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## **Do maternal pushing techniques during labour affect obstetric or neonatal outcomes?**

### **Le type de poussée maternelle pendant le travail a-t-il un impact sur les issues obstétricales ou néonatales?**

**Short title:** Maternal pushing during labour.

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Abstract:

Objectives. — To assess, through a literature review, the maternal and neonatal morbidity associated with the type of pushing used during the second stage of labour.

Methods. — We searched the Cochrane Library and the Medline database for randomised controlled trials from 1980 to 2015, using the following key words: “ delivery”, “birth”, “birthing”, “bearing down, coached, uncoached, pushing”, “second and stage and labour” and “randomised controlled trials”, “meta-analysis”.

Results. — Seven randomised controlled trials were found. Interventions varied between the studies. In the intervention groups, open-glottis pushing was spontaneous or coached. The groups did not differ for perineal injuries, episiotomies or type of birth. Impact on pelvic floor structure varied between the studies. Only one study found a better 5-minute Apgar score and a better umbilical artery pH in the “open glottis” group.

Conclusion. — The low methodological quality of the studies and the differences between the protocols do not justify a recommendation of a particular pushing technique. Further studies appear necessary to study outcomes with each of these techniques.

Résumé:

Objectifs. — Évaluer, par une revue de la littérature, la morbidité maternelle et néonatale liée aux différents types de poussées lors du 2<sup>ème</sup> stade du travail (glotte ouverte ou fermée).

Méthodes. — Nous avons recherché les essais randomisés publiés entre 1980 à 2015, en utilisant la banque de données du Medline, avec les mots clés suivants : “ delivery”, “birth”, “birthing”, “bearing down, coached, uncoached, pushing”, “second and stage and labour” et “randomised controlled trials”, “meta-analysis”.

Résultats. — Sept essais cliniques randomisés ont été retrouvés. Le type de poussée différait selon les études. La poussée en expiration pouvait être soit spontanée soit dirigée. Il n’y avait pas de différence entre les deux groupes concernant la survenue de déchirures, d’une

épisiotomie ou le mode d'accouchement. L'impact sur la statique pelvienne variait selon les auteurs. Seule une étude a retrouvé un meilleur Apgar à 5 minutes et un meilleur pH artériel dans le groupe « glotte ouverte ».

Conclusion. — La faible qualité méthodologique des études et leurs différences ne permettent pas de recommander un type particulier de poussée. D'autres études semblent nécessaires afin d'étudier les issues maternelles et néonatales avec chaque type de poussée.

## **Introduction**

Practices concerning childbirth have evolved considerably in recent centuries. Until the 17th century, births traditionally took place at home with an attendant who had little or no training [1]. Later, childbirth slowly became more and more medicalised; practices for the management of parturients during labour and childbirth today are very different than they were. Since the end of the 20<sup>th</sup> century, however, the medicalisation of childbirth has come under increasing challenge. A school of thought promoting a return to so-called "natural childbirth", which is less medicalised, has grown. In some countries, even some professionals doubt, among other things, the dogma of the dorsal decubitus position and the appropriate type of pushing during the second stage of labour.

Closed-glottis pushing, also called "Valsalva", is widely used in Western countries, but the origin of this obstetric practice is obscure. Pushing while exhaling was nonetheless described in obstetrical treatises until the end of the 19<sup>th</sup> century [2,3]. Valsalva pushing probably developed with the dissemination of forceps births, but without any convincing scientific data to support it.

There are currently no French guidelines for the management of normal childbirth. These depend on the training and beliefs of each obstetrician, general practitioner and midwife as well as on the policies in each obstetrics department. Today, the customers, so to speak, of obstetrics care demand less medicalisation and more involvement in the decision making concerning their children's births. Professionals must therefore provide their patients with the best possible care according to up-to-date scientific data as well as inform them of the

different alternatives for care. In this context, an analysis of the risks and benefits of the type of pushing during the second stage of labour is useful.

The principal objective of this work was to assess, through a critical analysis of the literature, maternal morbidity according to type of pushing (open or closed glottis) during the second stage of labour. Similarly, the secondary objective was to assess the neonatal morbidity associated with these two types of pushing.

## **Methods**

### *Definition of types of pushing during the second stage of labour*

In closed-glottis pushing, the woman is asked to inhale completely and fill her lungs completely with air, to hold her breath, and to push downward very strongly during contractions, for as long as possible, normally three times for each contraction. In French practice, this type of pushing is often directed, or coached. Many French professionals consider it the reference technique for pushing. Anyone who has been in a French delivery room has heard this advice: "Inhale deeply, hold your breath, and push for as long as you can!" There is nonetheless another type of pushing used less often by professionals: called open-glottis pushing, it occurs while exhaling (and can be coached or spontaneous). In France, open-glottis pushing is not frequently used, although it is a spontaneous, physiological, and sometimes overwhelmingly urgent way of pushing among parturients, especially those without epidural analgesia (so called Ferguson's reflex).

### *Databases searched*

We searched the Cochrane Library, which includes 6 databases (Pregnancy and Childbirth Group's Trials Register, Cochrane Database of Systematic Reviews, etc.), and the Medline database to identify all randomised trials on this topic. This research was completed manually

by studying the references of articles and book chapters published on this subject. The following keywords were used: "delivery", "birth", "birthing", "bearing down", "coached", "uncoached", "pushing", "second and stage and labour", and "randomised controlled trials" or "meta-analyses". We looked at English and French articles published between 1980 and the end of February, 2016.

Articles were retained for more detailed assessment when they described randomised clinical trials comparing the two types of pushing (open- or closed-glottis), including those comparing pushing coached by a professional to pushing without professional coaching during the second stage of labour.

The outcome measures considered were the following:

- for the mother: episiotomy, perineal lacerations, especially third and fourth degree, type of birth (spontaneous or not), and delayed damage to pelvic floor function.
- for the child: 5-minute Apgar score, cord artery pH, and need for resuscitation in the delivery room or admission to the neonatal intensive care unit (NICU).

#### *Methodological quality assessment*

The methodological quality of the studies was assessed independently by two of the authors, according to the recommendations of Chalmers et al. [4]. In particular, we looked for four factors creating a risk of bias: selection bias (inadequate random sequence generation and allocation concealment, subjects excluded after randomisation, or large numbers of women lost to follow-up), performance, attrition and detection bias. We also researched differences in co interventions, apart from pushing.

## **Results**

Two meta-analyses [5,6] and seven single-centre, randomised trials reported in nine articles were identified [7-15]. Neither participants nor personnel can be blinded to the intervention we consider here.

Neither of the two meta-analyses compared exclusively directed open-glottis with directed closed-glottis breathing, although directed pushing is the usual practice in France. The meta-analysis of Prins et al., published in 2011, compared instructed closed-glottis pushing only with spontaneous pushing, although as we have underlined, in view of the lack of spontaneous practices in France, this was not the focus of our work. Moreover, the total number of cases was quite low for a meta-analysis (three studies, n = 425) [9,11,12,16], and it was limited to primiparous women without epidural analgesia [5]. The authors concluded that Valsalva type pushing should not be routinely recommended because it could have a deleterious effect on pelvic floor function. They also agreed that the studies on this topic are rare, heterogeneous, and often biased [5]. Lemos et al. published a second meta-analysis, in 2015, comparing spontaneous (in practice, undirected open-glottis) vs. directed (in practice, closed-glottis) pushing [6]. The authors included seven studies [9-17], all of which involved potential bias. Their principal analysis (five studies, n= 598) concerned the duration of the second stage, which was not an outcome we chose to consider. Except for the spontaneous vaginal deliveries (five studies, n=688), their sub-analyses concerned maternal and fetal comorbidities (perineal lacerations, etc.) and were based on only one to three studies. They found no differences for any of the criteria studied, except for the duration of expulsive efforts, which appeared shorter in the spontaneous pushing (mean difference -5.20 minutes [95%CI; -7.78 to -2.62], one study, n=100). They also concluded that randomised trials of good quality were



necessary for the reliable determination of the potentially beneficial and harmful effects of these different techniques.

To meet our objectives we review the published randomised controlled trials. The intervention studied varied between them: although the control groups always used coached Valsalva pushing, the open-glottis breathing in the intervention group was sometimes spontaneous (not coached) [9-12,14,15] and sometimes coached [7,8,13] (Table 1). Study inclusion criteria included a gestational age of at least 36 weeks' gestation or more, cephalic presentation, and a singleton pregnancy. All but two trials included only nulliparas [8,14]. Co-interventions varied between studies (Table 1). The mother's position during the second stage of labour differed between the studies; it was not specified in two [11,12,15], was left to the woman's choice in two others [8-10], and was mandated in two more: dorsal decubitus position in one [13] and semi-recumbent in the other [7]. In another study, position differed according to the study group (a vertical position for the intervention group and dorsal decubitus position for the control group) [14]. Cervical dilatation was specified in only two studies [9-12] (Table 1).

Globally, the quality of randomisation was not good in the randomised studies, especially in the study of Barnett et al., which does not report its randomisation method and indeed mentions randomisation only in the abstract [7]. Four studies reported using randomisation tables without providing further information [9-12,14,15] (Table 2). Two studies used sealed envelopes [8-10], another opaque envelopes [11,12], and the others did not specify the kind of envelope used [13,14] (Table 2). The timing of the randomisation was either not specified [7] or varied according to the study (Table 2).

Compliance with the allocated intervention was not described in three studies [11-14] and varied in the others [7-10,15] (Table 2). In one study, compliance was assessed by a self-administered questionnaire (from which we could not extract data because the trial tested perineal massage as a co-intervention and did not separate out those results) [15].

Most studies did not use an intention-to-treat analysis [8,11-15]. Only one study described the orientation of the fetal head at the start of pushing, and it did not consider it in its statistical analysis [9,10]. One study did not adjust its results for the children's weight, although it was higher in the closed-glottis group [8]. Post-randomisation exclusions were observed in some studies [8,11,12,14,15] (Table 2). Two studies had a relatively high number of women lost to follow-up (randomisation of women during pregnancy, and follow-up at six and twelve months post partum [15] or follow-up at three months post partum [11,12]).

The heterogeneity of the interventions studied, the other care and co-interventions provided, and the timing of the onset of pushing, as well as the relatively poor methodological quality of the studies (Table 2), made it impossible for us to perform a meta-analysis. Moreover, the outcomes measured varied according to the study.

Nonetheless, some results can be underlined. No woman in the open-glottis pushing group began pushing when uterine contractions began [9,10]. The duration of the second stage of labour varied according to the study. For Thomson [9,10] and for Bloom et al., it was shorter among the women in the coached Valsalva pushing group than among those in the open-glottis pushing group (58 minutes  $\pm$  42 versus 121.4 minutes  $\pm$  58.4;  $P=0.002$ ) (second stage: 46.3 minutes  $\pm$  41.5 versus 59.1 minutes  $\pm$  49.1;  $P=0.014$ )[11,12]. On the other hand, for both Barnett et al. and Parnell et al, this did not differ between the two groups [7,8]. For Yildirim

et al., the duration of the second stage of labour was shorter for the open-glottis pushing group than for the coached Valsalva group (40.8 minutes  $\pm$ 19.1 versus 50.1 minutes  $\pm$  23.3 minutes;  $P=0.045$ ) [13]; this was also true for Jahdi et al., with both primiparous and multiparous patients (respectively 47.38 minutes  $\pm$  36.75 versus 57.12 minutes  $\pm$ 33.1,  $P < 0.0001$  and 26.12 minutes  $\pm$  23.43 versus 33.20 minutes  $\pm$  22.76,  $P < 0.0001$ ) [14]. Only Yildirim et al. found that the duration of the expulsive (pushing) phase was shorter in the open-glottis pushing group than in the coached Valsalva group (9.6 minutes  $\pm$ 5.5 versus 14.8 minutes  $\pm$  7.5;  $P=0.001$ )[13], while Parnell et al. found no difference between the two groups [8].

There was no statistically significant difference for the mode of birth (Table 3) for Barnett et al., Thomson, Schaffer et al., Low et al. or Jahdi et al.[7,9-11,14,15]. Similarly, Schaffer et al. and Yildirim et al. found no difference for operative vaginal births [11-13] (Table 3). The maternal outcomes did not differ statistically for perineal tears or lacerations, for Thomson, Schaffer et al., or Yildirim et al. [9-13]; nor did Schaffer et al. or Yildirim et al. find any difference for episiotomies [11-13] (Table 3). Few authors have looked at immediate postpartum haemorrhages [9,11,13]. The methods for estimating blood loss have varied substantially between studies.

For neonatal outcomes, Yildirim et al. found that the pH of the umbilical artery was significantly higher in the open-glottis compared with the Valsalva group [13] (Table 3), although Barnett et al., Parnell et al. and Schaffer et al. found no statistically significant differences [7,8,11,12] (Table 3). The Apgar score was also significantly higher in the open-glottis than in the Valsalva group, at both 1 minute and 5 minutes for Yildirim et al. (1 minute: 7.9  $\pm$ 0.6 versus 7.3  $\pm$ 0.8;  $P =0,001$ )[13] (Table 3), although Parnell et al. found no significant difference between the two groups for either of these Apgar scores [8] (Table 3).

Finally, Thomson and Schaffer et al. found no difference between the two groups for resuscitation in the delivery room or for NICU admission [9-12].

Two studies have looked at the consequences on pelvic floor function [11,15]. For Schaffer et al., urodynamic testing at 3 months post partum showed no reduction in bladder capacity (427 mL versus 482 mL,  $P=0.51$ ), but did observe a reduction in the first urge to void (160 mL versus 202 mL,  $P=0.025$ ) in the closed-glottis pushing group [9]. Detrusor overactivity increased in the closed-glottis group, but not significantly (16% versus 8%;  $P=0.17$ ); the same was true for urodynamic stress incontinence ( $P=0.42$ ) [11]. Low et al. found no difference between the two groups when they used the “leakage index” one year after birth [15].

## **Discussion**

It is difficult to draw convincing scientific conclusions from the meta-analyses and randomised studies about the optimal type of pushing for reasons beyond their poor methodological quality and their frequent lack of power. The studies often do not consider either prognostic or confounding factors (direction of the fetal head, birth weight, maternal position during the second stage of labour, station when pushing begins, policy of early coaching and active management of labour, etc.). Moreover, most of these studies excluded patients with epidural analgesia, which is widely used in some western countries. In France, almost 80% of parturients receive epidural analgesia [18].

Questions have been raised about Valsalva-type pushing for many years. The exertion of pushing may increase intrathoracic and intra-abdominal pressure and thus lead to maternal haemodynamic modifications, including a drop in venous return followed by reduced oxygenation of the maternal blood and therefore also of the uterus, placenta, and fetus

[19,20]. Fetal cerebral oxygenation then drops, while cerebral blood volume increases [21]. These modifications of the oxygenation of maternal blood may not be observed during spontaneous pushing since women use their residual respiratory volume without exaggerated forced inspiration and with shorter pushing efforts in general (less than 6 seconds) [22]. The lithotomy position, principally used for patients with epidural analgesia in most western countries, may also reduce fetal oxygenation through maternal aortocaval compression by the gravid uterus [23].

Moreover, it is not clear that professionals are well trained in the different types of pushing. Open-glottis pushing is accompanied by noise made by the woman (grunts and groans). These noises are often interpreted by professionals as the expression of severe pain or loss of control by the woman. Generally, professionals respond by giving instructions and coaching the woman, instead of reassuring and encouraging her [24]. It is also unlikely that women in labour have been well trained in any of these different types of pushing. Labour is probably not the best moment to learn different types of pushing methods. However, this was the case in all randomised publications, except one [15].

One randomised study explored the influence of prenatal education on the type of pushing and on maternal outcomes, but found no difference between the two groups [25]. A meta-analysis about prenatal childbirth preparation, either individual or in groups, did not find any consistent results [26]. We also note that compliance with the specific type of pushing assigned is never 100%. Moreover, open-glottis pushing can be envisioned either by coaching women to exhale during contractions, or by encouraging them to push spontaneously [27,28]. Women's spontaneous physiological instinct might well be to push instinctively, to listen to

their bodies. In other words, at any given moment, they may be pushing with glottis intermittently open and closed.

After flexion, descent and intrapelvic rotation, the leading part of the fetus reaches the pelvic floor. The spontaneous reflex to push (Ferguson's reflex) can occur earlier, once the fetal head reaches station 0 to + 1 in the plane through the ischial spines [29]. Moreover, we know that a policy of late pushing compared to early pushing once full dilatation is reached does not appear to be harmful [30]. In a meta-analysis of 12 trials (1,584 women with immediate and 1,531 with delayed pushing), there were more spontaneous births (pooled RR = 1.09; 95% CI: 0.98-1.26) and a shorter duration of expulsive efforts in the delayed pushing group [30]. The meta-analysis of Lemos et al. reported (12 trials, n= 3,114) that there were more spontaneous births (pooled RR = 1.07; 95% CI: 1.03-1.11) and a 20-minute decrease in the duration of pushing in the delayed pushing group of women with epidural analgesia [6]. It is important to bear in mind that epidural analgesia may attenuate the physiological augmentation of oxytocin that takes place during the second stage of labour and therefore the reflex of spontaneous pushing [31]. Moreover, an older study reported that women who push spontaneously do not start until intrauterine pressure reaches at least 30 mm Hg [19]. Pushing therefore does not occur simultaneously with the beginning of a contraction.

A consequence of Valsalva-type pushing is increased pressure on perineal tissue and the prevention of venous return to the inferior vena cava. Although the study by Schaffer et al. lacks power [11], it is possible that this type of pushing is more harmful to pelvic floor function some time after childbirth. Low et al. found no difference between the two types of pushing, but the utility of the "leakage index" is questionable, in view of the rarity of its use in the literature [15]. Theoretically vulvar oedema may also increase in the closed-glottis

pushing group, which could increase perineal injuries, particularly if the mother's position magnifies this phenomenon, as the seated position does. The randomised trials about the type of pushing nonetheless do not support this risk [8,11-13]. The same is true for the question of fetal oxygenation. Nonetheless, one randomised study found that the Apgar score and arterial pH at birth were best in the open-glottis pushing group [13]. Buhimschi et al. report that Valsalva-type pushing during a contraction during the second stage of labour is associated with a 62% increase in intrauterine pressure, compared with baseline tone. This increased pressure is correlated with body mass index but inversely correlated with myometrial thickness, ultrasound-estimated fetal weight, and the need for oxytocin during labour [32].

## **Conclusion**

Because of the low methodological quality of the studies, the lack of study power, the variability of their selection and outcome criteria, and of the co-interventions, these studies do not allow us to recommend a particular type of pushing. Moreover, most of the studies and meta-analyses compared spontaneous, non-coached open-glottis pushing to coached closed-glottis pushing. There is a lack of studies that compare coached open-glottis exhalation pushing to coached Valsalva-type pushing.

This assessment thus makes clear that a better understanding of the different modes of pushing might result in improving maternal satisfaction and even perhaps maternal and foetal morbidity during childbirth.

While awaiting such a study, the choice about the type of pushing during the active stage of birth should be given to the woman. Management must evolve by giving them more autonomy at the same time as we provide them the quality of care expected in light of current scientific data [27,33].

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### **Author's contribution**

All the authors have reviewed the contents of this article before its submission.

### **Disclosures**

The authors have no conflicts of interest to declare.



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Table 1. Methodological characteristics of the studies

| Study                                | Year of study | Description of the study population  | Parity                   | Eligible | Interventions studied            |                          |
|--------------------------------------|---------------|--|--------------------------|----------|----------------------------------|--------------------------|
|                                      |               |  |                          |          | IG                               | CG                       |
| Barnett et al.[7]                    | ?             | USA, uncomplicated pregnancies ♀ between 16-30 years and between 38-42 weeks, EFW 2500-4000 g, no FHR abnormalities, no EA   | Nulliparas               | ?        | Coached open-glottis pushing     | Coached Valsalva pushing |
| Parnell et al.[8]                    | 1990-91       | Denmark, ♀, > 18 years, ≥37 weeks, singleton in CP, planned vaginal birth, 1 previous caesarean possible   | Nulliparas or primiparas | 1413     | Coached open-glottis pushing     | Coached Valsalva pushing |
| Thomson [9,11]                       | ?             | England, spontaneous pregnancies, ♀ aged 18-40 years, between 37-42 weeks, singleton in CP, uncomplicated, no EA, dilatation ≥ 6 cm  | Primiparas               | ?        | Spontaneous open-glottis pushing | Coached Valsalva pushing |
| Schaffer et al.; Bloom et al.[11,12] | 2000-02       | USA, uncomplicated pregnancy, spontaneous labour (RG, dilatation ≥ 4 cm) between 36-41 weeks, singleton in CP, EFW < 4000 g, no pelvic prolapse or urogenital incontinence | Nulliparas               | 1534     | Spontaneous open-glottis pushing | Coached Valsalva pushing |

|                     |         |  |                                     |     |  |                                |
|---------------------|---------|--|-------------------------------------|-----|--|--------------------------------|
| Yildirim et al.[13] | 2003-04 | Turkey, ♀ at low risk, spontaneous labour, planned VB, between 38-42 weeks, singleton, no disease in CP and EFW 2500-3999 g, without EA  | Nulliparas                          | 174 | Coached<br>open-glottis<br>pushing     | Coached<br>Valsalva<br>pushing |
| Jahdi et al.[14]    | 2009    | Iran, ♀ between 18- 40 years, pregnancy at low risk and planned VB, spontaneous labour or induction for SRM or post-term and between 37-42 weeks, singleton, alive, in CP with EFW 2500-4000 g | Parity<br>ranging<br>from 0 to<br>5 | 258 | Spontaneous<br>open-glottis<br>pushing | Coached<br>Valsalva<br>pushing |
| Low et al.[15]      | 2000-06 | USA, ♀ >18 years, no urogenital disease (negative stress test) and continent before 20 weeks   | Nulliparas                          | 345 | Spontaneous<br>open-glottis<br>pushing | Coached<br>Valsalva<br>pushing |

Abbreviations: weeks (weeks of gestation); EFW (estimated fetal weight); FHR (foetal hart rate); EA (epidural analgesia); CP (cephalic presentation); RG (regular contractions); VB (vaginal birth); SRM (spontaneous rupture of the membranes); IG (interventional group); CG (control group); USA (United States of America).

Table 2. Description of the studies' other methodological criteria

| Studies                                 | Mode of randomisation                              | Time of randomisation         | Women randomised | Exclusion post-randomisation   | Score of studies | Compliance with the intervention |      |
|---|--|-------------------------------|------------------|--------------------------------|------------------|----------------------------------|------|
|   |  |                               |                  |                                |                  | IG %                             | CG % |
| Barnett et al.[7]                       | ?  | ?                             | 10?              | ?                              | C                | 100                              | 100  |
| Parnell et al.[8]                       | Drawing by 1/3 women<br>Sealed envelopes           | Admission for childbirth      | 350              | 44 exclusions: 24 IG and 20 CG | C                | 34.4                             | 84.5 |
| Thomson[9,10]                           | Sealed envelopes<br>Randomisation table            | At 6 cm dilatation?           | 32               | 0                              | B                | 86.7                             | 88.2 |
| Schaffer et al.<br>Bloom et al. [11,12] | Randomisation table<br>Opaque envelopes            | Beginning second stage        | 325              | 5 without data?                | B                | ?                                | ?    |
| Yildirim et al. [13]                    | Envelopes  | During first stage            | 100?             | ?                              | C                | ?                                | ?    |
| Jahdi et al. [14]                       | Drawing 1 envelope of 10.<br>Randomisation blocks? | At full dilatation            | 258              | 67                             | C                | ?                                | ?    |
| Low et al. [15]                         | Randomisation table /<br>computer                  | First appointment at 20 weeks | 249 <sup>a</sup> | 55 <sup>b</sup> ?              | C                | ?                                | ?    |

Abbreviations: weeks (weeks of gestation); IG (interventional group); CG (control group).

<sup>a</sup>This is the total number for the four study groups (control group, spontaneous open-glottis pushing group, perineal massage group, and perineal massage + spontaneous open-glottis pushing group).

<sup>b</sup>Total exclusions for the four study groups described in the note above.



Table 3. Maternal and neonatal outcomes

| Studies                                    | Episiotomies    |                 | Spontaneous birth |                  | 5-minute Apgar score   |                               | Umbilical artery pH    |                               |
|--|-----------------|-----------------|-------------------|------------------|------------------------|-------------------------------|------------------------|-------------------------------|
|  | IG<br>n/N (%)   | CG<br>n/N (%)   | IG<br>n/N (%)     | CG<br>n/N (%)    | IG<br>Mean [ $\pm$ SD] | CG<br>Mean [ $\pm$ SD]        | IG<br>Mean [ $\pm$ SD] | CG<br>Mean [ $\pm$ SD]        |
| Barnett et al.[7]                          | ?               | ?               | 5/5<br>(100%)     | 5/5<br>(100%)    | ?                      | ?                             | 7.32 <sup>c</sup>      | 7 <sup>c</sup>                |
| Parnell et al.[8]                          | 54/151<br>(36%) | 46/155<br>(30%) | ?                 | ?                | 9.9 [ $\pm$ 0.4]       | 9.9 [ $\pm$ 0.3]              | 7.22 [ $\pm$ 0.08]     | 7.24 [ $\pm$ 0.08]            |
| Thomson [9,10]                             | ?               | ?               | 12/15<br>(80%)    | 15/17<br>(88.2%) | ?                      | ?                             | ?                      | ?                             |
| Schaffer et al.<br>Bloom et al.<br>[11,12] | 32/157<br>(20%) | 42/163<br>(26%) | 149/157<br>(95%)  | 152/163<br>(93%) | ?                      | ?                             | 7.2 [ $\pm$ 0.7]       | 7.2 [ $\pm$ 0.8]              |
| Yildirim et al.[13]                        | 45/50<br>(90%)  | 43/50<br>(86%)  | -                 | -                | 9.9 [ $\pm$ 0.3]       | 9.5 [ $\pm$ 0.6] <sup>b</sup> | 7.3 [ $\pm$ 0.1]       | 7.3 [ $\pm$ 0.1] <sup>d</sup> |

|                   |   |   |                               |                               |   |   |   |   |
|-------------------|---|---|-------------------------------|-------------------------------|---|---|---|---|
| Jahdi et al. [14] | ? | ? | 97/99<br>(98%)                | 90/91<br>(98.9%)              | ? | ? | ? | ? |
| Low et al. [15]   | ? | ? | 24/34<br>(68.6%) <sup>a</sup> | 31/39<br>(86.1%) <sup>a</sup> | ? | ? | ? | ? |

Abbreviations: IG (interventional group); CG (control group).

<sup>a</sup>Note that for Low et al. there is a discordance in the tables between total number by categories and the addition of different numbers of individuals in the table.

<sup>b</sup> $P=0.001$  for the authors (9.9 vs. 9.5).

<sup>c</sup>Standard deviation found in the original article but value inconsistent with the umbilical artery pH values normally found at birth.

<sup>d</sup> $P=0.004$  for the authors (7.3 vs. 7.3).