IMMUNOEXPRESSION OF MUTATED BRAFV600E PROTEIN IN PAPILLARY THYROID CARCINOMA

Abstract

Background and Objectives: In papillary thyroid cancer (PTC), BRAF V600E is the most prevalent genetic alteration, and in different populations, its frequency ranges from 29% to 83%.BRAF mutation is mostly detected by DNA-based molecular methods, which are labor-intensive and time-consuming. A method, immunohistochemistry (IHC), was recently introduced to detect BRAF-mutated proteins. This method enables a monoclonal BRAF V600E mutation-specific antibody that can distinguish BRAF V600E from wild-type protein in conventionally processed, formalin-fixed, paraffin-embedded tissue and the mutant proteinthat was directly visualized in tumour cells in a tissue context.This study aimed to determine the BRAF V600E-mutated protein's immunoexpression in papillary thyroid carcinoma.

Methodology: The study was a laboratory-based descriptive cross-sectional study. A total of 44 histologically proven paraffin-embedded tissue blocks of PTC were collected. Anti-BRAF V600E rabbit monoclonal primary antibody was used for immunohistochemistry on tissue sections, and the staining intensity was scored from 0 to 3(+): 0, no cytoplasmic staining in tumour cells; 1: faint cytoplasmic staining in over 10% of tumour cells; 2+, moderate cytoplasmic staining in over 10% of tumour cells; 3+, strong cytoplasmic staining in over 10% of tumour cells.

Results: Among44 cases, 34 (77.3%) were positive, and 10 (22.7%) were negative for the mutated BRAF V600Eprotein by IHC staining. In terms of staining intensity, 4 (9.1%), 20 (45.5%), and 10 (22.7%) cases had IHC scores of 1+, 2+, and 3+, respectively. This study reported a high-frequency rate (77.3%) of mutated BRAF protein, similar to the frequency reported in other Asian countries. There was no association between mutated BRAF V600E protein status and either age or gender.

Conclusion: The most effective PTC diagnostic marker is BRAF V600E mutation. The IHC technique using BRAF V600E mutation-specific antibodies is relatively simple and faster and is therefore proposed as the most reliable first-line method for detecting BRAF V600E-mutated proteins.

Keywords: Myanmar, Immunohistochemistry (IHC), BRAF V600E, Papillary thyroid carcinoma, Formalin-fixed paraffin-embedded tissue, Monoclonal antibody, Cytoplasmic staining

1. Introduction

Papillary thyroid carcinoma (PTC) contributes to 80–90% of all thyroid malignancies [1].Despite the fact that PTC is generally a highly curable disease, 25–35% of cases still have a poor prognosis, and patients tend to be more susceptible to recurrence following surgery and metastasis. Therefore, prognosis prediction of papillary thyroid cancer and customisingindividualised treatment has become a topic of interest [2].

Mutations involving the mitogen-activated protein kinase (MAPK) pathway, such as RET/PTC, RAS, and B-type Raf kinase (BRAF), are frequently observed in PTC [3]. The BRAF mutation fundamentally influences the pathogenesis of PTC and is reported to be present in 25-82% of PTC cases [4].

The BRAF V600E mutation, the most reliable diagnostic marker of PTC, is typically linked to more aggressive clinical behaviour.The mutation of BRAF V600E in cancer is linked with a faster growth rate and metastasis, as well as an increased mortality risk[4]. The MAPK pathway is, therefore, a potential therapeutic target for PTC, and potent MEK inhibitors may be the first effective therapeutic agents for thyroid cancer, suggesting that the BRAF V600E mutation should be tested in every case of papillary thyroid cancer. Testing for this mutation can aid in selecting initial treatment and monitoring [3].

Several techniques are available in routine clinical practice for BRAF mutation detection. These include allele-specific real-time PCR, colorimetric mutant assay, high-resolution melting (HRM) analysis, deoxysequencing, and pyrosequencing. These techniques vary in terms of sensitivity, assay complexity, and cost [5].Immunochemistry (IHC) technique was recently developed to detect mutated BRAF proteins using anti-BRAF V600E antibodies specific to this BRAF-mutant protein [6]. This study was conducted to determine mutated BRAF V600Eprotein immunoexpression in histologically diagnosed papillary thyroid carcinoma.

2. Materials & Methods

The histologically proven, paraffin-embedded tissue blocks of 44 papillary thyroid carcinoma patients who attended the Otorhinolaryngology, Head and Neck Surgery Specialist Hospital, Yangon, were collected. Immunohistochemistry using the peroxidase-anti-peroxidase method was performed with a commercially available recombinant rabbit monoclonal BRAF V600E mutation-specific primary antibody (RM8) (Catalog No. MA5-24661, Invitrogen, Thermo Fisher Scientific, Massachusetts, USA).

2.1 Immunohistochemical staining procedure

IHC was performed on formalin-fixed, paraffin-embedded tissue. A 3 µm thick section for immunohistochemical staining was transferred to a salinized slide and dried at 55 °C on a slide-warmer for 2 hours. Antigen retrieval is done by immersing the slides in pre-warmed citrate buffer in the microwave three times at a high temperature (not more than 98ºC) for five minutes, and endogenous peroxidase was blocked at room temperature for 30 minutes with 3% H_2O_2.

The tissue sections were covered with the primary antibody using prediluted antibodies and incubated overnight at 4ºC in a wet chamber. The tissue sections were then incubated for 30 minutes at room temperature with a secondary antibody (N-histofine, Simple StainTM MAX PO-MULTI, Nichirei Biosciences Inc., Japan). Tissue sections were immersed for 5–10 minutes in freshly prepared DAB (diaminobenzidine) solutions. The slides were rinsed with water before being counterstained with hematoxylin for thirty seconds. The sections were dehydrated, cleared, and mounted with distyrene (DPX) and a coverslip.

In every immunohistochemical staining batch, both positive and negative controls were performed. BRAF V600E mutation-positive melanoma tissue was used as a positive control in every batch, as was the omission of the application of primary antibodies to the tissue section for the negative control.

2.2 Reporting of the Slides

The immunostained slides were examined using a light microscope by two observers. IHC scoring was done on the basis of the intensity of brown cytoplasmic staining in tumour cells the results were rated as follows, on a scale from 0 to 3 (+): 0, the absence of cytoplasmic staining in tumour cells; 1+ indicated faint cytoplasmic staining in more than 10%

of tumour cells; 2+ indicatedmoderate cytoplasmic staining in more than 10% of tumour cells; and 3+ indicated strong cytoplasmic staining in more than 10% of tumour cells [7]. The tumour cell was considered positive for mutated BRAF V600E expression if the score was 1+ or higher and negative if it was 0 [8]. The immunohistochemical results were interpreted and assessed for consistency between the two observers. The photomicrographs were taken with a CETI microscope (Medline Scientific Limited, UK). This study was permitted by the University of Medical Technology, Yangon, Institutional Review Board.

2.3 Data analysis

Statistical analysis was conducted using version 20 of the SPSS software (SPSS, Inc., Chicago, IL, USA). The data were described with descriptive statistics, including frequencies, percentages, and crosstabs. Fisher's exact test was used to assess the differences between categorical variables, and the P value of less than 0.05 was considered statistically significant.

3.Results

This study was designed to investigate the immunoexpression of mutated BRAF V600E protein in papillary thyroid carcinoma using the peroxidase anti-peroxidase method.A total of 44 paraffin blocks of papillary thyroid carcinoma were histologically confirmed with haematoxylin, and eosin staining, and then immunohistochemical staining for mutated BRAF V600E protein was performed.

3.1 Age distribution of patients with papillary thyroid carcinoma

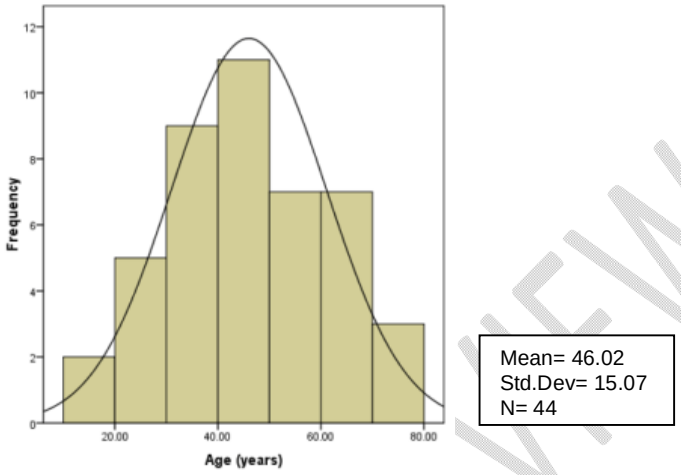

Fig. 1. Age distribution of patients with papillary thyroid carcinoma

Fig. 1 indicates the age distribution of papillary thyroid cancer patients.A mean age of 46.02 years and a median age of 45 were found in the study population, ranging from 17 to 75. Nearly half of the patients were between the ages of 41 and 60, while 22.7% were over 60. The remaining 36.4% were aged 40 years and below.

3.2Gender distribution of papillary thyroid carcinoma patients

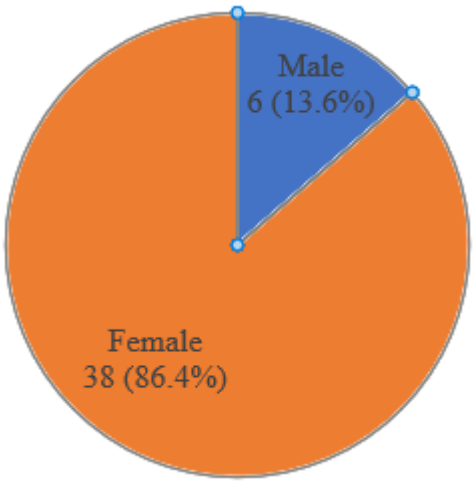

Fig. 2. Gender distribution of papillary thyroid carcinoma patients

Fig. 2 presents the gender distribution of patients with papillary thyroid carcinoma; most patients were female, representing 38 (86.4%) of the study population. Out of 44 patients, only 6 (13.6%) were male.

3.3 . BRAF V600E protein immunoexpression score in papillary thyroid carcinoma

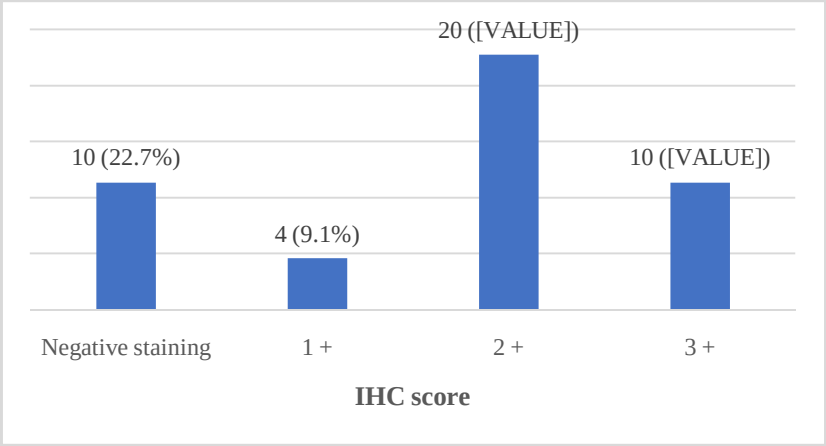

Fig. 3. BRAF V600E proteinimmunoexpression scorein papillary thyroid carcinoma

Fig. 3 showsmutated BRAF V600E protein immunoexpression in papillary thyroid carcinoma, in which, on a scale from 0 to 3, the staining intensity of BRAF V600E in tumour cells was quantified. Mutated BRAF V600E proteinpositive IHC staining was 3+ in 10 (22.7%), 2+ in 20 (45.5%), 1+ in 4 (9.1%), and negative in 10 (22.7%) cases, respectively. Based on an examination of BRAF status on PTC samples, BRAFV600 mutated protein positivity was found in 34 (77.3%) of the patients studied.

3.4 Age group and BRAF V600E immunoexpression

Table 1. Age group and BRAF V600E immunoexpression

Age Group	BRAF V600E Immunoexpression				Fisher's exact test p value
	Negative		Positive		
	Number	%	Number	%	
≤ 40	5	31.2	11	68.8	0.46
41- 60	3	16.7	15	83.3	
> 60	2	20.0	8	80.0	
Total	10	22.7	34	77.3	

Table 1 shows the association between age group and BRAF V600E immunoexpression. Out of 44 cases, 34 (77.3%) were positive for BRAF V600E immunoexpression, and 10 (22.7%) were negative for BRAF V600E immunoexpression. Positive BRAF V600E immunoexpression was more common in 41- 60 age groups, while negative BRAF V600E immunoexpression was more common in those aged ≤ 40 years. However, the correlation between age group and BRAF IHC score in papillary thyroid carcinoma was not statistically significant ($P = 0.46$).

3.5Comparison of ages according to the BRAF V600E IHC score

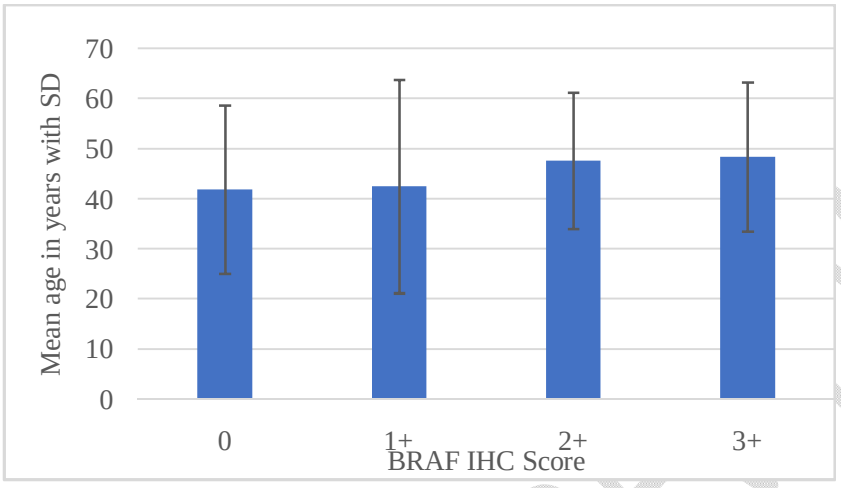

Fig. 4. Comparison of ages according to the BRAF V600E IHC score

The comparison of ages according to the mutated BRAF V600E protein IHC score is shown in Fig. 4, and the mean age of patients increases as the mutated BRAF V600E protein IHC score increases. Among the scores of 0, the mean age was 41.9 years, which increased to 42.5 years, 47.6 years, and 48.4 years when the score was raised to 1+, 2+, and 3+, respectively.

3.6 Gender and BRAF V600E immunoexpression

Table 2. Gender and BRAF V600E immunoexpression

Gender	BRAF V600E Immunoexpression				Fisher's exact test p value
	Negative		Positive		
	Number	%	Number	%	
Male	2	33.3	4	66.7	0.43
Female	8	21.1	30	78.9	
Total	10	22.7	34	77.3	

As shown in [Table 2], among the six male patients, 2 (33.3 %) were negative for BRAF V600E immunoexpression, and 4 (66.7%) were positive for BRAF V600E immunoexpression. Among the 38 female patients, 8 (21.1%) were negative for BRAF V600E immunoexpression, and 30 (78.9%) were positive for BRAF V600E immunoexpression. There was no considerable difference between male and female BRAF V600E immunoexpression (P = 0.43).

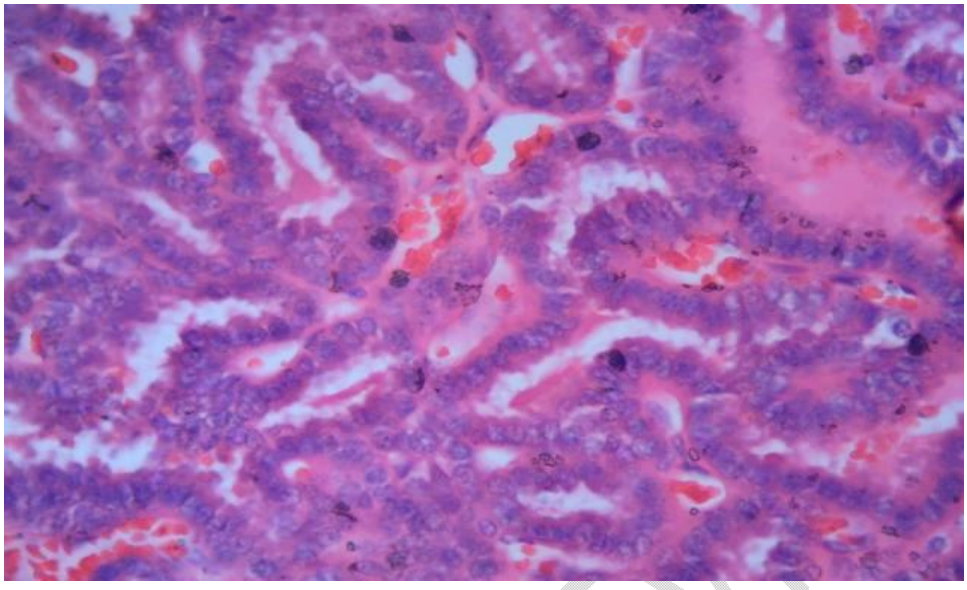

Fig. 5.Papillary Thyroid Carcinoma (H&E x 400)
(Case No. 21)

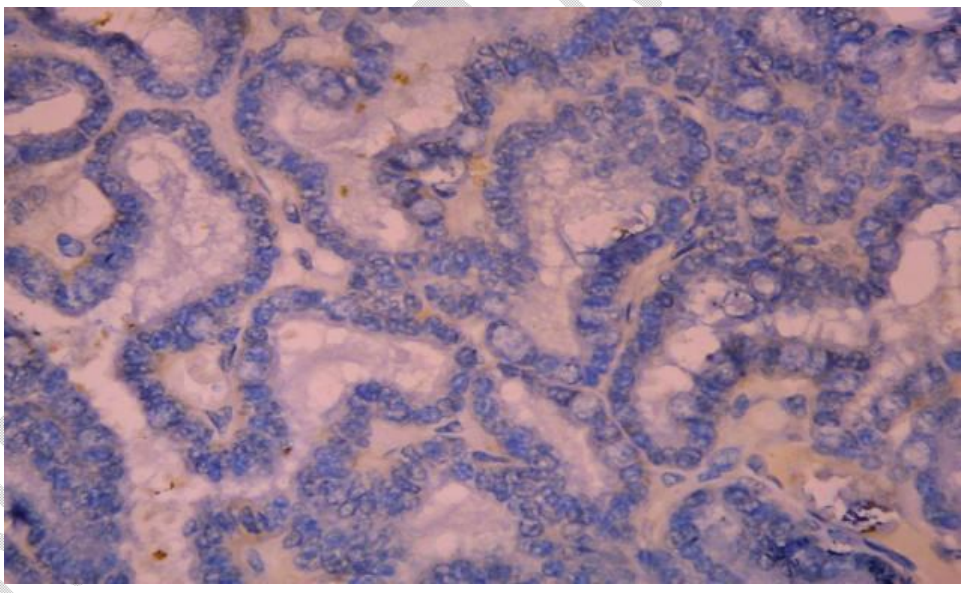

Fig. 6.BRAF V600E Score 0 (Negative expression)
in papillary thyroid carcinoma,(IHC x 400)(Case No. 21)

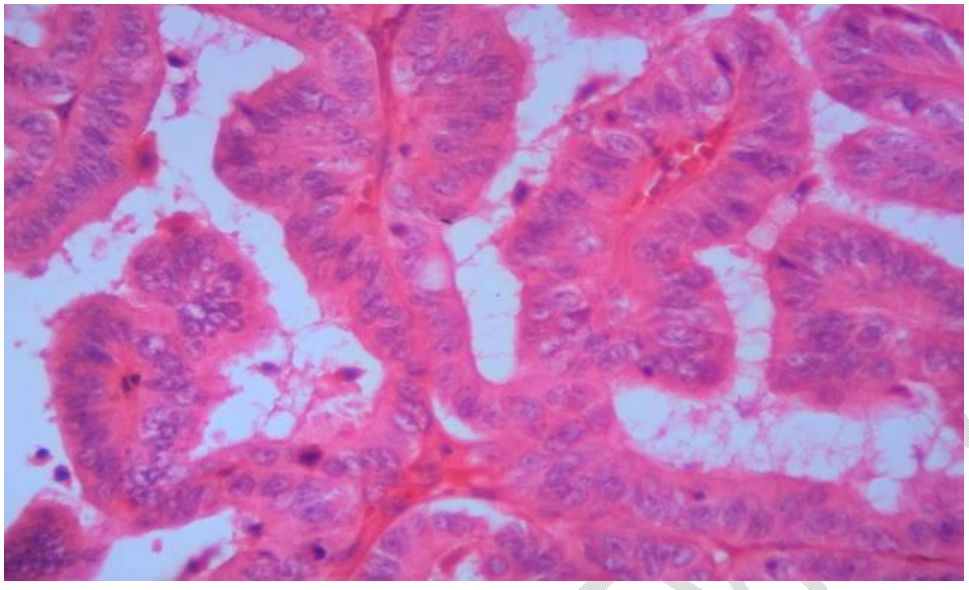

Fig. 7. Papillary Thyroid Carcinoma (H&E x 400)
(Case No. 14)

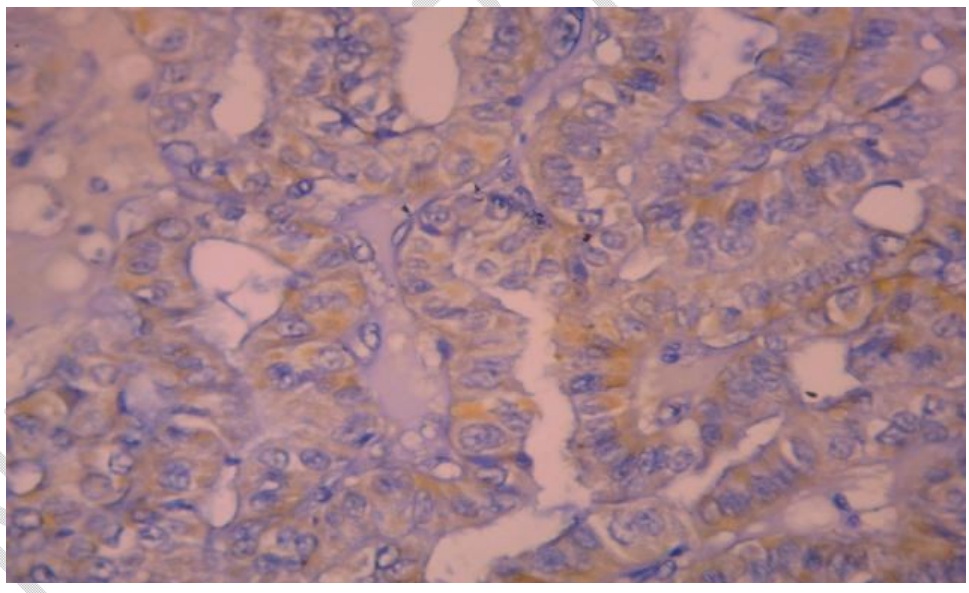

Fig. 8. BRAF V600E Score 1+ (Weak positiveexpression)
in papillary thyroid carcinoma, (IHC x 400) (Case No. 14)

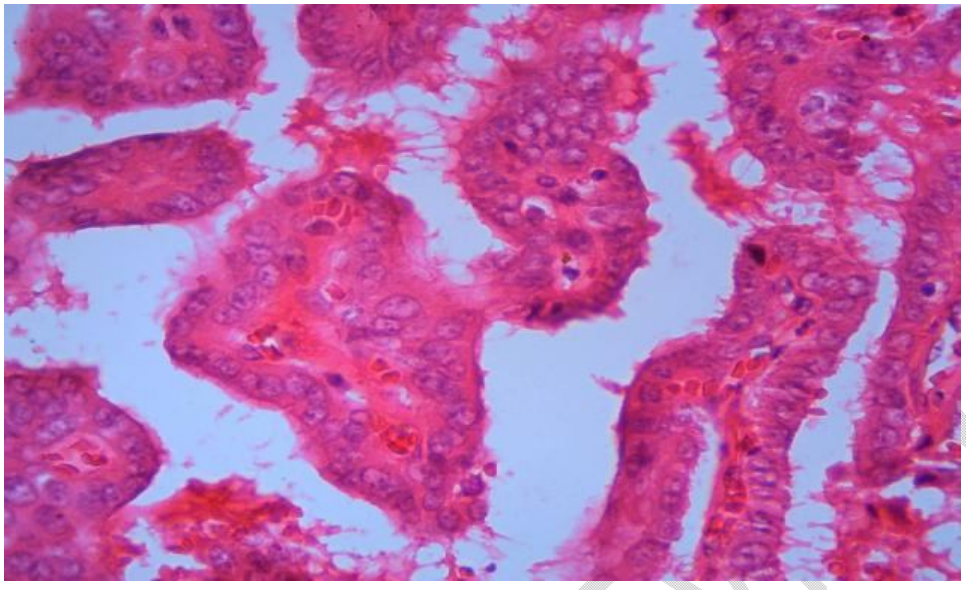

Fig. 9.Papillary Thyroid Carcinoma (H&E x 400)
(Case No. 19)

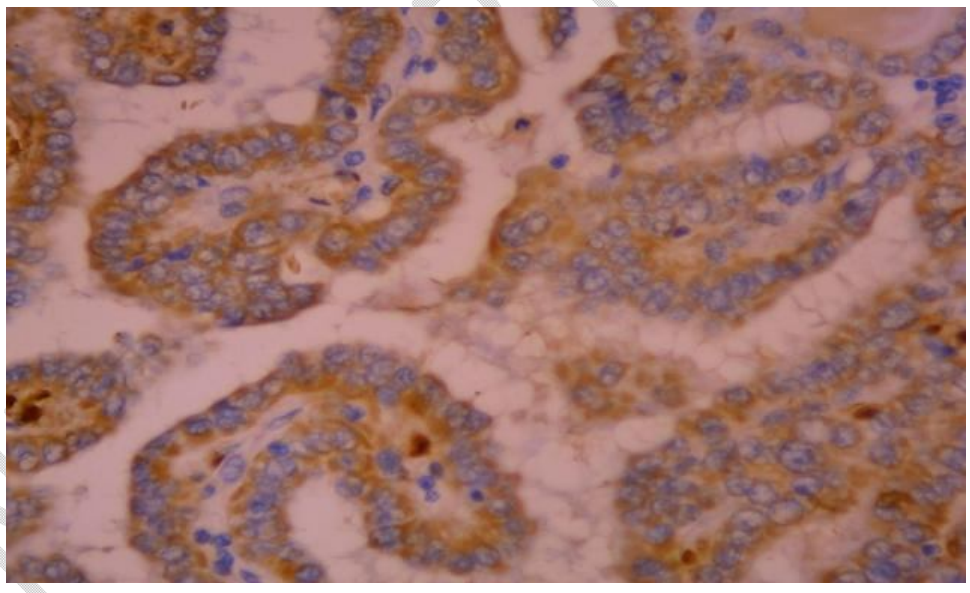

Fig. 10. BRAF V600EScore 2+ (Moderately positiveexpression)
in papillary thyroid carcinoma (IHC x 400) (Case No. 19)

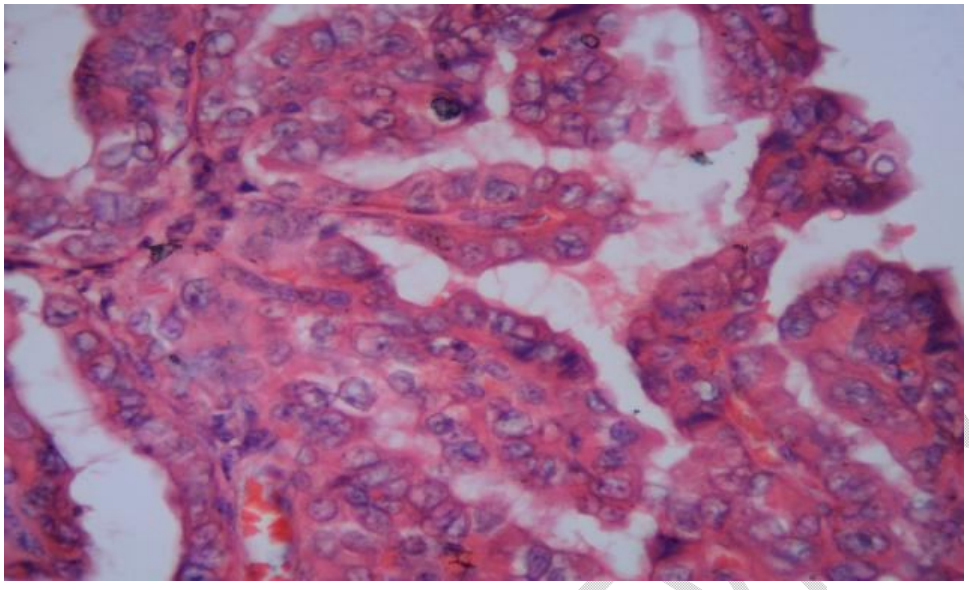

Fig. 11. Papillary Thyroid Carcinoma (H&E x 400) (Case No. 31)

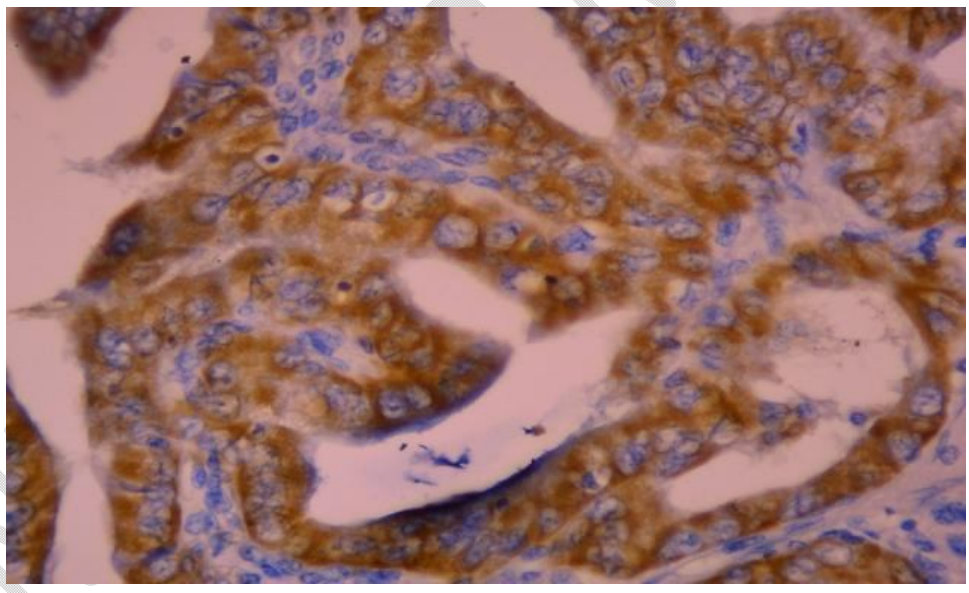

Fig. 12. BRAF V600E Score 3+ (Strong positive expression) in papillary thyroid carcinoma (IHC x 400) (Case No. 31)

4.Discussion

The majority of diagnostic tests were developed to detect only the BRAF V600E mutation, which accounts for approximately 95% of all BRAF mutations.Among these tests, monoclonal antibodies against the BRAF V600E-mutated protein have been developed and used in immunohistochemistry to detect the presence of the mutant protein[9]. In addition to being a well-established diagnostic and prognostic marker for PTC and other subtypes of thyroid carcinoma, mutations in BRAF V600E provide a valuable target for specific inhibitors of BRAF V600E [10, 11]. This study reported the institutional experience of detecting mutated BRAF V600Eprotein on PTC specimens using immunohistochemistry. It confirmed the usefulness of the IHC method for detecting mutated BRAF V600E protein.

All PTC cases were initially evaluated on hematoxylin-eosin stained slides to ensure the presence of the tumour. The presence of complete nuclear changessuch as overlap, clear nuclei, oval nuclei, irregular nuclear membrane, intranuclear clefts, and intranuclear pseudo inclusionwas reviewed. Furthermore, the presence or absence of round eosinophilic cytoplasm-containing cells (“plump pink cells”), psammoma bodies that have invaded tumour borders, and stromal reactions were also evaluated [12].

4.1 Age Distribution in papillary thyroid carcinoma

PTC is distinct from other cancers in that the patient's age is included in the staging criteria [13]. PTC can occur at any age but is typically diagnosed between the third and fifth decades of a patient's life, with a mean age of 40 years[14]. Therefore, the age threshold for papillary thyroid cancer may be variable between 40 and 55 years of age [15].

In this study, regarding the age distribution of papillary thyroid cancer, the mean ageof 44 cases was 46 ± 15.07 years, and most prevalent age range was 41 to 60 years old, accounting for 28 patients (40.9%). In the studies of Cho et al., (2012) [16], Szymonek et al., (2017) [17], and Girardi (2017) [18],papillary thyroid carcinoma was most commonly seen in those aged 35 to 55years, with mean ages of 47, 52 years, and 48 years, respectively. The finding of the present study was nearly consistent with those studiesshowing that the risk of papillary thyroid carcinoma increases with increasing age.

4.2 Gender distribution in papillary thyroid carcinoma

Regarding gender distribution, it is known that, due to hormonal effects, thyroid cancer is only cancer that occurs predominantly in women [10].In this study, 38 cases (86.4% of all cases) were female, while only six patients (13.6%) were male, for a ratio of female-to-male6.3:1, supporting the fact that papillary thyroid cancer is more prevalent in females.This finding was very similar to the reports of Kaliszewski et al., 2020 [13], LeClair et al., 2021 [19], and Jonklaas et al., 2012 [20], female to male ratio in PTC were 6.8:1, 4.28:1, and 2.7:1 respectively. Estrogen could be a risk factor for thyroid cancer as it probably has a growth-promoting effect in benign and malignant thyroid tumours and may play a role in its progression [21]. It could be one of the reasons for female predominance in PTC.

4.3 Immunohistochemical detection of mutated BRAF V600Eprotein

To perform immunohistochemical screening for BRAF-mutant tumours, a BRAF V600E mutant-specific antibody has been developed.According to initial studies, this antibody detects mutant BRAF V600E in various cancer types, such as papillary thyroid cancer [22].In the present study, the BRAF V600E mutated protein IHC was conductedon 44 cases of papillary thyroid carcinoma by immunohistochemical staining with positive and negative controls.

Immunohistochemistry is significantly impacted by pre-analytical factors, such aspoor tissue handling and delayed fixation. Improper tissue preparation, such as the fixation (type,length of time, temperature and pH of the fixative), dehydration, clearing, wax impregnation, and embedding processes, can render IHC inconsistent, complex, or impossible to perform, as well as a result in the loss of antigens and alterations antigen expression level that affect immunoreactivity. To overcome these conditions, the temperature and quality of reagents used in tissue processing were constantly monitored, and H&E stained slides were examined prior to IHC staining.The optimal conditions for staining BRAF V600E have been established through previous studies, including fixatives, fixation times, and the pH of solutions used to retrieve the stain[23].

The type and pH of the antigen retrieval buffer solution and the antigen retrieval method can affect the final IHC results. Some antigens are retrievable in a low-pH solution, while others are retrievable in a high-pH solution [24, 25]. Currently, heat treatment in citrate buffer(10 mM sodium citrate, pH 6.0) is the most common method for the retrieval of

antigens[26]. This study used citrate buffer pH 6.0 with microwave oven heat-induced epitope retrieval (HIER) method for antigen retrieval, and phosphate buffer saline pH 7.2-7.6 was used as washing buffer. The constituents of stock buffer solutions were balanced with standardized electrical balance and dissolved in distilled water. The stock buffer solutions were kept in the refrigerator (2-8˚C), and working buffer solutions were freshly prepared before use. The pH of the buffer solution was measured by a standardized pH meter to produce satisfactory immunostaining in PTC samples [25].

Heating temperature and time are also essential factors in the HIER process.Antigens require either a higher temperature for a shorter period of time or a lower temperature for a longer period of time to achieve the same retrieval effect [25, 27]. In this study, to maintain the consistency of heating between runs, the same number of tissue sections were placed in the Coplin jar, filled with a suitable amount of antigen retrieval solution. The jar was also covered with aluminium foil to prevent evaporation during the HIER method. At some point, heat-induced antigen retrieval caused cancer cells to have nonspecific or false-negative nuclear staining.Increasing the retrieval time may enhance the BRAF V600E IHC positive signalbut substantially increase the likelihood of nuclear nonspecific staining[23].So, the sections were left in the microwave oven at high temperature, and an antigen retrieval time of 5 minutes three times worked best in this study. After antigen retrieval, the Coplin jar was placed in tap water for 15 minutes to prevent immediate temperature change and achieve a perfect staining result.

As an analytical variable, the primary antibody incubation is a fundamental step in any immunostaining and starting with a high-quality antibody is very important. It is also essential to determine the optimal titers of the primary antibody before putting them into diagnostic procedures to avoid unsatisfactory results. In this study, a series of titers (1:50, 1:100, and 1:200) was prepared to determine optimal titers with the first titer of 1:50 suggested by the manufacturer and further 2-fold dilutions and studied on several different known positive cases as well as many known negative cases.

Critical criteria for evaluating staining results include differential staining between cells and proper staining localization. Common causes of false positive stains are edge and trapping artefacts, bubble artefacts, chromogen freckles, hemosiderin or melanin pigmentation, drying artefacts, and inadequate fixation artefacts [26,28]. Both positive and

negative control slides were run simultaneously in each experiment to ensure the consistency of performance and reproducibility of results.

Mutated BRAF V600E proteinimmunoexpression was evident as brown cytoplasmic staining. In the past few decades, numerous scoring systems have been developed [29]. For evaluating the BRAF V600E status of PTC samples, a 4-tiered scoring system is more appropriate, and most studies assessed staining intensity using a 4-tiered system (0, 1+, 2+, 3+)[23].In this study, grading IHC staining was based on both staining intensity and percentage of positively stained cells same as Zhao et al.,2019 [7], in which a score of 1+ (> 10% of tumour cells showing weak cytoplasmic brownish staining), 2+ (> 10% of tumour cells displaying moderate cytoplasmic distinct brownish staining), and 3+ (> 10% of tumour cells presenting strong cytoplasmic brownish staining) were regarded as positive staining for BRAF V600E, whereas score 0 (no staining in tumour cells) was considered as negative IHC staining

4.4 Distribution of mutated BRAF V600Eprotein in papillary thyroid carcinoma

In the present study, regarding BRAF V600E IHC, positive staining was detected in 34 (77.3%) cases and negative in 10 (22.7%) cases. Nearly half of the cases showed moderate staining, and a significant number (30 of 44) of BRAF mutated proteins presented strongly to moderate IHC staining. Immunostaining-positive (score 3) tumours displayed diffuse and strong staining throughout the entire tumour area. Non-homogeneous staining was mainly found in the 1+ stained tissue section, and the scoring system determined the positivity. The distribution of tumour cells that had mutations in the positive cases also varied. The strongly positive stained cells ranged from 50-100% of tumour cells. This result is consistent with research conducted by De Biase et al. [30], and heterogeneous staining was not caused by improper tissue fixation or preservation [31].

Clinicopathological characteristics (age, histological type) and the study population have a significant impact on the incidence of the BRAF V600E mutation in papillary carcinoma.According to studies, 45–50% cases of PTC in the Western series, originating from the United States and Europe, have a BRAF V600E mutation. However, prevalence is more variable in the Asian population, with reported percentages ranging from 31% to 87% [32].

In the current study, the overall mutated BRAFV600protein positivity was identified in 34 cases (77.3%) of PTC patients.This study reported a high-frequency rate of

mutated BRAF protein compared to the previous studies done by immunohistochemistry on the FFPE PTC tissue; Pakistan, Thai, Indonesian, and Indian populations reported that the prevalence of mutated BRAF protein in PTC as 29%, 61%, 34%,and 44% respectively [10,11,31,33].Possibly, the differences in BRAF V600E frequencies may be due to selection bias in samples, but more importantly, to ethnic heterogeneity [10].Furthermore, exact cancerous tissues were detected and scraped from the slice, significantly reducing false-negative results from the pericarcinousportion [34].

The present study's findings were comparable to those of other Asian investigations;Choden et al., (2020)andJung et al., (2014)reported a prevalence rate of 86% and 84.2%, respectively, in Korea [32,35]. China-based studies by Zhang et al., 2018 [23], Zhao et al., 2019 [7], and Zhang et al., 2021 [36]also reported a high prevalence rate of 84%, 76.8%, and 96.8%, respectively.

4.5 Association of BRAF V600E immunoexpression with age

The prognosis of patients diagnosed with PTC is highly influenced by their age.Historically, a risk stratification cutoff age of 45 has been used.However, this threshold only makes sense if all patients over 45 have the sameprobability of death and recurrence, regardless of how close they are to the cutoff. Recent data has suggested that the survival rate of patients over 45 declines with age. Consequently, a new age limit of 60 years has been considered [37].

Patientsover 60 have lower disease-specific survival and disease-free survival following a diagnosis of PTC, regardless of disease stage. These findings support the addition of three age categories, 18-44 years, 45-59 years, and 60 years, as survival and recurrence predictor irrespective of the existing staging recommendations because survival declines with age in patients older than 45 years [37].

In this study, out of 44 patients, 10 (22.7%) were negative for BRAF V600E immunoexpression, and 34 (77.3%) were positive for BRAF V600E immunoexpression. The mean age of patients also increased according to the increase in BRAF IHC score.Among the total positive rate of BRAF V600E-mutated protein, 25% (11/44) were detected in the ≤ 40 age group, whereas 52.3% (23/44) were found in those older than 40, indicating that BRAF V600E-mutated protein positivity increases with age; however, it was not statistically significant ($P = 0.46$).

Similarly, a meta-analysis by Carol Li in 2012 [38] showed nine studies, including 2015 patients, indicating a higher prevalence of BRAF V600E in elderly patients. Several studiesby Koperek et al., 2012 [39],Sun et al., 2015 [40], Szymonek et al., 2017 [17] and Choden et al., 2020 [32] have observed that patient age and BRAF mutations are related.Nevertheless, a significant association between age and the BRAF V600E rate was not observed in the present study, which was similar to the studies by many other authors, Zagzag et al., 2013 [41], Zhang et al., 2016 [34],Barreno et al., 2022 [42], Rashid et al., 2021 [10] and Kristiani et al., 2021 [31].

4.6 Association of BRAF V600E immunoexpression with Gender

In this study, 38 cases (86.4%) were female, and 6 patients (13.6%) were male. Out of 6 male patients, 4 (66.7 %) were BRAF V600E positive, while among the 38 female patients, 30 (68.2 %) were BRAF positive. There was no significant difference in BRAFV600 positivity between males and females (P = 0.43). Some studies, McKelvie, 2013 [43] and Kristiani et al., 2021[31], stated BRAF V600E mutation is linked with the male gender. However, in this study, gender was not associated with BRAF status. This finding was in concordance with many other studies, Zagzag et al., 2013 [41]; Zhang et al., 2016 [34]; Barreno et al., 2022 [42]; Rashid et al., 2021 [10]; and Choden et al., 2020 [11].

The strength of this study was the use of IHC to establish the presence or absence of BRAF V600E mutations.A false positive result could be substantially reduced or avoided by employing a negative control. In addition, IHC yields faster results than other molecular tests, hence, decreasing turnaround time in diagnostic laboratories. Therefore, in time, targeted therapy can be given to an aggressive BRAF V600E mutated thyroid cancer. Furthermore, the BRAF IHC technique can be introduced in small centers without sophisticated equipment. This IHC procedure also requires fewer human resources because it can be carried out in the same department using the same sample as the traditional histology procedure.

Nevertheless, the present study has several limitations. Firstly, the study did not include PTC variants other than the conventional type; however, many past studies have shown that BRAF immunostaining and subtypes of PTC have a strong link[44].Secondly, due to limited

resources, BRAF status in the present study could not be confirmed by molecular genetic studies. Finally, this study is a single-center, small-patient study; therefore, a substantial sample size should be used to validate the clinical effectiveness of IHC in detecting BRAF V600E.

5.Conclusion

In conclusion, the current study showed the feasibility of IHC performed on paraffin sections in identifying the mutated BRAF V600E protein in papillary thyroid carcinoma. The process of IHC using BRAF V600E mutation-specific antibodies is relatively simple, rapid, and helpful in screening for BRAF V600E mutant papillary thyroid carcinoma. In addition, it should be validated by molecular genetic studies prior to implementation.

Ethical Approval

This study was approved by the University of Medical Technology, Yangon, Institutional Review Board (Ethics Review Committee) (IRB Approval No. IRB/UMTY/2-2022/002).

Competing Interests

Authors have declared that no competing interests exist.

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Authors' Contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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