

# Comparison of Franseen and fork-tip needles for EUS-guided fine-needle biopsy of solid mass lesions: A systematic review and meta-analysis

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## ABSTRACT

Franseen-tip and Fork-tip needles have been widely used in EUS guided fine-needle biopsy (FNB) of solid organs. There is conflicting data on the performance of these needles and unanswered questions on the ideal number of needle-passes and the requirement of an onsite cytopathologist (ROSE). We conducted a comprehensive search of multiple electronic databases and conference proceedings including PubMed, EMBASE, and Web of Science databases (from inception through July 2018) to identify studies that reported on the use of Forktip and Franseen-tip needles in EUS-FNB of solid organs. The primary outcome was to estimate and compare the pooled rates of diagnostic-yield. A subgroup analysis compared the outcomes based on the number of needle-passes and the availability of ROSE. A total of 23 study-arms were available for analysis. The pooled rate of diagnostic yield with Fork-tip needle was 92.8% (95% CI 85.3 - 96.6,  $I^2 = 73.1$ ) and the pooled rate of diagnostic yield with Franseen-tip needle was 92.7% (95% CI 86.4 - 96.2,  $I^2 = 88.4$ ).

**Key words:** Fine-needle biopsy, fork-tip needle, Franseen-tip needle, rapid onsite evaluation

## INTRODUCTION


Multiple different fine-needle biopsy (FNB) needles have been released for commercial use in the past several years. These devices are designed primarily to obtain core tissue samples under EUS guidance.

The Franseen-tip needle (Acquire; Boston Scientific, Natick, MA, USA) and the Fork-tip needle (SharkCore;

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Medtronic Corporation, Newton, Mass and Covidien, Dublin, Ireland) are designed to get larger tissue samples. The Franseen design has a tip with three symmetric cutting edges designed to get deep into the tissue and obtain ample tissue volume due to its large crown-tip area. The Fork-tip needle has a second sharp tip on the opposite side of the lumen giving it six asymmetric cutting surfaces to aid in tissue capture [Figure 1].

Two recently published studies have compared, head-to-head, the tissue adequacy and the diagnostic yield with these needles, with varying results. Bang *et al.*,<sup>[1]</sup> in their randomized study, reported comparable performance of both needles. Abdelfatah *et al.*<sup>[2]</sup> did a retrospective cohort study and reported better diagnostic yields with Fork-tip needle as compared to that of the Franseen-tip needle.

There are questions unanswered on the need for rapid onsite evaluation (ROSE) by a cytopathologist when using FNB needles, and on the ideal number of needle-passes in EUS-FNB, especially with these newer needles. We, therefore, conducted this meta-analysis to evaluate and compare the overall performance of the Franseen-tip and the Fork-tip needles in EUS-FNB of all solid mass lesions (pancreatic masses, lymph nodes of the gastrointestinal (GI) tract, submucosal lesion, hepatobiliary masses, and other unclassified masses) accessible through EUS.

## METHODS

### *Search strategy*

We conducted a comprehensive search of several databases and conference proceedings, including PubMed, EMBASE, and Web of Science databases (earliest inception to July 2018). We followed the Preferred Reporting items for Systematic Reviews and Meta-Analyses guidelines,<sup>[3]</sup> by using the predefined protocol, to identify studies reporting the use of



**Figure 1.** Franseen and Fork-tip needles

Franseen-tip FNB needle and/or Fork-tip FNB needle. An experienced medical librarian using inputs from the study authors helped with the literature search.

Key words used in search included a combination of “EUS-guided biopsy,” “EUS core biopsy,” “Franseen needle,” “Fork-tip needle,” “SharkCore,” and “Acquire needle.” The search was restricted to studies in human subjects and published in the English language in peer-reviewed journals. Three authors (M.B., S.M., G.R.) independently reviewed the title and abstract of studies identified in primary search and excluded studies that did not address the research question, based on pre-specified exclusion and inclusion criteria. The full text of the remaining articles was reviewed to determine whether it contained relevant information. Any discrepancy in article selection was resolved by consensus and in discussion with a co-author.

The bibliographic section of the selected articles as well as the systematic and narrative articles on the topic was manually searched for additional relevant articles.

### *Study selection*

In this meta-analysis, we included studies that met the following criteria: (1) EUS-FNB with the use of Franseen-tip or acquire needle for solid organ biopsy of the GI tract, (2) EUS-FNB with Fork-tip or Sharkcore needle in the biopsy of solid organs of the GI tract, and (3) studies reporting diagnostic yield data with either of these needles. Studies irrespective of the study design, irrespective of the needle type used in the control group, irrespective of the reason for biopsy, organ site of biopsy, needle size (22G, 25G, and 19G), presence or absence of ROSE, geography, and abstract/manuscript status, were included as long as they provided data needed for the analysis.

Following were our exclusion criteria: (1) studies that reported the use of these needles in non-GI organs, (2) studies that reported biopsy of cystic lesions, (3) studies that reported exclusively on liver lesions, (4) studies that reported their results as sensitivity and/or specificity of the needle and/or the EUS-FNB procedure, without information on actual number of successful diagnoses made, and (5) studies that reported their results as risk-ratio and/or Odds ratio without information on actual number of successful diagnosis made.

In the case of multiple publications from the same cohort, data from the most recent and/or most appropriate comprehensive report were included. In our search process, we encountered one such study by Naveed *et al.*<sup>[4]</sup>

#### *Data abstraction and quality assessment*

Data on study-related outcomes in the individual studies were abstracted onto a standardized form by at least two authors (M.B., S.M.) independently, and four authors (M.B., S.M., G.R., A.R.) did the quality scoring independently.

In the situation of randomized trials, retrospective case-control studies and cohort studies, the data collection was done as a number of reported events (*n*) out of a total number of patients (*N*) from each study. The collected data were treated akin to cohort studies, and therefore, we used a scale modified from the Newcastle-Ottawa scale for cohort studies to assess the quality of studies.<sup>[5]</sup> This quality score consisted of seven questions: Representative of the average adult in the community (1 point for population-based studies, 0.5 point for multi-center studies, 0 point for a single-center hospital-based study); large cohort size (1 point if >30 patients, 0.5 point if between 15 and 30 patients, 0 point if <15 patients); information on diagnostic yield (1 point if reported, 0.5 point if not reported and had to be derived, 0 point if not reported); information on pathology assessment of sample (1 point if ROSE information reported, 0.5 point if information reported with limited clarity, 0 point if not reported); information on adverse-events (1 point if reported, 0 point if not reported); type of article write-up (1 point if original manuscript, 0.5 point if abstract); attrition rate (1 point if all patients were accounted for, 0.5 point if <50% of patients lost to follow-up, 0 point if >50% of patients lost to follow-up). A score of ≥6, 4–5, and ≤3 was considered suggestive of high-quality, medium-quality, and low-quality study.

#### *Outcomes assessed*

The primary analysis focused on calculating and comparing the pooled rates of diagnostic yield with Fork-tip and Franseen-tip needles in EUS-FNB. Subgroup analyses were performed based on the use of ROSE and based on the number of needle-passes.

The secondary analysis focused on calculating and comparing the pooled rates of reported adverse-events with these two needles.

#### *Statistical analysis*

We used meta-analysis techniques to calculate the pooled estimates in each case following the methods suggested by DerSimonian and Laird using the random effects model and our application can be seen to fit within their general approach (where the effect is measured by the probability of risk).<sup>[6]</sup> When the incidence of an outcome was zero in a study, a correction of 0.5 was added to the number of incident cases before statistical analysis.<sup>[7]</sup> We assessed heterogeneity between study-specific estimates by using two methods.<sup>[8,9]</sup> First, the Cochran's Q statistical test for heterogeneity, which tests the null hypothesis that all studies in a meta-analysis have the same underlying magnitude of the effect, was done.<sup>[10]</sup> Second, when heterogeneity was present, in order to estimate what proportion of total variances across studies was due to heterogeneity rather than chance, the *I*<sup>2</sup> statistic was calculated. In this, values of <30%, 30%–60%, 61%–75%, and >75% were suggestive of low, moderate, substantial, and considerable heterogeneity, respectively.<sup>[11]</sup> Since the random effects model estimates an average effect, we also calculated the 95% prediction interval, which deals with the dispersion of the effects.<sup>[12,13]</sup> This helps us to analyze the effect in actual individual setting. Publication bias was ascertained, qualitatively, by visual inspection of funnel plot and quantitatively, by the Egger test.<sup>[14]</sup> When publication bias was present, further statistics using the fail-safe N test and Duval and Tweedie's trim and fill test was used to ascertain the impact of the bias.<sup>[15]</sup> Three levels of impact were reported based on the concordance between the reported results and the actual estimate if there were no bias. The impact was reported as minimal if both versions were estimated to be same, modest if effect size changed substantially, but the final finding would still remain the same, and severe if basic final conclusion of the analysis is threatened by the bias.<sup>[16]</sup>

All analyses were performed by using comprehensive meta-analysis software, version 3 (BioStat, Englewood, NJ, USA).

## **RESULTS**

#### *Search results and population characteristics*

From an initial total of 125 citations identified by using our search strategy, our screening resulted in 56 relevant records. Twenty-five full-text studies were assessed for eligibility. Three studies were excluded due to insufficient information, and one study was

removed due to overlapping cohorts. Twenty-one studies (1632 patients) were included in the final analysis.<sup>[1,2,4,17-34]</sup>

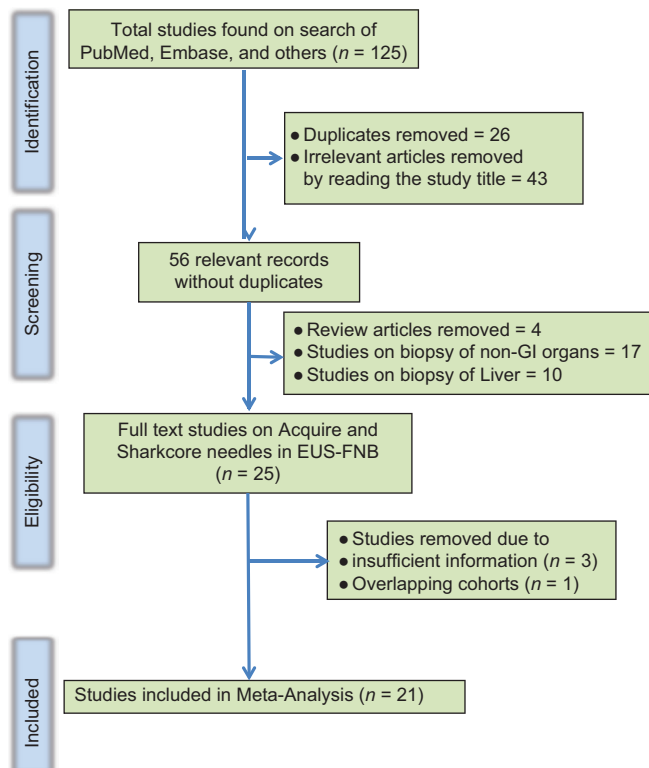
The schematic diagram of the study selection is illustrated in Figure 2.

The data collected for Fork-tip and Franseen-tip needle, from individual studies, was treated as cohort reports for the purpose of this analysis. Studies done by Bang *et al.*<sup>[1]</sup> and Abdelfatah *et al.*<sup>[2]</sup> had one arm each for Franseen-tip and Fork-tip, giving a total of 23 study-arms for our analysis.

The mean and/or median age was between 16 years to 89 years, with predominantly male population (range 45%–70%). The median number of needle pass was 1–4 and was similar in Fork-tip and Franseen-tip groups. Five studies had  $\leq 2$  needle-passes done on all of their study patients.<sup>[1,21,23,25,28]</sup> Majority of EUS-FNB was done for solid pancreatic masses (1041 cases), followed by lymph nodes of the GI tract (217), submucosal lesions (145), hepatobiliary masses (76), and others (54). Table 1 summarizes the population characteristics.

### Characteristics and quality of included studies

Table 1 describes the characteristics of the included studies.



**Figure 2.** Study flow and selection. GI: gastrointestinal, EUS-FNB: EUS guided fine-needle biopsy

None of the studies were population based. Four studies were from multicenter data.<sup>[4,17,22,27]</sup> All studies except three<sup>[18,23,31]</sup> had a cohort size of more than 30 patients. All studies reported clear data on the diagnostic yield except one,<sup>[19]</sup> where the data were obtained directly from the primary study author. Four studies<sup>[25,28,30,31]</sup> had no information on ROSE, another four studies<sup>[2,24,26,34]</sup> were not specific about the use of ROSE, whereas 13 studies<sup>[1,4,17-23,27,29,32,33]</sup> mentioned clearly if ROSE was used or not, and if used what percentage of the study population, it was utilized in. Six studies did not report on adverse events.<sup>[2,18,25,28,31,34]</sup> Six studies<sup>[19,25,28,31,33,34]</sup> were abstracts and rest were original manuscripts. None of the studies had patients lost to follow-up. Overall, 9 studies<sup>[1,4,17,20-22,27,29,32]</sup> were considered of high quality, 11<sup>[2,18,19,23-26,28,30,33,34]</sup> were of medium quality and one<sup>[31]</sup> was considered low quality.

### Fine-needle biopsy definition and technique

FNB was defined as the performance of needle-passes to obtain intact core tissue. The acquired tissue was then prepared for pathologic analysis. The specimens were placed on formalin, embedded into paraffin, and sectioned for standard staining per pathology protocol. For cell-blocks, the specimen was first preserved in methanol, then centrifuged and decanted before placing in formalin. The specimen was either touch-imprinted or gently rolled to create a smear and then air dried for ROSE. The majority of studies reported a positive diagnostic yield based on a benign or malignant diagnosis; designations of atypical or suspicious were considered nondiagnostic. Some studies reported a positive diagnostic yield only if the final diagnosis was positive for malignancy. The most common Fork-tip needle used was a 22G, followed by 25G and rarely 19G. The Franseen-tip needle used was a 22G in all reported cases.

In the studies analyzed, the most common methodology of the biopsy was to use a curvilinear array echoendoscope and to do a color Doppler before tissue sampling, to confirm the absence of intervening vessels. Patients were either under sedation (moderate-to-deep) in the majority of studies or under general anesthesia in some studies. Tissue sampling was achieved by the slow-pull technique, whereby the stylet is slowly withdrawn to a distance of 6–12 inches during needle actuations. Sometimes, this can result in more blood than actual tissue. In some studies, the wet-suction technique was employed where the air column in the lumen is replaced with saline for better tissue quality. This was then followed by the application of negative pressure during which additional actuations were done with or

**Table 1. Study and population characteristics**

Study	Year	Study design	Total (n)	Diag yield	Needle passes	ROSE	Age	Male (%)	Adverse events	Gauge	Quality
<b>Franseen-tip needle</b>											
Bang JY <i>et al.</i>	2018	RT	50	47	2	50	71.5	56	0	22	High
Abdelfatah MM <i>et al.</i>	2018	Retro	97	61	3.56±1.06	NR	63.7±10.8	47	NR	22	Medium
Hajj IIE <i>et al.</i>	2018	Retro	50	48	2.88	NR	NR	NR	2 bleeding, 2 pain	22	Medium
Bang JY <i>et al.</i>	2017	Retro	30	29	1.5±1.2	28	Median 71.5	70	1 bleeding	22	High
Mukai S <i>et al.</i>	2017	Retro	38	37	2	0	42 to 89	66	0	22	High
Mitri RD <i>et al.</i>	2017	Retro	59	55	2.8	0	68±12	50	0	22	High
Adler DG <i>et al.</i>	2017	Retro	200	198	3	200	63	60.5	0	22, 25	High
Sahai A <i>et al.</i>	2018	Retro	125	115	2.2	0	NR	NR	0	22	Medium
Asokkumar R <i>et al.</i>	2018	Retro	36	33	3	29	63.5±11	55.6	0	22	Medium
Ishigaki K <i>et al.</i>	2018	Retro	51	35	1	NR	69		NR	22	Medium
Miyano A <i>et al.</i>	2018	Retro	56	50	1	NR	72.5	54	NR	22	Medium
Temnykh L <i>et al.</i>	2018	Prosp	150	147	2.9	NR	59±14.5	55	NR	22	Medium
<b>Fork-tip needle</b>											
Bang JY <i>et al.</i>	2018	RT	50	49	2	50	71.5	56	0	22	High
Abdelfatah MM <i>et al.</i>	2018	Retro	97	75	3.4±1.02	NR	62.8±15.5	52	NR	22	Medium
Adler DG <i>et al.</i>	2016	Retro	15	11	1.5	15	NR	NR	NR	22, 25	Medium
Ayres LR <i>et al.</i>	2018	Retro	43	43	2	0	33-83	58	1 bleeding, 1 pancreatitis	22, 25, 19	High
DiMaio <i>et al.</i>	2016	Retro	194	157	3	149	18-92	50	Total 10 of 250, 5 pain, 4 pancreatitis, 1 cholangitis	22, 25	High
El Chafic <i>et al.</i>	2016	Retro	15	13	1	15	65±13	60	0	22, 25, 19	Medium
Kandel P <i>et al.</i>	2016	Retro	39	37	2	39	26 to 85	49	0	22, 25, 19	Medium
Nayar MK <i>et al.</i>	2016	Retro	101	100	3	NR	66.4	58	0	22, 25	Medium
Rodrigues-Pinto E <i>et al.</i>	2016	Retro	38	38	4	0	16-83	45	2 bleeding	22, 25	High
Naveed M <i>et al.</i>	2018	Retro	115	115	1	115	66	51	2 pancreatitis	22	High
Patek <i>et al.</i>	2016	Retro	33	29	NR	NR	NR	NR	NR	NR	Low

NR: Not reported, RT: Randomized trial, retro: Retrospective, Prosp: Prospective, ROSE: Rapid onsite evaluation

without fanning when feasible. Some studies did not use suctioning to minimize bleeding.

### *Performance of Fork-tip and Franseen-tip needles in EUS-fine-needle biopsy*

A total of 21 studies with 1632 patients were included in the analysis.<sup>[1,2,4,17-34]</sup>

The overall pooled rate of FNB diagnostic yield was 92.8% (95% CI 88.3–95.6,  $I^2 = 83.4$ ).

The pooled rate of diagnostic yield with Fork-tip needle (11 studies, 740 patients) was 92.8% (95% CI 85.3–96.6,  $I^2 = 73.1$ )<sup>[1,2,4,18,20,22,23,26,30-32]</sup> and the pooled rate of diagnostic yield with Franseen-tip needle (12 studies, 942 patients) was 92.7% (95% CI 86.4–96.2,  $I^2 = 88.4$ )<sup>[1,2,17,19,21,24,25,27-29,33,34]</sup> [Figure 3].

There was no statistical difference between them ( $P = 0.98$ ).

### *Subgroup analysis*

The pooled FNB diagnostic yield rate without ROSE (5 studies, 303 patients) was 95.9% (95% CI 88.0–98.7,  $I^2 = 7.3$ )<sup>[20,27,29,32,33]</sup>. The pooled FNB diagnostic rate with ROSE (10 studies, 640 patients) was 93.7% (95% CI 87.4–97.0,  $I^2 = 77.4$ )<sup>[1,4,17-19,21-23,26]</sup> [Figure 4a].

There was no statistical difference ( $P = 0.25$ ) between the groups.

The pooled FNB diagnostic yield rate with  $\leq 2$  needle-passes (5 studies, 202 patients) was 90.6% (95% CI 78.1–96.3,  $I^2 = 75.9$ )<sup>[1,21,23,25,28]</sup>. The pooled FNB diagnostic yield rate with  $> 2$  needle-passes (16 studies,

1430 patients) was 93.3% (95% CI 88.5–96.2,  $I^2 = 85.7$ ).<sup>[2,4,17-20,22,24,26,27,29-34]</sup> [Figure 4b].

There was no statistical difference ( $P = 0.54$ ).

The results of subgroup analyses are summarized in Table 2.

**Adverse events**

The overall pooled rate of adverse events with both needles (16 studies, 1133 patients) was 4.2% (95% CI 2.8–6.4,  $I^2 = 0.0$ ).<sup>[1,4,17,19-24,26,27,29,30,32,33]</sup>

The calculated pooled rate of adverse events with Fork-tip needle (8 studies, 595 patients) was

3.7% (95% CI 2.3–6.0,  $I^2 = 0$ ).<sup>[1,4,20,22,23,26,30,32]</sup> and with Franseen-tip needle (8 studies, 588 patients) was 6.2% (95% CI 2.6–14.1,  $I^2 = 0.0$ ).<sup>[1,17,19,21,24,27,29,33]</sup> [Supplementary Figure 1].

There was no statistical difference ( $P = 0.31$ ) between the two needles.

**Validation of meta-analysis results**

**Sensitivity analysis**

To assess whether any one study had a dominant effect on the meta-analysis, we excluded one study at a time and analyzed its effect on the main summary estimate. On this analysis, no single study significantly affected the outcome or the heterogeneity.

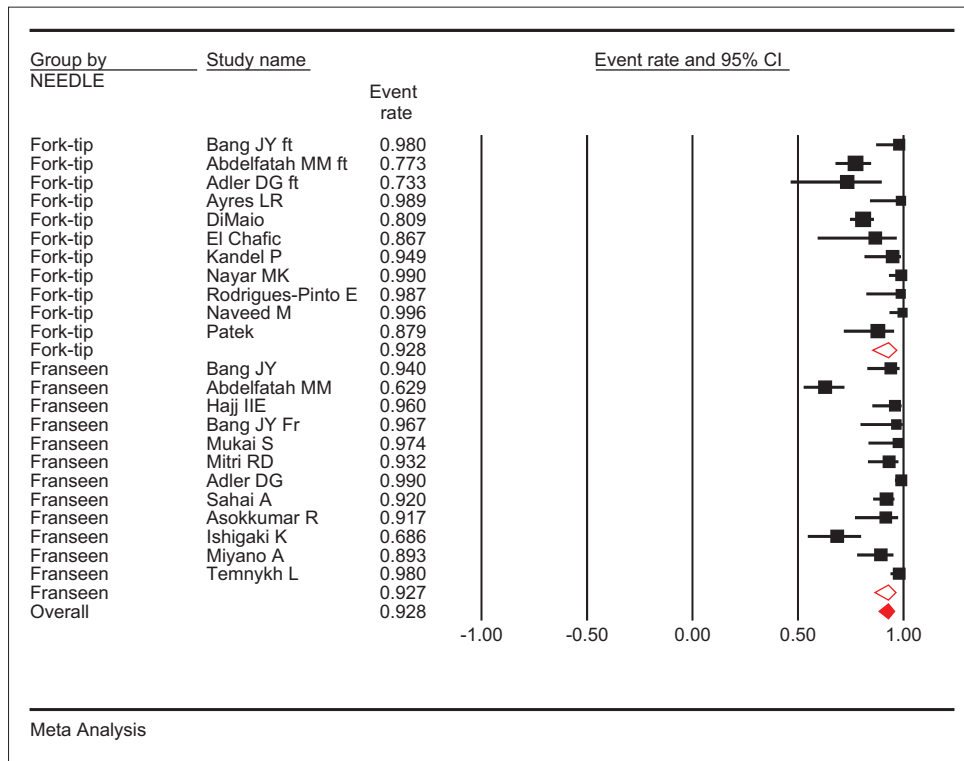


Figure 3. Forest plot. Diagnostic yield by needle type

Table 2. Results of subgroup analyses

Subgroup	Diagnostic yield (95% CI, P)		
	All	Franseen-tip	Fork-tip
ROSE			
Yes	93.7 (87.4-97.0, 77.4)	96.2 (88.1-98.9, 51.5)	91.2 (79.4-96.6, 71.7)
No	95.9 (88.0-98.7, 7.3)	94.1 (80.5-98.4, 0.0)	98.8 (88.1-99.9, 0.0)
Statistical difference (P)	0.25	0.26	0.26
Needle pass			
≤2	90.6 (78.1-96.3, 75.9)	89.5 (66.1-97.4, 80.6)	93.9 (74.4-98.8, 60.8)
>2	93.3 (88.5-96.2, 85.7)	94.4 (85.5-97.9, 91.1)	91.2 (83.5-95.5, 74.9)
Statistical difference, (P)	0.54	0.46	0.68

CI: Confidence interval, ROSE: Rapid onsite evaluation

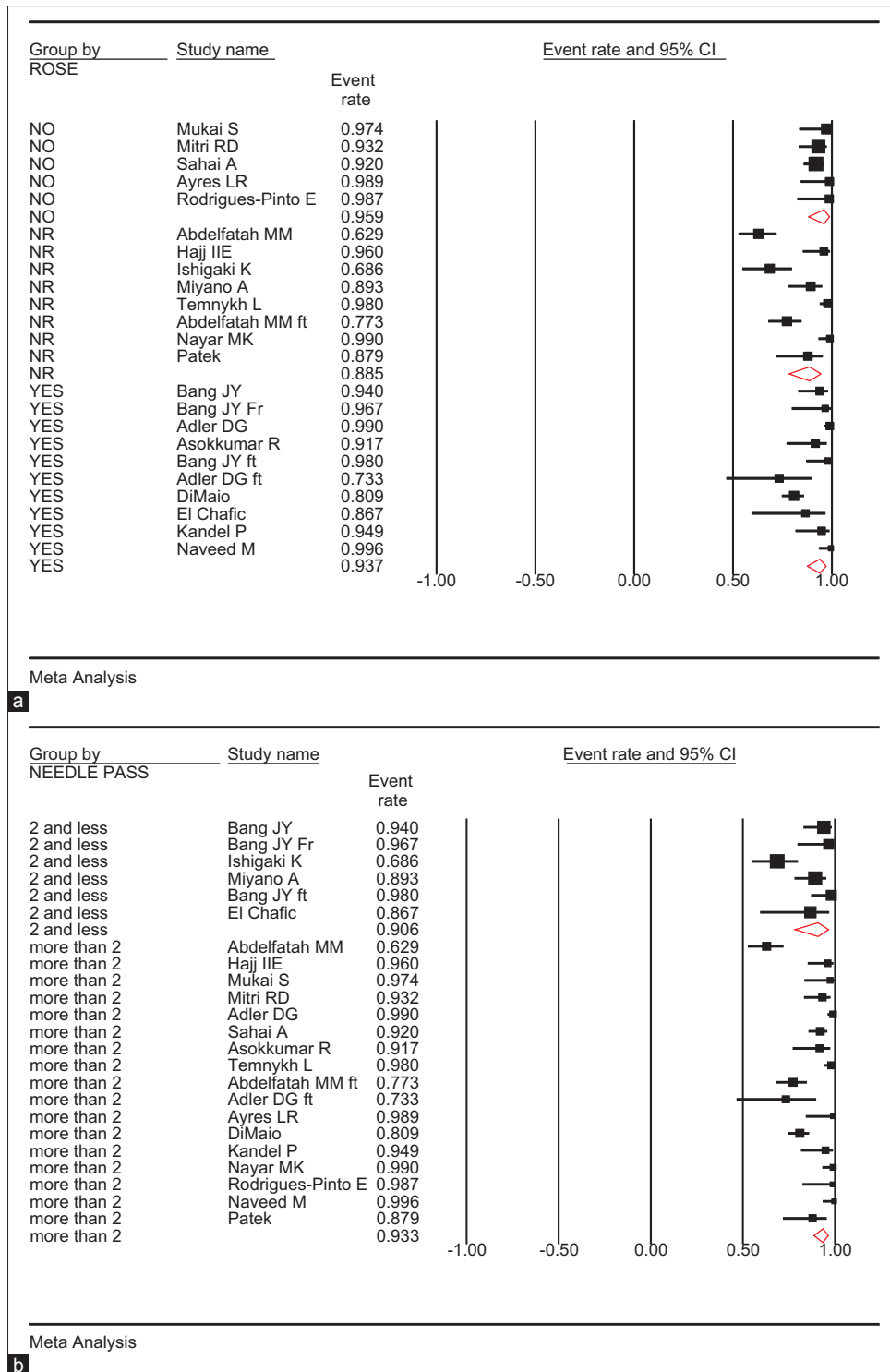


Figure 4. (a) Forest plot. Diagnostic yield by rapid onsite evaluation. (b) Forest plot. Diagnostic yield by needle pass

### Heterogeneity

Based on Q statistics, and  $I^2$  analysis for heterogeneity, considerable heterogeneity ( $I^2 = 88.4$ ) was noted in the analysis of diagnostic yield with Franseen needle, and substantial heterogeneity ( $I^2 = 73.1$ ) was noted in the analysis with Fork-tip needle. No heterogeneity ( $I^2 = 0$ )

was noted in the analysis of adverse events with either of these needles.

### Publication bias

Based on visual inspection of the funnel plot as well as quantitative measurement that used the Egger

regression test, there was evidence of publication bias. There was likelihood that small, negative-outcome studies were not published. Further statistics using the fail-Safe N test and Duval and Tweedie's "Trim and Fill" test reveal that the impact of the possible publication bias appears to be minimal and would not change the calculated estimate or the conclusion of this meta-analysis [Supplementary Figure 2].

### Prediction interval

Since we used the random effects model to calculate the pooled rate, we calculated the prediction-interval, which deals with the dispersion of the effects. The calculated prediction interval for EUS-FNB with Franseen-tip needle was 0.927 (−1.85–3.70, range = 5.55) and with Fork-tip needle was 0.928 (−0.931–2.79, range = 3.72).

## DISCUSSION

EUS-FNA (FNA), when combined with ROSE, has for many years been considered the gold standard for tissue acquisition from solid organs of the GI tract. Samples from FNA aspirates are often insufficient to run ancillary studies such as immunohistochemistry and molecular profiling of cancer tissue. These limitations have led to the development and dissemination of EUS-FNB devices.

EUS-FNB devices can be broadly classified as noncutting and cutting needles, of which the cutting needles can be further classified into side-type cutting and end-type cutting. The Franseen and Fork-tip needles are considered end-type cutting needles due to their opposing bevel tip design. The majority of studies published in the literature have compared either of these needles to EUS-FNA controls, and have been retrospective in nature with unequal number of subjects in the study and control group. Despite published literature, there are no established standards to suggest the optimal needle gauge, the required number of needle passes, the need for ROSE, and if the ability to procure core samples with FNB is advantageous.

This study is the first meta-analysis comparing the clinical performance of the Franseen-tip and the Fork-tip needles. Based on our analysis, there was no difference in the diagnostic-yield rate for Fork-tip and Franseen-tip needles in EUS-FNB (92.8% *vs.* 92.7%,  $P = 0.98$ ). The numbers of needle-passes performed to obtain a successful sample were comparable in both

groups (mean and/or median 1–4). Bang *et al.*,<sup>[1]</sup> in their randomized trial, demonstrated similar procurement of true histologic samples using both the needles.

The current study demonstrates that the end-type cutting needles give similar results with or without ROSE and hence, this may be seen as a potential argument to obviate the need for ROSE (95.9% without ROSE *vs.* 93.7% with ROSE,  $P = 0.25$ ). We, therefore, support the idea that Fork-tip and Franseen-tip needles can help establish the reliable histopathologic diagnosis in centers without access to on-site cytopathologist. A previous meta-analysis suggested that EUS-FNB without ROSE could supplant EUS-FNA with ROSE without the loss of diagnostic adequacy.<sup>[35]</sup>

This study is the first meta-analysis to evaluate the outcomes of EUS-FNB with end-type cutting needles based on the number of needle-passes. Although many of our included studies reported adequate tissue samples with  $\leq 2$  needle-passes, only five studies were consistent in using  $\leq 2$  needle-passes in all of their study patients. We report no difference in the diagnostic yield with  $\leq 2$  needle-passes as compared to  $> 2$  needle-passes (89.8% *vs.* 93.2%,  $P = 0.50$ ), although with heterogeneity. We, therefore, add to the literature that  $\leq 2$  needle-passes would provide adequate tissue sample and there seems to be no added advantage of doing  $> 2$  needle-passes when using the end-type cutting needles in EUS-FNB of solid organs of the GI tract. The adverse events reported in the EUS-FNB with these needles were not statistically different (3.7% *vs.* 6.2%,  $P = 0.31$ ). The most commonly reported ones were self-limited abdominal pain, bleeding, and pancreatitis.

The strengths of this review are as follows: systematic literature search with well-defined inclusion criteria, carefully excluding redundant studies, inclusion of many good quality studies, detailed extraction of data with rigorous evaluation of study quality, subgroup analysis to evaluate the performance with and without ROSE, subgroup analysis based on the number of needle-passes, and statistics to establish and/or refute the validity of the results of our meta-analysis.

There were limitations to this study too. The included studies were not entirely representative of the general population and community practice, with most studies being performed in tertiary-care referral centers. Considerable heterogeneity was noted in our analysis,



which seemed to stem from the variability in the utilization of ROSE, the variability in the number of needle passes, and possible technical-bias arising from the fanning-technique utilized for tissue acquisition. The influence of this on FNB is unknown. This was explained by our subgroup analysis, where the heterogeneity dropped significantly among studies that did not use ROSE at all. We were not able to analyze the data based on the organ of biopsy, access to the lesion, size of the lesion, and needle-gauge. There was operator dependent variability too. Currently, there is no globally validated definition for diagnostic and nondiagnostic samples with EUS-FNB, and the included studies did vary on the definitions used. Understandably, better-conducted prospective randomized trials are needed, especially to ascertain the ideal number of needle-passes and on the use of ROSE in EUS-FNB with end-type cutting needles. Nevertheless, this estimate is still the best estimate that may be used when addressing the performance of Franseen-tip and Fork-tip needles. A cost-effectiveness analysis is also warranted to see if the newer FNB needles without ROSE and with  $\leq 2$  needle-passes might help in overall cost reduction.

## CONCLUSION

Both Franseen-tip and Fork-tip needles seem to demonstrate similar diagnostic yield, with comparable adverse events in the EUS-FNB of solid organs of the GI tract. They seem to provide ample sample with  $\leq 2$  needle-passes and may reduce or even potentially obviate the need for ROSE at some centers.

### Supplementary Materials

Supplementary information is linked to the online version of the paper on the *Endoscopic Ultrasound* website.

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Nil.

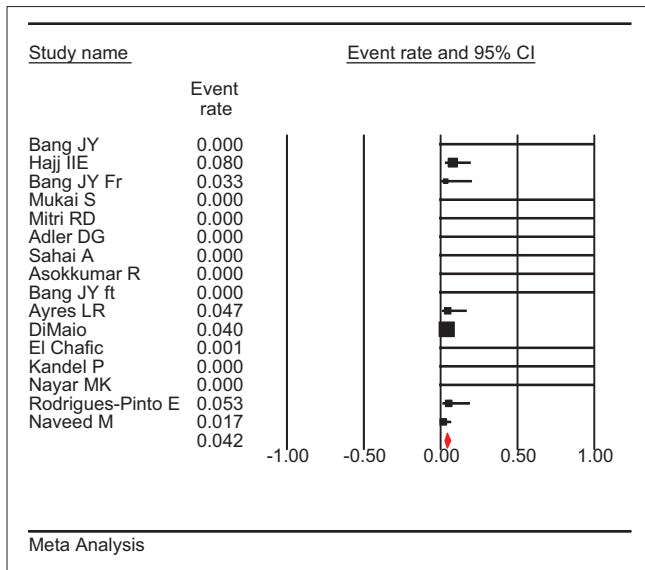
### Conflicts of interest

There are no conflicts of interest.

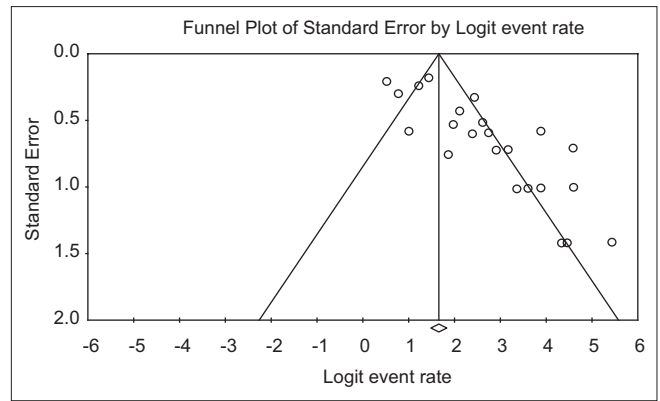
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Supplementary Figure 1. Forest plot. Adverse events



Supplementary Figure 2. Funnel plot