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High Resolution Ultrasonic Imaging in the Evaluation of the Posterior Segment Disorders

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ABSTRACT

Purpose: to evaluate the role of high resolution 20 MHz ultra sound in assessment of posterior segment disorders.

Patients and Methods: a prospective, case series study was conducted on 40 patients who attended the ophthalmology outpatient clinic of Al-Azhar university hospitals (2014-2018). All should have a posterior segment disorder either retinal, vascular, vitreo-macular, optic nerve head or choroidal disorder. They should be with clear media, therefor we can reach a diagnosis based on clinical examination and augmented by optical coherence tomography (OCT) and fundus fluorescein angiography (FFA) whenever indicated, the patients were evaluated using both high resolution 20 MHz ultrasound(US) and conventional 12.5 MHz US and compare their results to the gold standard clinical diagnosis to assess their sensitivity to reach the diagnosis.

Results & Conclusion: we have two main characters for well diagnosis by any US tool, resolution and sensitivity, and neither the 20 MHz nor 12.5 MHz could combine both of them. Therefore, we recommended tocombine the examination by both of them as they are complementary to each other.

Keywords: High Resolution US, OCT, FFA, 20MHz US

INTRODUCTION

Ultrasonography is one of the most valuable diagnostic tool in ophthalmology. It is a safe, reliable, non-invasive diagnostic tool that accepted as an integral tool in diagnosis and management of a wide spectrum of intra ocular and orbital pathologies even in opaque media as corneal and anterior chamber opacities, cataract and vitreous hemorrhage [(1)].

Developments in transducer, pulser/receiver, and digital signal-processing technologies particularly development of sensitive, broadband 20-MHz transducers have allowed higher frequencies to be valuable for evaluation of the posterior segment [(2)].

OCT had filled the gap in high-resolution imaging of the posterior segment of the eye, which is more valuable than resolution provided by 10-MHz US, it can provides an axial resolution of 10 µm and a lateral resolution of 20 µm, however OCT can be used only when all optical media (cornea, lens, vitreous) are mostly clear and is limited to the central fundus (i.e., images are acquired through the pupil) [(3)].

Recently, the availability of higher frequency probes such as the 20-MHz has made the evaluation of the posterior segment structures much better with higher resolution in comparison to the previous 10-MHz probe [(4)].

AIM OF THE WORK

To evaluate the use of higher frequency ultrasound to provide improved resolution of the posterior segment in comparison to the conventional frequencies in ***clear media***, keeping the clinical diagnosis augmented by OCT & FFA as the gold standard, therefore we can assess the high frequency US reliability and dependability in ***opaque media.***

PATIENTS AND METHODS

The study protocol adhered to the tenets of Helsinki and was approved by ethical board of Al-Azhar uniVersity and informed written consent was taken from each patient in the study, A prospective case series study was conducted on forty eyes of thirty-three patients who attended the ophthalmology outpatient clinic of Al-Azhar university hospitals (2014-2018) with different posterior segment disorders.

Inclusion criteria, *All patients should have:* 1- Cornea, anterior segment, crystalline lens and vitreous gel all are clear enough for fundus examination and OCT, FFA imaging. 2- Posterior segment pathology, that could be either posterior vitreal, retinal, optic nerve head or choroidal pathology. Uncooperative patients and patients who had unclear media (like central corneal opacities, dense cataract, dense vitreous hemorrhage, etc.) that prevent fundus viewing and (or) FFA or OCT. to be taken when been indicated for diagnosis were excluded from this study.

Each patient subjected to the following: **1- Complete ophthalmological examination** including

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best corrected visual acuity (BCVA) will be measured using a Snellen chart. Anterior segment examination using slit lamp biomicroscopy using (Haag-Streit, BM90, slit lamp, Haag-Streit®™, Germany.)**.** Intra ocular pressure (IOP) measurement by applanation tonometry. (Haag-Streit, AT900, applanation tonometry, Haag-Streit®™, Germany.). Dilated funduscopy will be performed using indirect ophthalmoscopy (Keeler®™ Ltd, Windsor, UK) and stereoscopic biomicroscopy with a non-contact +90 or +78 diopter lens. **2- Ophthalmic ultrasound evaluation using two different techniques**

A- First scan with an immersion technique using 20 -MHz High frequency ultrasound probe of OTI scan® (OTI, B\A high frequency ophthalmic ultrasound scan (OTI ophthalmic technologies inc toronto, canada). The patient lying supine and after instilling anesthetic drops, the appropriate shell size was chosen and placed beneath the eyelids and filled with methyl cellulose depending on the size of the shell, it may be necessary to allow fluid (normal saline) to overflow the edges of the shell to prevent air bubbles formation on the surface in front of the probe. For posterior segment evaluation, axial scans may not be optimal due to sound attenuation from the lens, Para axial scans facilitate the evaluation of the peripapillary area, longitudinal and transverse (cross section) through the macula was obtained by both high and medium gain settings then decrease the gain to evaluate the macular area and improving contrast.

B- Second B scan through closed eye lid using Conventional ultrasound 12.5-MHz of (Mentor ® Advent TM A\B system, mentor ophthalmic inc) The patient lying supine and the probe was placed over the closed eyelid at the temporal equator, aiming nasally and posteriorly after application of a coupling gel (Hydroxy- propyl methyl cellulose) to facilitate sound transmission and allow better contact of the surface of the probe with the eye lid. Fine adjustment of the probe was made while the patient fixated gaze at the primary position or slightly infero- temporally. Transverse (cross-section) and longitudinal (long-section) scans were performed on optic nerve head giving vertical and horizontal sections of the disc cup. B-scan examination was performed with medium gain setting; initially, we displayed the nerve at a high gain level then decreased the gain setting.

3- Optical coherence tomography (OCT) and (or) fundus fluorescin angiography (FFA) whenever indicated using Topcon triton swept source OCT & fundus fluorescein angiography scan (Topcon® DRI OCT triton series, topcon corporation, Japan).

The patients were classified into four main groups: **(I)** Retinal and vascular disorders (17 eyes of15 patients) **(II)** Vitreo-macular interface disorders (6) eyes, (6) patients **(III)** Optic nerve head disorders (9) eyes (6) patients **(IV)** Choroidal disorders (8) eyes (6) patients.

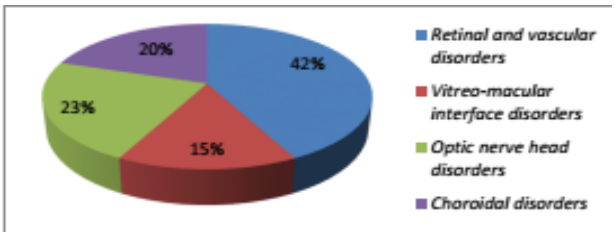

Fig. (1): Pie chart shows Classification of the study group according to clinical diagnosis.

Statistical analysis:

Analysis of data was performed using SPSS v. 25 (Statistical Package for Scientific Studies) for Windows & MedCalc v. 18 and compared the output of each group by odds ratio and Forest plot, The significance of the results was assessed in the form of P-value that was differentiated into: non-significant when P-value > 0.05, significant when P-value ≤ 0.05, highly significant when P-value ≤ 0.01.

RESULTS

This study included forty eyes of thirty-three patients.17 males and 16 females. The mean age was 36 years (range from 5 to 67 years); they were enrolled, as they were fitted in the inclusion criteria, and examined in our prospective case report study.

In group (I) According to ***pathology detection*** there was statistically no significant difference between both types of US and they were comparable to the clinical diagnosis which augmented by either OCT, FFA or both of them, However, according to the ***quality of the pathology detection*** there was statistically ***significant*** difference between clinical and both types of US with (OR=9.47, P.< 0.05) but still comparable to it. There was also statistically total insignificant increase of pathology qualification of **Retinal and vascular disorders** 1.533 times by 20MHz US more than by 12.5MHzUS (OR=1.533; P > 0.05). Regarding ***retinal pathology quantification*** There was statistically total ***insignificant*** increase of pathology quantification of **Retinal and vascular disorders** 5 times by OCT-FFA more than by 20MHz US (OR=5, P.> 0.05).

Table 1: Comparing pathology qualification of retinal and vascular disorders by each method of investigation using odds ratio and Forest plot in the study group (n= 17cases)

Investigation (Retinal& vascular disorders)	Pathology qualification		Odds ratio (OR)	95% CI	P.value
	Yes	No			
OCT-FFA	17/17	0/17	**1225**	22.9 to 65270.9	**0.0005**
20 MHz US	11/17	6/17	3.361	0.82 to 13.723	0.0912
12.5 MHz US	10/17	7/17	2.041	0.521 to 7.999	0.3060
Total (fixed effects)	38/51	13/51	**5.986**	2.72 to 13.132	**<0.001**
Total (random effects)	38/51	13/51	9.265	0.81 to 105.53	0.073

- There was statistically **significant** increase of cases with pathology qualification of **Retinal and vascular disorders** by OCT-FFA more than cases without qualification OR=1225, P.< 0.05).
- There was statistically insignificant increase of cases with pathology qualification of **Retinal and vascular disorders** by 12.5MHz and 20MHz US more than cases without qualification (P.>0.05).

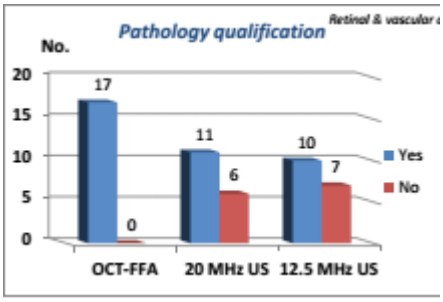

Fig. (2) Column chart comparing pathology qualification of retinal and vascular disorders by each method of investigation

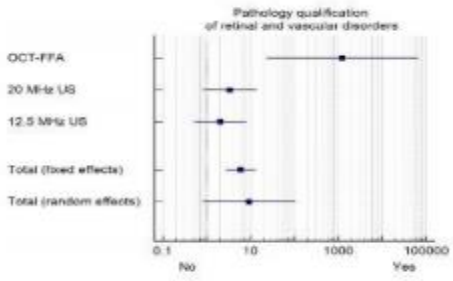

Fig. (3) Forest plot chart comparing pathology qualification of retinal and vascular disorders by each method of investigation.

Case No. 1

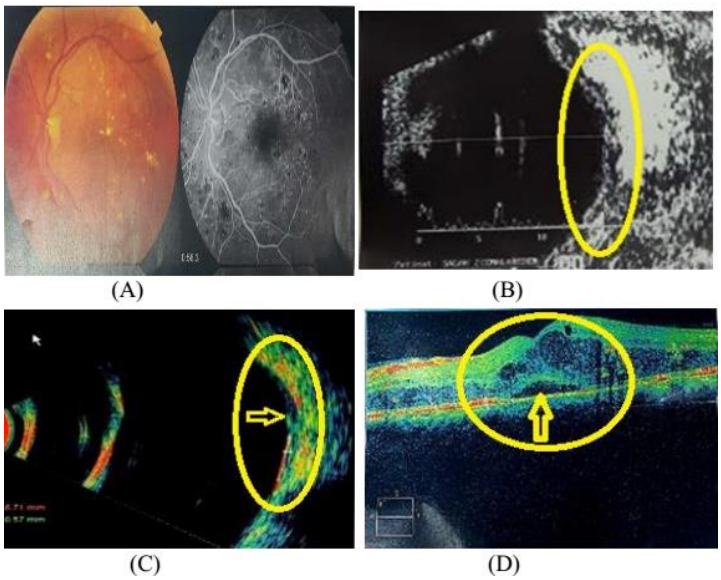

Figure 4: LT NPDR with CME and neurosensory detachment (A): FFA shows NPDR with DME **(B)**: conventional (12.5 MHz) U\S: Retinal fuzziness could be detected which indicates macular edema with demonstration of small cystic spaces within the lesion {yellow circles}. **(C)**: longitudinal B-scan (20 MHz U\S) through the macula shows moderately elevated lesion that indicates DM {yellow circles}. In addition to an area of neurosensory detachment that could be seen clearly (yellow arrow) with central macular thickness ±570µm **(D)** OCT shows CME with evidence of NSD with central macular thickness measuring 611 µm, with thickness difference ± 49µm than that measured by US.

Case No. 2

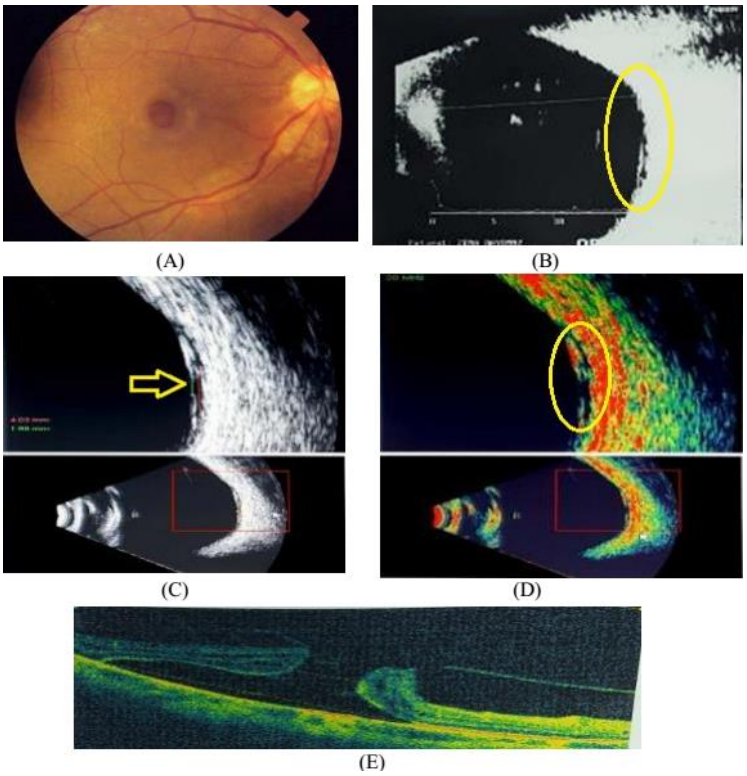

Figure 5: RT full thickness Macular hole (A) Colored fundus photo shows loss of foveal reflex with large macular hole (B) Para axial B-scan (12.5MHz) displaying a hole with overlying partial PVD (C) & (D): reverse longitudinal (20 MHz) B-scan at reduced gain demonstrates full thickness macular hole with shallow RD, although it didn't show the Vitero macular traction well as being in the OCT fig (E), but still superior in resolution and tissue differentiation than conventional US fig (b). There some differences in operculum and hole base measurement, as by 20MHz U\S the operculum measurement was 1.95mm, and the base measured 4.09mm, while by OCT it's operculum measured 760µm, and it's base was 3.43mm.

In group no. (II) patients with (***Vitreo-macular interface disorders)*** we found that:

While assessment of the posterior vitreous, presence or absence of ERM, presence of any vitreous floaters or subhyaloid hemorrhage, the 12.5 MHz US was more valuable than 20 MHz, although it was statistically insignificant (OR=2.231; P > 0.05).

On assessment of the retinal tissue itself, macular contour and vitreomacular interface, the resolution power and well tissue differentiation of 20 MHz US was more beneficial, the difference between both was also statistically insignificant (OR=0.448; P > 0.05) however, practically the difference was obvious.

Table 2: Comparing Posterior vitreous lesion qualification of vitreo macular disorders by each method of investigation using odds ratio and Forest plot in the study group (n=6 cases)

Investigation (Vitreo macular disorders)	**Posterior vitreous lesion qualification**		**Odds ratio (OR)**	**95% CI**	**P.value**
	Yes	**No**			
OCT-FFA	6/6	0/6	169	2.89 to 9876.1	**0.0134**
20 MHz US	4/6	2/6	4	0.36 to 44.115	0.2577
12.5 MHz US	6/6	0/6	169	2.89 to 9876.1	**0.0134**
Total (fixed effects)	16/18	2/18	19.968	3.94 to 101.11	**<0.001**
Total (random effects)	16/18	2/18	31.231	1.99 to 488.59	0.014

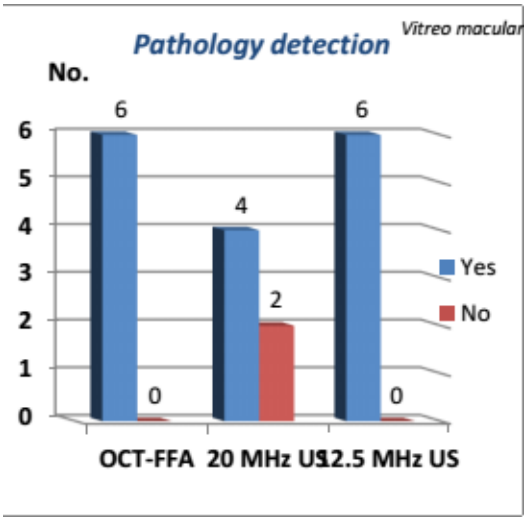

Fig. (6). Column chart comparing pathology detection of vitreo macular disorders by each method of investigation

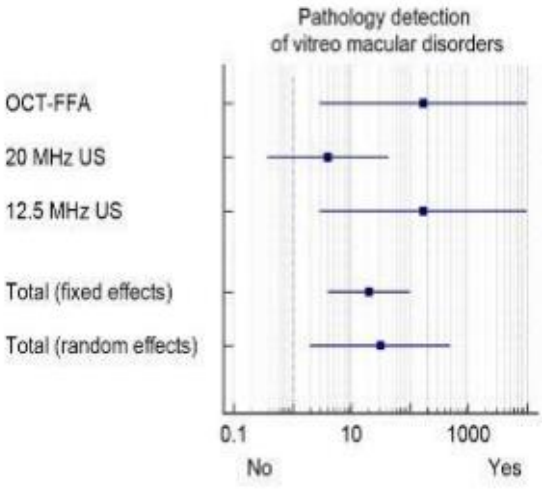

Fig. (7). Forest plot chart comparing pathology detection of vitreo macular disorders by each method of investigation

Case No.5

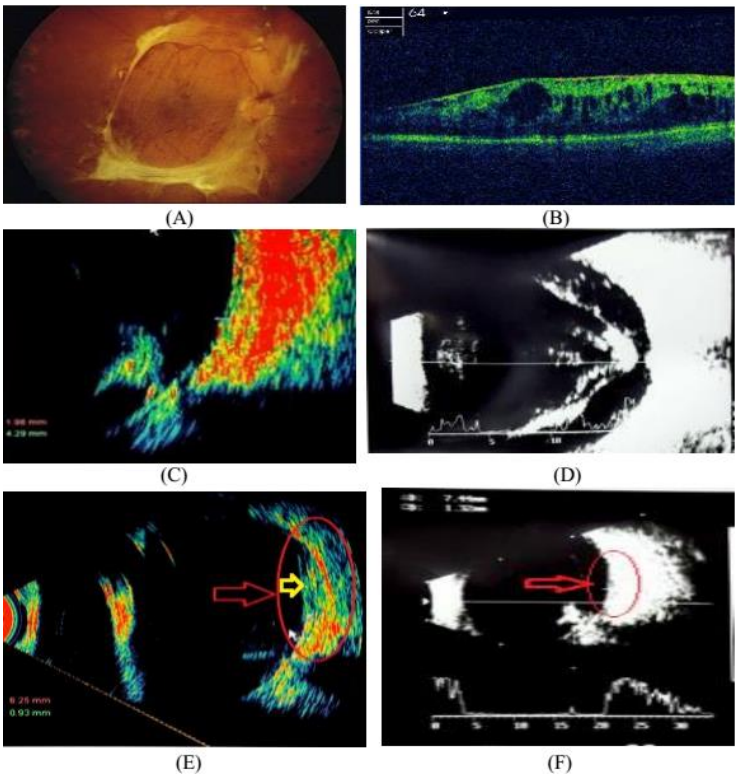

Figure 8: Rt PDR with TERM This female patient 62 years old, diabetic 21 years ago, presented by diminution of vision and by dilated funduscopy using indirect ophthalmoscopy and stereoscopic bio microscopy she had grade 1 vitreous hg, with aggressive tractional ERM. with TRD (A) fundus colored photo shows sever PDR with TERM (B) OCT shows TERM with macular bucker and tractional RD In fig **(C)** with 20MHz U\S we can see just the site of VMT with minimal viewing of vitreous Hg nor ERM, however on fig **(D)** by conventional U\S we could see that clearly. On the other hand in fig **(E)** we can detect the extensions of the ERMs and the site of tractional macular detachment {arrow head}, which couldn't differentiated well by conventional one in fig **(F).**

In group (III) of patients with **(Optic nerve head disorders)** we found that both of 20 MHz US and 12.5 MHz US could easily detect the optic disc pathology with accepted quality, There was statistically total insignificant increase of pathology detection and qualification of **Optic nerve head disorders** 9 times by clinical + OCT-FFA more than by 20MHz US (OR=9; P > 0.05).

Table 3: Comparing pathology qualification of optic nerve disorders by each method of investigation using odds ratio and Forest plot in the study group (n=9 cases).

Investigation (Vitreo macular disorders)	Pathology qualification		Odds ratio (OR)	95% CI	P.value
	Yes	No			
OCT-FFA	9/9	0/9	361	6.4 to 20145	**0.0041**
20 MHz US	7/9	2/9	12.250	1.32 to 113.06	**0.0271**
12.5 MHz US	7/9	2/9	12.250	1.32 to 113.06	**0.0271**
Total (fixed effects)	23/27	4/27	21.790	5.62 to 84.488	**<0.001**
Total (random effects)	23/27	4/27	20.516	3.99 to 105.25	**<0.001**

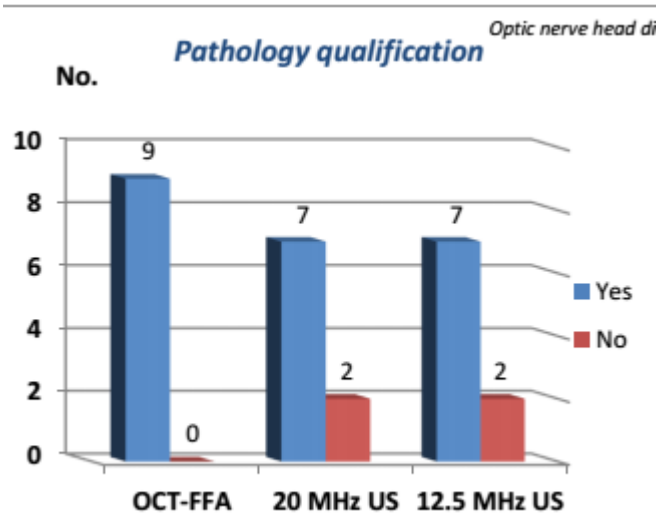

Fig. (9). Column chart comparing pathology qualification of optic nerve disorders by each method of investigation.

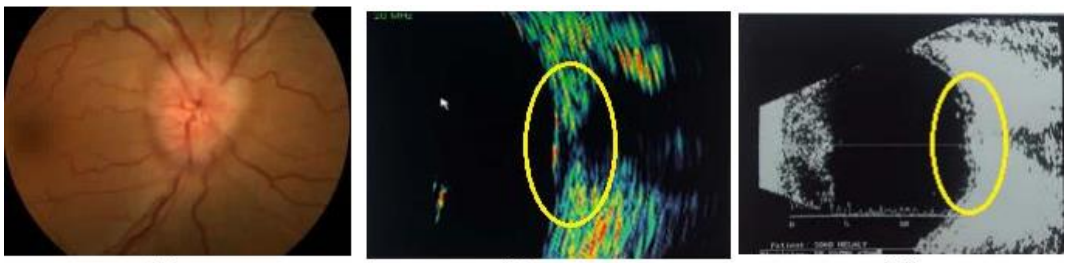

Fig. (10) Female Pt 45years with pseudo tumor cerebri& bilateral disc edema (papilledema) **(A)** fundus picture of both eyes shows hyperemic swollen disc with ill-defined margins and obliterated cup with dilated tortious BVs.**(B), (C)** are high resolution 20 MHz and conventional 12.5 MHz U\S respectively, they could easily side by side detects the elevated swollen disc, with multiple small hypo-echoic fluid filled spaces resembling disc edema.

In group (IV) of patients with ***(Choroidal disorders)*** we found that:

According to ***pathology detection*** each type US was useful in pathology detection and there was no statistically difference between each of them. However, about the ***pathology qualification*** the clinical diagnosis augmented by OCT and FFA was more valuable than both types of US but statistically There was statistically total insignificant increase of pathology qualification of **Choroidal disorders** 9 times by OCT-

FFA more than by 20 MHz US (OR=9; P > 0.05). There was also there was statistically total insignificant increase of pathology qualification of **Choroidal disorders** 1.828 times by 20MHz US more than by 12.5 MHz US (OR=1.828; P > 0.05).

Table 4: Comparing pathology qualification of choroidal disorders by each method of investigation using odds ratio and Forest plot in the study group (n=9 cases).

Investigation (Choroidal disorders)	Pathology qualification		Odds ratio (OR)	95% CI	P.value
	Yes	No			
OCT-FFA	8/8	0/8	289	5.1 to 16318.8	**0.0059**
20 MHz US	4/8	4/8	1	0.141 to 7.099	1
12.5 MHz US	3/8	5/8	0.360	0.047 to 2.725	0.3226
Total (fixed effects)	15/24	9/24	2.164	0.798 to 5.872	**0.129**
Total (random effects)	15/24	9/24	2.865	0.12 to 63.596	0.506

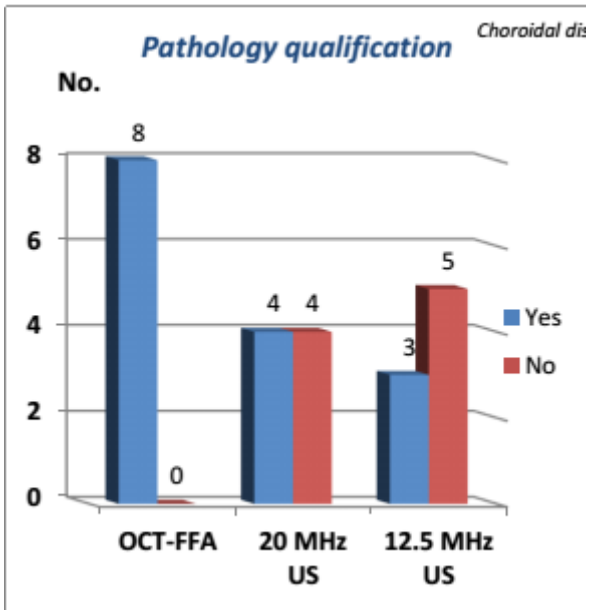

Fig. (11). Column chart comparing pathology qualification of choroidal disorders by each method of investigation

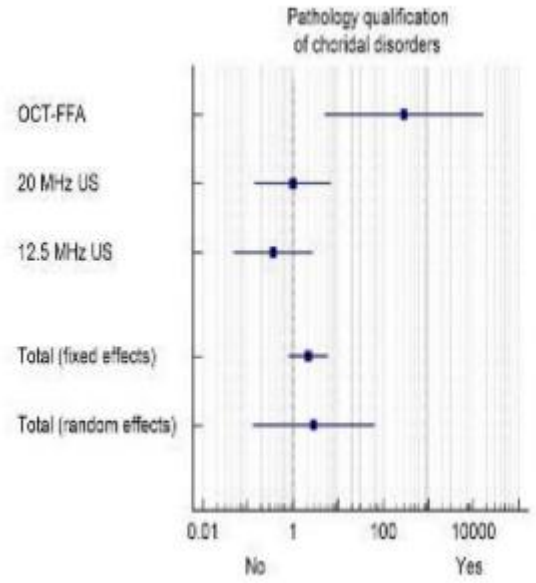

Fig. (12). Forest plot chart comparing pathology qualification of choroidal disorders by each method of investigation

DISCUSSION

In the presenting study, we assessed the accuracy and reliability of the 20 MHz US in the evaluation of different posterior segment pathologies, side by side with conventional 12.5 MHz US, by the help of clear media in our patients we keep the clinical diagnosis augmented by the OCT and FFA Is the gold standard. We classified the patients according to their pathology into 4 main groups.

In the 1st group of the study **(retinal and vascular disorders)** regarding quality of the pathology detection our results agrees with ***Coleman and Ronald (2).*** who proved that for clinical evaluation of retinal pathologies such as breaks and macular holes, OCT provides better resolution and sensitivity than US. However, 20-MHz US offers advantages in case of opaque media or peripheral location of the pathology makes OCT impracticable Regarding **retinal pathology quantification** There was statistically total insignificant increase of pathology quantification of Retinal and vascular disorders 5 times by OCT-FFA more than by 20MHz US (OR=5, P.> 0.05). This agrees with what was reported by Singh et al.(2015) they proved that the difference between high resolution (immersion technique) was less than 10% in measuring retina and choroidal thickness (RCT) from that measured by EDI-OCT and thus could be considered as a reliable tool for these measurements when EDI-OCT is impracticable.

In the 2nd group of the study **(Vitreo-macular interface disorders)** our results agrees with what's reported by ***hewick et al. (4)***who reported that 20 MHz probe has a better resolution and can be useful in detection of details of the posterior segment and in the orbital scanning. The 10 MHz probe has better sensitivity and could be used to evaluate low intensity structures, such as those in the vitreous gel that cannot be easily detectable by a higher frequency probe.

In the 3rd group of the study ***(Optic nerve head disorders)*** we found that both of 20 MHz US and 12.5 MHz US could easily detect the optic disc pathology with accepted quality, There was statistically total insignificant increase of pathology detection and qualification of **Optic nerve head disorders** 9 times by clinical + OCT-FFA more than by 20MHz US (OR=9; P > 0.05).

In the 4th group of the study ***(Choroidal disorders)*** According to ***pathology detection*** each type US was useful in pathology detection and there was no statistically difference between each of them. However, about the ***pathology qualification*** the clinical diagnosis augmented by OCT and FFA was more valuable than both types of US but statistically There was statistically total insignificant increase of pathology qualification of **Choroidal disorders** 9 times by OCT-FFA more than by 20 MHz US (OR=9; P > 0.05). There was also There was statistically total insignificant increase of pathology qualification of **Choroidal disorders** 1.828 times by 20MHz US more than by 12.5 MHz US (OR=1.828; P > 0.05).

Unfortunately, no more studies discussed the use of Immersion high resolution 20 MHz US in any other pathologies or disorders, and so many pathologies in our study we ***were the firist*** to discuss it. ***Nevertheless***, we could not completely cover the whole of posterior segment disorder and we were unlucky to find any case of choroidal melanoma or tumors throughout the duration of our study, but we hope that we put a ***step forward*** for other researches in this topic in the future.

CONCLUSION

We have two main characters for well diagnosis by any US tool, **resolution** and **sensitivity**, and neither the 20 MHz nor 12.5 MHz could combine both of them. **Therefore,** we recommended to combine the examination by of both of them as they are **complementary** to each other, **the 10 MHz** probe for initial screening of the globe and for evaluation of vitreoretinal disorders, in particular the detection of posterior vitreous detachment, vitreous hemorrhage, and subtle vitreous change such as inflammatory cells, etc. **The 20 MHz** probe is best utilised to better identify ocular wall and its lesions including optic nerve head, retinal and choroidal tissues in a high resolution. **So, we recommend** to use them in all of posterior segment lesions with opaque media, in which OCT & FFA are of no role, as they could change the treatment plan or change the surgical decision.

CONFLICTS OF INTEREST

There are no conflicts of interest.

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