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Airway Changes during Labor and Delivery

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Background: **There are no prospective studies that evaluated airway changes during labor. The purpose of this study was to evaluate airway changes in women undergoing labor and delivery.**

Methods: **Two studies were undertaken to evaluate airway changes during labor. The first study used the conventional Samsoon modification of the Mallampati airway class. The airway was photographed at the onset and the end of labor. Women with class 4 airways were excluded from initial participation. In the second study, upper airway volumes were measured using acoustic reflectometry at the onset and the conclusion of labor. Acoustic reflectometry software computed the values for the components of upper airway, oral volume, and pharyngeal volume.**

Results: **In study 1 (n = 61), there was a significant increase in airway class from prelabor to postlabor ($P < 0.001$). The airway increased one grade higher in 20 (33%) and two grades higher in 3 (5%) after labor. At the end of labor, there were 8 parturients with airway class 4 ($P < 0.01$) and 30 parturients with airway class 3 or class 4 ($P < 0.001$). In study 2 (n = 21), there were significant decreases in oral volume (n = 21; $P < 0.05$), and pharyngeal area ($P < 0.05$) and volume ($P < 0.001$) after labor and delivery. No correlation was observed between airway changes during labor and duration of labor, or fluids administered during labor in either study.**

Conclusion: **Airways can change during labor. Therefore, a careful airway evaluation is essential just before administering anesthesia during labor rather than obtaining this information from prelabor data.**

THE incidence of failed tracheal intubation in the pregnant population is perhaps eight times higher than in the nonpregnant population.[1] Difficult or failed intubation after induction of general anesthesia for cesarean delivery remains the major contributing factor to anesthesia-related maternal complications.[2,3] The first national study of anesthesia-related maternal mortality in the United States revealed that 52% of the deaths resulted from complications of general anesthesia predominantly related to airway management problems.[4] Despite decreases in the number of obstetric general anesthetics and better awareness of obstetric airway difficulties, a recent survey has shown that the incidence of difficult intubation and subsequent complications have not diminished with time.[5] Furthermore, a critical evaluation of anesthesia-related maternal deaths in Michigan, 1985–2003, showed that airway obstruction or hypoventilation during emergence and extubation were the cause of five maternal deaths.[6] Obvious factors such as enlarged breasts have been implicated, but simple maneuvers for dealing with these problems did not seem to decrease the incidence of difficult intubation.[5,7,8] There is no known bone or joint abnormalities in pregnancy that could pose difficulties during intubation. However, soft tissue changes such as airway edema are an invariable association of pregnancy, and this may contribute to difficult intubation.[8] Pilkington *et al.*[8] demonstrated that airway edema can increase during the course of pregnancy and result in increases in Mallampati score. There is speculation and an anecdotal report that airways can also change during labor and delivery.[9] There is no comprehensive study that has prospectively evaluated airway changes in pregnant women undergoing labor and delivery. To evaluate airway changes associated with labor and delivery, we undertook two studies that used two different approaches of airway evaluation. In the first study, we used the conventional Samsoon modification of the Mallampati score to evaluate airway changes, and in the other, we used acoustic reflectometry to objectively analyze airway changes. Acoustic reflectometry offers a distinct advantage of studying the concealed portion of the upper airway extending from the uvula to the glottis (pharyngeal volume), in addition to the visible portion (oral volume). The Samsoon modification of the Mallampati airway classification is based on the visibility of the soft palate, faucial pillars, and uvula.[1,10] The visibility of structures is dependent on the relative capacity of the oropharyngeal cavity and the volume of the base of the tongue.[10] If the base of the tongue is disproportionately large, it can mask the visibility of faucial pillars and the uvula (increasing airway class) by encroaching into the oropharyngeal cavity.[10] This leads to a relative decrease in the oropharyngeal volumes. Therefore, the outcomes of the two studies, airway evaluation by the Samsoon modification of the Mallampati airway classifi-

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cation and airway volume determinations by acoustic reflectometry, can complement each other in determining changes in the airway during labor.

Materials and Methods

There are no previous studies to determine sample size. These studies were undertaken as exploratory feasibility studies to build an appropriately powered trial in the future. The studies were approved by the Partners Human Research Committee, Brigham and Women's Hospital, Boston, Massachusetts.

Study 1

After obtaining written informed consent, we studied airway changes in 70 healthy pregnant women who were admitted to the labor and delivery suite (early active labor; cervical dilatation 2–3 cm). Initial airway examination was graded according to the Samsoon modification of the Mallampati classification. The parturients were trained to understand our perspective of airway evaluation so that they could open their mouth as wide as permissible without phonation. Women with a class 4 airway were omitted from enrollment because there is no further description of an airway class higher than 4 in visual airway classification. Airway photographs were obtained using a Polaroid Macro 5 SLR camera (Polaroid Corporation, Bedford, MA), with parturients in the sitting position. The head was in the neutral position, and the camera was held horizontal to the ground at the level of the uvula of the pregnant women. A unique feature of the camera enabled the distance from the camera lens to the uvula, or soft palate (if uvula was not visible), to be exactly 10 inches in all exposures. This was achieved *via* two red light beams from the camera that converged precisely at 10 inches from the lens, thus enabling us to obtain pictures without artifacts arising as a result of distance and angular variations. Airway photographs were also obtained at 20 min after the completion of stage 3 of labor, and at 36–48 h in the postpartum period in the sitting position. The photographs were given numerical coded numbers. A senior anesthesiologist, who was blinded to the origin of the photographs, analyzed and graded the airway into four classes (Samsoon modification of Mallampati airway class). Parturient characteristics, as well as labor and delivery variables, which included duration of stages of labor (stage 1 = onset of uterine contractions to full cervical dilatation; stage 2 = full cervical dilatation to delivery of the neonate; stage 3 = delivery of the neonate to delivery of the placenta; total duration of labor includes stages 1, 2, and 3), fluids administered during labor, and type of labor analgesia, were recorded.

Study 2

After obtaining informed written consent, 28 healthy pregnant women who were admitted to the labor and delivery suite (early active labor; cervical dilatation 2–3 cm) were recruited into the study. Acoustic reflectometry was used to study length *versus* cross-sectional area map of the airway. The acoustic reflection device (E. Benson Hood Laboratories, Pembroke, MA) consists of two microphones, and one horn driver mounted on a 30-cm-long, 1.89-cm-ID wave tube.[11] The operating principle of the acoustic device is that sound pulses driven by a horn driver loudspeaker are transmitted through a tube into the airway. The reflectometer impulse, 2 ms in duration, is characterized by a flat spectral range from 0 to 5,000 kHz (low-pass filter) and is repeated at the rate of 5 pulses per second. Expansions and constrictions along the airway reflect incident sound (pressure) waves. Incident and reflected waves are recorded by microphones mounted within the tube. The amplitude and phase of the reflected sound are determined by the airway local area, whereas the timing of arrival of the reflected sound is a function of the distance the sound has traveled. Therefore, pressure–time relations are converted to cross-sectional areas–*versus*–length relations. The digital-to-analog and analog-to-digital converters and software of the device displayed acoustic waveforms on the computer screen as shown in figure 1. The software of the system also computes and displays values for oral volume, mean oral area, pharyngeal volume, mean pharyngeal area, and total airway volume. Other data it can provide include the distances of the uvula and glottis from the incisor teeth. The parturients, seated comfortably, breathed room air *via* a mouthpiece attached to the wave tube without phonation. The computer screen of the device displayed the processed acoustic waveforms. When steady waveforms were obtained, the waveforms were saved to compute airway variables (oral volume, pharyngeal volume, mean oral and pharyngeal areas). The airway acoustic reflection measurements were also made at 20 min after labor and delivery. Physical characteristics of women, and labor and delivery variables were recorded.

A precondition for both studies was to include only those pregnant women who had spontaneous vaginal delivery for data evaluation. Women who underwent cesarean delivery were omitted from the studies.

Statistical Analysis

Means, SDs, medians, and interquartile ranges are presented as descriptive statistics for both studies. In study 1, the Wilcoxon signed rank test was used to compare prelabor and postlabor airway class, and ordinal classifications taken on the same patient. For analyses of individual airway classes prelabor and postlabor, the McNemar test was used. The Wilcoxon rank sum test was used to determine whether a significant number of women in

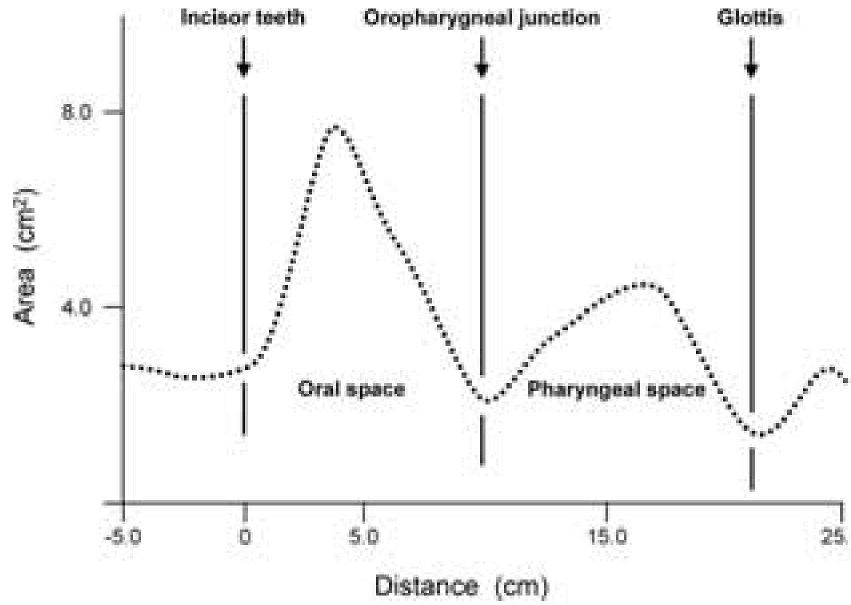

Fig. 1. Acoustic reflectometry tracing showing various components of upper airway beginning from incisor teeth to glottis.

the prelabor group progressed to class 4 airway at the conclusion of the labor. Spearman correlation analysis of the change in prelabor and postlabor airway class with weight at time of pregnancy, height, duration of labor, and intravenous fluids administered during labor were conducted.

In study 2, a paired *t* test was used to evaluate the statistical significance of differences between prelabor and postlabor acoustic reflectometry parameter values. The changes in prelabor and postlabor oral and pharyngeal volumes were correlated with weight at time of pregnancy, height, duration of stages of labor, and intravenous fluids administered during labor by Spearman correlation.

For all analyses, a *P* value less than 0.05 was considered statistically significant, and we used SAS version 9.1 software (SAS Institute Inc., Cary, NC) for all analyses.

Results

In study 1, 70 women were recruited and 61 completed the study by way of spontaneous vaginal delivery. Nine parturients underwent cesarean delivery and hence were eliminated from the study analysis. Forty women opted for epidural analgesia for labor and delivery. Characteristics of the pregnant women are shown in table 1. Table 2 shows the distribution of the Samsoon modification of the Mallampati airway prelabor and postlabor. Wilcoxon signed rank test revealed a significant change in airway class between prelabor and postlabor airway data. The results were significant ($P < 0.001$), with each of the 23 subjects who exhibited a difference moving to a higher class. The airway increased by one grade higher in 20 parturients (33%) and two grades higher in 3 parturients (5%) by the end of labor as compared with that in early labor. There were eight parturients in the prelabor group who progressed to class 4 airways at the end of labor compared with those who did not (Wilcoxon rank sum test, $P < 0.01$). There were 30 parturients with airway class 3 or 4 in the postlabor group compared with 17 in the prelabor group (McNemar test, $P < 0.001$). Figure 2 shows airway pictures before (class 1 airway) and after labor (class 3 airway). Labor and delivery variables are shown in table 3. There was no significant correlation of changes in airway class with weight, height, duration of various stages of labor, or fluid administered during labor (table 4). Nineteen of the 23 patients (82%) who had a worsened airway class with labor reverted to admission grade within 36–48 h postpartum.

In study 2, 28 parturients participated in the study for initial evaluation and 21 women completed the postlabor/delivery study after spontaneous vaginal delivery. The remaining had cesarean delivery and therefore were excluded from the study. Twenty women received epidural analgesia. There was a significant decrease in oral volume ($P < 0.05$), pharyngeal volume ($P < 0.001$), and

Table 1. Patient Characteristics in Studies 1 and 2

	Age, yr	Height, cm	Weight, kg	Gravida	Para	Gestation, wk	Cervical Dilatation at First Measurement, cm
Study 1	31.1 (4.9)	162 (7.0)	79.0 (12.3)	2.6 (1.3)	1.4 (1.1)	38.6 (1.0)	2.4 (0.5)
Study 2	32.0 (4.6)	160 (4.5)	79.3 (15.0)	2.7 (1.4)	1.3 (1.0)	38.9 (1.1)	2.4 (0.5)

Data are presented as mean (SD).

Table 2. Influence of Labor on Airway Class Distribution Evaluated Using the Samsoon Modification of Mallampati Class in Study 1

		Postlabor Airway Class			
Prelabor Airway Class		1	2	3	4
1	9	4	4	1	0
2	35	0	23	10	2
3	17	0	0	11	6
4	0	0	0	0	0
Total	61	4	27	22	8

Significant change in airway class between prelabor and postlabor ($P <$ 0.001). There is significant increase in class 3 and 4 airways (30) at the end of labor compared with prelabor (17) ($P < 0.001$).

mean pharyngeal area ($P < 0.05$) after labor and delivery as compared with prelabor values in 21 parturients who completed the study (table 5). A scatter plot of individual pharyngeal volumes before and after labor is presented with an identity line (fig. 3). There was no significant correlation between decreases in oral and pharyngeal volumes and various parameters obtained during labor (tables 3 and 4).

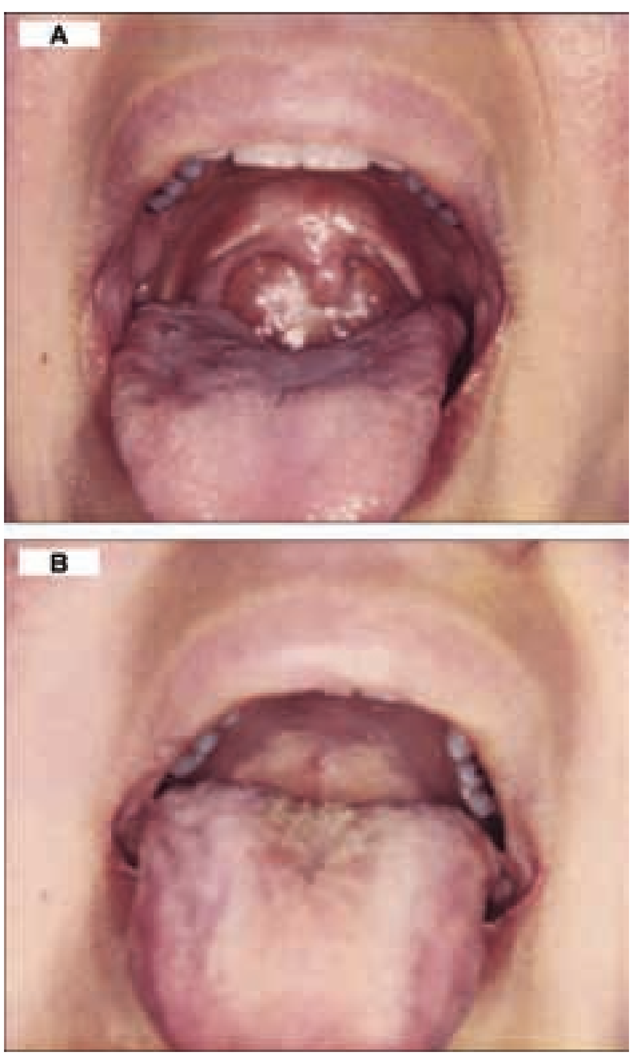

Fig. 2. Airway pictures prelabor (Samsoon modification of Mallampati class 1 airway; *A*) and postlabor (Samsoon modification of Mallampati class 3 airway; *B*).

Discussion

Airway changes have been observed during the course of pregnancy. There is an increase in the number of the Samsoon modification of the Mallampati class 4 by 34% at 38 weeks of gestation from those at 12 weeks of gestation.[8] The underlying cause for this change is attributed to fluid retention that occurs with pregnancy.[8] Our studies show that labor and delivery are also associated with further airway changes, thus confirming previous anecdotal observations.[9] Study 1 used the standard airway evaluation criteria that are currently in daily practice. Although pregnant women with a class 4 airway at the beginning of the study were excluded, there were 8 women with a class 4 airway at the conclusion of the study. Fifty percent of women (30) at the conclusion of labor had a class 3 or class 4 airway. The relation between increasing airway classification and relative ease or difficulty at intubation in term pregnant women undergoing cesarean delivery during general anesthesia was studied by Rocke *et al.*[12] The relative risk of encountering difficult intubation in pregnant women with a class 3 airway was 7.58 times more compared with parturients with a class 1 airway during general anesthesia. This relative risk increased to 11.3 in pregnant women with a class 4 airway. This suggests that a change in airway class from 2 to 4 in parturients is associated with enhanced relative risk of encountering difficult intubation from 3.23 to 11.3. Therefore, women undergoing labor may be at increased risk of difficult intubation, particularly if labor is associated with airway changes. Hence, it is prudent to reevaluate the airway in women in labor presenting for cesarean delivery just before commencement of the anesthetic, rather than obtaining the information from the prelabor evaluation data sheet. Although the majority of cesarean deliveries may be performed during regional anesthesia, general anesthesia cannot altogether be avoided. It may be needed in emergent circumstances with no or inadequate regional anesthesia. Increases in airway class by one grade can increase the relative risk of difficult intubation, particularly in the presence of other coexisting factors. The factors that are likely to increase the risk of difficult intubation are short neck, receding mandible, protruding maxillary incisors, and morbid obesity.[12,13] In the presence of these factors, changes in airway class during labor can potentially increase the cumulative risk of encountering difficulties in securing the airway at induction of general anesthesia and may necessitate implementation of backup airway management strategies.

We understand that there are some limitations of study 1. There is always a subjective error on the part of the

Table 3. Median (IQR) for Labor and Delivery Variables in Studies 1 and 2

	Fluids Administered During Labor, ml	Time Interval between Evaluations, min	First Stage of Labor, min	Second Stage of Labor, min	Third Stage of Labor, min	Total Duration of Labor, min
Study 1	2,300 (1,100)	420 (390)	570 (360)	75 (90)	11 (8)	668 (379)
Study 2	2,500 (900)	480 (215)	660 (240)	45 (65)	7 (6)	698 (390)

IQR = interquartile range.

parturients in opening their mouth for airway evaluation. To obviate this, we trained each subject beforehand to open the mouth as wide as possible without phonation. To minimize evaluator errors, all photographs were taken with the camera lens at 10 inches from the uvula, or the most distant visible portion of the palate if the uvula was not visualized. The angulation errors were also minimized by ensuring that the parturient was seated upright with head in the neutral position and the camera held such that the lens axis was parallel to the ground. The photographs were evaluated by an anesthesiologist not involved in the study to eliminate the evaluator's bias of airway evaluation. However, the study personnel obtaining the airway evaluation pictures knew whether the pregnant woman was in the prelabor or postlabor period. This was unavoidable because of the location of these parturients in the labor and delivery floor or postpartum floor in the hospital.

Because of inherent unavoidable limitations of study 1, we studied airway changes using an altogether different approach to airway analysis. Acoustic reflectometry is a noninvasive test that produces a length–*versus*–cross-sectional area map of the airway.[11] A unique advantage of this measurement is that it can also measure pharyngeal volume (fig. 1). Upper airway (airway volume) has two components: an oral component and a pharyngeal component. The oral component is the one normally assessed using Mallampati classification. The pharyngeal volume is concealed and not evaluated in clinical practice. An airway volume less than 40.2 ml has been shown to be associated with diminished ability to view glottis openings in nonpregnant subjects undergoing general anesthesia and intubation.[11] In addition, acoustic reflectometry has been shown to accurately predict complete inability to ventilate a patient *via* a mask. However, it did not predict the absolute inability to intubate a patient.[14] Acoustic reflectometry airway volumes have been found to match computed tomography measured airway volumes.[15] Hence, it is a reasonable noninvasive method to evaluate airway changes during labor and delivery. Our results in study 2 showed that there is a significant decrease in oral airway volume, which is in accord with the Samsoon modification of the Mallampati airway class changes in study 1. However, in addition, the pharyngeal volumes and mean pharyngeal area also decreased significantly after labor and delivery. We do not know whether these decreases in the volume of the pharyngeal portion of the airway would contribute to difficult intubation, because none of the pregnant women enrolled in the study had general anesthesia. There are also no data demonstrating the relation between pharyngeal volume and intubation difficulties. However, it is conceivable that decreasing pharyngeal volumes could potentially pose an impediment to intubation. This belief is supported by the case reports of difficult intubation in cases of pharyngolaryngeal edema consequent to pregnancy-induced hypertension, fluid overload in conjunction with the antidiuretic properties of oxytocin, and prolonged strenuous bear-down efforts.[16–21] Our finding of decreased pharyngeal volume after labor assumes great importance in parturients who may have class 4 airways at the beginning of labor. These women must be examined carefully for any other associated factors that may contribute to difficult intubation to minimize surprises of encountering a difficult airway at intubation. Furthermore, it is also likely that variations in pharyngeal volume changes from parturient to parturient could be responsible for decreased predictability

Table 4. Correlation Analysis of Change in Prelabor and Postlabor Measurements with Weight, Height, Duration of Labor, and Fluids for Study 1 (n = 61) and Study 2 (n = 21)

Variable	Study 1 Change in Airway Class ρ* (P Value) Airway	Study 2 Change in Airway Volume ρ* (P Value): Oral Volume	Study 2 Change in Airway Volume ρ* (P Value): Pharyngeal Volume
Weight	−0.16 (<0.2)	−0.41 (<0.06)	−0.24 (<0.3)
Height	0.05 (<0.7)	−0.08 (<0.7)	−0.03 (<0.9)
Fluids	0.06 (<0.6)	0.03 (<0.9)	0.08 (<0.4)
Duration of labor			
First stage	0.01 (<0.9)	0.01 (<0.9)	0.01 (<0.9)
Second stage	0.09 (<0.5)	0.08 (<0.7)	0.40 (<0.07)
Third stage	−0.05 (<0.7)	0.15 (<0.5)	0.09 (<0.7)

* Rho (ρ) is the Spearman correlation coefficient.

Table 5. Airway Volume Data, Prelabor and Postlabor, in Study 2

Parturients, n = 21	Oral Volume, ml	Mean Oral Area, cm^2	Pharyngeal Volume, ml	Mean Pharyngeal Area, cm^2
Prelabor	49.10 (14.6)	5.84 (1.3)	26.87 (10.4)	3.10 (1.6)
Postlabor	44.40 (15.0), $P < 0.05$	6.06 (1.9)	21.80 (8.4), $P < 0.001$	2.70 (1.4), $P < 0.05$

Data are presented as mean (SD). Oral volume and pharyngeal volume data were computed from acoustic waveforms for each patient prelabor and postlabor using acoustic reflectometry software.

of intubations from the Samsoon modification of the Mallampati airway class.

The most likely cause of decreasing airway caliber in women undergoing labor and delivery is escalating soft tissue mucosal edema. We did not find a correlation between airway changes and amount of fluids administered during labor or duration of labor. It is possible that the predominant factor responsible for aggravating airway edema is straining and pushing, which is an integral part of labor and delivery. Our data in study 2 give some credence to this speculation. There is a positive relation between the duration of stage 2 of labor, which is associated with maximum pushing and straining, with decreases in pharyngeal volume ($P < 0.07$; table 4). Further studies with a larger sample size may confirm this relation. Nonetheless, it is difficult to quantify the degree of pushing and straining during labor, and its effect on airway edema. Moreover, stress and straining varies enormously from woman to woman. Straining and pushing can increase central venous pressure and intracapillary pressure. This can favor the Starling equation toward exacerbating mucosal edema in the presence of decreased oncotic pressure, which is a normal accompaniment of pregnancy. Additional intravenous fluids can exacerbate this response by further decreasing oncotic pressure and increasing airway edema.[22]

In conclusion, pregnant women undergoing labor and delivery may be vulnerable to developing airway changes. This may increase the risk of confronting difficult intubation, particularly in the presence of other predisposing factors contributing to difficult intubation. It is imperative to examine the airway immediately before cesarean delivery, rather than relying solely on information from prelabor evaluation. Further studies should analyze whether women with preeclampsia have a greater susceptibility to develop airway changes compared with healthy pregnant women.

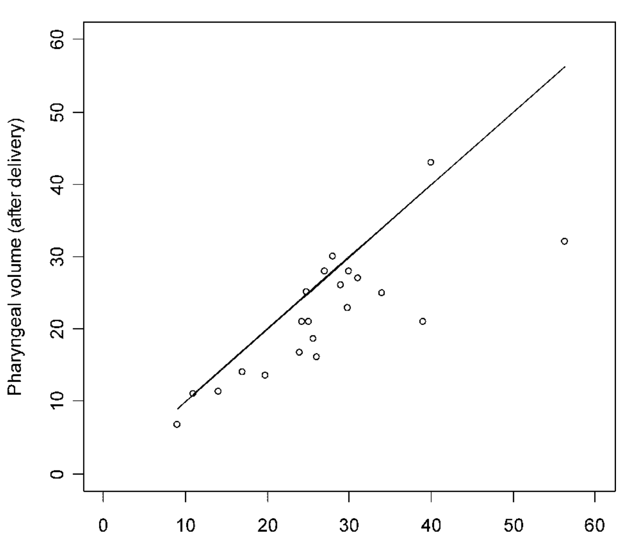

Fig. 3. Plot of pharyngeal volume (ml) before and after delivery.

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