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Comparison Between 4D and 2D Ultrasound in Detection of The Causes of Oligohydramnios (An Observation Study)

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Abstract:

The objective of this study is to compare between 2D and 4D Ultrasound in the detection of the causes of Oligohydramnios. A total 100 pregnant women with oligohydraminos were included in this study. The results showed that 6 cases (6.0%) had positive TORCH infection and the examined fetuses were abnormal in 36 cases (36.0%). Causes for oligohydraminos were detected in 37 cases (37.0%) and the most common detected cause was autosomal recessive polycystic kidney in 13 cases (35.2%) followed by bilateral multicystic dysplastic kidney in 8 cases (21.6%) and posterior urethral valve in 6 cases (16.2%) and obstructive uropathy was recorded in 4 cases (10.8%) however, 3 cases, 2 cases and 1 case was recorded for bilateral renal agenesis, Meckle Gruber syndrome and unilateral renal aplasia, respectively. The mean duration of examination was significantly higher in 4D compared to 2D. Thermal index was slightly lower in 4D while in contrary, mechanical index was significantly higher in 4D compared to 2D. In detection of fetal causes for oligohydraminos, the 2D ultrasound had a sensitivity of 94.6%, specificity of 100%, PPV was 100%, NPV was 96.9% and the accuracy was 98.0%. While, the 4D ultrasound had a sensitivity of 97.3%, specificity of 100%, PPV was 100%, NPV was 98.7% and the accuracy was 98.7%. In conclusion, both 2D and 4D US are equally effective in detecting causes of oligohydramnios but, the difference between the two procedures was not statistically significant "with a slight preference for 4D US".

Keywords: 4D, 2D, Ultrasound, causes, Oligohydramnios

1. Introduction

Amniotic fluid (AF) surrounds the fetus after the first few weeks of gestation and it functionally protects the fetus and the umbilical cord from trauma and compression and in addition, it has anti-bacterial effects and provides the necessary conditions for normal development of fetal organs [1].

Oligohydramnios is a condition in pregnancy that have been associated with many adverse outcomes, it is defined as deficiency of amniotic fluid to less than 5^{th} percentile volume expected for gestational age and its rate have been reported between 0.5-8.0% [2,3]. It has been reported that patients with Oligohydramnios in the second trimester have a higher prevalence of structural malformation compared to those in the third trimester (50.7% vs. 22.1%) [4].

A dramatic improvement in the evaluation of fetal anomalies was achieved by using Three and Four-dimensional ultrasounds [5].

Many fetal causes of Oligohydramnios were reported including renal agenesis, autosomal dominant polycystic kidney, bilateral multicystic kidney, hydro-nephrotic changes of fetal kidneys, posterior urethral valve obstruction, obstructive cystic dysplasia, impaired feto-maternal circulation and Meckel Gruber syndrome [6].

Detailed fetal ultrasound examination is crucial for the detection of renal and extra-renal causes of Oligohydramnios [7]. In addition, prenatal determination of birth defects is advantageous and desirable because the care of disabled and handicapped persons is a significant healthcare burden that facing both the mother and the community [8].

The application of 3D/4D ultrasonography continues to develop and becomes ever more available for accurate and early detection of fetal anomalies, 3D/4D ultrasound gives a volumetric database and allows the investigator to visualize organs of the fetus in multi-planar and rendered pattern and to present planes that could not be evaluated by 2D ultrasound [9].

Detailed renal scan by chrome colorization acts a vital role in the evaluation of the renal size and site in addition to cortico-medullary differentiation using 3D and 4D US volume contrast images. Also, the inversion mode plays a key role to differentiate between cyst and hydronephrotic changes with accurate determination of the hydronephrosis and its level [10].

Fetal renal scan in addition to duplex evaluation in associate with 3D and 4D US plays important role in the evaluation of the causes of Oligohydramnios for rapid judgment

and to early ascertain of lethal causes without let the mother carries such burdens [11].

The objective of this study is to compare between 2D and 4D Ultrasound in the detection of causes of Oligohydramnios.

2. Patients and methods

This is an observational study that was carried out at Kasr El-Aini and Beni-suef University Hospitals during the period of 9 months (from March to December 2019). The study included a total of 100 pregnant women with oligohydraminos who were attending the mentioned hospitals during the study period. Informed consents were obtained from all patients. During the study period, cases of Oligohydramnios were selected by doing a percentile curve of assessment of amniotic fluid for them according to [12].

2.1 Inclusion criteria:

1) All singleton pregnancies with gestational age > 20 weeks.
2) Oligohydramnios detected by USG (less than 5^{th} percentile curve).
3) Membranes are intact .
4) Pregnant women or their legally acceptable representative willing to provide their voluntary written informed consent for participation in the study.

2.2 Exclusion criteria:

1) Premature rupture of membrane (PROM), uterine anomaly, multiple gestation, placental insufficiency and high risk pregnancy.
2) Chronic renal or cardiac disease and hypertensive disorders of pregnancy.

All included women were subjected to:

A. Full history taking: including personal history (Name, age, education level, residence, consanguinity, history of medications, etc..), past history of chronic medical disorders and obstetric history including parity, mode of delivery of the previous pregnancies, either spontaneous or instrument-assisted or by cesarean section.

B. Clinical examination: including

1) General examination, local, physical examination and measurements (weight, respiration rate and heart rate, routine obstetric examination, anomaly scan and assessment of amniotic fluid).

2) Diagnosis by 2D and 4D Ultrasonography: The used device was TOSHIBA Xario 200 ® diagnostic ultrasound equipment. All cases were subjected to the following:

- Detailed anomaly scan with complete fetal survey for evaluation of the brain, neck, chest abdomen, spine as well as both upper and both lower limbs.
- Detailed renal scan including:

a) Evaluation of the kidney for size and echogenicity: Fetal kidneys were identified.

b) Renal pelvis evaluation.

c) 2 D and 4D US renal evaluation: Fetal kidneys and bladder were analyzed in all 3 planes (X, Yand Z) in 3D multiplanar mode in order to confirm urinary tract anomaly and obtain volumetric data. Inversion mode of 2D and 4DUS examination was used to detect hydronephrotic changes [13].

Statistical methodology:

All statistical analyses were performed using Statistical Package for Social Science (SPSS) version 21 under windows 7 operating system. Results were expressed as means ± SD for quantitative data and by No. (%) for qualitative data. Comparisons for parametric quantitative data were done by Student's t test and by Mann-Whitney test for Non-parametric data. Chi-Square test was used for comparisons regarding qualitative data or fisher exact test when appropriate. Probability level (P-value) was assumed significant if less than 0.05 and highly significant if P-value was less than 0.01.

3. Results:

The mean age of them was 26.3 ± 5.2 ranged between 18:40 years and the majority of them (87.0%) were > 20-35 years, 59 cases (59.0%) were from rural areas and 31 cases had positive consanguinity. Regarding parity, 42 cases were primigravida and 58 cases were multigravida (Table, 1). Of the total 100 included cases, 6 cases had positive TORCH infection (fig. 1). The examined fetuses were normal in 64 cases (64.0%) and were abnormal in 36 cases (36.0%) (fig. 2).

The results presented in table (2) showed that no cause was detected for oligohydraminos in 63 cases (63.0%) however, there were detected causes in the rest of 37 cases (37.0%). Of the 37 cases, the most common cause of oligohydraminos in our study was autosomal recessive polycystic kidney in 13 cases (35.2%) followed by bilateral multicystic dysplastic kidney (in 8 cases, 21.6%) and posterior urethral valve in 6 cases (16.2%) and obstructive uropathy was recorded in 4 cases (10.8%) however, 3 cases, 2 cases and 1 case was recorded for bilateral renal agenesis, Meckle Gruber syndrome and unilateral renal aplasia, respectively. The results of our study revealed that 2D and 4D US are equally effective in detecting causes of oligohydramnios.

The mean duration of examination was significantly higher in 4D US compared to 2D (2.8 ± 1.1 vs. 2.2 ± 1.8 minutes, P≤ 0.01). Thermal index was slightly "non significant" lower in 4D while in contrary, mechanical index was significantly higher in 4D compared to 2 D (1.16 ± 0.26 vs. 0.78± 0.24, P≤ 0.01), (Table, 3). The results showed that the 4D ultrasound detected 36 cases (97.3%) of the

total of 37 cases with fetal cause for oligohydraminos while, the 2D ultrasound detected 35 cases (94.6%) and this difference was not significant (p=0.56). In cases with autosomal recessive polycystic kidney (n=13), both 2D and 4D ultrasound detected 12 cases (92.3%) of them. While, in cases with bilateral renal agenesis (n=3), the 4D ultrasound detected all of them while the 2D ultrasound only detected 2 cases of them (fig. 3). Figure (4) showed congenital hydronephrosis and hydroureter by 2D and 4D.

In detection of fetal causes for oligohydraminos, the 2D ultrasound had a sensitivity of 94.6%, specificity of 100%, PPV was 100%, NPV was 96.9% and the accuracy was 98.0%. While, the 4D ultrasound had a sensitivity of 97.3%, specificity of 100%, PPV was 100%, NPV was 98.7% and the accuracy was 98.7% (Table, 4). These results demonstrated that both 2D and 4D US are equally effective in detecting causes of oligohydramnios and the difference between the two procedures was not statistically significant.

Table (1): Baseline characteristics of all included cases.

Variable		**Descriptive (n=100)**
Age (year)		26.3 ± 5.2 (18-40)
Age	**< 20 years**	8 (8.0%)
	> 20-35	87 (87.0%)
	> 35	5 (5.0%)
Residence	**Urban**	41 (41.0%)
	Rural	59 (59.0%)
Consanguinity	**Negative**	69 (69.0%)
	Positive	31 (31.0%)
Parity	**Primigravida**	42 (42.0%)
	Multigravida	58 (58.0%)

Quantitative data were presented as mean ± SD (range). Qualitative data were presented as No. (%).

Table (2): Fetal cause for oligohydraminos and types of anomalies.

Variable		Descriptive (n=100)
Cause for oligohydraminos	**Not found**	63 (63.0%)
	Found	37 (37.0%)
Types of causes with anomalies (n=37)	**Autosomal recessive polycystic kidney**	13 (35.2%)
	Bilateral multicystic dysplastic kidney	8 (21.6%)
	Posterior urethral valve	6 (16.2%)
	Obstructive uropathy	4 (10.8%)
	Bilateral renal agenesis	3 (8.1%)
	Meckle Gruber syndrome	2 (5.4%)
	Unilateral renal aplasia	1 (2.7%)

Table (3): Comparison between 2D and 4D regarding examination duration and acoustic output.

Variable	2D	4D	P. value (Sig.)
Examination duration (min)	2.2 ± 1.8 (1.5–5)	2.8 ± 1.1 (2–6.5)	**<0.01****
Thermal index (TI)	0.31± 0.12 (0.12–0.65)	0.28 ± 0.11 (0.13–0.52)	0.07^{NS}
Mechanical index (MI)	0.78± 0.24 (0.4–1.4)	1.16 ± 0.26 (0.6–1.4)	**<0.01****

*NS Not significant. ** Significant (P≤ 0.01).*

Table (4): Sensitivity, specificity, PPV, NPV and diagnostic accuracy of 2D and 4D.

Parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Diagn. Accuracy (%)
2D US	94.6	100	100	96.9	98.0
4D US	97.3	100	100	97.4	98.7

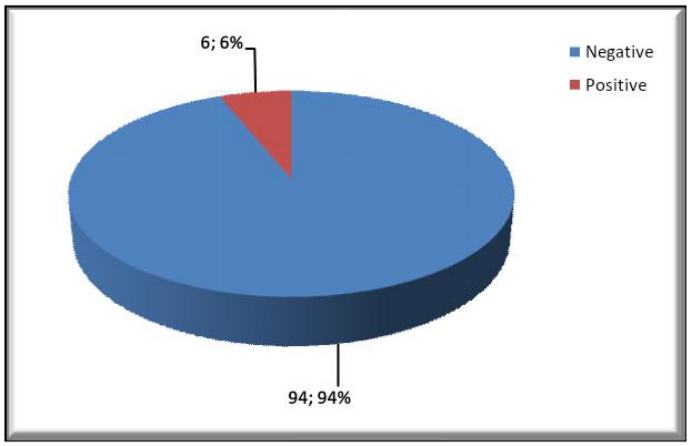

Figure (1): TORCH infection in all cases.

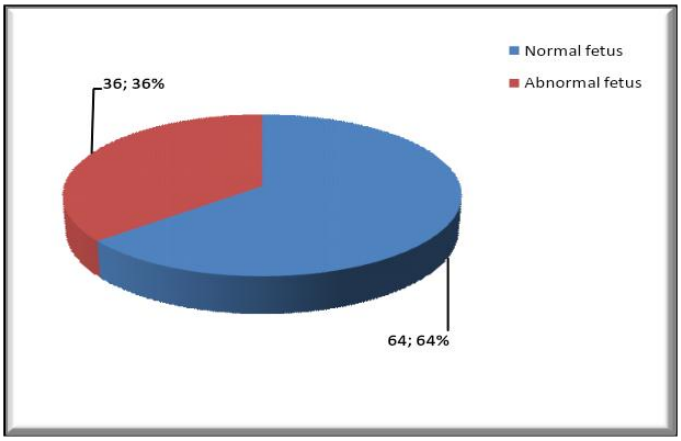

Figure (2): Normal and abnormal fetuses with oligohydraminos.

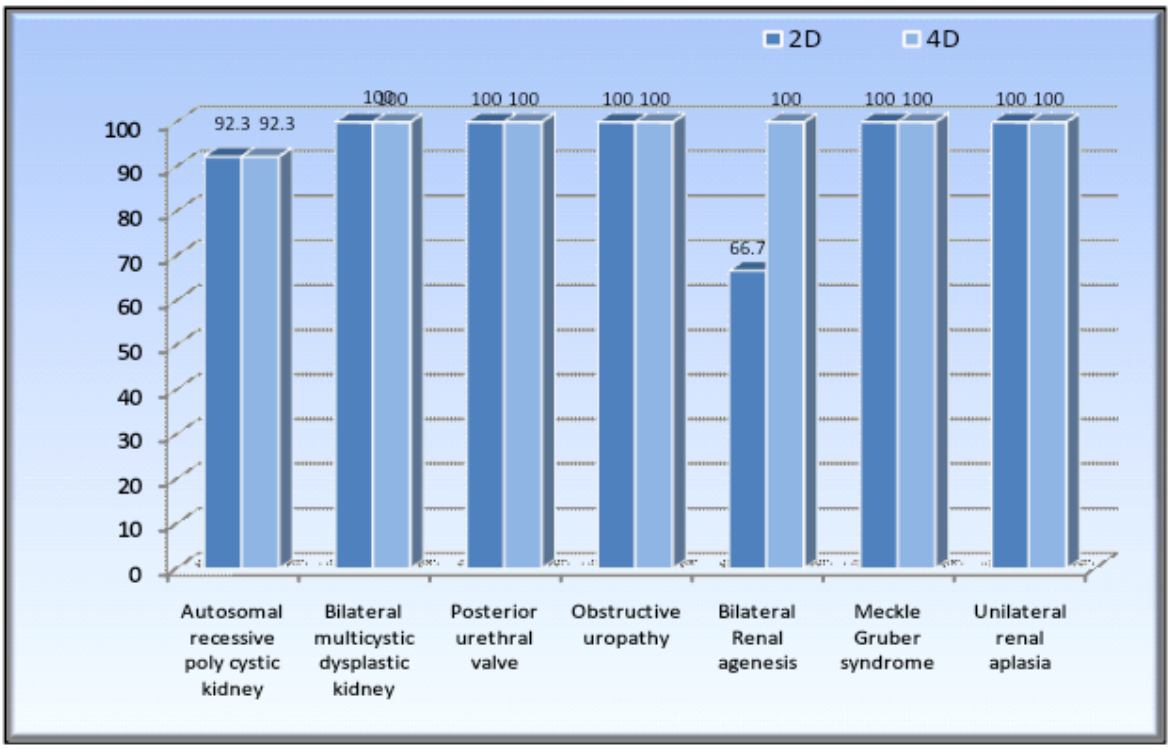

Figure (3): Detection of fetal cause for oligohydraminos and types of anomalies.

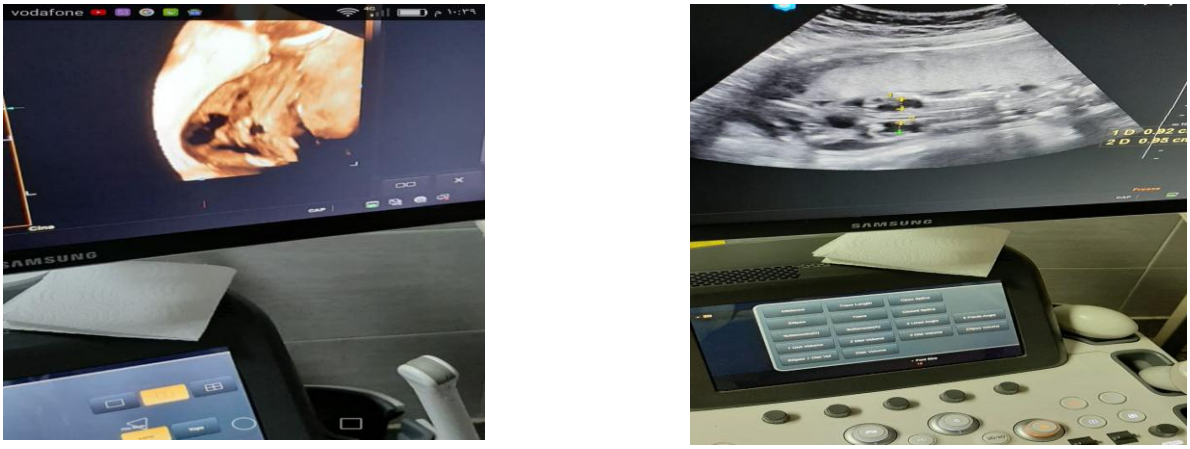

Figure (4): Congenital hydronephrosis and hydroureter by 2D and 4D.

4. Discussion:

Oligohydramnios is an adverse pregnancy condition that is associated with fetal anomaly and its rate was reported between 0.5-8.0% [3].

Many maternal conditions were reported to be associated with Oligohydramnios such as hypertension, preeclampsia, uteroplacental insufficiency, diabetes, chronic hypoxia, PROM, in addition to dehydration and post-term gestation [14].

In addition, many fetal causes of Oligohydramnios were reported including renal agenesis, autosomal dominant polycystic kidney, bilateral multicystic kidney, hydro-nephrotic changes of fetal kidneys, impaired feto-maternal circulation and Meckel Gruber syndrome [6].

The invention of 3D and 4D US had made a significant improvement in the evaluation of fetal anomalies over the 2D US. The current study aimed to compare between 2D and 4D Ultrasound in the detection of the causes of Oligohydramnios. To achieve this aim, a total 100 pregnant women with oligohydraminos were included. To the best of our knowledge, few studies worked in the comparison between 2D and 4D US in the detection Oligohydramnios causes.

In our study, the mean age of the included cases was 26.3 ± 5.2 years and the majority of them (87.0%) were between 20-35 years. In addition, 31 cases had positive consanguinity, 58 cases were multigravida and 6 cases (6.0%) had positive TORCH infection. Similar to our findings, Figueroa *et al.* [15] found that 70% of women with oligohydramnios had the age between 25:35 years and 52% of them were multigravida. Additionally, Pasquini *et al.* [16] reported that consanguinity was significantly related to oligohydramnios and TORCH infection was found in a small percentage of cases with oligohydramnios. Also, Mohammed *et al.* [17] found a strong relationship between consanguinity and oligohydramnios.

The current results showed that the fetuses were abnormal in 36 cases (36.0%) and the causes for oligohydramnios were detected in 37 cases (37.0%) and the most common cause of oligohydraminos was autosomal recessive polycystic kidney in 13 cases (35.2%) followed by bilateral multicystic dysplastic kidney (in 8 cases, 21.6%) and posterior urethral valve in 6 cases (16.2%) and obstructive uropathy was recorded in 4 cases (10.8%) however, 3 cases, 2 cases and 1 case was recorded for bilateral renal agenesis, Meckle Gruber syndrome and unilateral renal aplasia, respectively. Also, the results of our study revealed that 2D and 4D US are almost similar in detecting these causes of oligohydramnios. Similar to our findings, Adel *et al.* [5] evaluated the role of 3D and 4D US in detection of fetal causes of oligohydraminos. They found no fetal causes for oligohydraminos

were detected in about Two-thirds of cases. Autosomal recessive polycystic kidney disease (ARPKD), Potter type I) was the commonest fetal cause for oligohydraminos in about 24.0% of patients followed by bilateral multicystic dysplastic kidney (Potter type II) in 19% patients while, unilateral renal aplasia was the lowest cause. They concluded that both 3D and 4D ultrasounds are effective in detecting fetal causes of oligohydraminos and early determination of lethal causes. It has been reported that fetal causes of Oligohydramnios include renal agenesis, autosomal dominant polycystic kidney, bilateral multicystic kidney, hydro-nephrotic changes of fetal kidneys, posterior urethral valve obstruction, obstructive cystic dysplasia, impaired feto-maternal circulation and Meckel Gruber syndrome [6, 18].

Oligohydramnios with bilateral renal disease indicates significant fetal renal dysfunction and is a risk factor for the development of pulmonary hypoplasia [19]. The detailed renal scan was beneficial in the detection of fetal abnormalities seen in the renal parenchyma [20]. In addition, impaired fetoplacental circulation is the main cause of growth restriction as well as oligohydraminos and also, obstructive uropathy is one of the important causes of oligohydraminos [21].

In a study by Brace, [22], they found that bilateral renal agenesis belongs to a group of prenatally lethal renal diseases and often detected by fetal ultrasound because of oligohydramnios. Furthermore, it has been reported that 3D and 4D US play an important role in the evaluation of skull defects especially if the defect is in an unattainable plane [18, 23].

Using the amniotic fluid index to identify oligohydramnios in at-risk pregnancies is a better choice because it leads to an increase in the diagnosis of oligohydramnios [24]. A careful fetal structural survey is necessary in the case of oligohydramnios because of the possibility of a previously unrecognized anomaly "especially renal" [25]. Recently, Figueroa *et al.* [15] reported that polycystic kidney disease could cause prenatal renal impairment, in which cysts form in normally developing kidneys, making them appear cystic and echogenic upon the ultrasound. Two forms were detected: autosomal dominant and autosomal recessive, the latter manifests as large hyperechogenic kidneys and oligohydramnios, and can be lethal [26]. On contrary, autosomal dominant polycystic kidney disease manifests later in life and typically is not found on prenatal ultrasound, although cyst formation begins *in utero* [25].

Severe oligohydramnios may cause in deformation syndromes such as craniofacial deformities and limb defects, although detection is often because inadequate fluid results in a poor acoustic window and the fetus may have Potter facies (a silk stocking effect) with

flattened nose and low-set, flattened, enlarged external auricles [27].

In the current study, in the detection of fetal causes for oligohydraminos, the 2D ultrasound had a sensitivity of 94.6%, specificity of 100%, PPV was 100%, NPV was 96.9% and the accuracy was 98.0%. While, the 4D ultrasound had a sensitivity of 97.3%, specificity of 100%, PPV was 100%, NPV was 98.7% and the accuracy was 98.7%. Both 2D and 4DUS are equally effective in detecting causes of oligohydramnios and the difference between the two procedures was not statistically significant with a slight preference for 4D US. In a study by Kurjak *et al.* [28], who reviewed and analyzed the published literature on the use of 3D and 4D US in perinatal medicine including 438 studies. They found that 3D and 4D US provided additional information for the diagnosis of facial anomalies and evaluation of neural tube defects in addition to skeletal malformations. However, in a study done by Gonçalves *et al.* [29] on 99 fetuses where fetuses were first evaluated with 3D/4D and later with 2D ultrasound; 54 normal and 45 anomalous fetuses were detected by 2D US. They found that the sensitivity was 96% in 2D and 92% in 3D/4D when compared with postnatal diagnosis; specificity was 73% in 2D and 76% in 3D/4D and they concluded that no statistically significant difference was found between procedures. On the other hand, Öcal *et al.* [30] evaluated 1379 pregnant women with 2D and 4D ultrasound, they detected 194 anomalies among 174 pregnancies, and 2D US was found to be superior in detecting anomalies compared to 4D ($p<0.001$). It has been reported that ultrasound detects fetal obstructive uropathy with a sensitivity of 95% and specificity of 80% [31].

In a previous study included 204 patients, 3D US achieved a 62% advantage in showing fetal defects; 36% of the patients had the same information in 2D US and 2% of the patients were found to have disadvantages when imaged with 3D [32]. It has been reported that 3D/4D provided many advantages in fetal imaging; also contributed to improve the accuracy of 2D fetal screening [33].

Also, Kırmızı, [34] reported that 2D US is an integral component of 3D/4D technology and the latter will not be able to take its place, but they provide significant additional benefits to 2D. Besides this, the superiority of 4D ultrasound for the detection of movement and general surface anomalies is certain.

5. Conclusion:

In conclusion, both 2D and 4D US are equally effective in detecting causes of oligohydramnios and the difference between the two procedures was not statistically significant "with a slight preference for 4D US". In the detection of fetal causes for oligohydraminos, the 2D ultrasound had a

sensitivity of 94.6%, specificity of 100% and the accuracy was 98.0%. While, the 4D ultrasound had a sensitivity of 97.3%, specificity of 100% and the accuracy was 98.7%. Finally, further research and larger studies are warranted to confirm our results.

6. References:

1. Beall MH, Beloosesky R, Ross MG. High risk pregnancy; Abnormalities of amniotic fluid volume. The placental membrans and amniotic fluid retention; in The placental from development to disease. Wiley-Blackwell, 2011, 12; 197–208.
2. Ekin A, Gezer C, Taner CE, Solmaz U, et al. Prognostic Value of Fetal Thymus Size in Intrauterine Growth Restriction. J Ultrasound Med 2016; 35:511–517.
3. Han CS. Fetal Biophysical Profile.Obstet Imaging Fetal Diagnosis Care [Internet]. Elsevier; 2018;537–540.
4. Hamza A, Herr D, Solomayer EF, and Meyberg-Solomayer G. Polyhydramnios: Causes, Diagnosis and Therapy. Geburtshilfe Frauenheilkd. 2013; 73(12): 1241-1246.
5. Adel NM, Abd-ElGawad EA, Abdel Hakeem AK. Diagnostic value of four dimensional ultrasound in detection of fetal causes of oligohydraminos: An observational study. The Egyptian Journal of Radiology and Nuclear Medicine 48 (2017)1141–1147.
6. Touboul C, Boulvain M, Picone O, et al. Normal fetal urine production rate estimated with 3-dimensional ultrasonography using the rotational technique (virtual organ computer-aided analysis). Am J ObstetGynecol 2008;199:57e1–5.
7. Hindryckx A and De Catte L. Prenatal diagnosis of congenital renal and urinary tract malformations. Facts Views Vis Obgyn. 2011; 3(3): 165– 174.
8. Al-Gailani S. Making birth defects ‘preventable’: Pre-conceptional vitamin supplements and the politics of risk reduction. Stud HistPhilosBiol Biomed Sci. 2014; 47: 278–289.
9. Behairy NH and Talaat S. Fetal Neurosonography: Ultrasound Findings in Different Types, Associated Syndromes and Impact on Fetal Outcome . Med. J. Cairo Univ., 2012; 80, (1): 605-611.
10. Kristoffer LH, Nielsen MB, and Ewertsen C. Ultrasonography of the Kidney: A Pictorial Review. Diagnostics (Basel). 2016; 6(1):2.
11. O’Neill WC. Renal relevant radiology: Use of ultrasound in kidney disease and nephrology procedures. Clin. J. Am. Soc. Nephrol. 2014;9:373–381.
12. Fischer, R, Glob. libr. women's med., (ISSN: 1756-2228) 2008.

13. Nguyen HT, Herndon CDA, Cooper C, et al. The society for fetal urology consensus statement on the evaluation and management of antenatal hydronephrosis. J Pediatr Urol 2010;6:212–31.
14. Cunningham FG, Williams JW (John W. Williams Obstetrics. McGraw-Hill Medical; 2010. https://www.ncbi.nlm.nih.gov/nlmcatalog/101510655.
15. Figueroa L, McClure EM, Swanson J, Nathan R, Garces AL, et al. (2020). Oligohydramnios: a prospective study of fetal, neonatal and maternal outcomes in low-middle income countries. Reproductive Health, 17 (1).
16. Pasquini L, Seravalli V, Sisti G, Battaglini C, Nepi F, Pelagalli R, Di Tommaso M (2016). Prevalence of a positive TORCH and parvovirus B19 screening in pregnancies complicated by polyhydramnios. Prenatal Diagnosis, 2016; 36(3), 290–293.
17. Mohammed YA, Shawky RM, Soliman AA, Ahmed MM. Chromosomal study in newborn infants with congenital anomalies in AssiutUniversity hospital: Cross-sectional study. Egyptian Journal of Medical Human Genetics, 2011; 12(1), 79–90.
18. Madendag Y, Madendag IC, Sahin E, Aydin E, Sahin ME, & Acmaz G. How Well Do the Popular Ultrasonic Techniques Estimate Amniotic Fluid Volume and Diagnose Oligohydramnios, in Fact? Ultrasound Quarterly, 2019; 35(1), 35–38.
19. Kehl S, Schlekle A, Thomas A, et al. Single deepest vertical pocket or amniotic fluid index as an evaluation test for predicting adverse pregnancy outcome (SAFE Trial): A multicenter, open label, randomized controlled trial. Ultrasound Obstet Gynecol 2016;47:674-679.
20. Schreuder MF, Westland R, Van Wijk AE. Unilateral multicystic dysplastic kidney: a meta-analysis of observational studies on the incidence, associated urinary tract malformations and the contralateral kidney. Nephrol Dial Transplant 2009;24:1810–8.
21. Lausman A, McCarthy FP, Walker M, Kingdom J. Screening, diagnosis, and management of intrauterine growth restriction. Obstet Gynecol 2012;34 (1):17–28.
22. Brace RA. Physiology of amniotic fluid volume regulation. Clin Obstet Gynecol. 2013;40(2):280-89.
23. Ten Broek CM, Bots J, Varela-Lasheras I, Bugiani M, Galis F, Van Dongen, S. Amniotic Fluid Deficiency and Congenital Abnormalities both Influence Fluctuating Asymmetry in Developing Limbs of Human Deceased Fetuses. PLoS ONE, 2013; 8(11), e81824.

24. Magann EF, Sandlin AT, Ounpraseuth ST. Amniotic fluid and the clinical relevance of the sonographically estimated amniotic fluid volume: oligohydramnios. J Ultrasound Med. 2011;30(11):1573-85
25. Friedman, P., & Ogunyemi, D. Oligohydramnios. Obstetric Imaging: Fetal Diagnosis and Care, 2018; 511–515.e1.
26. Vanderheyden T, Kumar S, Fisk NM. Fetal renal impairment. Semin Neonatol. 2003;8:279-289.
27. Graham JM. Smith's Recognizable Patterns of Human Deformation. 3rd ed. Philadelphia: Saunders; 2007.
28. Kurjak A, Berivoj M, Wiku A, et al., How useful is 3D and 4D ultrasound in perinatal medicine?. J. Perinat. Med. 2007; 35 10–27
29. Gonçalves LF, Nien JK, Espinoza J, et al. What does 2-dimensional imaging add to 3- and 4-dimensional obstetric ultrasonography? J Ultrasound Med 2006; 25: 691-699.
30. Öcal DF, Nas T, Güler I. The place of four-dimensional ultrasound in evaluating fetal anomalies.Ir J Med Sci 2015; 184: 607-612.
31. Lissauer D, Morris RK, Kilby MD. Fetal lower urinary tract obstruction. Semin Fetal Neonatal Med. 2007;12:464-470.
32. Merz E, Bahlmann F, Weber G. Volume scanning in the evaluation of fetal malformations: a new dimension in prenatal diagnosis. Ultrasound Obstet Gynecol 1995; 5: 222-227.
33. Yagel S, Cohen SM, Messing B, Valsky DV. Three-dimensional and four-dimensional ultrasound applications in fetal medicine. Curr Opin Obstet Gynecol 2009; 21: 167-174.
34. Kırmızı D. A. The Significance of 4D Ultrasonography in Fetal Anomaly Screening. East J Med, 2017; 22(4): 230-232.