Early Human Development 85 (2009) 621–626

Contents lists available at ScienceDirect

Early Human Development

journal homepage: www.elsevier.com/locate/earlhumdev

Best Practice Guideline article

What (not) to do at and after delivery? Prevention and management of meconium aspiration syndrome

Nestor E. Vain [a,b,*], Edgardo G. Szyld [b,c], Luis M. Prudent [b,d], Adriana M. Aguilar [b,c]

[a] Hospital Sanatorio Trinidad, University of Buenos Aires, Buenos Aires, Argentina
[b] FUNDASAMIN, (Fundación para la Salud Materno Infantil), Honduras 4160, Buenos Aires, Argentina
[c] Hospital Diego Paroissien, University of Buenos Aires, Buenos Aires, Argentina
[d] Hospital Clinica Suizo Argentina, Sanatorio Otamendi, University of Buenos Aires, Buenos Aires, Argentina

ARTICLE INFO

Keywords:
Infant
Newborn
Meconium aspiration
Suction
Intubation
Endotracheal
Resuscitation
Pulmonary hypertension

ABSTRACT

Meconium aspiration syndrome (MAS) is a life-threatening disorder in newborn infants. Universal intrapartum suction of infants with meconium stained amniotic fluid (MSAF) and postnatal suction of vigorous infants have been used in an attempt to decrease the incidence and severity of the disease by clearing the airway. Both procedures have been proven fruitless when challenged through randomised control trials (RCTs). Endotracheal intubation and suctioning are currently recommended only for non-vigorous infants. Respiratory failure in infants with MAS is frequently treated initially with conventional or synchronized mechanical ventilation. Surfactant administration and high-frequency ventilation (HFV) are commonly used as rescue therapy for severe cases. Nitric oxide (NO) is added when severe pulmonary hypertension is demonstrated. ECMO is an option when other treatments have failed. In the pathophysiology of severe MAS, asphyxia and pulmonary hypertension are considered to be more important than the obstruction of the airways and/or damage to the lung produced by meconium.

Contents

1. Delivery room management

The approach to the management of infants with MSAF in the delivery room has been changing for over 30 years. The initial clinical studies were based on the belief that respiratory distress occurring in infants with MSAF was primarily caused by obstruction of the airways and filling of

* Corresponding author. Hospital Sanatorio Trinidad, University of Buenos Aires, Chenaut 1831, Buenos Aires, 1426, Argentina. Tel.: +54 11 4127 5534; fax: +54 11 4127 5536.
E-mail addresses: nvain@fundasamin.org.ar (N.E. Vain), eszyld@fundasamin.org.ar (E.G. Szyld), lprudent@fundasamin.org.ar (L.M. Prudent), aaguilar@fundasamin.org.ar (A.M. Aguilar).

0378-3782/$ – see front matter © 2009 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.earlhumdev.2009.09.013

alveoli with meconium. Chemical pneumonitis, inflammation, infection and surfactant inhibition by meconium were also considered important aspects in the pathophysiology of MAS.

Not surprisingly then, during the 70s, oro- and nasopharyngeal suctioning before the delivery of the shoulders and immediate postnatal intubation and tracheal suctioning were practices considered as valuable measures to prevent MAS in infants born through MSAF [1–3]. During the 80s and 90s, a more selective approach for intubation was taken. But it is only in 2000 that results from large RCTs became available [4–6].

As is the case in many other areas of medicine, evidence-based studies demonstrated that some of the therapeutic approaches traditionally advocated by obstetricians and neonatologists for patients with MSAF were in fact useless. The results of those trials have led to changes of current recommendations.

1.1. Delivery room intrapartum management: Suction of the oro- and nasopharynx before the delivery of the shoulders

In 1976, Carson et al. published a study aimed at evaluating the impact of suctioning of the hypopharynx before delivery of the shoulders in infants born through MSAF [3]. They evaluated a group of 273 infants managed with a combined approach consisting of intrapartum suctioning before delivery of the infant's shoulders, laryngoscopy, and intubation when meconium was visualized at the level of the vocal cords. The authors compared this cohort with a historical control group in which no intrapartum suctioning had been performed. The patients managed with this combined approach had a lower incidence of MAS (1 out of 273 [0·4%] vs. 18 out of 947 [1·9%]). Although these differences did not reach statistical significance ($p = 0·071$), the authors suggested that a combined approach of intrapartum and postnatal suction of the oropharynx and large airways decreased the risks and mortality in this group of infants. Widespread adoption of this approach followed publication. A few years later, Falciglia compared 742 infants born with MSAF in whom intrapartum suctioning had not been performed with a group of 755 infants born at the same centre after the adoption of prenatal suction. The incidence of MAS was similar in both groups (~2%) in this study [7]. In a subsequent prospective observational study, Falciglia et al. compared the incidence of MAS in infants who were or were not suctioned before delivery of the shoulders. He found an incidence of 10 and 7% respectively [8]. The 8 cases of pulmonary air leak in the study (pneumothorax or pneumomediastinum) occurred all in the intrapartum suctioned group.

In spite of the methodological limitations of Carson's study and the opposite results reported by Falciglia in papers of comparable design and quality, the combined approach of intrapartum and immediate postnatal suctioning of meconium stained infants was widely accepted and led to its inclusion in the guidelines of the American College of Obstetricians and Gynaecologists (ACOG) and the American Academy of Pediatrics (AAP) [9,10].Interestingly, the extremely low incidence and mortality rates of MAS reported by Carson were never demonstrated by any patient series published thereafter in the medical literature.

Because the procedure to perform prenatal suction was not well standardized and there was no agreement regarding the device to be used, the depth of insertion, amount of negative pressure and duration of the procedure, we suspected that such practice could not be crucial for the prevention of MAS [11,12]. Moreover, there were different views about the pathophysiology of MAS, among them the thought that the presence of meconium was a marker of asphyxia and cardiovascular changes rather than the cause of the disease [13]. These facts and the lack of scientific background to support the use of a so widely performed procedure led us to recognize the need for a study to appropriately evaluate the effectiveness of prenatal suction. Therefore, we designed a large masked multicentre RCT which was performed in 11 hospitals in Argentina and 1 in the USA [5]**.** 2514 term infants with MASF were randomised to intrapartum suction vs. no suction. The incidence of MAS (4% vs. 4%), as well as mortality, the need of mechanical ventilation and the need and duration of oxygen therapy were similar in both groups. (Table 1) No benefits of intrapartum suctioning on the same variables when we analysed the subpopulations at higher risk (thick meconium, foetal distress, need for resuscitation, caesarean section), no benefits of intrapartum suctioning on the same variables were detected. We concluded that suctioning of the naso- and oropharynx before delivery of the shoulders in newborns with MSAF decreases neither the incidence nor the severity of MAS.

Based on these results and current recommendations by the AAP through the Neonatal Resuscitation Program, the International Liaison Committee on Resuscitation (ILCOR), and the ACOG, intrapartum management of these pregnancies has radically changed. Intrapartum suction of infants with MSAF is not recommended anymore [14–16].

Despite the described evidence and recommendations, some authors still recommend intrapartum suction if there is MSAF, especially for infants born in communities with limited resources, on the feeling that "the procedure is simple and does not carry significant adverse effects". They follow different approaches according to the meconium consistency [17,18]. To base on feelings and assumptions such a strong assertion – that intrapartum suction may be different in low resources populations – is a rather weak argument; feelings and expert opinions are considered Levels of evidence 5. Even more, since

Table 1
Effect of intrapartum suction on clinical aspects (Ref. [5]).

Characteristic		Suction	No suction	RR	P^a
		$n = 1263$	$N = 1251$	(CI 95%)	
Meconium aspiration syndrome	*n*	52	47	0.9	–
	%	4%	4%	(0.6–1.3)	
	99% CI	2.8–5.8	2.5–5.4		
Need for mechanical ventilation	*n*	24	18	0.8	–
	%	2%	1%	(0.4–1.4)	
	99% CI	1.1–3.1	0.7–2.6		
Mortality	*n*	9	4	0.4	–
	%	1%	0.3%	(0.1–1.5)	
	99% CI	0.2–1.6	0.1–1.0		
Need for endotracheal intubation, suction and PPV in the delivery room		106 (8%)	113 (9.0%)	1.1 (0.8–1.4)	–
Other respiratory disorders	*n*	61	79	1.3	–
	%	5%	6%	(0.9–1.8)	
	99% CI	3.4–6.6	4.7–8.3		
Pneumothorax		3 (0.2%)	3 (0.2%)	1.0 (0.12–8.25)	–

Outcomes (SD = standard deviation)

Characteristic	Suction $n = 1263$	No suction $n = 1251$	P
Range of one-minute Apgar scores			
0–3	22 (2%)	15 (1%)	0.29
4–6	65 (5%)	73 (6%)	
7–10	1174 (93·0%)	1163 (93·0%)	
Unknown	2 (0·1%)	0	
Range of five-minute Apgar scores			
0–3	0	0	0.29
4–6	13 (1·0%)	5 (0·4%)	
7–10	1230 (97%)	1231 (98%)	
Unknown	2 (0·2%)	0	
Duration of oxygen therapy (days) in infants with MAS (mean ± SD) (*n*)	5.7 ± 8.8 ($n = 52$)	5.1 ± 7.1 ($n = 47$)	0.91
Duration of mechanical ventilation (days) in infants with MAS (mean ± SD)	5.1 ± 4.9 (n = 21)	4.2 ± 4.6 (n = 14)	0.49
Duration of hospitalisation (days) in infants with MAS (mean ± SD)	8·2 ± 10·7 ($n = 50$)	9·0 ± 8·6 ($n = 43$)	0·14

MAS—Meconium aspiration syndrome. ppV—positive-pressure ventilation.
[a] *p* values calculated for continuous variables.

there is a Level of evidence 1 study on the issue, revised and accepted by many prestigious scientific societies and international committees, the authors of this study wonder why to propose such a non-scientific approach then. Moreover, our findings – that suction before delivery of the shoulders is a useless procedure – were based on a study which included several hospitals giving assistance to extremely low resources communities.

We recently carried out a national survey to assess current delivery room approaches in infants born through MSAF in Argentina and evaluated the adherence to NRP/AAP recommendations in different centres. We found that intrapartum suctioning, postnatal intubation and suctioning of vigorous infants with MSAF are still commonly performed, while in depressed newborns the latter procedure is not always carried out. Adherence to practice guidelines by different institutions is not uniform which confirms the frequent gaps among evidence, guidelines and clinical practice [19]. A previous study carried out in French maternities found that almost half of the surveyed centres systematically performed oropharyngeal suctioning before delivery of the shoulders and laryngoscopy in half of the newborns. Endotracheal suctioning was systematically performed in 27% of the institutions. They concluded – just like our study did – the necessity of harmonization of the practices for the management of births with MSAF since the practices performed in these infants were very varied [20].

Suctioning of the hypopharynx is not a risk-free procedure. Potential complications such as delay in the delivery of the infant and in the onset of resuscitation efforts, damage to the mouth and hypopharynx, and cardiac arrhythmias secondary to vagal stimulation may result from this practice [7,8,21].Based on currently available literature routine suctioning is more likely to cause harm than good and should therefore be abandoned as a routine procedure [22].

1.2. Delivery room postnatal management: Endotracheal intubation and suction

James described endotracheal intubation and suction in MSAF infants in 1960 and Burke was the first author to publish a series of suctioned patients. However, the credit for this technique was given to subsequent authors [23]. In 1974, Gregory published a study with a series of 88 infants born through MSAF within a cohort of 1000 consecutive infants born during a period of 6 months [1]. All meconium stained infants were intubated and suctioned. The objective of the study was to describe the frequency of MSAF, the amount and consistency of meconium present in the nose, pharynx, and trachea, as well as the radiographic findings and the incidence of respiratory distress. The authors noted that among the 35 infants admitted to the NICU, the outcome was worse for those who were found to have meconium below the vocal cords. They also compared this group with 15 outborn babies not suctioned in the delivery room and found the prognosis to be worse in the latter.

The authors' recommendation for immediate endotracheal suction of infants born with thick particulate MSAF and the prevailing concept of the disease being caused by meconium obstruction led to the extensive use of this approach for vigorous and non-vigorous infants born with any type of MSAF and to the search for new strategies for clearing the airway.

Following this report, intubation and suction of vigorous and non-vigorous infants with MSAF progressively became a standard practice and mouth to tube suction was originally performed [24]. Later, the recognition of potential risks of contamination with various infectious agents for both patients and health professionals led to the use of a variety of suction devices [25].

In 1998, Linder et al. performed a non-randomised trial to evaluate the effect of intubation on 572 vigorous infants delivered vaginally with MSAF [26]. Intubation and suctioning were performed in 308 patients by the neonatologists who believed the procedure was useful. In the remaining 264, endotracheal suction was not performed. Tracheal suction did not decrease the incidence of MAS and some complications were related to intubation of vigorous infants in the delivery room.

Although this study had several design flaws, it was the basis for a change in practice towards a more selective approach to intubation in meconium stained newborns [27]. The guidelines for cardiopulmonary resuscitation from the AAP in 1992 recommended intubation and suction of babies born through MSAF for those at high risk for MAS (mainly thick and particulate consistency) [28].

A trend by many neonatologists to stop performing endotracheal intubation and suctioning of vigorous infants with MSAF prompted Wiswell et al. to design a large international multicentre RCT to test the hypothesis that endotracheal intubation decreases the incidence and/or severity of meconium aspiration. 2094 infants were randomised to intubation and suction vs. no intubation [4]. The frequency of MAS or other forms of respiratory distress was similar in both groups. (Table 2) There were no serious complications of endotracheal intubation.

Following the publication of these results, the Neonatal Resuscitation Program of the AAP and ILCOR modified the guidelines: intrapartum suctioning as well as postnatal endotracheal suctioning of vigorous infants with MSAF is no longer recommended [29,30]. Currently, endotracheal suction is recommended only in neonates born through MSAF who are not vigorous at birth [14].

The adoption of the new recommendations did not increase the frequency of meconium aspiration [31]. It should be noted that suctioning of the airway at birth to remove meconium before starting positive-pressure ventilation in non-vigorous infants with MSAF, as presently recommended by AAP and ILCOR, has not been evaluated through clinical trials.

1.3. Dangerous postnatal manoeuvres showing no benefit

Cricoid compression, blocking of the epiglottis to prevent meconium from entering the lower airways and lungs, and chest compression to avoid breathing while suctioning is being performed, were attempted, but none of these manoeuvres has shown to be useful [32]. Gastric lavage to eliminate meconium from the stomach, chest physical therapy and bronchial lavage with saline to remove meconium from the airways have all been used without solid scientific support [33,34].

All these techniques have potential risks and therefore cannot be recommended.

However, a recent survey in 227 neonatal units in the UK reported that 7.4% of centres still used saline lavage at resuscitation [35].

Table 2
Effects of endotracheal intubation and suction of vigorous meconium stained infants (Ref. [4]).

	Intubate ($n=1051$)	Expectant ($n=1043$)	Significance
Occurrence of MAS ($n=62$)			
Overall	34/1051 (3.2%)	28/1043 (2.7%)	NS
Thin MSAF	5/447 (1.1%)	2/453 (0.4%)	NS
Moderately-thick MSAF	7/301 (2.3%)	6/307 (2.0%)	NS
Thick MSAF	22/303 (7.3%)	20/283 (7.1%)	NS
Occurrence of other respiratory disorders ($n=87$)			
Overall	40/1051 (3.8%)	47/1043 (4.5%)	NS
Thin MSAF	6/447 (1.3%)	8/453 (1.8%)	NS
Moderately-thick MSAF	10/301 (3.3%)	15/307 (4.9%)	NS
Thick MSAF	24/303 (7.9%)	24/283 (8.5%)	NS
Occurrence of any type of respiratory distress ($n=149$)			
Overall	74/1051 (7.0%)	75/1043 (7.2%)	NS
Thin MSAF	11/447 (2.5%)	10/453 (2.2%)	NS
Moderately-thick MSAF	17/301 (5.6%)	21/307 (6.8%)	NS
Thick MSAF	46/303 (15.2%)	44/28/3 (15.5%)	NS

Some guidelines published in France continue to advise compression of the chest to hold the first breath and direct laryngoscopy as part of the recommended flowchart for thick meconium stained babies even when they are vigorous at birth [36].

Thus, non-recommended manoeuvres continue to be performed in delivery room settings [19,20].

1.4. Decrease in the frequency of MAS in the last decade

Yoder et al. reported a progressive decrease in the incidence of MAS within a period of 9 years and attributed this to changes in obstetrical practice, among them: [37]

- Use of amnioinfusion [6]
- A better diagnosis of abnormalities by electronic foetal monitoring,
- Higher frequency of caesarean sections,
- Increased use of prenatal ultrasound,
- Significant decrease of post-term deliveries.

2. NICU management of infants with meconium aspiration

From 3 to 14% of infants born with MSAF develop MAS [21,38]. This wide range in the frequency of MAS is related to characteristics of each study population and, more importantly, to the various criteria used by different authors to diagnose MAS.

We will discuss first the clinical management, which is essentially that of respiratory distress in term infants. Some aspects, however, have been subject of specific research and will also be discussed later in this chapter.

2.1. Radiographic findings

Typical radiographic findings described in infants with MAS are over-expansion of the lungs with widespread coarse infiltrates. However, the severity of the X-ray pattern does not always correlate with the clinical picture. Some patients with severe disease may have minimal X-ray findings, while others have marked X-ray findings without clinical disease. The lack of correlation between clinical severity and radiographic pattern suggests that the disease is less dependent on the amount of meconium obstruction and parenchymal damage than on other aspects of MAS, such as the presence and severity of pulmonary hypertension.

2.2. Respiratory support

In mild cases, oxygen can be supplied as part of treatment of pulmonary hypertension. High concentrations of oxygen need to be avoided to prevent pulmonary damage and the duration of oxygen therapy should be limited to avoid free oxygen radical damage. We currently use transcutaneous oxygen saturation limits of 90 and 95% and aim to maintain a paO_2 between 6.7 and 12 kPa (50–90 mm Hg). Assisted ventilation should be considered when O_2 concentrations needed to maintain these limits exceed 70%, or when respiratory acidosis or apnoeas are part of the clinical picture.

There is no evidence to recommend the use of CPAP in patients with MAS and CPAP may even increase the risk of pneumothorax.

The indications for mechanical ventilation in infants with MSAF are arbitrary [39].

We start conventional (IMV) or synchronized mechanical ventilation (SIMV) when the infant is requiring a FiO_2 of 0.7 or higher to maintain O_2 saturations above 90%, has repeated sudden drops of the O_2 saturations secondary to marked pulmonary hypertension, apnoea or respiratory acidosis ($paCO_2 > 8$ kPa (60 mm Hg), or $pH < 7.25$) which may exacerbate pulmonary hypertension.

There are no RCTs to support a specific strategy for mechanical ventilation in infants with MAS. We avoid the use of hyperventilation because it carries an extra risk of air leaks and harmful changes in cerebral blood flow. We aim to keep the $paCO_2$ between 5.3 and 6.7 kPa (40–50 mm Hg). In some infants, meconium is repeatedly obtained when the endotracheal tube is suctioned during the first hours of life, which indicates some degree of obstruction. In these patients, a longer than usual inspiratory time (IT) is used (0.5 to 0.7 s) with IMV rates of 30 or less. Intermediate or short inspiratory time is used when airways appear to be free of meconium.

Although HFV is used as rescue treatment for infants with MAS and severe respiratory failure, no advantages over the conventional or synchronized modes have been demonstrated. We do not recommend HFV as routine therapy as it is less successful in infants with various degrees of airway obstruction and those with asymmetrical disease, frequently the case for patients with MAS.

2.3. Additional therapies used in severe cases

Sedation, analgesia and muscle paralysis have been used in infants with MAS, mainly those with severe pulmonary hypertension and drops in oxygenation. Although no clinical trials have demonstrated clear advantages, these therapies are frequently administered because of difficulties in managing mechanical ventilation in active term infants.

Sodium bicarbonate has been used to raise the pH and decrease right to left shunting, again, more empirically than scientifically.

Vasoactive drugs are commonly administered to increase systemic blood pressure or improve heart contractility.

Nitric oxide is frequently used for pulmonary hypertension. The response in infants with MAS is variable and dependent on the lung areas that can be reached by the gas. However, NO is indicated in term infants with hypoxic respiratory failure without structural heart disease.

ECMO should be used, when available, for infants with MAS who do not respond to the aforementioned therapies. Several series reported that infants with MAS comprise 50% of the newborns treated with ECMO.

2.4. Surfactant

In vitro studies have shown that meconium interferes with surfactant in several ways: [32]

- Inactivation of its function depending on the concentration.
- Direct toxicity on type II pneumonocytes.
- Displacement of surfactant from the alveolar surface.
- Decrease of surfactant protein A and B levels.

Many studies assessed the benefits of surfactant use in animal models with controversial results [21]. Some clinical trials evaluated bolus administration of high doses of surfactant in infants. In 1998, Lotze et al. published a multicenter RCT of surfactant use in term newborn infants with severe respiratory diseases of various aetiologies (50% had MAS) [40].There were fewer infants with MAS requiring ECMO within the group randomised to receive surfactant. A smaller study suggested also some clinical benefits and a reduction on hospital stay [41]. More recently, Maturana et al. reported the results of a multicenter RCT using surfactant for less severe MAS [42]. The study demonstrated no differences between the treated and non-treated group. Another RCT from China showed some physiologic improvement following surfactant administration but no effect in major clinical outcomes [43]. A recent meta-analysis of these 4 studies in full term and near term infants by the Cochrane Library concludes that surfactant administration may reduce the severity of MAS and decrease the number of infants with progressive respiratory failure requiring ECMO support [44].

Therefore, although bolus administration of surfactant cannot be recommended for routine use in infants with MAS, its use in selected

patients with predominantly parenchymal disease and severe respiratory failure appears indicated.

Some case reports and small studies performing bronchoalveolar lavage with surfactant in infants with MAS have been published. The theory behind this technique is based on the potential removal of meconium, neutrophiles, remains of proteins, etc., leaving a therapeutic amount of surfactant in the lungs at the end of the procedure. Results of these studies are optimistic, but the technique is risky and should be tested by large clinical trials before it can be recommended for routine use [35,45–47].

2.5. Steroids

Based on studies suggesting that meconium generates an inflammatory response on lung tissue, steroids have been tried in infants with MAS [48]. Results are inconclusive and complications resulting from the use of these drugs are well known. However two recent studies suggested that systemic and inhaled steroids alter the course of MAS and favourably affect the outcome without serious adverse effects [49,50].

At present, there is insufficient evidence to propose routine steroid therapy in the management of meconium aspiration syndrome.

2.6. Antibiotics

The presence of meconium increases the chances of positive cultures from amniotic fluid in preterm and term infants. However, studies evaluating the development of sepsis in infants with MSAF failed to demonstrate a relationship [24]. Although prophylactic antibiotics in infants with MAS are not justified, most of these patients receive antibiotics during the first days of life, before the diagnosis of pneumonia can be completely ruled out [51,52].

3. Conclusions

Although the incidence decreases, MAS continues to be a neonatal disorder with high morbidity and mortality, in spite of changes in obstetrical and neonatal care. Attempts to prevent the disease by relieving obstruction of the airways have failed when challenged by RCTs. Asphyxia and pulmonary hypertension are likely to be more important as a cause of severe MAS than the obstruction or damage caused by meconium in the airways and lungs. Respiratory management of patients with MAS depends on the infants' pulmonary function. Surfactant administration may be of help. Maybe this is the time to change the name of the disorder to MSAF associated Respiratory Distress, which seems more appropriate than MAS.

Acknowledgements

We appreciate Waldemar Carlo M.D. for his support and advice and Juan Pablo Berazategui M.D. for collaboration in bibliographical search and interpretation.

References

[1] Gregory GA, Gooding CA, Phibbs RH, Tooley WH. Meconium aspiration in infants—a prospective study. J Pediatr 1974;85:848–52.
[2] Ting P, Brady JP. Tracheal suction in meconium aspiration. Am J Obstet Gynecol 1975;122:767–71.
[3] Carson BS, Losey RW, Bowes Jr WA, Simmons MA. Combined obstetric and pediatric approach to prevent meconium aspiration syndrome. Am J Obstet Gynecol 1976;126:712–5.
[4] Wiswell TE, Gannon CM, Jacob J, Goldsmith L, Szyld E, Weiss K, et al. Delivery room management of the apparently vigorous meconium-stained neonate: results of the multicenter, international collaborative trial. Pediatrics 2000;105:1–7.
[5] Vain NE, Szyld EG, Prudent LM, Wiswell TE, Aguilar AM, Vivas NI. Oropharyngeal and nasopharyngeal suctioning of meconium-stained neonates before delivery of their shoulders: multicentre, randomised controlled trial. Lancet 2004;364:597–602.
[6] Fraser WD, Hofmeyr J, Lede R, Faron G, Alexander S, Goffinet F, et al. Amnioinfusion for the prevention of the meconium aspiration syndrome. N Engl J Med 2005;353:909–17.
[7] Falciglia HS. Failure to prevent meconium aspiration syndrome. Obstet Gynecol 1988;71:349–53.
[8] Falciglia HS, Henderschott C, Potter P, Helmchen R. Does DeLee suction at the perineum prevent meconium aspiration syndrome? Am J Obstet Gynecol 1992;167:1243–9.
[9] Guidelines for cardiopulmonary resuscitation and emergency cardiac care. Emergency Cardiac Care Committee and Subcommittees, American Heart Association. Part I. Introduction. JAMA. 1992;268:2171–83.
[10] American Academy of Pediatrics and the American College of Obstetricians and Gynecologist. Guidelines for perinatal care. 4th ed. Elk Grove Village, IL, USA: Am Acad Pediatr 1997;117–18.
[11] Bent RC, Wiswell TE, Chang A. Removing meconium from infant tracheae. What works best? Am J Dis Child 1992;146:1085–9.
[12] Gage JE, Taeusch Jr HW, Treves S, Caldicott W. Suctioning of upper airway meconium in newborn infants. JAMA 1981;246:2590–2.
[13] Ghidini A, Spong CY. Severe meconium aspiration syndrome is not caused by aspiration of meconium. Am J Obstet Gynecol 2001;185:931–8.
[14] Kattwinkel J. Textbook of neonatal resuscitation. American Academy of Pediatrics and American Heart Association. 5 ed. 2006.
[15] The International Liaison Committee on Resuscitation (ILCOR) consensus on science with treatment recommendations for pediatric and neonatal patients: neonatal resuscitation. Pediatrics. 2006;117:e978–88.
[16] ACOG Committee Opinion No. 379. Management of delivery of a newborn with meconium-stained amniotic fluid. Obstet Gynecol 2007;110:739.
[17] Lin HC, Wu SY, Wu JM, Yeh TF. Meconium aspiration syndrome: experiences in Taiwan. J Perinatol 2008;28:S43–8.
[18] Bhutani VK. Developing a systems approach to prevent meconium aspiration syndrome: lessons learned from multinational studies. J Perinatol 2008;28:S30–5.
[19] Aguilar A, Satragno D, Vain N, Szyld E, Prudent L. [Delivery room practices in infants born through meconium stained amniotic fluid: a national survey]. Arch Argent Pediatr. in press.
[20] Chemin A, Thionois S, Saliba E, Cantagrel S. Early management of infants born to mothers with meconium-stained amniotic fluid: a survey in French delivery rooms. Arch Pediatr 2007;14:150–6.
[21] Wiswell TE, Bent RC. Meconium staining and the meconium aspiration syndrome. Unresolved issues. Pediatr Clin North Am 1993;40:955–81.
[22] Velaphi S, Vidyasagar D. The pros and cons of suctioning at the perineum (intrapartum) and post-delivery with and without meconium. Semin Fetal Neonatal Med 2008;13:375–82.
[23] James L. Resuscitation procedures in the delivery room. In: H.A., editor. Resuscitation of the newborn infant. St. Louis: CV Mosby Co; 1960. p. 141.
[24] Wiswell TE, Henley MA. Intratracheal suctioning, systemic infection, and the meconium aspiration syndrome. Pediatrics 1992;89:203–6.
[25] Ballard JL, Musial MJ, Myers MG. Hazards of delivery room resuscitation using oral methods of endotracheal suctioning. Pediatr Infect Dis 1986;5:198–200.
[26] Linder N, Aranda JV, Tsur M, Matoth I, Yatsiv I, Mandelberg H, et al. Need for endotracheal intubation and suction in meconium-stained neonates. J Pediatr 1988;112:613–5.
[27] Wiswell TE, Fuloria M. Management of meconium-stained amniotic fluid. Clin Perinatol 1999;26:659–68.
[28] Guidelines for cardiopulmonary resuscitation and emergency cardiac care. Emergency Cardiac Care Committee and Subcommittees, American Heart Association. Part VII. Neonatal resuscitation. Jama. 1992;268:2276–81.
[29] Kattwinkel J. Textbook of neonatal resuscitation. 4th ed. American Academy of Pediatrics; 2000.
[30] Kattwinkel J, Niermeyer S, Nadkarni V, Tibballs J, Phillips B, Zideman D, et al. An advisory statement from the Pediatric Working Group of the International Liaison Committee on Resuscitation. Pediatrics 1999;103:e56.
[31] Kabbur PM, Herson VC, Zaremba S, Lerer T. Have the year 2000 neonatal resuscitation program guidelines changed the delivery room management or outcome of meconium-stained infants? J Perinatol 2005;25:694–7.
[32] Cleary GM, Wiswell TE. Meconium-stained amniotic fluid and the meconium aspiration syndrome. An update. Pediatr Clin North Am 1998;45:511–29.
[33] Narchi H, Kulaylat N. Is gastric lavage needed in neonates with meconium-stained amniotic fluid? Eur J Pediatr 1999;158:315–7.
[34] Beeram MR, Dhanireddy R. Effects of saline instillation during tracheal suction on lung mechanics in newborn infants. J Perinatol 1992;12:120–3.
[35] Greenough A, Pulikot A, Dimitriou G. Prevention and management of meconium aspiration syndrome—assessment of evidence based practice. Eur J Pediatr 2005;164:329–30.
[36] Chabernaud JL. Neonatal resuscitation in delivery room: new advances. Arch Pediatr 2005;12:477–90.
[37] Yoder BA, Kirsch EA, Barth WH, Gordon MC. Changing obstetric practices associated with decreasing incidence of meconium aspiration syndrome. Obstet Gynecol 2002;99:731–9.
[38] Walsh MC, Fanaroff JM. Meconium stained fluid: approach to the mother and the baby. Clin Perinatol 2007;34:653–65.
[39] Goldsmith JP. Continuous positive airway pressure and conventional mechanical ventilation in the treatment of meconium aspiration syndrome. J Perinatol 2008;28:S49–55.
[40] Lotze A, Mitchell BR, Bulas DI, Zola EM, Shalwitz RA, Gunkel JH. Multicenter study of surfactant (beractant) use in the treatment of term infants with severe respiratory failure. Survanta in Term Infants Study Group. J Pediatr 1998;132:40–7.
[41] Findlay RD, Taeusch HW, Walther FJ. Surfactant replacement therapy for meconium aspiration syndrome. Pediatrics 1996;97:48–52.
[42] Maturana A, Torres J, Salinas R, Astudillo P, Gonzalez LH, Dias A, et al. "Meconium aspiration syndrome (mas)": 9. Pediatr Res 2005;57:921.

[43] Treatment of severe meconium aspiration syndrome with porcine surfactant: a multicentre, randomized, controlled trial. Acta Paediatr. 2005;94:896–902.
[44] El Shahed AI, Dargaville P, Ohlsson A, Soll RF. Surfactant for meconium aspiration syndrome in full term/near term infants. Cochrane Database of Systematic Reviews 2007, Issue 2. Art No.:CD002054.
[45] Salvia-Roiges MD, Carbonell-Estrany X, Figueras-Aloy J, Rodriguez-Miguelez JM. Efficacy of three treatment schedules in severe meconium aspiration syndrome. Acta Paediatr 2004;93:60–5.
[46] Wiswell TE, Knight GR, Finer NN, Donn SM, Desai H, Walsh WF, et al. A multicenter, randomized, controlled trial comparing Surfaxin (Lucinactant) lavage with standard care for treatment of meconium aspiration syndrome. Pediatrics 2002;109:1081–7.
[47] Dargaville PA, Mills JF, Copnell B, Loughnan PM, McDougall PN, Morley CJ. Therapeutic lung lavage in meconium aspiration syndrome: a preliminary report. J Paediatr Child Health 2007;43:539–45.
[48] Ward M, Sinn J. Steroid therapy for meconium aspiration syndrome in newborn infants. Cochrane Database Syst Rev 2003;4:CD003485.
[49] Tripathi S, Saili A. The effect of steroids on the clinical course and outcome of neonates with meconium aspiration syndrome. J Trop Pediatr 2007;53:8–12.
[50] Basu S, Kumar A, Bhatia BD, Satya K, Singh TB. Role of steroids on the clinical course and outcome of meconium aspiration syndrome—a randomized controlled trial. J Trop Pediatr 2007;53:331–7.
[51] Lin HC, Su BH, Tsai CH, Lin TW, Yeh TF. Role of antibiotics in management of non-ventilated cases of meconium aspiration syndrome without risk factors for infection. Biol Neonate 2005;87(1):51–5.
[52] Basu S, Kumar A, Bhatia BD. Role of antibiotics in meconium aspiration syndrome. Ann Trop Paediatr 2007;27:107–13.