Comparison of Number of Passes and Cytopathological Specimen Adequacy for Thyroid Fine-Needle Aspiration Biopsy in the Absence of an On-Site Pathologist

Taha Yusuf Kuzan^a Ceren Canbey Goret^b

^aDepartment of Radiology, Sancaktepe Sehit Prof. Dr. Ilhan Varank Training and Research Hospital, Istanbul, Turkey; ^bDepartment of Surgical Pathology, Sancaktepe Sehit Prof. Dr. Ilhan Varank Training and Research Hospital, Istanbul, Turkey

Keywords

Fine-needle aspiration · Biopsy · Nodule · Pathology specimen adequacy · Thyroid · Ultrasound

Abstract

Aim: Ultrasound-guided fine-needle aspiration biopsy (FNAB) is a reliable, minimally invasive diagnostic method with high sensitivity and specificity in the evaluation of thyroid nodules. Our aim in this retrospective study was to determine if there was a difference in the adequacy ratio based on the number of needle passes in the thyroid FNABs in the absence of rapid on-site evaluation (ROSE) by the pathologist and to determine the optimal needle pass number for FNAB. **Methods:** Between November 2018 and February 2019, thyroid FNABs of 121 (99 female, 22 male) patients were evaluated retrospectively. Samples for each biopsy were numbered according to the order of retrieval, and 4 pairs of slides were prepared by the radiologist without on-site microscopic evaluation. Cytological results were determined according to the Bethesda classification. **Results:** The rate of adequacy in the first, second, third, and fourth passes were 76.0, 82.6, 77.7, and 71.2%, respectively. No statistically significant difference was found between these four groups

in terms of adequacy ($p = 0.21$). The adequacy rates of the 1st, 1st+2nd, 1st+2nd+3rd, and cumulative evaluation of all four biopsies were 76.0, 87.6, 90.1, and 91.7%, respectively ($p = 0.001$). A statistically significant difference was found in the comparison of the 1st biopsy and the cumulative 1st+2nd biopsy in terms of adequacy rates ($p = 0.019$). However, there was no statistically significant difference between the cumulative 1st+2nd biopsy and the cumulative 1st+2nd+3rd biopsy in terms of adequacy rates ($p = 0.54$). **Conclusions:** In cases where ROSE cannot be performed, we recommend a minimum of 2 and a maximum of 3 needle entries for FNAB adequacy with the right technique and preparation.

© 2019 European Thyroid Association
Published by S. Karger AG, Basel

Introduction

Nodule development is a commonly seen entity in the thyroid gland, and 4–7% of the adult population has a palpable thyroid nodule [1]. With imaging modalities, especially the widespread use of ultrasound, nonpalpable thyroid nodules are being detected in 19–70% of the population [2, 3]. While ultrasound has a high sensitivity in

detecting thyroid nodules, it is not sensitive enough in differentiating between benign and malign nodules. The majority of thyroid nodules are benign, and 5–15% of them are thyroid malignancies. Fine-needle aspiration biopsy (FNAB) is a reliable, minimally invasive diagnostic method with high sensitivity and specificity in the evaluation of thyroid nodules [2, 4–7]. Despite the high accuracy of FNAB in the detection of malignancy, the percentage of inadequate samples is around 10%, and in some centers this rate remains as high as 20–34%. Repeated biopsies due to inadequacy can lead to patient anxiety, increased costs, and unnecessary surgery [2, 8]. There are different applications for FNAB in different centers, such as ultrasound versus palpation guidance, needle size, number of needle entries, need for on-site microscopic evaluation by the pathologist or cytotechnologist, preparation methods of cytology, etc. [5]. To reduce the risk of inadequate samples in the thyroid FNAB, the American National Cancer Institute recommends 2–5 needle entries using a 22G to 27G needle and that centers have an effective cooperation between the biopsy physician and the pathology department to ensure that samples are properly prepared and microscopically evaluated at the patient's bedside [9]. While the use of ultrasound guidance for FNAB is necessary, the presence of a pathologist during the biopsy procedure is controversial and not always logistically possible; the choice of needle size, number of entries, and aspiration technique often varies from one center to another [10–16]. Our aim in this retrospective study was to determine if there was a difference in the adequacy ratio based on the number of needle passes in the thyroid FNABs in patients in whom rapid on-site evaluation (ROSE) was not performed by the pathologist and to determine the optimal needle entry number for FNAB.

Materials and Methods

Patient Selection

A total of 123 patients who underwent thyroid biopsy at our hospital between November 2018 and February 2019 were included in the study. The nodule volume of all patients was calculated (using the following formula $\text{volume} = \text{width} \times \text{depth} \times \text{length} \times 0.52$) before the procedure and recorded. One patient with a pure cystic nodule and 1 patient with <3 aspirations were excluded from the study. In total, 121 single nodules of 121 patients were included in the study. In this study, the “Guidelines for Patients with Thyroid Nodules and Differentiated Thyroid Cancer” by the American Thyroid Association (ATA) was used as the standard of evaluation [17].

Table 1. The cytologic results according to The Bethesda System for Reporting Thyroid Cytopathology

Bethesda	Frequency	Percent
Category 1	10	8.3
Category 2	90	74.4
Category 3	7	5.8
Category 4	5	4.1
Category 5	5	4.1
Category 6	4	3.3
Total	121	100.0

Ultrasound-Guided Fine-Needle Aspiration Technique

The FNAB procedure was performed by a single radiologist with 5 years of experience in all 121 patients. All biopsies were performed with ultrasound guidance (Aplio 300 ultrasound system; Toshiba Medical Systems, Tokyo, Japan) using a linear 7.2–14 MHz probe and 26G fine needle. The radiologist had received basic training in cytopreparation from an experienced pathologist. The cytopathologist had not participated in any of the 121 FNAB procedures. The same biopsy technique was used in all cases; the patient was placed on the examination table, and a roll pillow was placed under their neck to ensure hyperextension and proper position. A ultrasound-guided (USG) probe was used to detect nodules, and localized lidocaine was administered in the direction of the nodule through the skin. After providing the appropriate time for topical anesthesia to be effective, the skin was cleaned with iodine solution.

Each aspiration was performed with the free-hand technique using sonographic guidance and a new 26G needle. The needle tip was inserted into the nodule. If the nodule contained cystic areas, the needle tip was placed in the solid parts of the nodule. Curettage was performed before negative pressure was applied. Curettage and aspiration were continued until a small amount of blood was observed in the aspiration material and syringe center. After each aspiration, the aspirated material was sprayed on two different slides. The slides were placed on one another, spreading the cells without breaking and slowly moving away from each other. One of the preparations was fixed with 95% ethanol solution and the other was air-dried. Except for 3 patients who could not tolerate four biopsies, four specimens were taken from each nodule in all cases. The samples were numbered according to their order, and four pairs of preparations were prepared for cytopathological evaluation.

The Cytopathologist's Definitive Cytological Diagnosis

Each slide was evaluated individually in terms of adequacy and diagnosis with needle entry order. The Bethesda classification criteria by Cibas and Ali [18] were taken into consideration. Based on these criteria, a minimum of 6 follicle groups, each with a minimum of 10 cells, needed to be seen. Cases that did not meet the criteria were reported as Category I “nondiagnostic” (ND) or “unsatisfactory” (UNS).

Although more than 6 groups of follicles with at least 10 cells were seen, in some preparations, cases where some parts were evaluated and others could not be clearly evaluated because cells were in fixation artifacts and blood-fibrin masses were evaluated as “borderline adequate” and were noted as such in the pathology report. Our borderline-sufficient cases had sufficient cellularity. These cas-

Table 2. Cytopathological specimen adequacy in USG thyroid FNAB

	Biopsy 1, frequency (%)	Biopsy 2, frequency (%)	Biopsy 3, frequency (%)	Biopsy 4, frequency (%)	<i>p</i>
Insufficient	29 (24.0)	21 (17.4)	27 (22.3)	34 (28.8)	0.21
Sufficient	92 (76.0)	100 (82.6)	94 (77.7)	84 (71.2)	
Total	121 (100.0)	121 (100.0)	121 (100.0)	118 (100.0)	

Table 3. Cumulative cytopathological specimen adequacy in USG thyroid FNAB

	Biopsy 1, frequency (%)	Biopsy 1+2, frequency (%)	Biopsy 1+2+3, frequency (%)	Biopsy 1+2+3+4, frequency (%)	<i>p</i>
Insufficient	29 (24.0)	15 (12.4)	12 (9.9)	10 (8.3)	0.001
Sufficient	92 (76.0)	106 (87.6)	109 (90.1)	111 (91.7)	
Total	121 (100.0)	121 (100.0)	121 (100.0)	121 (100.0)	

es were radiologically solid/cystic mixed-type hemorrhagic nodules and were interpreted in this way because of the presence of dense blood/fibrin or abundant histiocytes (cyst fluid) in cytological preparations. However, these cases were cytologically “sufficient” and were diagnosed. Due to intense blood/fibrin, pathology reports were given a warning note and were classified as “sufficient.”

According to Cibas’ and Ali’s Bethesda classification [18], the preparations were reported as Category II; benign, Category III; atypia of undetermined significance or follicular lesion of undetermined significance (AUS/FLUS), Category IV; follicular neoplasm or suspicious for a follicular neoplasm (Hurtle cells also noted), Category V; suspicious for malignancy and Category VI: Malignant. Based on the recommendation of Cibas and Ali, even though a sufficient number of cell groups did not accompany abundant colloidal material in some cases, they were reported as benign (Category II), and not inadequate (Category I). In the case of mixed solid-cystic nodules with solid areas, evaluation was made according to the presence of thyroid follicular epithelial cells.

Statistics

The continuous variables were expressed as the mean $\pm$ SD. χ^2 test was used to analyze the difference of adequacy rates between biopsy groups by order of sample taking and cumulative biopsy groups. The Mann-Whitney U test was used to analyze the relationship between nodule volume and diagnostic adequacy. *p* values calculated for two-tailed comparisons and *p* < 0.05 values were accepted as statistically significant.

Results

Of the 121 patients included in the study, 99 were female and 22 were male. The mean age of the patients was 52.08 ± 12.10 years (median 54.0, range 27–82). Aspirated

nodule volumes were in the range of 0.03–75.42 mL (mean, 5.22 ± 8.96 ; median, 2.37). Of all nodules, 64 (52.9%) were located on the left lobe, 55 (45.4%) on the right lobe, and 2 (1.7%) on the isthmus.

Cytological results were determined according to the Bethesda classification. Based on that, of 121 patients, 10 (8.3%) were reported as Category I, 90 (74%) as Category II, 7 (5.8%) as Category III, 5 (4.1%) as Category IV, 5 (4.1%) as Category V, and 4 (3.3%) as Category VI (Table 1). In conclusion, according to the Bethesda system, sample adequacy was achieved in 111 (91.7%) of the patients, and diagnostically adequate samples could not be obtained in 10 (8.3%) patients.

Adequacy status according to the sampling order is shown in Table 2. When evaluated separately based on the order of obtainment, for the first sample, the adequate and inadequate numbers are 92 (76%) and 29 (24.0%), respectively; for the second sample, the adequate and inadequate numbers are 100 (82.6%) and 21 (17.4%), respectively; for the third sample, the adequate and inadequate numbers are 94 (77.7%) and 27 (22.3%), respectively, and for the fourth sample, the adequate and inadequate numbers are 84 (71.2%) and 34 (28.8%), respectively (Table 2). During the cytological evaluation, from the first to the last intervention, all preparations were in the same morphology, and there were no cases in which the definite diagnosis changed in different interventions. Accordingly, no statistically significant difference was determined between these four groups in terms of adequacy ($\chi^2 = 4.51$, *p* = 0.21).

Biopsy cumulative adequacy rates are shown in Table 3. While the adequacy rate in the first biopsy was 76.0%, the cumulative rate of the first and second biopsies was 87.6%, the cumulative rate of the 1st, 2nd, and 3rd biopsies was 90.1%, and the cumulative rate of adequacy in the assessment of all four biopsies was 91.7%. A statistically significant difference was found between these four groups ($\chi^2 = 15.5$, $p = 0.001$). A statistically significant difference was found between the 1st biopsy and the cumulative 1st+2nd biopsy results in terms of the adequacy rates ($\chi^2 = 5.4$, $p = 0.019$). However, there was no statistically significant difference between the cumulative 1st+2nd biopsy and the cumulative 1st+2nd+3rd biopsy in terms of adequacy ratios ($\chi^2 = 0.37$, $p = 0.54$). Similarly, no statistically significant difference was found between the cumulative 1st+2nd+3rd biopsy and all four cumulative biopsy results in terms of adequacy ratios ($\chi^2 = 0.2$, $p = 0.65$).

The mean volume of nodules that could be sampled adequately for cytological diagnosis was 5.13 mL, whereas the mean volume of nodules that could not be adequately sampled was 6.19 mL ($p = 0.52$). For this reason, a statistically significant relationship was not found between nodule volume and diagnostic adequacy.

Discussion

FNAB is a commonly used, cheap, reliable, and simple method to evaluate both palpable and radiologically detectable, nonpalpable lesions. When supported with clinical and radiological findings, it is a valuable method that can be used instead of histopathological examination as a preoperative diagnostic method and can prevent unnecessary surgical interventions, also distinguishing between benign and malign lesions with a high accuracy rate. The advantage of this technique is that it can be performed within a maximum of 15–20 min in experienced hands [19]. However, despite the reliability and cost-effectiveness to distinguish between benign and malignant thyroid nodules, there are inadequacy rates ranging from 2–35% in the literature [20]. It has also been reported that 9–32% of the nodules reported as inadequate may be malignant [18].

For the repeat biopsy of cases previously reported as category I “ND” or “UNS”, it was recommended to wait for several months with the idea that the patient could have anxiety and because of the development of cellular atypia of the nodule from the previous biopsy [21, 22]. However, according to the ATA guidelines, it is stated

that FNAB can be repeated without waiting [23]. At our center, in line with the ATA guideline suggestion, we repeat FNAB for cases reported as inadequate without waiting for 2–3 months.

In their study with 1,381 patients where ROSE was either performed or not, de Koster et al. [2] reported that they generally performed 2–3 entries into the nodule, and 64.6% of a total of 1,381 cases were adequate. While the adequacy rate in the 414 cases with ROSE was 74.6%, the adequacy rate in 967 cases with no on-site adequacy evaluation was determined as 60.3%. Again, in the same study, during three different visits of the patients, different performing radiologists did not change the adequacy rate of the biopsy, so the inadequacy was not based on the radiologist but depended on the characteristics of the nodule, especially intranodularly vascularized nodules and secondary to not performing ROSE. In addition, the number of needle passes was evaluated only in ROSE cases. The mean entry number was 1.75, and adequacy rates were 72.0% in 3 entries, while it was 59.7% in 2 or less entries. de Koster et al. [2] reported that ROSE should be routinely performed since it has a higher adequacy rate in thyroid FNAB. However, if ROSE cannot be performed, the operator should have a minimum of 3 needle entries to obtain sufficient material.

In a study of 693 cases reported by Redman et al. [24], FNAB was performed with USG to 574 palpable nodules, and without USG to 109 nonpalpable nodules. Adequacy rates in all cases were reported as 96% (664/693). ROSE, the cystic structure of the nodule, and USG were found to affect the rate of adequacy. Cystic degenerative nodules had a lower adequacy ratio, and cases with ROSE and USG had statistically significantly higher rates of adequacy. They also reported the number of needle entries required for a sufficient FNAB in their study as 3.8 (median, 3.0; range 1–11).

In our study, ROSE was not performed during any FNAB procedure due to a lack of pathologists and cytotechnologists. Each procedure performed by the radiologist was numbered sequentially and was evaluated separately by the pathologist. A total of 4 needle entries were performed in all cases except 2 cases. The radiologist who performed the biopsy and the pathologist who performed the evaluation were always the same. In our study, there was a statistically significant difference between 1 and 2 biopsies in terms of adequacy ratios, while there was no statistically significant difference between 2 and 3 biopsies in terms of adequacy ratios. For this reason, the minimum number of needle entries required was determined to be 2 in cases without ROSE performed by pathologist

or cytotechnologist. When we look at the studies reporting needle pass numbers, the number of needle passes we recommend is lower than that in the literature. In other studies, the minimum needle entry number is reported as 3 [2, 24]. We believe that this is due to the experience of the radiologist doing the biopsy and the person who prepared the smear.

The limitations of our study include the collection of retrospective cases over a 4-month period and the small number of cases without ROSE evaluated within a short period of time. At the same time, biopsies always being performed by the same radiologist and evaluations always being made by the same pathologist are other limitations of our study. Due to the limited number of pathologists/radiologists who are interested in thyroid FNA in our center, we would like to conduct future studies with cases evaluated by several radiologists/pathologists as soon as there will be more specialists in our center who are interested in this subject.

In the literature, Collins et al. [25] reported the benefits of using cytotechnologists in ROSE cases and found that it was more cost-effective to have a cytotechnologist instead of a pathologist. Our center is a newly established center. As the experience of our pathology and radiology departments increase and a sufficient number of cytotechnologists and pathologists are available, ROSE will be implemented. Thus, we believe that our rates of inadequacy will decrease further in time, better quality smears will be prepared, and the radiologist/pathologist correlation will be better.

There are many studies in the literature reporting inadequacy rates and the number of entries, with cases of

many different organs, usually with ROSE [26, 27]. In our study, only thyroid FNAB was included. In time, we hope that there will be cases with lesions in different anatomical localizations presenting at our center.

Conclusion

ROSE decreases inadequacy rates, but in cases where it cannot be performed, the radiologist/pathologist should collaborate and decide on the best preparation method together. Incorrect preparation coupled with a perfect FNAB technique will cause the biopsy result to be evaluated as UNS and be classified as Category I.

In cases where ROSE cannot be performed, we recommend a minimum of 2 needle passes for a standard thyroid FNAB. However, this entry number can be increased when intranodular vascularization is high and there is a spongy mixed cystic degenerative nodule.

Statement of Ethics

Ethical approval by the local Ethics Committee of our institute was obtained prior to study onset. Informed consent in line with ethics committee guidelines was obtained from each patient before biopsy.

Disclosure Statement

The authors declare that they have no conflicts of interest to disclose.

References

- 1 Naïm C, Karam R, Eddé D. Ultrasound-guided fine-needle aspiration biopsy of the thyroid: methods to decrease the rate of unsatisfactory biopsies in the absence of an on-site pathologist. *Can Assoc Radiol J*. 2013 Aug; 64(3):220–5.
- 2 de Koster EJ, Kist JW, Vriens MR, Borel Rinkes IH, Valk GD, de Keizer B. Thyroid Ultrasound-Guided Fine-Needle Aspiration: The Positive Influence of On-Site Adequacy Assessment and Number of Needle Passes on Diagnostic Cytology Rate. *Acta Cytol*. 2016; 60(1):39–45.
- 3 Tan GH, Gharib H. Thyroid incidentalomas: management approaches to nonpalpable nodules discovered incidentally on thyroid imaging. *Ann Intern Med*. 1997 Feb;126(3): 226–31.
- 4 Gharib H, Goellner JR. Fine-needle aspiration biopsy of the thyroid: an appraisal. *Ann Intern Med*. 1993 Feb;118(4):282–9.
- 5 Paschke R, Hegedüs L, Alexander E, Valcavi R, Papini E, Gharib H. Thyroid nodule guidelines: agreement, disagreement and need for future research. *Nat Rev Endocrinol*. 2011 Jun;7(6):354–61.
- 6 Akpınar İN, Kuzan TY. Perkütan Biyopsi: İgne Secimi ve Görüntüleme Kılavuzları. *Türk Radyoloji Semin*. 2015;3(3):159–68.
- 7 Reuters KB, Mamone MC, Ikejiri ES, Camacho CP, Nakabashi CC, Janovsky CC, et al. Bethesda Classification and Cytohistological Correlation of Thyroid Nodules in a Brazilian Thyroid Disease Center. *Eur Thyroid J*. 2018 Jun;7(3):133–8.
- 8 Gharib H, Papini E, Paschke R, Duick DS, Valcavi R, Hegedüs L, et al.; AACE/AME/ETA Task Force on Thyroid Nodules. American Association of Clinical Endocrinologists, Associazione Medici Endocrinologi, and European Thyroid Association Medical guidelines for clinical practice for the diagnosis and management of thyroid nodules: executive summary of recommendations. *Endocr Pract*. 2010 May-Jun;16(3): 468–75.
- 9 Pitman MB, Abele J, Ali SZ, Duick D, Elsheikh TM, Jeffrey RB, et al. Techniques for thyroid FNA: a synopsis of the National Cancer Institute Thyroid Fine-Needle Aspiration State of the Science Conference. *Diagn Cytopathol*. 2008 Jun;36(6):407–24.

- 10 Baloch ZW, Cibas ES, Clark DP, Layfield LJ, Ljung BM, Pitman MB, et al. The National Cancer Institute Thyroid fine needle aspiration state of the science conference: a summation. *Cytojournal*. 2008 Apr;5(1):6.
- 11 Hatada T, Okada K, Ishii H, Ichii S, Utsunomiya J. Evaluation of ultrasound-guided fine-needle aspiration biopsy for thyroid nodules. *Am J Surg*. 1998 Feb;175(2):133–6.
- 12 Mittendorf EA, Tamarkin SW, McHenry CR. The results of ultrasound-guided fine-needle aspiration biopsy for evaluation of nodular thyroid disease. *Surgery*. 2002 Oct;132(4):648–53; discussion 653–4.
- 13 Cai XJ, Valiyaparambath N, Nixon P, Waghorn A, Giles T, Helliwell T. Ultrasound-guided fine needle aspiration cytology in the diagnosis and management of thyroid nodules. *Cytopathology*. 2006 Oct;17(5):251–6.
- 14 Nasuti JF, Gupta PK, Baloch ZW. Diagnostic value and cost-effectiveness of on-site evaluation of fine-needle aspiration specimens: review of 5,688 cases. *Diagn Cytopathol*. 2002 Jul;27(1):1–4.
- 15 O'Malley ME, Weir MM, Hahn PF, Misdraji J, Wood BJ, Mueller PR. US-guided fine-needle aspiration biopsy of thyroid nodules: adequacy of cytologic material and procedure time with and without immediate cytologic analysis. *Radiology*. 2002 Feb;222(2):383–7.
- 16 Zhu W, Michael CW. How important is on-site adequacy assessment for thyroid FNA? An evaluation of 883 cases. *Diagn Cytopathol*. 2007 Mar;35(3):183–6.
- 17 Cooper DS, Doherty GM, Haugen BR, Kloos RT, Lee SL, Mandel SJ, et al.; American Thyroid Association (ATA) Guidelines Taskforce on Thyroid Nodules and Differentiated Thyroid Cancer. Revised American Thyroid Association management guidelines for patients with thyroid nodules and differentiated thyroid cancer. *Thyroid*. 2009 Nov;19(11):1167–214.
- 18 Cibas ES, Ali SZ. The 2017 Bethesda System for Reporting Thyroid Cytopathology. *Thyroid*. 2017 Nov;27(11):1341–6.
- 19 Göret CC, Göret NE, Özdemir ZT, Özkan EA, Doğan M, Yanık S, et al. Diagnostic value of fine needle aspiration biopsy in non-thyroidal head and neck lesions: a retrospective study of 866 aspiration materials. *Int J Clin Exp Pathol*. 2015 Aug;8(8):8709–16.
- 20 Jing X, Michael CW, Pu RT. The clinical and diagnostic impact of using standard criteria of adequacy assessment and diagnostic terminology on thyroid nodule fine needle aspiration. *Diagn Cytopathol*. 2008 Mar;36(3):161–6.
- 21 Cibas ES, Ali SZ. The 2017 Bethesda system for reporting thyroid cytopathology. *J Am Soc Cytopathol*. 2017 Nov - Dec;6(6):217–22.
- 22 Lee HY, Baek JH, Yoo H, Kim JK, Lim MK, Chu YC, et al.; L. H.Y. et al. Repeat fine-needle aspiration biopsy within a short interval does not increase the atypical cytologic results for thyroid nodules with previously nondiagnostic results. *Acta Cytol*. 2014; 58(4):330–4.
- 23 Haugen BR, Alexander EK, Bible KC, Doherty GM, Mandel SJ, Nikiforov YE, et al. 2015 American Thyroid Association Management Guidelines for Adult Patients with Thyroid Nodules and Differentiated Thyroid Cancer: The American Thyroid Association Guidelines Task Force on Thyroid Nodules and Differentiated Thyroid Cancer. *Thyroid*. 2016 Jan;26(1):1–133.
- 24 Redman R, Zalaznick H, Mazzaferri EL, Mas-soll NA. The impact of assessing specimen adequacy and number of needle passes for fine-needle aspiration biopsy of thyroid nodules. *Thyroid*. 2006 Jan;16(1):55–60.
- 25 Collins JA, Novak A, Ali SZ, Olson MT. Cytotechnologists and on-site evaluation of adequacy. *Korean J Pathol* [Internet]. 2013 Oct; 47(5):405–10. Available from: <https://doi.org/10.4132/KoreanJPathol.2013.47.5.405>.
- 26 Alsohaibani F, Girgis S, Sandha GS. Does on-site cytotechnology evaluation improve the accuracy of endoscopic ultrasound-guided fine-needle aspiration biopsy? *Can J Gastroenterol*. 2009 Jan;23(1):26–30.
- 27 Burlingame OO, Kessé KO, Silverman SG, Cibas ES. On-site adequacy evaluations performed by cytotechnologists: correlation with final interpretations of 5241 image-guided fine-needle aspiration biopsies. *Cancer Cytopathol*. 2012 Jun;120(3):177–84.