CHAPTER 3

ESTIMATION OF NASAL BONE LENGTH IN SECOND TRIMESTER FETAL IMAGES

3.1 INTRODUCTION

Different screening strategies for DS detection have been suggested for Down Syndrome detection in the last few decades. Prenatal sonography has been useful in the detection of affected fetuses by relying on a variety of sonographic features. The goal of such prenatal screening is accurate detection of fetal aneuploidy and avoidance of unnecessary invasive testing (Lan 2005). Flat facial profile has been identified as common characteristics of DS genotype (Down 1866). Postmortem, radiologic and histologic studies of fetuses with DS document hypoplasia or delayed ossification of nasal bone (Keeling 1997, Stempfle 1999). Recent studies reveal that the nasal bone hypoplasia can be evaluated with sonography and appears as an absence or shortened nasal bone (Kanellopulos 2003, Otano 2002, Orlandi 2003) in prenatal screening.

Fetal nasal bone has been proposed as a novel marker for DS detection (Cicero 2001). The sonographic identification of this feature has increased the detection of 60% to 80% of DS fetuses with false positive rate of 5% (Nyberg 2001, Bromley 2002). The absence of nasal bone in second trimester of pregnancy has a sensitivity of 41% and specificity of 100% in detecting fetal Trisomy 21 (Anthony Vintzileos 2003).
Recent studies reveal that hypoplasia rather than absence of nasal bone much correlates with Trisomy 21 (Keeling 1997, Stempfle 1999, Kanellopulos 2003). The sonographic and pathomorphologic findings in fetuses with Trisomy 21 were compared (Minderer 2003). A retrospective review of sonographic images identified nasal bone in 5 of 6 cases in which they were initially reported as being absent on sonography were present but hypoplastic. Therefore an accurate nasal bone length measurement with good reproducibility has become more important than nasal bone identification. It has been reported that nasal bone hypoplasia during the second trimester is associated with a high risk of Trisomy 21 and has been suggested as a highly sensitive and specific sonographic marker for chromosomal aneuploidy (Bromley 2002, Cicero 2003, Odibo 2004, Guis Ville 1995).

The Nasal Bone Length (NBL) is measured manually by skilled sonographers with experience in NT measurement. It is measured by placing the electronic calipers from the base of the nose closest to the frontal bone to the farthest extent of ossification of the nose (Sadik Tamsel 2007). Several difficulties in the nasal bone length estimation has been identified. The nasal bone length (Bekker et al 2004) in the first trimester is relatively small compared with other fetal biometric measurements. Another major problem is the caliper placement because of lateral scattering and new ossification of the nasal bone. In cases with Trisomy 21, the nasal bone is found to be less echogenic due to delayed ossification.

Nasal bone evaluation in 11-13 weeks is difficult as the skin on fetus nose is mistaken for nasal bone. If it is not examined in an appropriate plane, it will lead to longer or shorter measurement of the nasal bone than normal (Derya Sivri 2006). It has also been revealed that minimum number of scans required for an experienced sonographer to examine the fetal nasal bone is on an average of 80.
The reported measurements so far have been made with the decision of skilled sonographers. Manual measurement leads to inaccurate and inconsistent results of nasal bone estimation due to subjective decision by the operator. In this work the nasal bone length has been measured for the detection of DS. The procedure is carried out on the second trimester fetal images.

The schematic representation of the implemented semi automated algorithm of parametric estimation of second trimester fetal images for DS prediction is shown in Figure 3.1 were the images are first preprocessed using median filter to suppress the speckles, segmented using mean shift analysis and finally subjected to edge detection.

![Figure 3.1  Block diagram for Down Syndrome detection in second trimester B mode US images](image)

3.2 DATA ACQUISITION

The US fetal images has been obtained from two types of scanning systems namely Wipro GE logic 400 curvilinear probe with transducer
frequency of 3-5 MHz and the Siemens G4 machine with curvilinear probe with transducer frequency of 2.5 MHz. The size of the image obtained is 768×576. A mid-sagittal view of the fetal face with the ultrasound transducer held parallel to the direction of the nose is obtained by the sonographers. The transducer is tilted from side to side to ensure that the nasal bone is visualized separate from the nasal skin. The magnification of the image is such that the head and thorax region occupy a major portion of the image in the neutral position. A 10-s movie is recorded for each subject showing the movement of the fetus. The movie is processed and stored as sequence of still images in the image data base. Still image which is suitable for the proposed work is chosen from the data base.

Figure 3.2 (a) shows the anatomical structure of the fetal image for measurement of NBL in the mid sagittal view. The fetal nasal bone can be visualized by sonography throughout pregnancy and is generally identified by the skin over the nasal bone, the nasal bone and the skin over the nasal tip. Three echogenic lines can be visualized: The first two lines, which are proximal to the forehead, are horizontal and parallel to each other, resembling an “equal sign”. The top line represents the skin and bottom one, which is thicker and more echogenic than the overlying skin, represents the nasal bone. A third line, which is almost in continuity with the skin, but at a higher level, represent the tip of the nose (Canda 2007). However the nature of the line may vary depending on the pose of the fetus during image acquisition. The NBL can be measured by the sonographers with electronic calipers from the base of the nose closest to the frontal bones to the farthest extent of ossification on the nose as shown in Figure 3.2(b). The measurement can be done carefully such that the echogenic skin surface of the nose is not mistaken as nasal bone.
3.3 IMPLEMENTATION PROCEDURE FOR ESTIMATION OF NBL

The overall block schematic representation of the image segmentation procedure is shown in Figure 3.3.

3.3.1 Median Filter

The first step in this approach is to filter the acquired image. The ultrasound images have speckle noise. It is difficult to define the nasal bone contour when poorly visualized. Ultrasound speckle is a phenomenon that occurs when a coherent imaging system is used. Speckle is often modeled as a multiplicative process because fully developed speckle has the property of constant signal to noise ratio. Speckle in ultrasound imaging is caused by the interferences of energy from randomly distributed scatters, too small to be resolved by the imaging system. The main drawback of ultrasound imaging is its poor quality. It takes considerable effort from the radiologist to extract boundary of nasal bone. This task requires a highly skilled radiologist. Also manual extraction of nasal bone region generates a result that is not
reproducible. The filtering process carried out in this work has been detailed in the previous chapter.

![Diagram of Implementation steps of the algorithm]

Figure 3.3 Implementation steps of the algorithm

3.3.2 Region of Interest

A well defined Region of Interest (ROI) helps reject interferences from irrelevant organs or tissues in the same scanning plane and reduces the computational time. The selection of suitable configuration is one of the main features of this approach. A rectangle, enclosing the contour of the nasal bone
is selected with manual assistance for the precise segmentation of the nasal bone.

### 3.3.3 Segmentation

The Mean shift analysis has been utilized for segmenting the Nasal bone region from the second trimester Ultrasound fetal images. The ROI has been cropped from the test image and considered as an individual segment. The theoretical aspects of the Mean shift analysis have been discussed in detail earlier in the thesis. Figure 3.4 gives the output of Mean shift segmentation applied for a normal fetus. The cluster formed is displayed in the figure with the value of the cluster label.

![Figure 3.4 Mean shift segmented image](image)

### 3.3.4 Canny Edge Detection

The Canny algorithm basically finds edges where the grayscale intensity of the image changes the most. These areas are found by determining gradients of the image. The edge segments are linked to form the contour of the nasal bone region.
3.4 RESULTS AND DISCUSSION

Experiments have been carried out on a set of sonographic images obtained from the ultrasound machine for the estimation of NBL. A total of 110 images including both normal and abnormal subjects under various weeks of gestation in the second trimester were considered for the analysis of NBL. Out of 110 images 84 subjects were normal and 26 were with DS. The images were preprocessed and the region of interest has been cropped for further analysis. Nasal bone has been segmented from the cropped image by applying the mean shift cluster analysis. The data at the edges has been detected using Canny operator to improve the visibility of the data. The nasal bone length has been measured using BLOB analysis (Chen 2007, Neatpisarnvanit 2006).

Figure 3.5 (a) Sample Input Image           Figure 3.5 (b) Output of Median Filter

The sample image and the despeckled images are shown in Figure 3.5(a) and 3.5(b) respectively. The median filter has been used to despeckle the noise present in the input image. It has been seen from the filtered image that the noise has been suppressed and the contour of the fetal image is clearly visible.
The region of interest has been obtained from the despeckled images for measuring the NB length. A rectangular region of interest that includes the nasal bone is chosen for further segmentation and is shown in Figure 3.6.

![Figure 3.6 Selection of ROI](image)

The algorithm developed for the measurement of NB length is implemented on a normal subject obtained in the second trimester. The experimental results obtained are discussed in detail in this section.

The speckles present in the US fetal images have been suppressed using median filter and the despeckled image is shown in Figure 3.7(a). The complete segmented output of normal fetus by applying Mean shift segmentation algorithm is shown in Figure 3.7(b).

The ROI cropped from the filtered image is subjected to the segmentation process and the segmented output of the nasal bone region is shown in Figure 3.7(c). Further visibility of the edges is improved by the Canny edge detector and the output can be seen in Figure 3.7(d).
Figure 3.7  (a) Experimental result obtained by subjecting the normal fetus from the database to Median filtering, (b) Output of Mean Shift analysis, (c) Segmentation of ROI, (d) Results of Canny Edge Detection and (e) Extracted Nasal Bone Region Superimposed on the Original Image
The contour of the nasal bone region that has been extracted using the mean shift analysis is superimposed on the original image and the resultant image is shown in Figure 3.7(e). The contour of the nasal bone is very clear and done as the verification process of the segmentation procedure. The above procedure is applied to all the 84 subjects with gestation weeks varying from 13 to 19 weeks.

As a first step, measurements have been made on the healthy fetuses. The nasal bone length is estimated for normal subjects and presented in the Table 3.1. It can be seen that the nasal bone length increases with gestational age of fetus. The observed results can be used to determine the euploid fetuses with normal growth rate of nasal bone.

Table 3.1  Nasal Bone length in second trimester measured for normal fetus with gestational period varying from 13 to 19 weeks

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Gestation Weeks</th>
<th>Number of subjects</th>
<th>Average (mm) $\bar{x}$</th>
<th>Standard Deviation $\sigma$</th>
<th>Variance $\sigma^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13</td>
<td>12</td>
<td>2.29</td>
<td>0.12</td>
<td>0.02</td>
</tr>
<tr>
<td>2</td>
<td>14</td>
<td>14</td>
<td>2.92</td>
<td>0.22</td>
<td>0.05</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>11</td>
<td>3.20</td>
<td>0.20</td>
<td>0.04</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>12</td>
<td>4.04</td>
<td>0.12</td>
<td>0.02</td>
</tr>
<tr>
<td>5</td>
<td>17</td>
<td>10</td>
<td>4.32</td>
<td>0.27</td>
<td>0.08</td>
</tr>
<tr>
<td>6</td>
<td>18</td>
<td>13</td>
<td>4.67</td>
<td>0.19</td>
<td>0.04</td>
</tr>
<tr>
<td>7</td>
<td>19</td>
<td>12</td>
<td>5.28</td>
<td>0.28</td>
<td>0.08</td>
</tr>
</tbody>
</table>

The above mentioned procedure is applied to the 26 aneuploid fetuses. Similar results have been obtained for the abnormal subjects and the results are shown in Figure 3.8.
Figure 3.8  (a) Experimental results obtained by subjecting the Abnormal fetus from the database to Median filter, (b) Output of Mean Shift Analysis, (c) Segmentation of ROI, (d) Results of Canny Edge Detection and (e) Extracted Nasal Bone Region Superimposed on the Original Image
Figure 3.8(a) shows the despeckled image of the abnormal subject. The despeckled output is subjected to mean shift segmentation algorithm and the complete segmented of abnormal fetus is shown in Figure 3.8 (b). The ROI, cropped from the filtered image and segmented is shown in Figure 3.8(c).

Further visibility of the edges for precise measurement of NBL is done by Canny edge operator and the result is shown in Figure 3.8(d). It is clearly observed from the results that the abnormal fetus has less edge detected nasal bone region compared to a normal fetus. In Figure 3.8(e) the extracted nasal bone region is superimposed on the original image and marked as red. It is made as a verification methodology for ensuring the segmentation process. It can be observed from the results that there is a variation in the fetal nasal bone length of the normal and abnormal fetus and this variation could be accounted for the possibility of occurrence of DS.

3.5 INTENSITY DISTRIBUTION OF NASAL BONE REGION

The pixel intensity distribution profile of nasal bone region is shown in the Figure 3.9(a) for normal fetus, abnormal fetus with short nasal bone in Figure 3.9(b) and fetus with absent nasal bone in Figure 3.9(c).

It may be seen from the figures that the distribution of intensity profile is maximum for normal and minimum for abnormal fetus. It is also estimated that the distribution of intensity of pixel for normal fetus is around 80% and it is 45% in the case of hypoplastic nasal bone. This is due to the under development and delayed less ossification of the nasal bone. Figure 3.9(c) gives the intensity profile of the fetus with absence of nasal bone. The intensity distribution is only due to the noise, since the ossification of nasal bone is reported as absent.
Figure 3.9  Plot of the pixel intensity Distribution of Nasal bone region of a) Normal fetus b) Abnormal fetus c) Absent nasal bone

The Nasal Bone Length is measured using blob analysis. The edge detected nasal bone region is subjected to binary masking for Blob analysis which gives a binary image where pixels in the background values are equal to 0 and the nasal bone region has pixel intensity value as 1. The application of blob analysis detects the blobs in the image and measures the length of the nasal bone in terms of pixels. The number of pixels is then converted to millimeter resulting in the length of the nasal bone.
The Mean, Standard deviation and the Variance are calculated using the following formulas:

\[
Mean = \bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{3.10}
\]

\[
Standard\ Deviation = \sigma = \sqrt{\frac{\sum_{i=1}^{n} d_i^2}{n}}, \text{ where } d_i = x_i - \bar{x} \tag{3.11}
\]

\[
Variance = \sigma^2 \tag{3.12}
\]

where \(x_i\) is the nasal bone length of the individual subject and \(n\) is the total number of subjects.

The details of the measured value of NBL for various subjects under different weeks of gestation is given in Table 3.1. The NBL has been estimated to vary from 2.29 ± 0.125 mm in the 13\textsuperscript{th} week to a maximum of 5.28 ± 0.283 mm at 19\textsuperscript{th} week. The NBL of the abnormal subject shown in the Figure 3.8(a) measures 2.34 ± 0.112 mm in the 19\textsuperscript{th} week whereas the average NBL of the normal fetus at 19\textsuperscript{th} week of gestation is estimated as 5.28 ± 0.283 mm. The remarkable decrease in the magnitude of NB length for the abnormal subject is ascribed due to the occurrence of DS. The observed results are in line with the earlier studies (Bromley 2002, Cicero 2002, Piotr Sieroszewski 2006). The results obtained are expected to help the physician for better diagnosis.

The estimated mean value of Nasal Bone Length for normal and abnormal fetuses in different gestation weeks are shown in Figure 3.10. It can be observed from the graphical results that there is a significant increase in the NBL with gestation for normal fetus. The average length of the nasal bone
for normal fetus in the 17\textsuperscript{th} and 19\textsuperscript{th} week of gestation is found to be $4.32 \pm 0.276$ mm and $5.28 \pm 0.283$ mm respectively. The average nasal bone length of the abnormal fetus for the same week of gestation is estimated to be $2.133 \pm 0.013$ mm and $2.44 \pm 0.132$ mm.

![Figure 3.10 Plot of Mean value of NBL for normal and abnormal Fetus](image)

It is evident from the analysis that the growth rate of NB during 17\textsuperscript{th} and 19\textsuperscript{th} week for normal fetuses increases remarkably compared to the abnormal fetus. The reduced growth rate of the nasal bone in the abnormal fetuses may be due to the lesser ossification of the nasal bone.

The three dimensional intensity plot of the segmented nasal bone region is shown in the Figure 3.11(a) for normal fetus and in Figure 3.11(b) for abnormal fetus. It can be observed from the plot that the length of the nasal bone for a normal fetus is represented by the two peaks P1 and P2 whereas in the abnormal fetus only one peak is visible. It may be due to the lesser ossification of the nasal bone resulting in shortened length.
Figure 3.11 Three dimensional plot of segmented Nasal bone region of 
a) Normal Fetus and b) Abnormal Fetus

The evaluated nasal bone length for the abnormal subject differ much as compared to the normal subject since the nasal bone region is much lesser from the result shown in Table 3.1. It is inferred that the normal fetus has nasal bone region length increasing linearly with gestational age. This is due to the normal growth of the fetus.
It has been observed from the segmented results that the nasal bone region extracted for a normal fetus is lengthier than the Down syndrome fetus. It is clearly viewed from the edge detected results of euploid and abnormal fetuses shown in Figure 3.7(d) and 3.8(d) respectively. It has been observed from the results that the contour of the nasal bone region obtained using the present technique provides accurate results. The observed remarkable decrease in the magnitude of NBL for abnormal fetuses is ascribed due to the occurrence of DS. The obtained results are in line with earlier studies (Cicero 2001, Otano 2002, Orlandi 2003).

3.6 CONCLUDING REMARKS

A semi automatic detection of DS fetuses using mean shift segmentation has been done for ultrasound B-mode fetal images obtained in the second trimester. The nasal bone length has been measured for 84 euploid fetuses and 26 DS fetuses. This proposed technique overcomes the difficulties of conventional detection method. Speckle noise and artifacts produced from non invasive ultrasound image have been reduced by image processing techniques.

The algorithm employed provides superior performance as compared to the conventional measuring techniques. It is also observed that the nasal bone length linearly increases as the weeks of gestation increases for normal fetuses. Whereas in case of aneuploid fetuses the growth rate of nasal bone is found to be less when compared with the normal subject for the same week of gestation. The present studies confirm that the Mean shift segmentation analysis can be successfully employed to estimate the nasal bone length for the early prediction of occurrence of DS in the second trimester fetal images.