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Original Article

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Optimizing tissue acquisition to improve the diagnostic yield of endoscopic ultrasound-guided fine needle biopsy of solid masses: a quality improvement initiative

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Abstract

Background: **A chart audit (pre-intervention, PRE) of endoscopic ultrasound (EUS)-fine needle biopsy (FNB) of solid masses identified a diagnostic yield of 75%. To improve diagnostic yield, a quality improvement intervention targeting tissue procurement and processing was developed and trialed (post-intervention, POST).**

Intervention: **Increase needle passes to ≥3/mass, limit the personnel preparing cytology slides, and replace saline with formalin for cell block preparation.**

Methods: **A POST chart audit was undertaken for solid mass EUS-FNB from January 2024-December 2024, with quarterly reviews. Only a definite diagnosis was used to calculate diagnostic yield.**

ResultsAbout: **241 patients underwent 262 EUS-FNBs. Diagnostic yield was 81% in POST vs. 75% in PRE (p = ns). Single passes decreased to 14% in POST vs. 20% in PRE (p = ns), with similar diagnostic yield (57% vs. 56%, respectively). Number of ≥3 passes increased significantly (47% POST vs. 12% PRE, $P < .0001$). In POST, 86% of single passes were performed in the first half vs. 14% in the second ($P = .012$). Only 25% of ≥3 passes were performed in the first half vs. 75% in the second ($P = .06$). Diagnostic yield improved significantly between the first and second halves (72% vs. 90%, $P < .0001$). Replacing saline with formalin for cell block improved diagnostic yield (57% vs. 75%, $P = .062$). Limiting the personnel making slides from 25 nurses (PRE) to 3 endoscopists (POST) had no impact on diagnostic yield.**

Conclusions: **Critical practice assessment, regular audit, and continued reinforcement led to a significant improvement in EUS-FNB diagnostic yield to 90% by increasing the number of needle passes to ≥3/mass.**

Key words: EUS; biopsy; outcomes; quality metrics.

Introduction

Endoscopic ultrasound (EUS)-guided fine needle biopsy (FNB) has become standard of care in the diagnostic evaluation of luminal gastrointestinal (GI) and juxta-luminal masses.[1]

The pooled diagnostic yield of EUS-FNB of solid masses is >90%.[2,3] However, these published results are those seen within the rigors of randomized controlled trials (RCTs) performed by expert endoscopists. In actual practice, the diagnostic yield may vary considerably depending on a number of variables including the nature and location of the mass, skill of the endoscopist, the size (19, 22, or 25 gauge) and type of needle used (FN aspiration [FNA] or FNB), the number of needle passes (individual puncture of the mass) and actuations (to-and-fro movements within the mass after each needle pass), presence of suction or stylet withdrawal, the "fanning" technique, presence of rapid on-site evaluation (ROSE) in the endoscopy suite, handling and preparation of the acquired tissue, and the skill of the pathologist/cytopathologist. The European Society for Gastrointestinal Endoscopy (ESGE) has published guidelines on recommendations for EUS-FNA and FNB recognizing that there is significant heterogeneity in techniques and variables involved.[4]

Most studies assessing the diagnostic accuracy of EUS-FNA and EUS-FNB have focused on needle type, needle passes, suction during actuations, and availability of ROSE.[3,5–8] Initial studies assessing ROSE have suggested a benefit by improving diagnostic

yield, but 2 recent RCTs and a meta-analysis of EUS-FNB with and without ROSE have suggested non-inferiority of EUS-FNB alone especially with the availability of FNB needles.[7–9] There were fewer needle passes, shorter procedure times, and less resource utilization without ROSE.

In addition to optimizing tissue procurement, specimen handling after procurement is also vital to ensuring viability of the tissue obtained and provide the samples in the most optimal condition so as to be adequately assessed by the pathologist/cytopathologist.[10–12]

Aim

To optimize the process of tissue acquisition and specimen handling to improve the diagnostic accuracy of EUS-FNB of solid masses.

Hypothesis

The diagnostic accuracy of EUS-FNB can be improved by 10% if tissue acquisition and specimen handling are optimized.

Methods

Setting

This study was conducted at the University of Alberta Hospital (UAH), Edmonton, Alberta, Canada. Three endoscopists perform approximately 750 EUS procedures annually, and 25 registered (RN) and licensed practical nurses (LPN) rotate through the EUS room. They have received cytology slide preparation training and have been responsible for specimen handling in the endoscopy room. We do not have access to ROSE at our institution.

EUS technique

EUS procedures were performed using Pentax linear echoendoscopes (therapeutic EG38-J10UT or slim EG4-J10U, Montvale NJ) with endoscopist-assisted conscious sedation or anesthesiologist-assisted deep sedation. End-cutting 22 or 19-gauge (g) Franseen FNB needles were used at the discretion of the endoscopist, as were the number of needle passes and actuations. All endoscopists withdrew the stylet 12-18 inches prior to needle actuations. Tissue obtained was expressed onto a slide and a smear prepared by the assisting nurse. The remainder of the sample, and material from subsequent needle passes, was expressed into formalin for surgical pathology and saline for cell block preparation, with the latter also being at the discretion of each endoscopist. Samples were transported to the Department of Anatomic Pathology for processing and interpretation.

Ethics

The Research Ethics Board (REB) of the University of Alberta, decided that the program evaluation/quality assurance nature of this project was not subject to a full REB review and approval (Study ID Pro00127958; January 23, 2023). All patient data were anonymized before analysis and handled in accordance with institutional privacy policies and data protection standards.

Approach

This study was conducted in 2 phases. The pre-intervention quality assurance (QA) phase, or PRE, aimed to assess the diagnostic yield of EUS-FNB and identify various factors that may influence it. The subsequent post-intervention quality improvement (QI) phase, or POST, included intervention development and trial, as well as assessment of the post-intervention impact.

QA/Pre-intervention phase (PRE)

This phase involved a chart audit of all patients that underwent EUS-FNB of solid masses at the UAH from January 2023-December 2023. Variables extracted included patient demographics, type of solid mass, type and size of FNB needle, and number of needle passes. The primary outcome was diagnostic yield of EUS-FNB, defined as the percentage of solid masses sampled for which a definite tissue diagnosis was obtained on the pathology report.[13] Secondary outcomes were to identify factors in the process of tissue procurement and processing, if any, that may need improvement to increase the overall diagnostic yield.

The intervention

The results of PRE were reviewed with the endoscopists, nursing staff, and the pathologist/cytopathologist(s). A number of potential improvement actions were identified. The consensus was to standardize the process of tissue procurement and processing in the endoscopy room. This was followed by appropriate education and training of personnel in preparation for implementation of the intervention phase. These improvement actions were:

- Increase the number of needle passes to 3 or more/mass
- Reduce the number of personnel preparing slides from 25 nurses to 3 endoscopists
- Replace formalin as transport medium for cell block preparation instead of saline
- Improve documentation of type/size of FNB needle and needle passes in EUS report

The 3 endoscopists received a tutorial in the technique of preparing cytology slides by a cytopathologist (LP). They, and any assisting endoscopy fellows, were instructed to optimize the documentation of type and size of FNB needle and needle passes performed. To ensure compliance with these improvement actions, quarterly chart audits were performed based on the PDSA (Plan-Do-Study-Act) cycle[11,12] with continued reinforcement, as needed. A total of 3 PDSA cycles were performed at the end of March, June, and September 2024.

QI/Post-intervention phase (POST)

Following the implementation of the intervention, a chart audit of all EUS-FNB of solid masses from January 2024-December 2024 was undertaken. Variables extracted included patient demographics, type of solid mass, type and size of FNB needle,

and number of needle passes. Quarterly audits were done to ensure compliance with the intervention. At the end of the 12-month period, the overall diagnostic yield was compared with PRE. Only a definite diagnosis on the pathology report was considered when assessing diagnostic yield.

Statistical analysis

Multivariate logistic regression models were applied to assess differences in the diagnostic yield associated with number of needle passes. Differences between the first and second 6-month intervals of the POST period were examined using interrupted time series (ITS) models. Comparisons between the PRE and POST cohorts were performed using 2-proportion *z*-tests for proportion-based metrics derived from continuous measures and Chi-square test for categorical measures to evaluate the statistical significance between groups. All statistical analyses were conducted using SAS Enterprise Guide version 8.3.

Results

QA phase (PRE)

Anout 184 patients (84 females and 100 males) with a mean age of 64 ± 13 years (range 14-89 years) underwent 200 EUS-FNBs for solid masses. Most patients underwent 1 procedure (184/200, 92%) whereas 14 (7%) and 2 (1%) patients underwent 2 and 3 procedures, respectively (Table 1). Pancreatic masses accounted for the majority of solid masses (118, 59%). The location and type of the remaining solid masses is detailed in Table 1. A 22 g FNB needle was used for 189/200 masses (95%), 19 g for 6/200 (3%) masses, and needle size documentation was not available for 5/200 (2%) masses.

Table 1 Clinical and demographic characteristics.

	PRE	POST
Total patients, *n*	184	241
Sex, F: M	84:100	101:140
Age ± SD, years (range, years)	64 ± 13 (14-89)	65 ± 13 (12-90)
Patients and procedures, *n*		
Total patients	184	241
Total procedures	200	262
Procedures per patient		
1	184	241
2	14	17
3	2	3
4	0	1
Type/location of mass biopsied, *n* (%)		
Pancreas	118 (59)	168 (64)
Lymph node	24 (12)	47 (18)
Subepithelial	22 (11)	15 (6)
Rectal/peri-rectal	11 (5.5)	6 (2)
Retroperitoneal	6 (3)	16 (6)
Bile duct	6	1
Ampulla	6	2
Liver	3	1
Mediastinal	2	0
Gallbladder	1	2
Other	1	1
Esophageal	0	3
Needle type, *n* (%)		
19G	6 (3)	2 (1)
22G	189 (95)	256 (97)
Unknown	5 (2)	4 (2)
Needle passes, *n* (%)		
Not reported*	51(26)	10 (4)
1	39 (20)	37 (14)
2	85 (42)	93 (35)
3+[a]	25 (12)	122 (47)
Total needle passes	285	599
Average passes/mass[a]	1.9	2.4
Specimen handling *n* (%)		
Tissue in formalin	190 (95)	261 (99)
Cytology Slides	170 (85)	226 (86)
Medium for cell block	Saline 41 (21)	Formalin 55 (21)

[a]Indicates a statistically significant difference between PRE- and POST-intervention, $P < .05$.

Only 1 needle pass was performed in 39/200 (20%) masses, whereas 2, and 3 or more needle passes were performed in 85/200 (42%) and 25/200 (12%) masses, respectively. Needle pass information was not documented in the endoscopy reports of 51/200 (26%) masses biopsied. In the 149/200 patients with documented needle passes, a total of 285 passes were performed for an average of 1.9 needle passes/mass.

Tissue obtained was transported in formalin for surgical pathology in 190/200 (95%) masses, with cytology slides in 170/200 (85%) masses, and in saline for cell block preparation in only 41/200 (21%) masses. Only 1 of the 3 endoscopists performing EUS-FNB consistently sent samples for cell block preparation.

The overall diagnostic yield was 75% (149/200 masses, Table 2). When stratified for needle passes/mass, the diagnostic yield was 56%, 84%, and 84% for 1, 2, and 3 or more needle passes, respectively. The diagnostic yield in the 51/200 masses with no documented needle pass information was 69%.

In a multiple logistic regression model (Table 3), the number of needle passes were significantly associated with diagnostic yield. Relative to 3 needle passes, performing a single pass was associated with significantly reduced odds of diagnostic yield (OR 0.2; 95% CI, 0.05-0.77; $P = .019$), while 2 passes did not reach statistical significance ($P = .886$).

The diagnostic yield obtained from cytology slides alone was 65% and that from cytology slides + cell block transported in saline was 57%.

QI phase (POST)

About 241 patients (101 females and 140 males) with a mean age of 65 ± 13 years (range 12-90 years) underwent 262 EUS-FNBs for solid masses. Most patients underwent 1 procedure (241/262, 92%) whereas 17 (7%), 3 (1%), and 1 (0.5%) patients underwent 2, 3, and 4 procedures, respectively (Table 1). Pancreatic masses again accounted for the majority of solid masses biopsied (168, 64%). The location and type of the remaining sold masses is detailed in Table 1. A 22 g FNB needle was used for 256/262 masses (97%), 19 g for 2/262 (1%) masses, and needle size documentation was not available for 4/262 (2%) masses.

Only 1 needle pass was performed in 37/262 (14%) masses, whereas 2, and 3 or more needle passes were performed in 93/262 (35%) and 122/262 (47%) masses, respectively. There was a reduction in the number of 1 needle passes compared to PRE but this did not reach statistical significance. However, there was a statistically significant increase in the number of 3 or more needle passes compared with PRE (12% vs. 47%, $P < .0001$). Needle pass documentation was not evident in the endoscopy reports in only 10/262 (4%) masses biopsied compared with 26% in PRE ($P < .0001$). In the 252/262 patients with documented needle passes, a total of 599 passes were performed for an average of 2.4 needle passes/mass, which was significantly higher than PRE (1.9, $P < .0001$) (Table 1).

Tissue obtained was transported in formalin for surgical pathology in 261/262 (99%) masses, with cytology slides in 226/262 (86%) masses, and in formalin for cell block preparation in only 55/262 (21%) masses. The practice of sending samples for cell block remained specific to only 1 of the 3 endoscopists performing EUS-FNB.

The overall diagnostic yield was 81% (211/262 masses) compared with 75% in PRE ($P = .12$). When stratified for needle passes/mass, the diagnostic yield was 57%, 78%, and 89% for 1, 2, and 3 or more needle passes, respectively. The diagnostic yield in the 10/262 masses with no documented needle pass information was 90% (Table 2).

In a multivariate logistic regression model (Table 4), the number of needle passes demonstrated the strongest association with diagnostic yield among other covariates. Compared with 3 needle passes, performing a single pass was associated with significantly lower odds of diagnostic yield (OR 0.217; 95% CI, 0.09-0.52; $P = .0007$). Two passes did not show a statistically significant difference compared with 3 passes ($P = .075$ respectively). Figure 1 shows the trendlines in the number of 1 vs. 3 or more needle passes/mass in the PRE and POST groups. There was no difference in these trendlines in PRE and this pattern continued during the first half of the POST. However, quarterly chart audits and continued reinforcement led to a significant separation of these trendlines during the latter half of the POST year. Figure 2 shows the differences between the first and second 6-month periods

Table 2 Diagnostic yields by needle passes.

	PRE	POST
Diagnostic yield, *n* (%)		
Overall	149 (75)	211 (81)
Stratified by needle passes, *n* (%)		
1 needle pass	22 (56)	21 (57)
2 needle passes	71 (84)	73 (78)
3+ needle passes	21 (84)	108 (89)
Not specified	35 (69)	9 (90)

Table 3 Predictors of diagnostic yield: multivariate logistic regression analysis in the PRE-intervention cohort.

Variable (ref)	Estimate (β)	*P*-value	Odds ratio (OR)	95% wald Confidence limits	
Intercept	4.731	.001			
Age (per year)	−0.037	.055	0.963	0.927	1.001
Gender (male)	−0.285	.502	0.752	0.327	1.728
Mass type (pancreas)					
Lymph node, subepithelial and others	−0.827	.060	0.438	0.185	1.034
Number of needle passes 3 passes					
1 pass	−1.595	.019	0.203	0.054	0.768
2 passes	−0.090	.889	0.914	0.259	3.220

Table 4 Predictors of diagnostic yield: multivariate logistic regression analysis in the POST-intervention cohort.

Variable (ref)	Estimate (β)	*P*-value	Odds ratio (OR)	95% wald Confidence limits	
Intercept	1.52	.0864			
Age (per year)	0.01	.5514	1.008	0.983	1.033
Gender (male)	0.62	.0839	1.868	0.920	3.793
Mass type (pancreas)					
Lymph node, subepithelial and others	−0.63	.0648	0.532	0.272	1.039
Number of needle passes 3 passes					
1 pass	−1.53	.0007	0.217	0.090	0.524
2 passes	−0.69	.0754	0.501	0.234	1.073

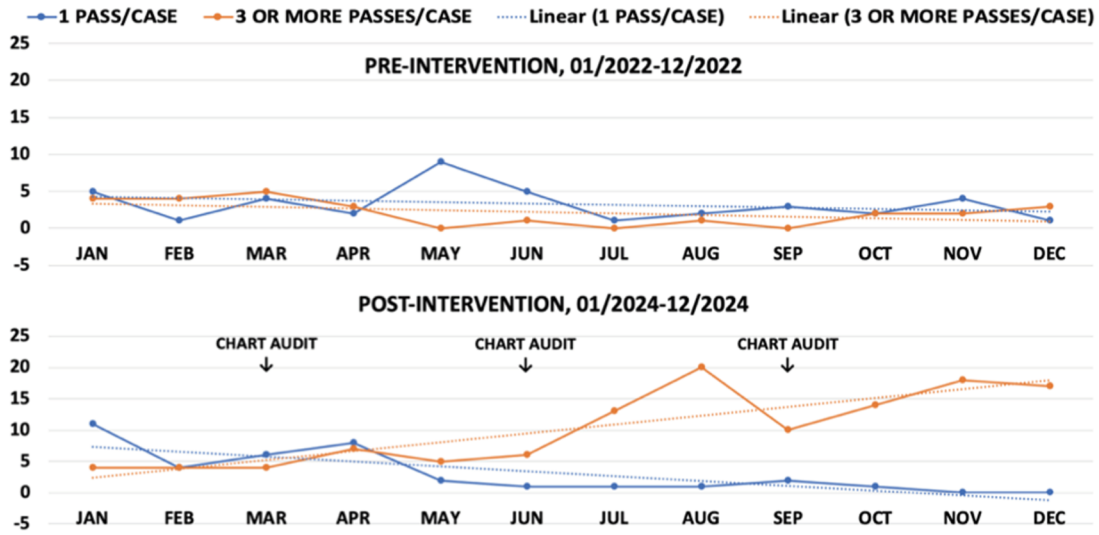

Figure 1 Total number of 1, 3, or more needle passes/mass for the PRE and POST intervention years, with trendlines.

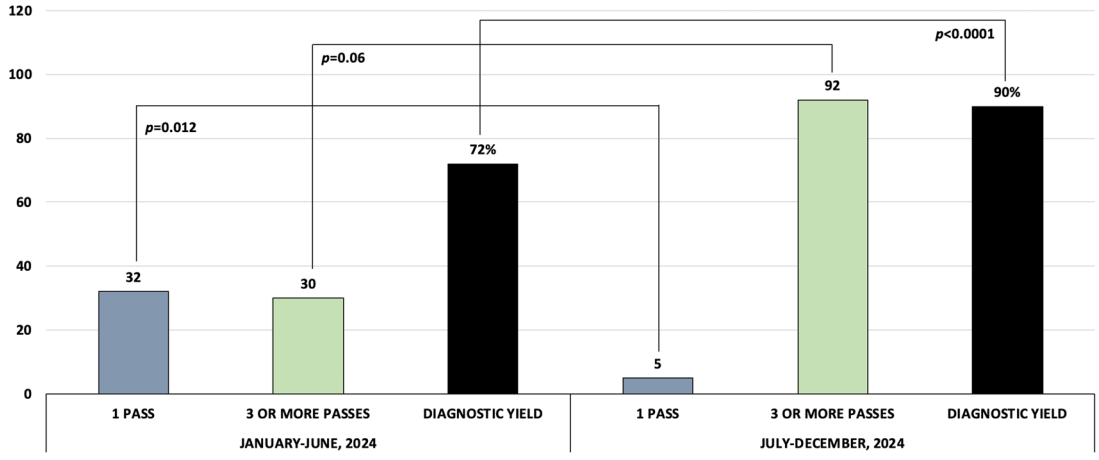

Figure 2 Number of needle passes/mass and diagnostic yield between the first and second 6-month period of POST intervention year.

of the POST year. There was a significant reduction in the number of 1 needle pass (32 vs. 5, $P = .012$), a borderline increase in 3 or more needle passes (30 vs. 92, $P = .06$, Table 5), and a significant improvement in the overall diagnostic yield (72% vs. 90%, $P < .0001$).

The diagnostic yield obtained from cytology slides alone was 67% and that from cytology slides + cell block transported in formalin was 75%. When comparing the diagnostic yield from cytology slides + cell block between the PRE (saline, 57%) and POST (formalin, 75%), the chi-square test indicated that this difference approached, but did not reach, conventional statistical significance ($\chi^2(1) = 3.48$, $P = .062$).

Table 5 Interrupted time series analysis of single-needle pass frequency and model estimates between first and second 6-month period of POST-intervention year.

Variable	Number of needle passes = 1		Number of needle passes = 2		Number of needle passes = 3	
	Estimate	*P*-value	Estimate	*P*-value	Estimate	*P*-value
Intercept	10.73	0	11.4	.01	3.4	.24
First 6-month (2024) trend	−1.54	.012	−0.11	.9	0.46	.53
Level change	0.26	.915	−0.45	.92	7.39	.06
Second 6-month (2024) trend	1.29	.091	−1.63	.21	0.06	.95

Discussion

A QA chart audit revealed a diagnostic yield of 75% for EUS-FNB at our centre. This is suboptimal for a high-volume tertiary care endoscopy unit and lower than what can be achieved as suggested in published literature.[1–3] Moreover, 20% of these patients just had a single needle pass per mass, yielding a diagnosis in only 56%. This likely contributed to the overall yield of 75% leading to diagnostic uncertainty in a significant proportion of patients.

A number of variables have a potential impact on the diagnostic yield of EUS-FNB. These include, but are not limited to, the technical skill and experience of the endoscopist, the optimal handling of the specimen obtained vis-à-vis cytology slide preparation and tissue transport medium used, as well as appropriate specimen processing and interpretation in the pathology department. Other factors, such as the tissue characteristics of the mass, the type and size of FNA or FNB needle, and the use of suction and/or stylet pull techniques, also have an impact on diagnostic yield. Prior to the development of dedicated FNB needles, tissue acquisition with FNA needles was less optimal with published literature recommending 4-7 needle passes per mass. Improvements in needle tip design led to the development of FNB needles with improved tissue acquisition. Cores of tissue were identified more readily when compared with FNA samples. However, the endoscopist's observation of a "core" seen with FNB samples does not always correlate with the adequacy of the specimen obtained. Nevertheless, 4-7 needle passes are not required when using an FNB needle, although there is no recommendation for an optimal number. These technical aspects of EUS needle sampling have been discussed in recently published guidelines of the ESGE.4 Another factor in optimizing the adequacy of tissue obtained is the availability of ROSE, although 2 recent RCTs and a recent meta-analysis showed that equivalent diagnostic accuracy can be achieved with EUS-FNB without ROSE, with fewer needle passes, and with a shorter overall procedure time.[7–9] Moreover, ROSE is not available routinely in most centres because of finite funding resources and cannot be relied upon as a consistent option. Our centre, like many other centres in various jurisdictions around the world, does not have routine access to ROSE in the endoscopy unit.

During the course of our initial inquiry, we identified a number of potential targets for improving the process of procurement and processing of the tissue samples obtained during EUS-FNB. These targets then became the focus of our QI strategy to see if we could optimize potential areas for improvement to increase the overall diagnostic yield. We found that the single most impactful intervention that led to a significant improvement in diagnostic yield was the number of needle passes performed per mass. Our QI strategy focused on achieving 3 or more needle passes per mass in order to reach our target of at least a 10% improvement in the overall diagnostic yield. This was not easily achieved as endoscopist practice patterns required regular chart audit and reinforcement of this intervention to reach the desired result. The average number of needle passes per mass increased from 1.9 in PRE to 2.4 in POST. We also made 2 very relevant observations.

Firstly, when comparing PRE and POST, there was a decrease in the number of single needle passes and a statistically significant increase in the number of 3 or more needle passes. Even though this was not corroborated with a significant overall improvement in diagnostic yield (75% vs. 81%), there was a significant difference in the diagnostic yield between those that had a single needle pass compared with those that had 3 or more needle passes (57% vs. 89%, $P < .0001$). Secondly, we observed that endoscopist's preference for performing single needle passes did not change in the initial part of the POST year. This was identified on the first quarterly chart audit and led to reinforcement of the desired QI strategy. A sub-group analysis comparing the first and second halves of the POST year clearly identified no change in the practice pattern of the number of needle passes or diagnostic yield in the first 6 months, but with continued reinforcement and feedback from our quarterly PDSA cycle audits, there was a significant improvement in the second 6 months with a reduction of single and increase in 3 or more needle passes, but most importantly and likely consequently, an improvement in the overall diagnostic yield from 72% to 90%, clearly outperforming our study hypothesis/aim of increasing diagnostic yield by at least 10% with this QI strategy.

In terms of secondary endpoints, there was no observed impact of other variables on the improvement in diagnostic yield, as the endoscopists, type and site of mass biopsied, and the type and size of needle used remained similar in PRE and POST groups. We did not observe any impact on diagnostic yield by reducing the number of personnel preparing cytology slides from 25 nurses in PRE to 3 endoscopists in POST. This may be attributed to the fact that both the nursing staff and the endoscopists underwent in-service training on how to properly prepare the cytology slides by the same cytopathologist. This has also been shown in published literature.[10]

Our hospital has recently undergone some changes requiring the transport of tissue specimens off-site for processing. It was felt that tissue specimens suspended in saline may undergo cellular degeneration with potential delays in transport. Therefore, it was

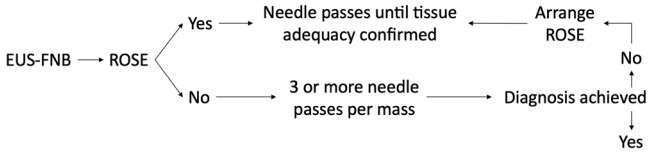

Figure 3 Suggested care pathway when considering EUS-FNB of solid masses, depending upon availability of ROSE.

suggested to consider switching from saline to formalin as the preferred medium, as formalin would preserve cellular architecture more effectively, even with any potential delays in the transport of tissue specimens. Both saline and formalin have been described as acceptable transport media for cell block preparation.[14,15] We identified an improvement in diagnostic yield by switching from saline to formalin as the transport medium for tissue intended for cell block preparation, suggesting that formalin may have played a role in better preservation of tissue. Notwithstanding the variation in practice at our centre with only 1 of the 3 endoscopists consistently sending tissue for cell block preparation in PRE and POST groups, we believe that there is considerable merit in sending additional samples for cell block preparation as cell blocks may be used for additional tests such as special stains, immunohistochemistry and molecular studies, especially since we are recommending a minimum of 3 passes be undertaken for each mass biopsied. These ancillary tests are crucial to exclude metastases, identify the nature of malignancy in poorly-differentiated neoplasms, and to identify prognostic/predictive markers.

We recognize that performing 3 or more needle passes may not be feasible for every single mass. There are technical issues that would limit this. The most common documented reason for performing single needle passes was either the presence of vascularity around the mass or the endosonographic observation of acute bleeding in the needle path following the first pass, precluding further needle passes. Performing an optimal and safe EUS-FNB will need to take these technical limitations into consideration, but we have shown that the number of single needle passes can be significantly reduced with no impact on adverse occurrences. Perhaps a case-by-case assessment may then necessitate arranging ROSE for those masses that are deemed technically difficult so as to maximize diagnostic yield, minimize the number of repeat procedures performed, and improve the overall safety of this diagnostic procedure.

Furthermore, we identified deficiencies in report documentation, with no reason being recorded for performing a single needle pass in the charts of a large proportion of patients. Documentation of needle passes was also identified as a quality metric that needed improvement. In the PRE, 26% of reports did not specify the number of needle passes performed. There was a significant improvement seen in the POST, as only 4% of reports were deemed deficient in this documentation.

Additionally, we recognize the potential for observer bias in both documentation and outcome assessment, particularly given the awareness of the ongoing QI initiative. The active involvement of the endoscopists in both implementing and assessing the intervention may have introduced unintentional bias in decision-making or reporting. Furthermore, practice change fatigue is a possible concern during a year-long intervention, especially in busy clinical settings. Despite ongoing audit and reinforcement, maintaining a long-term adherence to increased needle passes may require additional strategies such as automation of prompts in procedural documentation systems or scheduled re-education.

In conclusion, a critical assessment of the diagnostic yield of EUS-FNB of solid masses in our tertiary care endoscopy unit identified multiple areas for improvement. These were targeted in a QI intervention which, followed by regular audit and reinforcement, led to a significant improvement in the diagnostic yield simply by increasing the number of needle passes to 3 or more per mass. Figure 3 shows our recommended approach to EUS-FNB. ROSE can be utilized, where available, for optimizing the adequacy of tissue sampling with the least number of needle passes required. However, if ROSE is not routinely available, attempts should be made to perform at least 3 or more passes to achieve a high diagnostic yield. If technical difficulty precludes optimizing the number of needle passes, or if the initial FNB does not yield a definite diagnosis, arrangements should be made for ROSE in these select few cases to maximize tissue acquisition and improve diagnostic yield.

Author contributions

Samina Khan—data review and critical review of manuscript, Narges Ashrafinia—critical review of manuscript, Pamela Mathura—quality lead, design input, statistical analysis and critical review of manuscript, Lakshmi Puttagunta—design input, data review, and critical review of manuscript, Safwat Girgis—design input and critical review of manuscript, Aducio Thiesen—design input and critical review of manuscript, Julie Zhang—statistical analysis and critical review of manuscript, Jan-Erick Nilsson—critical review of manuscript, Shawn Wasilenko—critical review of manuscript, Sergio Zepeda-Gomez—critical review of manuscript, Gurpal Sandha—study concept, data retrieval and database entry, statistical analysis, drafting and critical review of manuscript.

All authors have approved the final draft submitted.

Supplementary material

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Conflicts of interest

Conflict of interest disclosure forms (ICMJE) have been collected for all co-authors and can be accessed as supplementary material.

Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

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