

# Ventilation, Chest Compression and Placental Circulation at Neonatal Resuscitation – ILCOR Recommendation 2015

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## Abstract

ILCOR now recommends delayed cord clamping of at least 30 seconds in term and preterm neonates. Due to insufficient evidence they provide no specific advice about the neonate that requires resuscitation. Hypovolaemia is well recognised to lead to a neonate who will not respond to positive pressure ventilation until the hypovolaemia is corrected. It is therefore essential that any clinical situation which may result in hypovolaemia is avoided if possible. Until the specific evidence becomes clear, the case for the default to be delayed cord clamping in all babies is provided.

**Keywords:** Resuscitation; Delayed cord clamping; Hypovolaemia; Coronary circulation; Chest compression

**List of abbreviations:** DCC: Delayed Cord Clamping; PPV: Positive Pressure Ventilation; Bpm: beats per minute; ILCOR: International Liaison Committee on Resuscitation

## Introduction

The 2015 ILCOR systematic review states that delayed cord clamping “for longer than 30 seconds is reasonable for both term and preterm infants who do not require resuscitation at birth [1].”

“There is insufficient evidence to recommend an approach to cord clamping for infants who require resuscitation at birth, and more randomized trials involving such infants are encouraged.” In this article we are largely restricting the evidence presented and the discussion to term infants or near term infants. Preterm infants will always require some degree of support or resuscitation at birth and the evidence of benefit of delayed cord clamping is clearest in these babies.

The statement that “there is at present insufficient evidence to recommend an approach to cord clamping for infants who require resuscitation” should not be interpreted that there is sufficient evidence for the current management nor is it a recommendation for maintaining the status quo. ILCOR are quite clear that there is insufficient evidence one way or the other and call for randomised trials to provide such evidence. It is logical and indeed simplest to make the default the same for both healthy and compromised babies, until such time there is clear evidence one way or the other. The default management of the cord at birth should be a delay of at least 30 seconds. We will provide evidence and logic to explain why starting with a default of delayed cord clamping provides the most straight forward clinical management and a good baseline for an effective clinical trial. Continuing the status quo simply on the grounds of tradition and convenience is neither logical nor supported by what evidence there is.

## Circulatory effects of early cord clamping in healthy term infants

In healthy term babies the evidence shows that clamping the cord earlier than 30 seconds results in instability in the circulation whereas if clamping is delayed until later and after the expansion of the lungs with air, this instability is not present. Expansion of the lungs with air results in a marked fall in pulmonary vascular resistance and a marked rise in pulmonary circulation. Lamb studies have shown that this protects both the afterload and preload of the heart. Although time and the circulatory changes are interconnected, it is the physiological changes which are critical to the stability rather than a precise time [2,3]. It is possible that interruption of a physiological transition at birth may lead to the need for resuscitation [4].

Multiple studies have shown improved blood pressure in the first 4 hours and less need for volume expansion (due to hypotension) or pressors, with delayed cord clamping [5].

Computer simulation of the circulation shows that clamping the cord before the pulmonary circulation is established must lead to a marked increase in afterload of the heart [6]. Without the presence of a low resistance pulmonary circulation, most of the output of the right ventricle must still pass largely through the ductus arteriosus and the output of both ventricles can then only pass through the systemic circulation. What effect will this have on the compromised heart? A high peripheral vascular resistance (total peripheral vascular resistance) will increase the end diastolic volume of the ventricles which in turn increases the end diastolic pressure and the myometrial pressure during diastole. This reduces subendocardial coronary circulation. In contrast to the rest of the circulation, coronary artery blood flow occurs during diastole when the pressure in the myometrium is normally low. In the adult heart, raised left ventricular end diastolic pressure lowers coronary perfusion pressure [7].

The sudden increase in afterload of the heart increases myocardial work which increases oxygen demand. Early cord clamping results in a complete loss of the placental oxygenated blood and reduces the oxygen saturation of the arterial blood. [8] There may be other additional underlying mechanisms for the reduction in arterial oxygen saturation. Thus at a time when oxygen is at a premium, early cord clamping results in a higher cardiac requirement and a reduced supply. All these factors will tend to prevent the rescue of cardiac activity.

## Neonatal resuscitation rationale

The rationale for providing positive pressure ventilation to the apnoeic neonate is based on the animal model which demonstrated the response of the fetus to asphyxia [9]. Dawes showed that spontaneous recovery will not occur after 20 minutes of complete asphyxia unless positive pressure ventilation is provided by that stage. However in another experiment he showed a remarkable recovery of a neonatal lamb fetus subjected to atraumatic cord clamping in utero for a period of 40 minutes, by which time the blood pressure and heart rate were extremely low. When the cord was unclamped there was a rapid recovery of the heart rate and blood pressure to previous levels [10]. These fetuses remained in utero with a functioning placental circulation. After the expulsion of the fetus, the uterus contracts leading to placental separation from the uterine wall and the loss of its respiratory function. However this change is not instantaneous and a useful level of oxygen within the umbilical vein returning to the neonate continues for at least 90 seconds [11].

More recently a similar experiment was performed on sheep [12]. Complete cord occlusion was limited to 10 minutes. During occlusion there was a profound fetal bradycardia and hypotension which resolved immediately the cord occlusion was released. In clinical practice cord compression will rarely be complete and is commonly intermittent and partial, preferentially obstructing the umbilical venous flow during uterine contractions. Both these studies provide evidence that initial restoration of a good placental circulation is at least as beneficial as ventilation. Although highly effective, PPV in the apnoeic neonate has never been subjected to a randomised trial.

## Bradycardia and hypovolaemia

Both bradycardia and hypovolaemia will inevitably lead to a low cardiac output. Very early cord clamping can cause hypovolaemia [13]. Most newly born infants who are bradycardic and apnoeic or breathing ineffectively will respond to ventilation although some will require chest compression in addition [4]. This may give the impression that early cord clamping is not a serious concern. Dunn emphasised the serious risk for babies with a nuchal cord clamped at birth [14]. These babies will only respond to ventilation after the hypovolaemia is corrected. Rennie teaches that extreme cord compression can lead to severe hypovolaemia in the neonate which requires an emergency transfusion of uncrossmatched O neg blood before the baby will respond to ventilation [15]. A tight nuchal cord leads to acute fetal blood loss which is converted into acute neonatal hypovolaemia by early cord clamping at birth. A tight nuchal cord is associated with neonatal anaemia, the consequence of fetal blood loss. This may lead to a low Apgar and needed PPV resuscitation. There was no evidence of intrapartum hypoxia to explain the low Apgar [16]. In a case controlled analysis Nelson and Grether found a tight nuchal cord was present in an appreciable proportion of children with unexplained spastic quadriplegia [17].

RCOG guidelines state that the tight nuchal cord should be clamped and cut before unwinding the cord from around the neonates neck [18]. Therefore the majority of tight nuchal cords are managed by clamping and cutting. However the somersault manoeuvre will usually allow the body to be delivered through the efforts of the mother with the cord remaining around the neonates neck. At this stage the cord can be unwound and the relief of cord pressure permits the redistribution of blood back into the baby [19,20]. Clamping the nuchal cord is a most extreme form of early cord clamping before the onset of respiration and is usually unnecessary with the somersault manoeuvre which needs to be much more widely taught.

As long ago as 1962 Brady and James reported that whether or not an infant had established spontaneous respirations before cord clamping was more important than the actual interval between birth and cord occlusion. They found that clamping of the umbilical cord before onset of respirations resulted in a rapid and profound bradycardia. However those infants whose cords were clamped at 30 s after birth maintained a heart rate >100 bpm provided they were breathing spontaneously by that time [21]. Bradycardia in the first minutes after birth is often thought to be normal [8] but in a recent series of healthy term births with the cord remaining intact for over 5 minutes the range of heart rates remained well above 120bpm [22].

The response of the fetal heart to hypoxia is bradycardia with a fall in cardiac output. Bradycardia increases the length of diastole so that there is slightly longer during diastole for the reduced oxygen content of the blood to provide oxygen to the myocardium. This is a physiological response to hypoxia. Without accurate and auditable assessment of the condition of the neonate at birth, it is possible that the intervention of early cord clamping may be applied outside the current recommendations without recognition and may be the cause of some babies failing to transition successfully at birth. As explained above cord compression results in redistribution of a volume of blood into the placenta from the baby. Given time after delivery, with the resolution of the cord compression, this redistribution will be reversed. The neonate will restore its physiological volume of blood. If the cord is clamped before the redistribution, it will be irreversibly hypovolaemic. Sometimes the hypovolaemia may be severe enough to significantly compromise the cardiac preload and cardiac output and initially the neonate is indistinguishable from the neonate with severe asphyxia.

### **Chest compression**

When the heart rate falls below 60bpm the cardiac output is unlikely to maintain the circulation of the brain, lungs and coronary arteries adequately and chest compression is recommended. This recommendation also includes those babies in whom asystole is suspected. However when cardiac activity is very low at birth it is likely to be clinically impossible to determine whether or not there is complete asystole. Cord clamping at this stage will result in a marked rise in the afterload of the heart, which could induce asystole in the weakened heart. While the high afterload is unlikely to be sufficient to prevent chest compression providing an adequate output and pressure, it will affect any natural cardiac activity.

Time is required between compressions for cardiac filling but also reduces the cardiac output achieved. In the absence of sufficient preload, the amount of time required to allow sufficient filling of the heart may be more than provides sufficient output. Thus for effective cardiac compression a normal preload and euvolaemia is critical.

An adequate output with external compression does require an adequate preload and leading to adequate filling of the heart. Early cord clamping, which limits the preload is likely to result in a serious reduction in cardiac output even with good chest compression. Concern about the presence of a low resistance placental circulation has been raised which would in theory “steal” the blood flow away from the systemic circulation. “The presence of a persisting low resistance placental circulation may reduce or restrict the increase in diastolic pressure required to restore spontaneous circulation.” [22]. This may be an element but exposure and handling of the umbilical cord will quickly induce constriction in the umbilical arteries, increasing the placental vascular resistance and reducing any placental steal, but will not affect the umbilical venous return. Any blood that does flow to the placenta will be returned via the umbilical vein and the significant hypovolaemia of early cord clamping avoided. Only further animal experiments and clinical experience may determine what is most advantageous in these situations but there is no logic in applying the additional intervention of early cord clamping without evidence of benefit.

Compression ratio should be 3 to 1 and synchronised with ventilation i.e. three compressions followed by one inflation. Chest compression has the effect of compressing the lungs as well as the heart. Provided the pulmonary circulation contains a significant amount of blood, chest compression will drive some of this blood out into the left atrium providing a preload for the left side of the heart. The rest of the preload will be required to come from the systemic venous return, up to 30% of which is made up by the placental cord venous flow. Thus hypovolaemia and the loss of the umbilical venous flow will seriously reduce the effectiveness of chest compression.

### **Cord milking**

Cord milking has been shown to have similar benefits to that of delayed cord clamping in term and preterm neonates [23]. While delayed cord clamping is the non-interventional approach, cord milking is an intervention. It has the effect of quickly transferring a volume of blood, equivalent to the placental transfusion into the neonatal circulation. This transfer occurs via the umbilical vein but it is possible that some transfer also occurs with retrograde flow through the umbilical arteries. The milking of the blood within the umbilical arteries may be under significant pressure and this pressure may be reflected in an increase in central arterial pressure. In the presence of cardiac arrest the aortic valves would prevent any retrograde blood flow back into the heart, and any blood flow generated will go to the systemic circulation. Thus cord milking could, in theory, supplement the circulation directly.

In the relatively rare situation when hypovolaemia is due to fetal blood loss, such as with a ruptured vasa previa, a persistent placental circulation will clearly allow continued blood loss. The clinical diagnosis of fetal blood loss from a vasa praevia should be possible, preparations made for an emergency transfusion of the neonate, and the cord clamped immediately at birth. After clamping, brief cord milking may have a role.

### **Assessment and diagnostic criteria for neonatal resuscitation**

How should the diagnosis of neonatal asphyxia sufficient to require resuscitation be reached. ILCOR recommend the tone, presence of breathing and heart rate are measured. Unless the neonate is crying, shallow breathing may not be easy to detect. In a child, muscle tone is highly dependent upon “consciousness” and birth may render the neonate briefly unconscious. Heart rate is

not well measured or documented in real time during the first minute after birth when decisions are required to be made. Sometimes the apnoea of a neonate at birth is completely unexpected, but more often, from the results of electronic fetal monitoring during labour, the need for neonatal resuscitation is anticipated and preparations made. With the neonatal team in place, assessment by the obstetrician or midwife may be quite cursory before the cord is clamped. ILCOR recommend that the heart rate is the major parameter to determine the condition of the neonate and this should be determined by auscultation. At caesarean section this requires a sterile stethoscope. Is it possible that sometimes the assessment of the neonate is much briefer than the recommendations? How accurately is the heart rate determined during the 30 seconds after birth? How often is the recommendation for auscultation disregarded in the interests of speed? In clinical practice real time documentation during the first minute after birth is never carried out [24]. Audit of intrapartum hypoxia may not be valid using current criteria and there is a need for new thresholds of cord blood gases when immediate cord clamping is not the practice.

## Excessive redistribution of blood volume into the neonatal compartment

This was commonly expressed as a concern for delayed cord clamping in the healthy neonate. Now it is sometimes expressed as a concern in the compromised neonate. The volume of blood which can finally end up in the neonate during a physiological transition is limited. If the whole volume of blood in the placenta is transferred to the baby, based on Farrar studies, it will not be more than an additional 21mls (+/- 11 mls) above the normal physiological blood volume [25]. In reality it is implausible that the whole of the residual placental volume could be transferred into the neonate.

With early cord clamping there will always be a degree of hypovolaemia in the neonatal compartment but the extent of this is highly variable [25]. While the extent of the hypovolaemia is highly variable, it is impossible to determine the precise volume in clinical practice. In case reports the diagnosis of significant hypovolaemia is reached partly by exclusion and partly by the response of the neonate to volume replacement [14]. Volume replacement must be estimated and titrated according to response. The risk of under-replacement or over-replacement depends on clinical experience and requires cannulation which takes time and skill. The neonate is deficient in blood but the fluid replacement is normally crystalloid or colloid. When blood is used it is cold uncrossmatched O neg blood. Allowing a physiological redistribution avoids all this uncertainty.

There is evidence that blood is transferred from the placenta into the fetal compartment as a result of hypoxia [26-28]. Whether or not this is true is not relevant to the question of cord clamping and resuscitation. As a result of the volume transfer these babies may indeed tolerate early cord clamping. If the transfer has occurred there will be little or no further transfer after birth but as explained above the neonate cannot receive an excessive blood volume. If the transfer has not occurred, early clamping will result in neonatal hypovolaemia. However it is impossible to know if transfer has occurred and the only rational management is to delay clamping while resuscitation is underway.

## Height of the neonate in relation to the placenta

Provided there is some pressure gradient between the placental bed and the neonate, the final volume of the placental transfusion is not affected but the rate of this redistribution of blood into the baby is affected [29]. Elevating the baby well above the mother, leading to a negative pressure gradient, must be avoided as this leads to a loss of blood from the baby. The placental transfusion will still occur when the neonate is up to 20 cms above the placenta (e.g. on the mother's abdomen skin to skin) but the rate of transfer is slow. If the neonate is kept at or below the level of the placenta, the pressure gradient is maximised leading to a more rapid transfer of blood volume. In a neonate that has suffered an acute and severe hypovolaemia (from cord compression), the rate of redistribution of blood back into the baby should be rapid allowing a rapid increase in preload and cardiac output. In the same way an oxytocic does not affect the final volume of the redistribution of blood but does increase the intrauterine pressure and thus the rate of transfer.

## Neonatal volume replacement

Bolus volume replacement is not equivalent to the placental transfusion. Firstly it is given via a syringe and there is no control of the pressure applied to the syringe. Significant over "transfusion" during delayed cord clamping, as explained above, is not possible however it is a real possibility as a result of bolus volume replacement where the volume required is unknown and the pressure gradient poorly controlled. Loss of the placental transfusion also results in the loss of a large number of stem cells, essentially the first natural stem cell transplant [30].

## Consent

Many parents nowadays do not consent to early cord clamping. Whether or not clamping the cord early would amount medicolegally to assault is untested and depends on the legal ownership of the cord, and her baby. However the legality of consent in the UK changed significantly last year [31]. The ruling means that doctors must take 'reasonable care to ensure that the patient is aware of any material risks involved in any recommended treatment and of any reasonable alternative or variant treatments.' Notably there is no requirement for any guidelines to be taken into account.

## Conclusion

Making the default management of the umbilical cord in the neonate consistent avoids the difficult decision on the condition of the neonate to be taken too hastily. Where the skills are available, ventilation with the cord intact is recommended by the WHO [32]. The advantages of DCC for the healthy term neonate are undisputed. The decision for need for ventilation takes time and careful assessment and there is no evidence or logic which suggests the compromised baby will benefit from clamping and resuscitation on a remote resuscitaire. Optimal ventilation and support with the cord intact at the side of the mother does require current equipment to be modified and procedures adapted. Preparation, co-operation between midwives, obstetricians and neonatologists is essential [33-35]. Practice using simulation will improve the effectiveness of the procedure. All this is of great importance but outside the remit of this paper.

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