Ultrasound Normogram for the Lateral Ventricular Atrial Diameters of Normal Nigerian Foetuses at the University College Hospital (UCH) Ibadan, Nigeria

ABSTRACT

Aims: The atrial diameter of the lateral cerebral ventricles (ADLV) does not vary substantially in size during foetal development and has thus become a stable marker for the identification of foetal hydrocephalus in developed countries. Currently, the accepted upper limit of ADLV is 10 mm. Ventricular atrial diameters greater than 10mm require more radiological evaluation to rule out hydrocephalus. The aim of this study was to establish the normal range of values for the atrium of foetal lateral ventricles in our environment and to determine a cut-off value for prenatal diagnosis of hydrocephalus.

Study design: A Cross – Sectional Study.

Place and Duration of Study: Antenatal Clinic in the Obstetrics and Gynaecology Department of University College Hospital, Ibadan, Nigeria, from January to December 2010.

Methodology: The mean of two measurements was obtained from the transverse diameter of the atrium of the lateral ventricles of 404 apparently normal foetuses as part of the routine obstetric ultrasound scan at the antenatal clinic. The inclusion criterion was pregnancies between 14 and 38 weeks gestational age which corresponded with patient’s last menstrual period. A pretested questionnaire was administered to all the participants to obtain their biomedical data, past obstetric and medical history, presence of intercurrent illness or complication of index pregnancy.

Results: The mean ADLV was 6.5mm with standard deviation (SD) 1.3mm and mean ±2SD 3.9–9.1mm. Male foetuses had larger atrial diameters than female.

Conclusion: With the existing resources in our environment, prenatal screening for hydrocephalus during routine obstetric scan is achievable. Measurement of 10mm is a reasonable upper limit of normal in our environment. Foetuses with larger values need further evaluation to rule out hydrocephalus.
Keywords: Foetal, Ultrasound, Lateral Ventricle, Prenatal, Hydrocephalus.
INTRODUCTION

The cerebral lateral ventricles are complex fluid filled tubular cavities, which develop as part of the ventricular system \[1, 2\] within the brain, during embryogenesis of the central nervous system (CNS) at the 5th week of embryonic life \[3\]. These complex structures are seen on either side of the brain and differ in shape in the Frontal, Temporal and Occipital lobes of the brain. The lateral ventricles also change in shape with the developing brain until they attain their permanent shape in the third trimester.

On ultrasound (USS), the lateral ventricles appear as anechoic tubular structure surrounded by the hypoechoic cerebral mantle with echogenic cortical rim in the first and early second trimesters. However in the late second and third trimester, the maturing cerebral mantle becomes isoechoic surrounding the anechoic lateral ventricles. The choroid plexus is an integral part of the ventricular system and is a major landmark in the evaluation of the lateral ventricles. It appears as an echogenic structure within the body and trigone of the lateral ventricles. Other structures in the foetal cranium can also be assessed; the thalamus is a diamond shaped hypoechoic midline structure throughout gestation. The cerebellum in the posterior fossa shows similar echo signature as the cerebral mantle. All these structures are surrounded by anechoic cerebrospinal fluid (CSF) in the subarachnoid space and the cranial bones. The falx cerebri is an echogenic midline structure dividing the entire cranial contents into two halves. Other imaging modalities that have been used in evaluation of the foetal cranium include X-ray, Computed Tomography (CT) and Magnetic Resonance Imaging (MRI).

Objective imaging of the CNS is unreliable in the first trimester due to a number of errors which are prone to occur even with transvaginal ultrasound (USS) \[4,5,6\]. However, CNS imaging is practicable from the second trimester. Transabdominal USS is the ideal modality in terms of ease of performance and cost benefit considerations to the patient. Sonographic inspection, measurement and characterization of the foetal cerebral ventricles are possible and reliable as early as the 14th week of gestation \[7\]. Though numerous and varied approaches have been studied for lateral ventricular evaluation, the measurement of the lateral ventricular atrial diameter has gained the most wide-spread acceptance \[8\]. This measurement is reported among other benefits
to remain constant throughout the 2nd and 3rd trimester of gestation and 10mm is usually considered the upper limit of normal size [9]. Several authors using the same procedure have documented the association of even mild degrees of ventriculomegaly with dramatic increases in perinatal morbidity and mortality [10]. In some studies, more than 88% of foetuses with sonographically detected central nervous system anomalies had an abnormally wide lateral ventricular atrium greater than 10mm [10]. The presence of mild dilatation of the lateral ventricular atrium might be a clue to subtle structural defects and unsuspected karyotypic anomalies [11]. Accurate recognition of ventricular abnormality is based on proper understanding of the normal ranges of size, shape and experience.

Anomalies of the central nervous system (CNS) are among the most common, yet devastating, of congenital anomalies. Infants with ventriculomegaly often survive but may be severely handicapped with a good number of these infants contributing to the perennial poor infant mortality rate that is usually reported in third world countries like Nigeria [12]. Interestingly, the diagnosis of foetal ventriculomegaly could be made as early as the 14th menstrual week of gestation. At this time, proper information and counselling on the outcome of the pregnancy could be achieved with less risk to the mother.

To the best of our knowledge, there has been no documented literature on normogram for foetal atrial lateral ventricle in sub-Saharan Africa. It is worthy to note that although similar studies have been done in developed countries, these have not created enough impact for a national guideline or policy to be developed for prenatal ultrasound scan in Nigeria. Hence most foetuses that could have had early intervention are born with these defects undetected. They often present late with complications and poor outcome, increasing perinatal and infant mortality rates in our environment.
MTHODOLOGY

This was a prospective study carried out among four hundred and four consecutive pregnant women attending routine Antenatal Clinic in the Obstetrics and Gynaecology Department of University College Hospital, Ibadan, Nigeria, from January to December 2010. The inclusion criterion was pregnancies between 14 and 38 weeks gestational age which corresponded with patient’s last menstrual period. A pretested questionnaire was administered to all the participants to obtain their biomedical data, past obstetric and medical history, presence of intercurrent illness or complication of index pregnancy. A written consent was obtained from the patients and additional information was extracted from the antenatal booking record where necessary.

Images were acquired with the Logic P5/A5 General Electric ultrasound machine, 2007 China or the ALOKA SSD 1700, 1996 Japan. A 2 to 5MHz curvilinear transducer was used for optimal visualisation of the foetal cranium depending on the patient’s habitus. Values for biparietal diameter (BPD), head circumference (HC), femoral length (FL) and abdominal circumference (AC) were measured and the machine generated the ultrasound estimated foetal weight (EFW) and gestational age (GA) using the Hadlock IV equation\(^\text{13}\). Foetuses with gross anatomic defects were excluded from the study.

An axial image was obtained at the level of the lateral ventricles, with the ultrasound beam directed approximately perpendicular to the long axis of the ventricle, just above the normal plane used for measurement of biparietal diameter. The widest part of the body of the ventricle, where the glomus of the choroid plexus fills the ADLV farthest from the transducer was measured in this study. The electronic callipers were positioned from the inner to inner margins of the ventricular wall. Two measurements were taken and a mean diameter calculated to minimize intra-observer errors. All scans were performed by the corresponding author to avoid inter-observer errors. At the transventricular
plane reverberation artefact often obscures the ADLV nearest to the transducer [7, 10] [figure 1], hence the ADLV farthest from the transducer was measured in this study. Also the probability of which ventricle is measured is determined by nature since foetal presentation is random, this will naturally minimize the possibility of measuring only one ventricle during the study [10]. Figure 1 shows how measurements were taken with electronic callipers on the luminal walls of the lateral ventricles.

**Figure 1.** Transabdominal USS at the level of the atrium of the lateral ventricle arrow tip and black arrow show cranial vault with reverberation artefact. Double arrow tips show measurement of ADLV at the glomus of the echogenic choroid plexus in the distal lateral ventricle.
The data obtained was analysed using the statistical package for social sciences (SPSS, version 15) Inc, Chicago Illinois. The results are presented in tables, histograms and box plots and associations were explored with the Student's t-test and Pearson’s correlation coefficient. The level of significance was set at $P = 0.05$.

**RESULTS**

A total of 404 pregnant women met the inclusion criteria and were included in this study. Table 1 shows the sociodemographic characteristics of the subjects. The age range of the respondents was 14 – 44 years with a mean age of 30.9 years. The range in parity was 0-9 with a median of 3. Most of the respondents had tertiary education 311(76.4%), only 5 (1.2%) respondents had no formal education. The studied foetuses were between 14 to 38 weeks gestational age (GA) with a mean GA of 30.52 weeks (table 2). The mean ADLV in this study was 6.5mm (1.3mm) [4.0-11.5mm], (figure 2).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age in years.</strong></td>
<td></td>
</tr>
<tr>
<td>19 and below</td>
<td>7 (1.7)</td>
</tr>
<tr>
<td>20 – 29</td>
<td>137 (33.9)</td>
</tr>
<tr>
<td>30 - 39</td>
<td>252 (62.4)</td>
</tr>
<tr>
<td>40 and above</td>
<td>8 (2)</td>
</tr>
<tr>
<td>Total</td>
<td>404 (100)</td>
</tr>
<tr>
<td><strong>Level of Education</strong></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>5 (1.2)</td>
</tr>
<tr>
<td>Primary</td>
<td>24 (5.9)</td>
</tr>
<tr>
<td>Secondary</td>
<td>67 (16.6)</td>
</tr>
<tr>
<td>Tertiary</td>
<td>308 (76.2)</td>
</tr>
<tr>
<td>Total</td>
<td>404 (100)</td>
</tr>
<tr>
<td><strong>Parity</strong></td>
<td></td>
</tr>
<tr>
<td>Primipara</td>
<td>177 (43.8)</td>
</tr>
<tr>
<td>1 – 4</td>
<td>224 (55.4)</td>
</tr>
<tr>
<td>5 and above</td>
<td>3 (0.7)</td>
</tr>
<tr>
<td>Total</td>
<td>404 (100)</td>
</tr>
</tbody>
</table>
Figure 2: A histogram showing the distribution of ADLV in the foetuses.
Most of the foetuses, 278 (68.8%) were scanned in the third trimester of pregnancy. In the third trimester the mean ADLV was 6.5(1.3) [4-11.5], while the mean ADLV was 6.4mm (1.3mm) [4 – 11.5mm] for the second trimester.

Three hundred and ninety nine subjects had ADLV value ≤ 10mm while five patients had ADLV >10mm (10.5mm -11.5mm). The normal range of values (i.e mean ±2SD) for the 2nd and 3rd trimester for which 95% of foetuses are expected to lie as shown in Table 3 is (3.76-9.12) and (3.92 -9.16) respectively. There was no statistical significance between the ADLV values for second and third trimester.

**Table 2:** Values of ADLV at different gestational ages.*

<table>
<thead>
<tr>
<th>VARIABLES GA (in weeks)</th>
<th>N</th>
<th>Mean ADLV (mm)</th>
<th>Standard Deviation (SD)</th>
<th>Range (mm)</th>
<th>Mean±2SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 – 19</td>
<td>26</td>
<td>6.6</td>
<td>1.2</td>
<td>4.5 - 10</td>
<td>4.2 - 9.0</td>
</tr>
<tr>
<td>20 – 25</td>
<td>45</td>
<td>6.4</td>
<td>1.3</td>
<td>4.6 - 10.5</td>
<td>3.8 - 9.0</td>
</tr>
<tr>
<td>26 – 30</td>
<td>102</td>
<td>6.2</td>
<td>1.4</td>
<td>4 – 11.5</td>
<td>3.4 - 9.0</td>
</tr>
<tr>
<td>31 – 35</td>
<td>114</td>
<td>6.5</td>
<td>1.4</td>
<td>4 – 11</td>
<td>3.7 - 9.3</td>
</tr>
<tr>
<td>≥36</td>
<td>117</td>
<td>6.7</td>
<td>1.2</td>
<td>4 – 10.5</td>
<td>4.3 - 9.1</td>
</tr>
</tbody>
</table>

Subjects could be ascertained in only one hundred and seventy six
of the foetuses scanned, one hundred and seven of these were male (60.7%) while sixty nine (39.2%) were female. The ADLV values for males and female foetuses are shown in (table 4). The normal range of values for male foetuses i.e mean±2SD was 4.1-9.3mm while 95% of female foetuses had ADLV values between 3.6-8.8mm; the mean difference was 0.5mm.

**Table 4**: Values of ADLV in male and female foetuses.

<table>
<thead>
<tr>
<th>VARIABLE (gender)</th>
<th>N (%  )</th>
<th>Mean ADLV (mm)</th>
<th>Standard Deviation</th>
<th>Range</th>
<th>Mean ±2SD</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>107(60.7)</td>
<td>6.7</td>
<td>1.3</td>
<td>4.5–11.5</td>
<td>4.1-9.3</td>
<td>0.04</td>
</tr>
<tr>
<td>Female</td>
<td>69(39.2)</td>
<td>6.2</td>
<td>1.3</td>
<td>4.0–9.5</td>
<td>3.6-8.8</td>
<td></td>
</tr>
</tbody>
</table>

Figures 3 & 4 are box plots showing the distribution of ADLV in the second and third trimesters. The five point’s summary for the 2nd and 3rd trimesters are shown below:

- Minimum value: 4mm, 4mm
- 25th percentile: 5.5mm, 5.5mm
- Median: 6mm and 6.5mm
- 75th percentile: 7.5mm and 7.8mm
- Maximum value 9.8mm and 10.5mm

There were three outliers with values of 10.1mm, 10.5mm and 11.5mm in the 2nd trimester and 11mm and 11.5mm in the 3rd trimester.
Figure 3: Box plot showing the distribution of ventricular sizes in the second trimester.
Figure 4: Box plot showing the distribution of ventricular sizes in the third trimester.
DISCUSSION

The increasing awareness and need for qualitative care as well as the ever increasing role of technology in modern day medical care, has placed a huge responsibility on imaging practitioners. Among the many challenges facing the radiologist and/or obstetrician in obstetric care today, early and accurate diagnosis of all diagnosable foetal anomalies as well as prognosticating the outcome of foetal anomalies, may be the most difficult. In countries where foetal anatomic survey is mandatory, the mere mention of a potential intracranial abnormality justifiably elicits parental anxiety, whereas misdiagnosis or failure to diagnose may have catastrophic consequences. Various studies have shown up to 84% association of foetal ventriculomegaly with different types of intracranial and extracranial foetal anomalies. This in effect is a strong reason for the establishment of an acceptable cut-off value for ventricular size, beyond which further evaluation by trained personnel becomes imperative. Cardoza et al in their pioneering work on foetal ventricle proposed 10mm as the upper limit of normal for the lateral ventricle at the level of the atrium. This value was arrived at from a mean value of 7.6mm plus 4 standard deviations (0.6mm). This has received wide acceptance by other investigators because measurement of the atrial diameter of the lateral ventricle is simple and reproducible as proposed by Cardoza et al and the echogenic choroid plexus is a stable and reliable landmark in this region.

In our study the mean value of ADLV of 404 foetuses was 6.5mm (SD 1.3mm), and the mean plus 2.5 standard deviation was 9.8mm (table 3). This result is similar to those of Heiserman et al (52 subjects), Ravi et al (500 subjects) and Achiron et al (5,400 subjects) who recorded mean values of 6.5mm (SD 1.3mm), 6.6mm (SD 1.4mm) and 6.6mm (SD 1.2mm) respectively.
prospective studies. However, Thomas et al. [7] in another prospective study of 739 foetuses in Durham USA recorded a mean value of 5.4mm (SD 1.2mm) which is lower than our value. Their study also considered ADLV of 8mm as the upper limit of normal for foetuses 17 weeks or less. No explanation is given for these differences so far. Compared to Cardoza et al. [18] who recorded a mean value of 7.6mm (SD 0.6mm) and 10mm (mean +4SD) in their retrospective review of 100 foetuses; most prospective studies including ours recorded lower ADLV. It thus appears that the realistic mean for the atrium of the lateral ventricle would be significantly below the value proposed by Cardoza et al. [18], since most prospective studies where the criteria were set and followed properly by different investigators have constantly recorded mean ADLV value of 1mm or more lower than the 7.6mm recorded by Cardoza et al. [18]. However, despite the difference in the mean values obtained from the retrospective and prospective studies, previous investigators have accepted 10mm as a convenient upper limit of normal for ADLV, probably in order to accommodate the few outliers as noted in 5 of the foetuses in this study (figures 3 & 4).

The concept of mild idiopathic lateral ventricular dilatation (MILVD) has been proposed by some investigators because of the varying outcomes of MILVD dilatation with or without other associated foetal anomalies. Mahony et al. [14] in their study of 20 fetuses with mild ventriculomegaly, defined MILVD as the separation of more than 3mm-8mm between the echogenic choroid plexus and the wall of the lateral ventricle irrespective of the size of ADLV. On the other hand Goldstein et al. [11] and Bromley et al. [22] in their study of 55 and 44 foetuses with mild ventriculomegaly respectively defined MILVD in terms of the size of ADLV. They considered measurements of 10-15mm as mild ventriculomegaly[22]. In the three studies quoted above, the investigators noted that the atrium of the lateral ventricle like any other biological medium may occasionally dilate [18]. Mild ventricular dilatation can be divided into three categories: (i) those that are isolated with no other associated foetal anomaly
which undergo spontaneous resolution before term and show good prognosis\cite{23} as was seen in 100% of all their cases. (ii) those cases of MILVD that remain stable throughout gestation, they show unpredictable outcome and (iii) those with other associated foetal anomaly which consistently show poor prognosis, the outcome being dependent on the cause of the mild ventriculomegaly\cite{14,24}.

Only few studies have so far showed the relationship between the ADLV and the foetal gender. In our study, gender was assignable to only 176 (43.6%) of the subjects, this low number of foetuses with assigned gender was largely due to the late presentation of most of the subjects. The mean value of ADLV for male 6.7mm (1.3mm) was higher compared to the values for female 6.2mm (1.29mm). The mean difference of 0.5mm was statistically significant (P= 0.04) but the clinical value of this difference is yet to be established as more studies are needed to evaluate the perinatal characteristics of neonates with regards to the ventricular size. However, this result is similar to the studies of Nadel and Benacerraf \textit{et al} \cite{8,10} in their prospective assessment of 543 foetuses; 316 (58.2%) male and 227 (41.2%) females. They recorded a total mean ADLV of 6.5mm (1.4mm) with a mean value 6.7mm (1.3mm) and 6.3mm (1.3mm) for males and females respectively. Their mean difference of 0.4mm is similar to our study. Patel \textit{et al} \cite{25} in their study also recorded a mean difference of 0.6mm between male and female foetuses which is also similar to previous studies and ours. The absolute maximum values in this study were 11.5mm and 9.5mm for the male and female foetuses respectively. The 2mm difference in the absolute maximum values for the male and female foetuses has been reported to be far more significant statistically, than the mean difference \cite{10,14}. This may presuppose that female foetuses with mildly dilated ADLV are more likely to have poor prognosis compared to their male counterpart \cite{24,26}. 
CONCLUSION

This study has shown that with the existing resources in our environment, intra-utero assessment of the foetal intracranial anatomy with a view to making prenatal diagnosis of hydrocephalus is possible, as the ADLV remains stable in the second and third trimester of gestation. A Measurement of 10mm for the ADLV is a reasonable upper limit beyond which foetuses should be evaluated properly to rule out hydrocephalus. The previously reported larger size of the ADLV in male foetuses compared to their female counterpart is also confirmed in our study population. However, further studies are needed to evaluate the significance of this difference with regards to the perinatal outcome of neonates in the study area.

COMPETING INTEREST

There is no conflict of interest to declare by the authors in this study.

ETHICAL APPROVAL AND FUNDING

Ethical approval for the study was given by the Institutional Review Board of UCH. No funding was received for the study.

REFERENCES


