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Estimation of Fetal Brain Volume from MRI of Human Fetus

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Abstract

Monitoring of fetal brain growth during the pregnancy period is essential to have a healthy fetus. Fetal brain volume is a biomarker to identify any deformity in the fetal brain. In this paper we propose a method to estimate the fetal brain volume by manually segmenting the MRI of human fetus.

Keywords: Fetal Brain; Fetal Brain Volume; Fetal MRI

Abbreviations: GW: Gestational Week; CNS: Central Nervous System; US: Ultrasound; MRI: Magnetic Resonance Imaging; TOP: Termination of Pregnancy; IUFD: In Utero Fetal Death: SSFSE: Single Shot Fast Spin Echo; FOV: Field of View; ST: Slice Thickness; ISG: Inter Slice Gap

Introduction

The human fetus undergoes rapid changes in every gestational week (GW). The fetus is to be monitored by an obstetrician for its healthy growth. An important organ that is to be monitored is the fetal brain. Fetal brain starts developing from the 3rd GW and continue to grow in its shape and structure [1]. Some of the abnormalities that may occur in the central nervous system (CNS) in the early stages are encephalocele, anencephaly, hydrocephalus and microcephaly [2]. To understand the pathology and structure of the fetus, non-invasive imaging techniques such as ultrasound (US) and magnetic resonance imaging (MRI) are used. MRI is more suitable to image soft tissues such as brain and also gives a high contrast image. Identification of brain abnormalities helps to make informed decisions like termination of pregnancy (TOP) or in utero fetal death (IUFD) [3]. Votino et al. [3] have estimated the brain volume using MRI and weight using autopsy of the fetal brain. Estimation of fetal brain at different GW helps to identify normal and abnormal brain growth [4,5]. Estimating the brain volume through MR imaging has become an accepted technique [6,7] In this paper, we propose a method to estimate the fetal brain volume from MRI of human fetus in the range of 20-38 GW by extracting the brain portion manually by an expert.

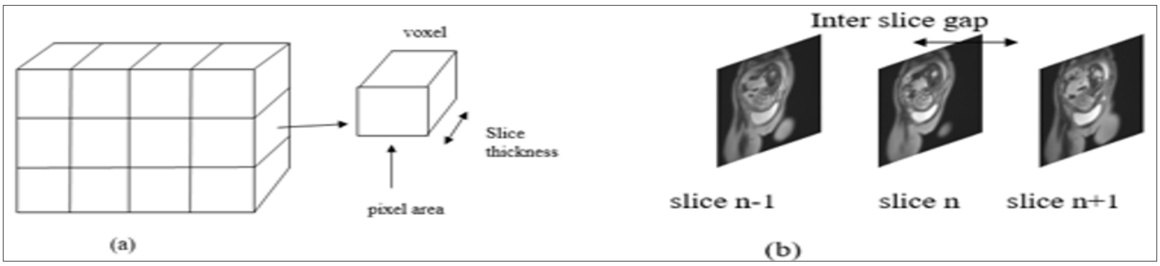

Figure 1: Slice terminology.
(a) Image matrix; (b) Stack of slices.

Materials Used

We used twenty volumes of retrospective T2 - weighted single-shot fast spin echo (SSFSE) MRI collected from Sri Ramachandra Medical University and Hospital, Chennai, India. Ethical approval was granted by the Ethical Committee (ethics no. IEC-NI/14/OCT/43/65) of the same University. The datasets were imaged between 20 and 38 GW. Brain portion in all the volumes were manually segmented by a medical expert specialized in the fetal brain anatomy and are used for estimating the brain volume. The details of the dataset are given in Table 1. The data sets pertain to different subjects. This set was arranged to cover range of 20-38 GW period to form 12 volumes from the 20 sets. To estimate the fetal brain volume, we make use of the manually segmented fetal brain images. Fetal brain area is calculated for every MRI slice in the data set. An MR imaging volume contains collection of slices. Each slice displays an area of anatomy as the field of view (FOV). The FOV is divided into pixels. Every pixel of an MR image corresponds to a voxel, a volume element, whose value represents the tissue and MR signal, respectively. The volume of a voxel depends on MR imaging parameters, i.e. slice thickness (ST) and pixel spacing (Figure 1a). The physical thickness is specified in the parameters embedded in the MR image. Between two slices there will be a gap called inter slice gap (ISG) (Figure 1b).

Table 1: Details of retrospective T2- w fetal image.

No.	GW	Flip Angle	Slice Thickness (mm)	Slice gap (mm)	TR (ms)	TE (ms)	FoV (mm)
1	20-21	170	4	4	850	86	188x280
2	20-21	170	3.5	3.5	1350	89	280
3	20	170	3.5	3.5	800	89	270
4	29	90	4.5	5	718	92	350
5	36	170	3.5	3.5	1790	89	270
6	31	90	4.5	4.8	473	91	380
7	29	170	4	4.2	1350	91	300
8	27	90	5	5.2	642	93	350
9	26	170	4.5	4.5	700	89	280
10	23	170	4	4.2	1350	91	320
11	29	170	4	4.2	1350	91	300
12	33	90	4	4	1062	88	320
13	20-21	170	5	5.5	1350	91	320
14	35-36	170	4	4	1350	91	300
15	38	90	4	4.5	676	88	400
16	28-29	170	4	4.2	1350	91	280
17	31	90	3.5	3.7	709	90	420
18	32-33	160	3	3	900	89	279x350
19	22-23	160	3.5	3.9	1000	85	350x279
20	35-36	90	4	4.5	695	92	420

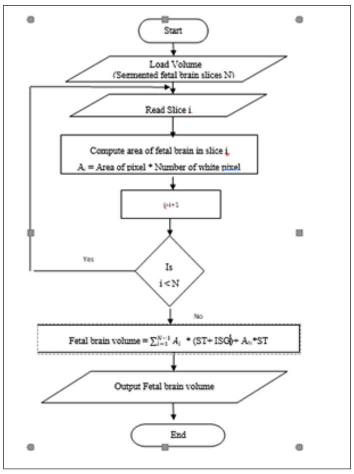

Figure 2: Flowchart of the proposed method.

Method

The proposed method includes computing fetal brain area in each slice and estimating volume of fetal brain. The flowchart of the proposed method is shown in Figure 2.

Computing Area of Fetal Brain in Each Slice

For each segmented fetal brain from MRI slice, a binary mask is obtained. The pixels which have the intensity values greater than zero are assigned to one (white) and the rest of the pixels are assigned a zero value (black). The area is computed by counting the white pixels. In order to compute the area of the fetal brain in a slice, first the area of each pixel is computed in cm^2. This is done by reading the pixel spacing tag from the DICOM header of the corresponding MRI slice. The pixel spacing tag represents the spacing between the centers of any two adjacent pixels [8]. Half the length of the pixel spacing represents half the length of a pixel and the other half represents half the length of the adjacent pixel. Assuming that all the pixels in the image have the same length in both x and y direction, the pixel spacing (in mm) is equal to the pixel length. The area of any pixel is computed as:

$$\text{Area of pixel} = \left(\frac{pixelspacing}{10}\right)^2 cm^2 \quad (1)$$

Figure 3 shows that the pixel spacing is equal to the pixel length

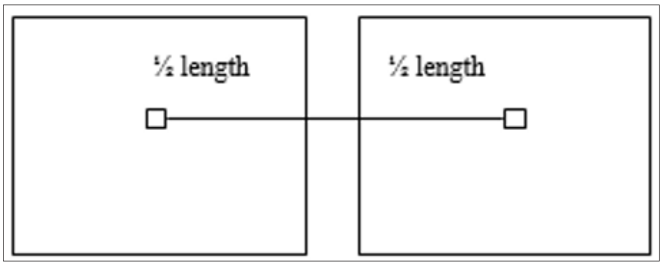

Figure 3: Pixel spacing is equal to pixel length.

The area of the brain in the i^{th} slice is computed as:

$$A_i = \text{Area of pixel} * N_W \quad (2)$$

where, N_W is the total number of white pixel in the slice. This process is repeated for all the slices in that volume.

Computing Fetal Brain Volume

The brain volume is computed by multiplying the area and slice thickness (ST). While acquiring the images, a physical gap is left in between two slices and is measured by inter slice gap (ISG). It is assumed that the area of the brain in the ISG is the average of the two adjacent slices. The ST and ISG are obtained by reading the header of DICOM images. The fetal brain volume BV is computed as:

$$BV = \sum_{i=1}^{N-1} A_i * (ST + ISG) + A_N * STmL \quad (3)$$

where, N is the total number of slices in the volume and A_i represents the area of the fetal brain in the i^{th} slice, and A_N is the N^{th} slice.

Results and Discussion

The computed values of BV for 12 different gestational weeks are given in Table 2.

Table 2: Computed Fetal brain volume BV (mL).

Vol Label	GW (weeks)	BV in mL
1	20	66.84
2	21	75.2
3	22	81.3
4	23	90.1
5	26	112.1
6	27	117.4
7	29	132.87
8	31	145.65
9	32	158.27
10	33	201.6
11	36	320.2
12	38	439.17

Conclusion

We have developed a method to estimate the fetal brain volume from hand segmented brain portion from the MRI of human fetus. The fetal brain volumes at different gestational week were estimated. We found that the brain volume increases almost linearly till32 GW and thereafter at a higher rate. It is 67mL at 20GW, 114mL at 26 GW and 438mL at 38 GW.

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