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Reference Centile Charts for Fetal Umbilical Artery Doppler Velocimetry Waveform of Thai Fetuses

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ABSTRACT

Objective To create reference centile charts for fetal umbilical arteries Dopper velocimetry waveforms of Thai fetuses.

Design Prospective, cross-sectional study.

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Subjects and Methods A total of 621 pregnant women, who attended the antenatal clinic at Siriraj Hospital, Mahidol University, Bangkok, were recruited between 12 and 41 weeks of gestation. Each fetus was measured only once for the purpose of this study. Using a Duplex pulsed wave Doppler Ultrasound with a 3.5 MHz convex transducer, we measured systolic/diastolic ratio (S/D ratio), pulsatilily index (PI), and resistance index (RI) of fetal umbilical arteries. The mean and standard deviation (SD) of each Doppler indices were estimated at each week of gestation using stepwise linear regression modeling.

Results A total of 617 fetuses were measured for systolic/diastolic ratio (S/D ratio), pulsatilily index (PI), and resistance index (RI) of fetal umbilical arteries. Regression models were fitted to estimate the mean and standard deviation for each parameter at each gestational age. The centile charts of each parameter were derived from regression equations and are presented.

Conclusion We have presented reference centile charts for systolic/diastolic ratio (S/D ratio), pulsatilily index (PI), and resistance index (RI) of fetal umbilical arteries of Thai fetuses.

Key words: Doppler, umbilical artery, centile chart

To date, the utility of Doppler ultrasonography as a mean of assessing potential alterations of vascular resistance prior to fetal or maternal compromise is very attractive. Since umbilical arteries carry fetal blood to the placenta, obstetricians studied flow velocity waveforms in these vessels to assess placental blood flow. There are three main indices in use for assessment of Doppler ultrasound umbilical artery waveforms. These are the systolic/diastolic ratio (S/D ratio), the pulsatility index (PI), and the resistance

index (RI)

In normal pregnancy, Doppler studies have shown a progressive fall in peripheral vascular resistance comparing with gestational age.[1-2] There is no doubt that there is a correlation between Doppler indices of umbilical arteries and adverse perinatal outcome especially in growth-retarded fetuses.[3] In this group, abnormal Doppler measurements precede the ultrasonic diagnosis of growth retardation,[4] therefore, we can use Doppler studies for early detection abnormal conditions in antepartum fetal surveillance in high-risk pregnancies.

Normal reference values for umbilical artery waveforms have been published by several groups in Western countries. Unfortunately, there is no standard reference of this for Thai fetuses. In this study we established reference ranges throughout pregnancy from 12-41 weeks of gestation in order to use indices in clinical management.

Materials and Methods

Data collection procedures were designed specifically for the purpose of this study that each fetus was measured only once. We recruited pregnant women and their fetuses between 12 and 41 weeks of gestation, who attended the antenatal clinic at Siriraj Hospital, Mahidol University, Bangkok, Thailand. We identified pregnant women who had previous regular menstrual period for at least 3 months without contraception prior to current pregnancy, and uterine size at that time of examination was compatible with menstrual age. Exclusion criteria were as follow:

1. Uncertain date of last menstrual period
2. Maternal conditions which may affect fetal growth (i.e., diabetes mellitus, hypertension, etc.)
3. Multiple pregnancies
4. Fetal or neonatal malformation or abnormal karyotype

A total of 621 pregnant women were recruited. Measurements were made at randomly assigned gestational age so that approximately equal number of fetuses were measured at each week of gestation.

Using a Duplex pulsed wave Doppler ultrasound scanner (Acuson 128XP4) with a 3.5 MHz convex transducer we measured the S/D ratio, PI, and RI of the umbilical arteries at the free loop of umbilical cord. Peak systolic to end diastolic velocities of four or five cardiac cycle were measured by electronic calipers. Recording were made during periods of fetal apnea because fetal breathing movements are known to have marked effect on fetal blood flow.[5] Breathing movements at the time of umbilical artery recording were early recognized by fluctuation or irregular traces in the spectral waveforms.

Statistical analysis

The mean of each index measurement (S/D ratio, PI, and RI) is estimated at each week of gestation using stepwise linear regression modeling. This is based on the assumption that the data in each gestational age are normally distributed. The standard deviation (SD) is then modeled as a function of gestational age using linear regression model. All the final models chosen are the simplest ones which provide a good fit to the observed data. Reference centiles for each gestational age are then derived from the fitted mean and SD.

Reference centiles for each resistance index parameter are then derived from the fitted mean and SD. The 100 αth centile can be estimated from mean + $Z\alpha$ (SD), where $Z\alpha$ is the corresponding value from the standard normal distribution.

Results

Fetal umbilical artery data were available from 617 of 621 measurements due to unfavorable position in 4 fetuses. The number of fetuses measured at each weeks of gestation is shown in Table 1.

Table 1. Number of fetuses measured at each week of gestation

Gestational ages (weeks)	Number of fetuses	Percentage
12	12	1.9
13	14	2.3
14	14	2.3
15	19	3.1
16	22	3.6
17	22	3.6
18	21	3.4
19	22	3.6
20	21	3.4
21	21	3.4
22	24	3.9
23	26	4.2
24	22	3.6
25	26	4.2
26	27	4.4
27	23	3.7
28	22	3.6
29	21	3.4
30	26	4.2
31	20	3.2
32	21	3.4
33	22	3.6
34	19	3.1
35	17	2.8
36	23	3.7
37	21	3.4
38	19	3.1
39	18	2.9
40	16	2.6
41	16	2.6
Total	**617**	**100.0**

The models for the mean fetal umbilical artery Doppler indices were estimated using the stepwise linear regression technique. Standard deviations (SD) were modeled as a function of gestational age using the same regression technique. The regression equations for mean and SD are

UA S/D Ratio = -0.404 + (102.955/W)
SD = -0.291 + (21.158/W)

UA PI = 1.081 - 0.015 W + (11.23/W)
SD = -0.189 - (0.0026/W)

UA RI = 1.09 - 0.0175 W - 0.0001 W2
SD = -0.0025 + 0.0032 W - 0.00005 W2

Where UA = umbilical artery, SD = standard deviation, and W = gestational age (weeks)

Figure 1 - 3 show a scatter plot of fetal umbilical artery indices (S/D ratio, PI, and RI, respectively) against gestational age with the fitted line from the equations above. Reference centiles were calculated from the estimated means and SDs at each week of gestation.

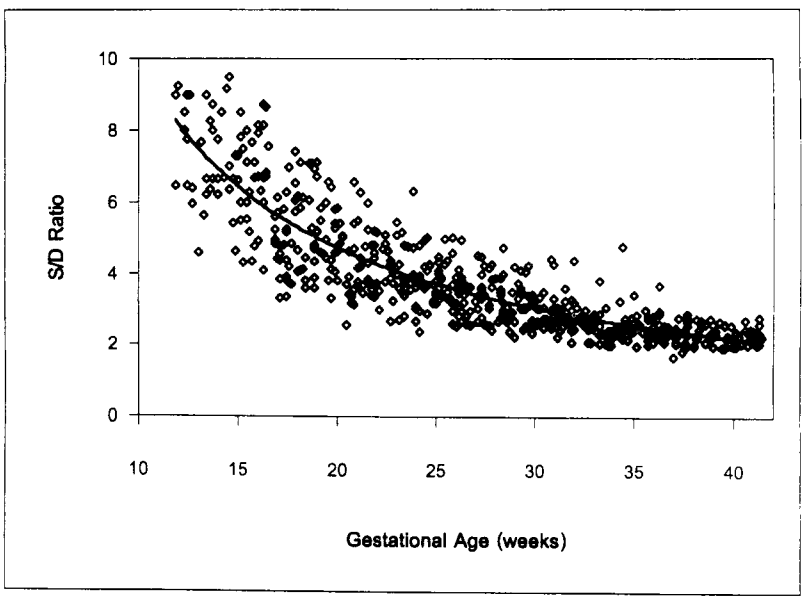

Fig. 1. Scatter plot of S/D ratio and gestational age with the curve of the fitted mean.

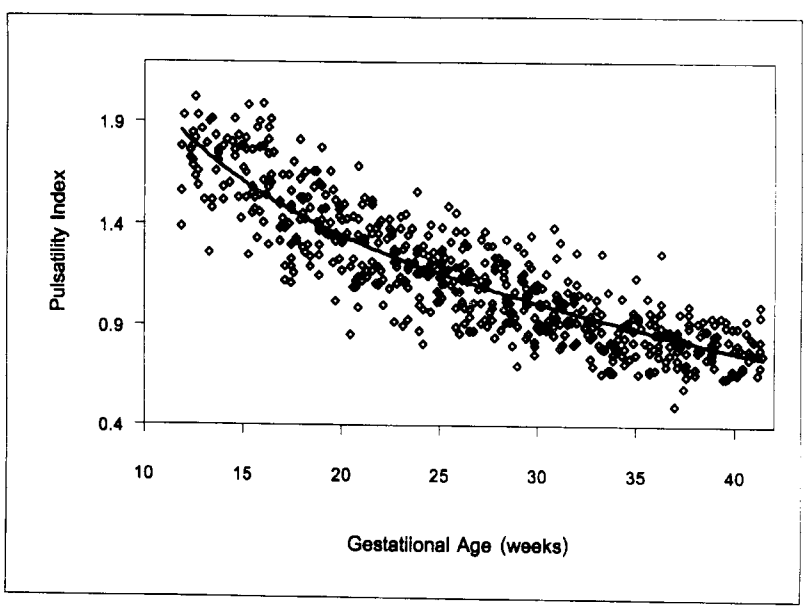

Fig. 2. Scatter plot of Pulsatility Index (PI) and gestational age with the curve of the fitted mean.

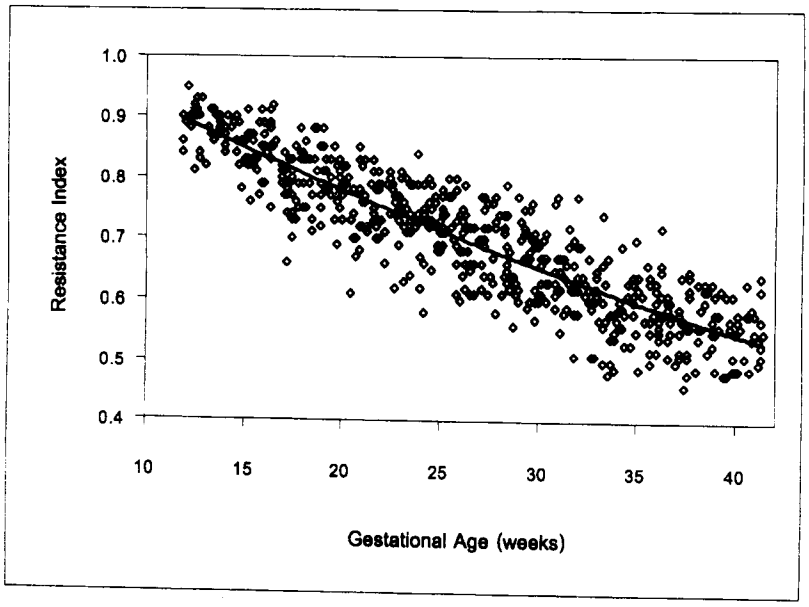

Fig. 3. Scatter plot of Resistance Index (RI) and gestational age with the curve of the fitted mean.

The fitted centiles are shown in Table 2 - 4. The reference 3rd, 10th, 50th, 90th, and 97th centile lines of S/D ratio, PI, and RI were plotted and are shown in Figure 4 - 6.

Table 2. Fitted centiles of Thai fetal S/D ratio

GA	Centile					SD
(weeks)	3rd	10th	50th	90th	97th	
12	5.41	6.29	8.18	10.06	10.94	1.47
13	5.00	5.80	7.52	9.23	10.03	1.34
14	4.66	5.39	6.95	8.51	9.24	1.22
15	4.35	5.03	6.46	7.89	8.57	1.12
16	4.09	4.71	6.03	7.35	7.97	1.03
17	3.86	4.43	5.65	6.87	7.45	0.95
18	3.65	4.18	5.32	6.45	6.98	0.88
19	3.47	3.96	5.01	6.07	6.56	0.82
20	3.30	3.76	4.74	5.73	6.19	0.77
21	3.15	3.58	4.50	5.42	5.85	0.72
22	3.01	3.42	4.28	5.13	5.54	0.67
23	2.89	3.27	4.07	4.88	5.26	0.63
24	2.78	3.13	3.89	4.64	5.00	0.59
25	2.67	3.00	3.71	4.43	4.76	0.56
26	2.57	2.89	3.56	4.23	4.54	0.52

(Continued)

GA	Centile					SD
(weeks)	3rd	10th	50th	90th	97th	
27	2.48	2.78	3.41	4.04	4.34	0.49
28	2.40	2.68	3.27	3.87	4.15	0.46
29	2.32	2.58	3.15	3.71	3.97	0.44
30	2.25	2.50	3.03	3.56	3.81	0.41
31	2.18	2.42	2.92	3.42	3.65	0.39
32	2.12	2.34	2.81	3.29	3.51	0.37
33	2.06	2.27	2.72	3.16	3.37	0.35
34	2.00	2.20	2.62	3.05	3.25	0.33
35	1.95	2.14	2.54	2.94	3.13	0.31
36	1.90	2.08	2.46	2.84	3.01	0.30
37	1.85	2.02	2.38	2.74	2.91	0.28
38	1.81	1.96	2.31	2.65	2.81	0.27
39	1.76	1.91	2.24	2.56	2.71	0.25
40	1.72	1.87	2.17	2.48	2.62	0.24
41	1.68	1.82	2.11	2.40	2.53	0.23

Table 3. Fitted centiles of Thai fetal pulsatility index

GA	Centile					SD
(weeks)	3rd	10th	50th	90th	97th	
12	1.54	1.64	1.84	2.04	2.14	0.16
13	1.46	1.55	1.75	1.95	2.04	0.16
14	1.39	1.48	1.68	1.87	1.96	0.15
15	1.33	1.42	1.61	1.80	1.89	0.15
16	1.27	1.36	1.55	1.74	1.82	0.15
17	1.22	1.30	1.49	1.68	1.76	0.15
18	1.17	1.26	1.44	1.62	1.71	0.14
19	1.13	1.21	1.39	1.57	1.65	0.14
20	1.09	1.17	1.35	1.52	1.60	0.14
21	1.05	1.13	1.31	1.48	1.56	0.13
22	1.02	1.10	1.27	1.43	1.51	0.13
23	0.99	1.06	1.23	1.39	1.47	0.13
24	0.96	1.03	1.19	1.36	1.43	0.13
25	0.93	1.00	1.16	1.32	1.39	0.12
26	0.90	0.97	1.13	1.28	1.36	0.12
27	0.87	0.95	1.10	1.25	1.32	0.12
28	0.85	0.92	1.07	1.22	1.29	0.12
29	0.83	0.89	1.04	1.18	1.25	0.11
30	0.80	0.87	1.01	1.15	1.22	0.11
31	0.78	0.85	0.98	1.12	1.19	0.11

(Continued)

GA (weeks)	Centile					SD
	3rd	10th	50th	90th	97th	
32	0.76	0.82	0.96	1.09	1.16	0.11
33	0.74	0.80	0.93	1.07	1.13	0.10
34	0.72	0.78	0.91	1.04	1.10	0.10
35	0.70	0.76	0.88	1.01	1.07	0.10
36	0.68	0.74	0.86	0.98	1.04	0.10
37	0.66	0.72	0.84	0.96	1.01	0.09
38	0.64	0.70	0.81	0.93	0.98	0.09
39	0.63	0.68	0.79	0.90	0.96	0.09
40	0.61	0.66	0.77	0.88	0.93	0.09
41	0.59	0.64	0.75	0.85	0.90	0.08

Table 4. Fitted centiles of Thai fetal Resistance Index

GA (weeks)	Centile					SD
	3rd	10th	50th	90th	97th	
12	0.841	0.858	0.894	0.929	0.946	0.028
13	0.823	0.841	0.879	0.917	0.934	0.030
14	0.805	0.824	0.864	0.904	0.923	0.031
15	0.787	0.807	0.849	0.891	0.911	0.033
16	0.770	0.791	0.835	0.879	0.899	0.034
17	0.753	0.775	0.821	0.866	0.888	0.036
18	0.737	0.759	0.807	0.854	0.876	0.037
19	0.721	0.744	0.793	0.842	0.865	0.038
20	0.705	0.729	0.779	0.829	0.853	0.039
21	0.690	0.714	0.766	0.817	0.841	0.040
22	0.675	0.700	0.752	0.805	0.830	0.041
23	0.661	0.686	0.739	0.793	0.818	0.042
24	0.647	0.672	0.726	0.781	0.806	0.043
25	0.633	0.659	0.714	0.769	0.795	0.043
26	0.620	0.646	0.701	0.757	0.783	0.043
27	0.607	0.633	0.689	0.745	0.771	0.044
28	0.594	0.621	0.677	0.733	0.760	0.044
29	0.582	0.609	0.665	0.722	0.748	0.044
30	0.571	0.597	0.654	0.710	0.736	0.044
31	0.559	0.586	0.642	0.698	0.725	0.044
32	0.549	0.575	0.631	0.687	0.713	0.044
33	0.538	0.564	0.620	0.675	0.701	0.043
34	0.528	0.554	0.609	0.664	0.690	0.043
35	0.519	0.544	0.598	0.653	0.678	0.042
36	0.509	0.534	0.588	0.641	0.666	0.042

(Continued)

GA	Centile					SD
(weeks)	3rd	10th	50th	90th	97th	
37	0.501	0.525	0.578	0.630	0.655	0.041
38	0.492	0.516	0.567	0.619	0.643	0.040
39	0.484	0.508	0.558	0.608	0.631	0.039
40	0.477	0.499	0.548	0.597	0.619	0.038
41	0.469	0.491	0.538	0.586	0.608	0.037

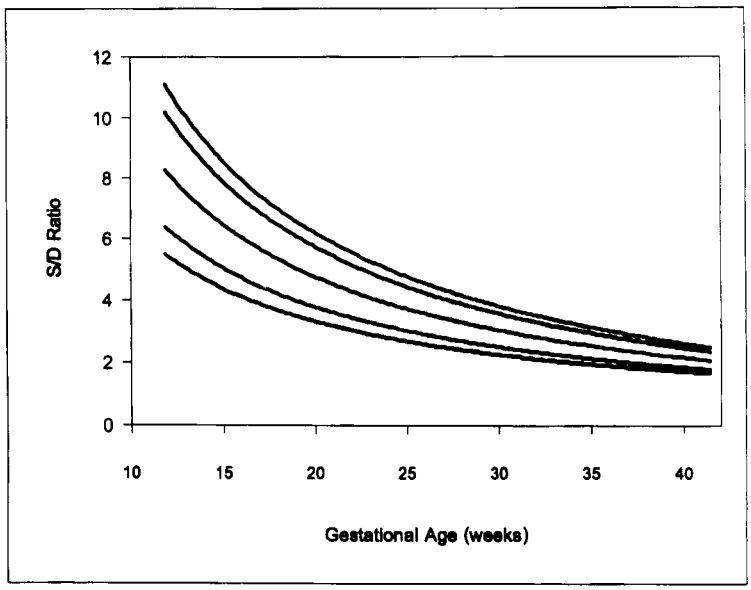

Fig. 4. The fitted 3rd, 10th, 50th, 90th, and 97th centile lines of S/D ratio.

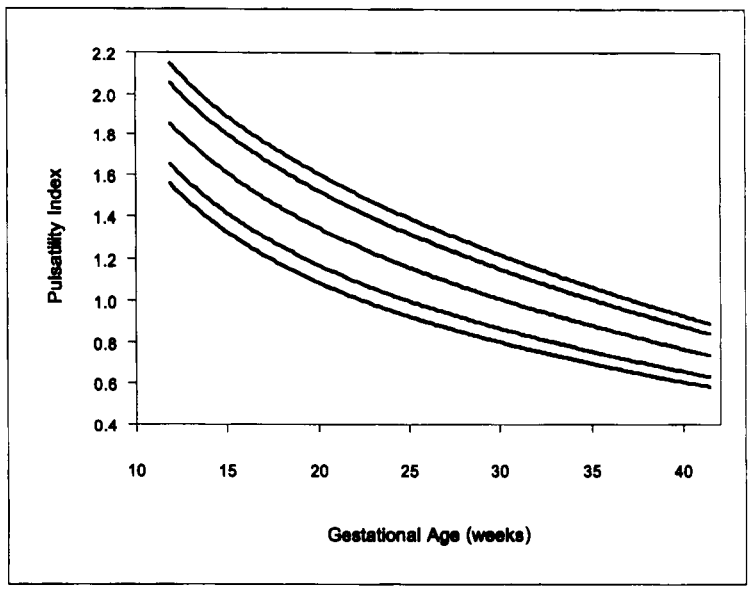

Fig. 5. The fitted 3rd, 10th, 50th, 90th, and 97th centile lines of Pulsatility Index.

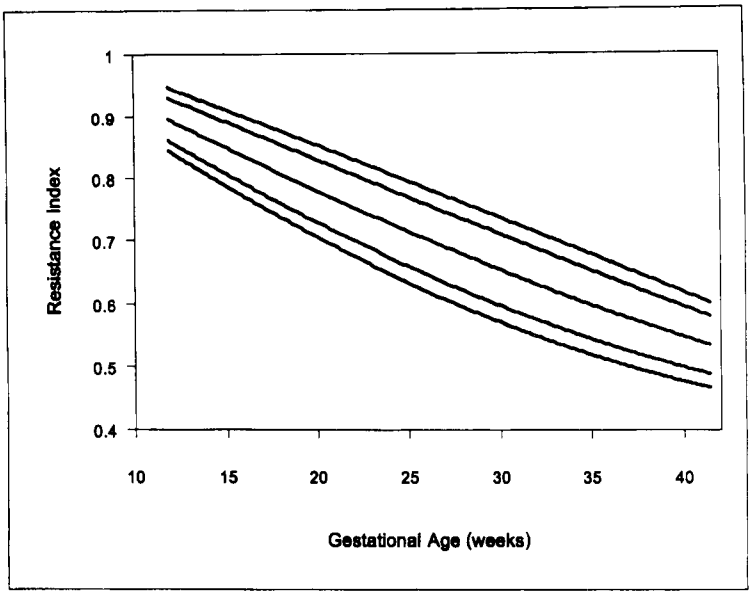

Fig. 6. The fitted 3rd, 10th, 50th, 90th, and 97th centile lines of Resistance Index.

Discussion

Normal reference values for fetal Doppler umbilical artery waveform indices have been studied by many investigators[6-8] as a measurement of fetal well-being since original reports by Fitzgerald[9] and McCallum.[10] Various investigators have found a good correlation between increased Doppler indices of umbilical arteries and intrauterine growth retardation, [11-15] subsequent neonatal outcome,[16-17] high-risk pregnancies[18-27] (e.g., diabetes mellitus, hypertension, and multifetal pregnancy). Some have found a high predictive value of Doppler indicies in predicting fetal distress and chronic hypoxia. There is no doubt that umbilical artery Doppler indices can help obstetricians to manage high-risk pregnancies. However, there is no standard reference chart for Thai fetuses. Knowledge of normal values for umbilical artery Doppler indices in Thai fetuses permit identification and assessment of our high-risk pregnancies at earlier gestational age among our population. This creates the possibility of earlier intervention and therapy to prevent fetal morbidity and mortality.

Many obstetricians use mostly the S/D ratio and RI, however, in this study we present all of the Doppler indices (S/D ratio, RI and PI) because the PI can be used when there is absence of end diastolic flow or reverse flow.

The data was collected in a cross-sectional fashion, measuring all the indices only once for each fetus, specifically for the purpose of the study. The date of measurement was randomly assigned to each woman, so that approximately the same number of fetuses was measured at each week of gestation. For the analysis, we used regression analysis technique to model the mean of the measurements. Changes in the variability were assessed by examining the residuals and they were modeled as a function of gestational age. Models were selected based on the goodness of fit with the data and whether or not they reached the assumption of normality. Our Methodology is the same as Royston and Wright,[28] and Altman's.[29] They have published methodology on how to design time-related reference range which change smoothly with gestational age; therefore our data differs from previous reports.[6-8] Recent publications of fetal biometries correspond to this kind of methodology.[30-35]

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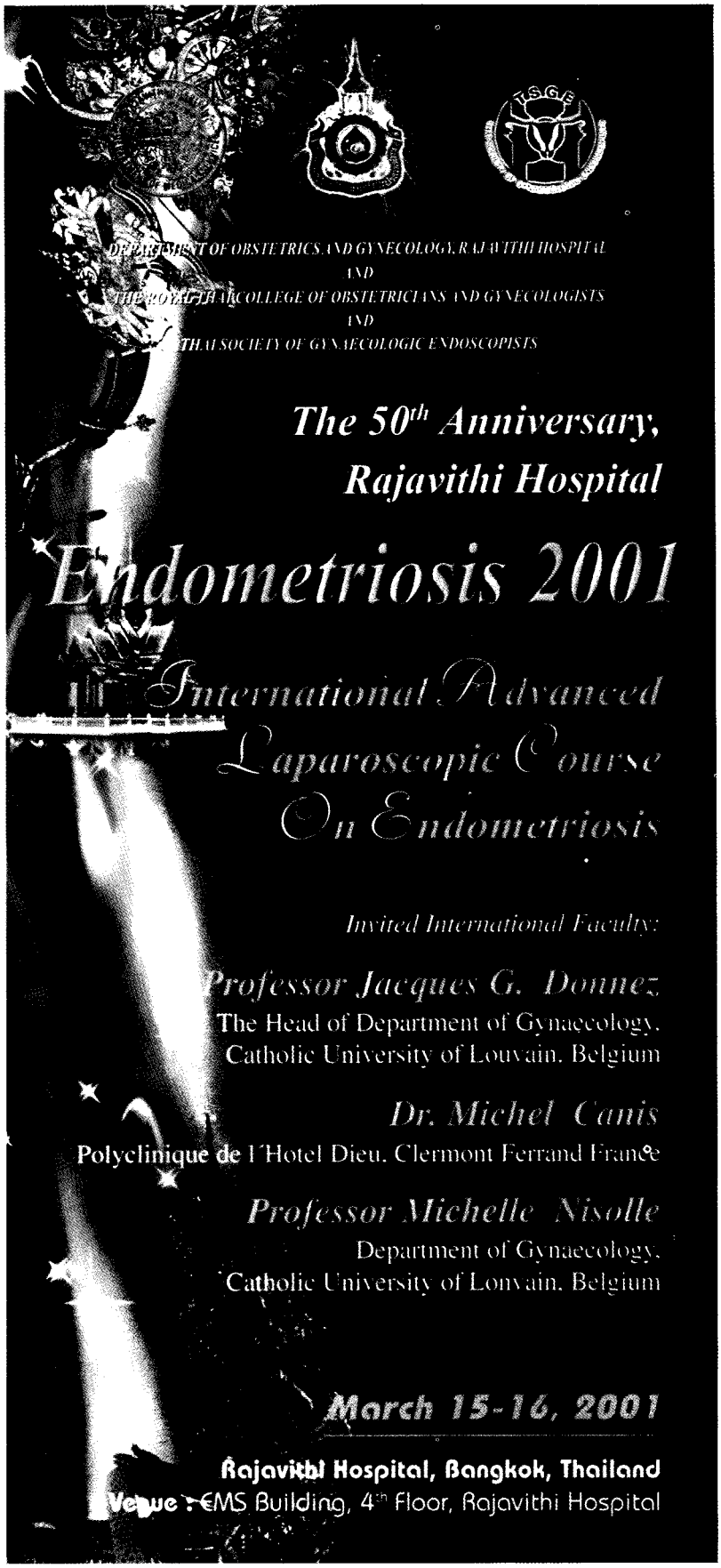
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Laparoscopic Course
On Endometriosis
Invited International Faculty:
Professor Jacques G. Donnez
The Head of Department of Gynaecology,
Catholic University of Louvain, Belgium
Dr. Michel Canis
Polyclinique de l'Hotel Dieu, Clermont Ferrand France
Professor Michelle Nisolle
Department of Gynaecology,
Catholic University of Lonvain, Belgium
March 15-16, 2001
Rajavithi Hospital, Bangkok, Thailand
Venue : EMS Building, 4th Floor, Rajavithi Hospital