently low across all

Table 6. League table of the effects of suction techniques specifying the needle type expressed as risk ratios with their 95% confidence intervals on accuracy diagnosis.

Capillarity 19g	-	**1.00 (0.84 – 1.18)**	-	-	**0.97 (0.82 – 1.14)**	-
0.98 (0.82 – 1.17)	Capillarity 22g	1.01 (0.95 – 1.08)	0.95 (0.64 – 1.42)	1.18 (1.02 – 1.37)	-	0.97 (0.88 – 1.07)
1.00 (0.85 – 1.19)	1.02 (0.96 – 1.09)	Dry suction 22g	-	1.09 (0.99 – 1.19)	0.97 (0.82 – 1.14)	0.94 (0.87 – 1.01)
0.98 (0.79 – 1.21)	1.00 (0.82 – 1.22)	0.98 (0.80 – 1.19)	Dry suction 25g	-	0.98 (0.84 – 1.14)	-
1.10 (0.91 – 1.32)	1.12 (1.01 – 1.23)	1.09 (1.00 – 1.19)	1.12 (0.91 – 1.39)	No suction 22g	-	-
0.96 (0.82 – 1.13)	0.98 (0.83 – 1.15)	0.96 (0.82 – 1.12)	0.98 (0.85 – 1.14)	0.88 (0.74 – 1.05)	No suction 25g	-
0.94 (0.79 – 1.13)	0.96 (0.89 – 1.03)	0.94 (0.88 – 1.00)	0.96 (0.78 – 1.18)	0.86 (0.77 – 0.95)	0.98 (0.83 – 1.15)	Wet suction 22g

Lower triangle: results from network meta-analysis (column vs row); Upper triangle: results from direct comparisons (row vs column). Effects in bold are statistically significant.

Table 7. Ranking of suction techniques specifying the needle type per outcome according to p-scores.

Suction techniques with the needle type	Specimen tissue adequacy	Accuracy diagnosis
Capillarity 19g	0.55	0.45
Capillarity 22g	0.57	0.44
Dry suction 22g	0.53	0.59
Dry suction 25g	0.28	0.45
No suction 22g	0.87	0.93
No suction 25g	0.45	0.36
Wet suction 22g	0.23	0.19

Cells in green and red are the highest and lowest p-score values, respectively. A higher p-score means such a suction technique ranks better than others with lower p-scores for a given outcome.

comparisons. All included studies were judged to have some concerns regarding risk of bias, while heterogeneity was moderate across the network ($I^2 \approx 58\%$). No important incoherence was detected between direct and indirect evidence. Indirectness was not considered a major concern for most comparisons due to clinical and methodological similarity across studies; however, the network structure and reliance on indirect evidence contributed to downgrading in several comparisons. Detailed CINeMA assessments for each outcome and comparison are provided in the Supplementary Appendix.

DISCUSSION

The present meta-analysis synthesized randomized controlled trials comparing various suction techniques: dry suction (DS), wet suction (WS), stylet slow-pull (SSP), and modifications such as heparinized WS, for endoscopic ultrasound-guided fine-needle aspiration or biopsy (EUS-FNA/B) in solid pancreatic and other gastrointestinal lesions. Across pooled data, no single suction method demonstrated unequivocal superiority in diagnostic accuracy, although certain approaches showed advantages in secondary outcomes such as tissue integrity and reduced blood contamination. These findings provide a nuanced perspective, aligning partially but not entirely with previous literature.

When examining DS versus WS, our analysis found comparable diagnostic accuracy, consistent with the recent large multicenter noninferiority trial by Xu *et al*. in 2025 [7], which demonstrated diagnostic accuracy of 97.9% for DS and 96.9% for WS, with no statistically significant difference. These authors also reported no differences in sample adequacy or blood contamination between the two methods, although WS required additional procedural steps. The similarity in diagnostic performance between DS and WS observed in both our pooled analysis and the study of Xu *et al*, this suggests that choice between these techniques may be guided more by operator preference, equipment availability, and workflow considerations rather than inherent diagnostic advantage.

However, some individual studies have highlighted qualitative benefits of WS over DS. Lin *et al*. in 2022 [6] showed that heparinized WS yielded significantly longer aggregated white tissue length and less blood contamination compared with DS. On the other hand, Chen *et al*. [21], found that WS produced better tissue integrity and higher cellularity compared to DS, though overall specimen quality scores were only modestly higher.

Table 8. CINeMA assessment of certainty of evidence for pairwise comparisons of specimen tissue adequacy.

Comparison	Within-study bias	Indirectness	Imprecision	Heterogeneity	Incoherence	Overall rating
Capillarity vs Dry suction	Some concerns	No concerns	Some concerns	Major concerns	No/Some concerns	Low
Dry suction vs Wet suction	Some concerns	No concerns	Some concerns	Major concerns	Some concerns	Low
Dry suction vs No suction	Some concerns	No concerns	Some concerns	Major concerns	Some concerns	Low
Capillarity vs No suction	Some concerns	Some concerns	Some concerns	Major concerns	Major concerns	Very low
Capillarity vs Wet suction	Some concerns	Some concerns	Some concerns	Major concerns	Major concerns	Very low
No suction vs Wet suction	Some concerns	Major concerns	Some concerns	Major concerns	Major concerns	Very low

Table 9. CINeMA assessment of certainty of evidence for pairwise comparisons of accuracy diagnosis.

Comparison	Within-study bias	Indirectness	Imprecision	Heterogeneity	Incoherence	Overall rating
Capillarity vs Dry suction	Some concerns	No concerns	Some concerns	Moderate	No concerns	Low
Capillarity vs No suction	Some concerns	No concerns	Some concerns	Moderate	No concerns	Low
Capillarity vs Wet suction	Some concerns	No concerns	Some concerns	Moderate	No concerns	Low
Dry suction vs No suction	Some concerns	No concerns	Some concerns	Moderate	No concerns	Low
Dry suction vs Wet suction	Some concerns	No concerns	Some concerns	Moderate	No concerns	Low
No suction vs Wet suction	Some concerns	No concerns	Some concerns	Moderate	No concerns	Low

The slow-pull (SSP) technique itself has been variably reported in the literature. Our pooled results did not show significant superiority of SSP over DS or WS in diagnostic accuracy, which is consistent with the crossover trial by Crinò *et al.* [5]. In their multicenter study comparing WS and SSP for EUS-FNB, both techniques achieved similarly high rates of adequate samples and tissue integrity, with lower specimen bloodiness compared to historical DS data. The technical review of the European Society of Gastrointestinal Endoscopy (ESGE) in 2025 also supports this equivalence, recommending either WS or SSP over DS to optimize tissue quality while minimizing blood contamination [9]. In contrast, Palk *et al.* [4] observed no significant difference in diagnostic yield between suction and capillary sampling with stylet slow-pull when using 15 needle actuations. Their findings, performed in centers without rapid on-site cytopathology, suggest that in resource-limited settings, both methods can achieve high diagnostic yield if optimal actuation parameters are employed.

The only quantitative finding that reached statistical significance was a slight advantage of no suction over wet suction for diagnostic accuracy (RR DS vs NS 0.957; 95% CI 0.924-0.991). However, this result should be considered fragile because there are no studies that directly compare them. Consequently, the result is suggestive, not conclusive.

Regarding the role of needle type and design, Mendoza Ladd *et al.* [22] found no differences in cellularity, blood contamination, or number of passes required among DS, WS, and SSP when using two different 22G FNB needle designs. Delgado Cortes *et al.* [23] reported that WS achieved higher tissue integrity scores for lesions in the body and tail of the pancreas, whereas no differences were observed among techniques for head or uncinate lesions. Our pooled data did not show a statistically significant interaction between lesion location and suction method, possibly due to fewer location-specific subgroup analyses across included trials. Nonetheless, this anatomical variation warrants further study, as differences in needle trajectory, lesion mobility, and surrounding vascularity may alter the balance between yield and contamination.

From a network meta-analysis perspective, the systematic review and network meta-analysis by Giri *et al.* [8] ranked WS as the best modality across outcomes such as sample adequacy, cellularity, and reduced blood contamination. However, no technique showed clear superiority in diagnostic accuracy. Their conclusion of low confidence in effect estimates parallels the moderate heterogeneity and wide confidence intervals encountered in our own analyses. This reinforces the current evidence gap: while WS often scores highest in surrogate quality measures, these advantages have not consistently translated into higher diagnostic yields in RCTs.

Heparinized WS, as studied by Lin *et al.* [6], represents a promising refinement, potentially offering synergistic benefits of improved vacuum transmission and anticoagulant effects. Although data were still limited, the reduced blood contamination and longer tissue cores observed in this trial suggest a role for this technique in scenarios prioritising histomolecular testing. Whether these histological gains justify the additional preparation steps remains a matter for cost-effectiveness analyses. It is also noteworthy that most of the included RCTs, both in our meta-analysis and in the broader literature, were not powered primarily for diagnostic accuracy differences but rather for specimen quality endpoints. Xu *et al.* [7] is an exception, with diagnostic accuracy as its primary endpoint, yet even in this robustly powered setting, DS and WS were equivalent.

Our findings, when interpreted alongside prior evidence, suggest several practical implications. First, in settings where molecular profiling is a key clinical goal, WS, particularly heparinized, may be advantageous for maximizing core length and DNA yield [6]. Second, in scenarios without ROSE, either WS or SSP can be used to maintain high tissue adequacy with potentially less blood contamination than DS [5,21]. Third, lesion location and needle type should be considered in technique selection, as emerging data hint at interaction effects [22,23].

The limitations of the current evidence base include heterogeneity in outcome definitions (e.g., cellularity

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scoring systems), variable use of FNA versus FNB needles, and differences in operator experience and procedural protocols. Some key comparisons relied on only a few studies, and the uneven distribution of needle type, ROSE availability, lesion location, and number of needle passes across trials may have compromised the transitivity assumption and contributed to the observed between-study heterogeneity. Because these study-level characteristics were inconsistently reported and the number of studies per comparison was limited, formal subgroup analyses or meta-regression to explore potential sources of heterogeneity were not feasible. Furthermore, most trials were conducted in high-volume centres with expert endoscopists, which may limit the generalizability of our findings to lower-volume or training settings. Future research should focus on adequately powered, multicentre randomized trials with standardized histological quality metrics and reporting of procedural characteristics, enabling a more robust assessment of the impact of needle type, ROSE use, lesion location, and number of passes on clinical outcomes. Comparative cost-effectiveness analyses, particularly in relation to molecular testing needs, are also warranted.

In conclusion, this meta-analysis suggests that wet suction may be associated with lower diagnostic yield and reduced tissue adequacy compared to no suction, especially with 22G needles. However, outside of these comparisons, no consistent differences were observed among the other techniques. Future comparative studies with standardized methodology and stricter control of confounding factors are needed.

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