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Vacuum-assisted delivery: a review

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In 1992, the number of vacuum deliveries overtook the number of forceps deliveries performed in the USA. Most clinical experiences report that the vacuum is safe for both the fetus and the mother when used properly. Correct cup placement on the fetal head and knowing when to abandon the procedure, appear to be key components to conducting a safe and successful vacuum delivery. However, the focus and training that has been afforded forceps deliveries in the past has not been given to the vacuum, because of its perceived 'ease of use'. This apparent lack of understanding has led to increasing numbers of complications associated with its use. In addition, because forceps are being taught less in training programs, fewer and fewer physicians are being trained in the essential skills of operative vaginal delivery. This review is intended to emphasize the correct techniques and skills of vacuum-assisted vaginal delivery in an attempt to increase the success and decrease the complications associated with its use.

Key words: VACUUM-ASSISTED DELIVERIES; OPERATIVE VAGINAL DELIVERY COMPLICATIONS; BIRTH INJURIES

INTRODUCTION

James Young Simpson of Edinburgh is frequently recognized as one of the pioneer physicians to utilize the principle of the modern vacuum device to facilitate a vaginal delivery. However, it was not until the 1950s when Malmstrom introduced a stainless steel metal cup, that the practice of operative vaginal delivery was revolutionized. The acceptance of the vacuum device as a safe alternative to forceps was delayed in the USA as compared to European countries, but as of 1992, the rate of vacuum delivery surpassed the rate of forceps delivery in the USA[1].

However, over the past two decades, the overall rate of operative vaginal delivery has been decreasing, while the rate of Cesarean sections has been increasing. Nevertheless, about 10% of all births in the USA each year are forceps- or vacuum-assisted deliveries[1]. The overall decrease in operative vaginal delivery appears to stem from fear of litigation, patient resistance and diminishing numbers of experienced physicians. As a result, there are fewer and fewer opportunities for younger physicians to be trained. Inadequate training then leads to increased complications, which leads to more fear and patient resistance and so on – it becomes an unfortunate cycle of diminishing returns.

There are fewer physicians willing to teach the 'art' of forceps-assisted delivery, thus the brunt of the operative vaginal delivery is being placed on the vacuum device. However, the perception that the vacuum device is easier to use and requires less skill, leads to less concentrated efforts in learning the essential skills for vacuum delivery, leading to poor technique and less than optimal neonatal and maternal outcomes. Thus, it is important to undertake a full exploration of the literature on vacuum-assisted delivery to incorporate the techniques and guidelines that lead to the greatest success and best outcomes for both mother and baby.

CLASSIFICATION OF DELIVERIES

In February 1988, revisions were made to the forceps classification system of the American College of Obstetricians and Gynecologists (ACOG) (Table 1). The revisions were made to correct the apparent shortcomings of the previous system, reported as the outlet class being defined too narrowly and midforceps class defined too broadly. The revisions instituted three major changes: expansion of the category of outlet deliveries to allow

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Table 1 ACOG's 1988 revised classification of assisted vaginal deliveries according to station and rotation

Type of procedure	Classification
Outlet	Scalp is visible at the introitus without separating the labia Fetal skull has reached the pelvic floor Sagittal suture is in anteroposterior diameter or right or left occiput anterior or posterior position Fetal head is at or on perineum Rotation does not exceed 45 degrees
Low	Leading point of fetal skull is at station $\geqslant +2$ cm, and not on the pelvic floor Rotation $\leqslant 45$ degrees (left or right occiput anterior to occiput anterior, or left or right occiput posterior to occiput posterior) Rotation > 45 degrees
Mid	Station above +2 cm but head engaged
High	Not included in classification

American College of Obstetricians and Gynecologists. ACOG Committee Opinion 71. Washington, DC: ACOG, 1988

limited rotation from the anteroposterior position; restriction of the mid-level to those deliveries above the +2 cm station; and the creation of an intermediate classification of low forceps[2]. Although the original focus of the ACOG classification system was for forceps deliveries, it is important to realize that the same classification should be utilized in operative vaginal delivery. The definitions were created to stratify the risk of maternal and neonatal morbidity in operative vaginal deliveries (forceps- and vacuum-assisted delivery), and thus, should be utilized for both techniques.

The revised system recommended using the level of the leading bony point of the fetal head in centimeters at or below the level of the maternal ischial spines to define the station (0–5 cm), instead of the previously used method of dividing the birth canal into thirds (0–3+). In this system, 'engagement' implies that the biparietal diameter (BPD) has passed through the pelvic inlet and that the leading point of the fetal head is at least at the level of the ischial spines (0 station). However, the vaginal examination can be misleading in infants who have significant molding. Thus, in addition to the vaginal assessment of station, one should perform an abdominal examination as defined by Crichton in 1974[3]. This method allows the practitioner to evaluate the amount of fetal head – divided into fifths – that is palpable above the pelvic brim. No more than two-fifths of an unmolded fetal head should be palpated above the pelvic brim once the occiput has reached the ischial spines. If more than two-fifths of the fetal head is palpable above the pubic symphysis, regardless of station according to the vaginal examination, the fetus should be regarded as unengaged and an operative delivery should be avoided.

PATIENT SELECTION

The selection of candidates for vacuum-assisted vaginal delivery is of the utmost importance. Even when a valid indication for expediting the birth of the fetus exists, a number of other factors that may influence the outcome must be assessed and evaluated prior to attempting the assisted delivery. These factors can be grouped into four general categories: the history of the pregnancy and labor; the mother's condition; the fetus's condition; and the operator's experience/skills.

It is important to be aware of any risk factors associated with the pregnancy that may affect the progress of labor and a potential operative delivery (e.g. maternal bleeding disorder, history of cardiopulmonary disease, diabetes). In addition, the progress of the first and second stages of labor should be assessed. Recently, the accepted duration of the second stage of labor has been extended, owing to the increasing use of regional anesthesia and continuous fetal monitoring. It is important to realize that the more abnormal the labor process, the higher the rate of complications, regardless of the birthing technique[4,5].

Second, it is important to assess the mother's condition, and her willingness and ability to be a co-operative partner in the procedure. Maternal effort is required in the vacuum delivery. The greater the maternal expulsive efforts, the less traction force will be required to assist the delivery, thus reducing the incidence of complications. In addition to encouraging maternal efforts, the utilization of oxytocin, as necessary, is of the utmost importance. The operator should take full advantage of the contractile strength of the uterus that is available when conducting the delivery.

Third, assessment of the fetus includes an evaluation of the fetal heart-rate (FHR) tracing, as well as an estimated fetal weight (EFW). An assisted delivery in the face of a non-reassuring FHR tracing may be more challenging than one accompanied by a reassuring FHR tracing, because of the possible underlying fetal compromise, as well as the speed in which it is carried out. Although it is not an exact science, estimating the fetal weight remains important. A clearly marked EFW in the patient's chart is essential while practicing in today's increasingly litigious society.

Finally, to achieve optimal results with the vacuum delivery, the operator's level of experience should be appropriately matched to the clinical requirements and potential risks of the procedure. This area is rarely emphasized when reviewing the outcomes of operative vaginal deliveries, but has a significant impact on the results. Therefore, the goal of appropriately training and educating practitioners should be at the forefront of future efforts.

INDICATIONS

The following are indications for vacuum-assisted delivery, but it is important to keep in mind that these should be accompanied by full cervical dilatation and the fetal head being engaged: prolonged second stage of labor; suspicion of immediate or potential fetal compromise; and shortening the second stage of labor for maternal benefit[6].

CONTRAINDICATIONS

Knowing the contraindications to the procedure is just as important as having a valid indication. Contraindications include prematurity, generally defined as 36 weeks, although there are a few papers reporting the use of the vacuum on more premature infants with success[7,8]. However, the evidence is lacking to establish a definitive gestational age threshold at this point. Additional contraindications include a live fetus known to have a bone demineralization or bleeding disorder, the fetal head not engaged in the maternal pelvis, incomplete cervical dilatation, suspected cephalopelvic disproportion (defined as severe or increasing molding of the fetal head and a high presenting part failing to descend despite strong uterine contractions) and unknown position of the fetal head. Practitioners should discard the oft utilized erroneous notion that the vacuum device should be used, instead of forceps, when the position of the fetal head is unknown.[9] Finally, one should be wary of delivering a severely compromised fetus as a 'rescue procedure', because such infants may have already sustained an injury, which could then be blamed on the vacuum device or the vacuum operator.

The utilization of a fetal scalp electrode (FSE) or fetal scalp blood sampling are no longer considered contraindications to the use of the vacuum. Early literature described bleeding from the scalp and cephalohematoma formation after using these techniques to evaluate the infant[10]. However, the more recent literature has not confirmed these associated complications[11,12,13].

THE FLEXION POINT

In 1954, Rydberg reported that the fetal head was completely flexed when the mentovertical diameter pointed in the direction of the pelvic axis and that this diameter joined the sagittal suture 3 cm in front of the posterior fontanelle[14].This flexed position promotes synclitism and flexion of the fetal head, presenting the optimal diameters of the fetal head to the maternal pelvis. In 1976, Bird began stressing the importance of achieving a 'flexing median application' to promote safer and more successful vacuum deliveries[15]. He used this concept to modify the original Malmstrom vacuum cup and showed greater success delivering the malpositioned (occiput posterior and occiput transverse) infants with the vacuum. In 1990, Vacca coined the phrase 'flexion point' to describe the site on the fetal scalp over which the center of the vacuum cup should be placed to achieve a flexing median application[16,17]. Vacca used Rydberg's description and Bird's concepts to simplify and co-ordinate efforts in vacuum delivery and to provide a vacuum equivalent to Dennen's 'pivot point' for the forceps. Thus, the flexion point should be the center point of the vacuum cup when it is attached to the fetal head and is located 3 cm anterior to the posterior fontanelle along the sagittal suture.

MATERNAL COMPLICATIONS

The literature has made clear that, compared to forceps, vacuum-assisted delivery causes less maternal genital tract trauma, less blood loss, and requires less maternal analgesia. Recently, obstetric morbidity relating to postpartum pelvic floor damage and fecal incontinence has gained increasing attention. Fear of fecal and urinary incontinence is frequently quoted when women request an elective Cesarean section. In 2003, in a prospective, randomized clinical trial, Fitzpatrick and colleagues[18], compared differences in anal sphincter function following vacuum- and forceps-assisted deliveries. Their results showed that, in the short term, significantly more women complained of altered continence following forceps delivery when compared with vacuum delivery. These findings were also echoed by Sultan and co-workers[19], who found that 80% of primiparous women delivered by forceps developed sub-clinical sphincter defects, while no defects were identified after vacuum extraction. Thus, there should be little doubt remaining that vacuum assisted delivery is associated with fewer short-term injuries to the maternal perineum compared to forceps delivery. Additional long-term follow-up studies need to be completed and the role of labor itself needs to be evaluated before it is decided that forceps should go the way of the breech delivery.

NEONATAL COMPLICATIONS

The literature comparing the effects of the vacuum and forceps on the neonate has been somewhat mixed. However, it has consistently been reported that the vacuum is associated with a higher rate of cephalohematomas and neonatal jaundice[20,21]. In addition, the original reports of acute scalp injuries and later serious cranial injuries and deaths associated with the use of the vacuum, delayed its adoption in the USA. Several attempts were made to reduce these complications, but the root of the problem – correct cup placement and technique – continued to be lost in the background. In an attempt to decrease fetal scalp injuries, manufacturers began making

vacuum cups with silicone or plastic material, instead of the cold, hard metal of the original Malmstrom cups. The softer material was felt to be more esthetically pleasing and led practitioners to believe that it would decrease the complications associated with operative vaginal delivery[22], although the randomized trials since then have been less promising[23].

In 1998, the US Food and Drug Administration (FDA) issued a public health advisory to all practitioners, urging caution when using the vacuum device, as a result of an increase in the morbidity and mortality reported to the FDA. Proponents of the vacuum were quick to blame the increase in usage – from 3.5% of all deliveries to 5.9% from 1989 to 1995 – however, the FDA felt obligated to issue the advisory because of what they believed were 'avoidable complications'[24].

Scalp effects

Nearly all infants delivered with the assistance of a vacuum will exhibit visible scalp effects to a varying degree at the site of cup attachment. However, the majority are cosmetic, transient and of no clinical significance to the infant, but may cause considerable anxiety to the unprepared parent. The more significant injuries are, more often than not, related to misplacement of the cup, excessive or poorly directed traction, or cephalopelvic disproportion.

Chignon

The chignon or artificial caput succedaneum, is caused by a collection of interstitial fluid and micro-hemorrhages that occur under the cup site. This temporary anatomical defect keeps the vacuum cup more firmly attached to the fetal scalp. The fetal scalp fills the internal diameter of the vacuum cup in a 'key-in-lock' type fashion. It is less pronounced when using soft cups versus rigid, and mushroom-shaped cups, and is an effect not seen with forceps. It is created by the pressure gradient that is established between the vacuum (sub-atmospheric pressure) and the mean arterial pressure of the neonate. The chignon is most obvious immediately following removal of the cup from the scalp, but typically resolves within 12–18 h and importantly has no long-term clinical significance.

Scalp abrasions and lacerations

The reported incidence of scalp abrasions and lacerations ranges from 1 to 82%[25,26]; however, most studies report an overall occurrence rate of approximately 10% for lacerations, the majority of which are superficial and of a minor degree. The wide range of reported incidences appears to be due to inaccurate reporting and a lack of accepted definitions that differentiate scalp lacerations, abrasions and other effects. Clearly outlined definitions of scalp injuries would be helpful in further evaluating the safety of vacuum-assisted delivery. More difficult vacuum deliveries, such as in occiput posterior and transverse positioned infants as well as infants at mid-station, predispose to increased scalp injuries. However, the majority can be avoided with correct cup placement, avoidance of prolonged or misguided traction, and avoidance of cup detachments ('pop-offs').

Retinal hemorrhage

The literature has shown that retinal hemorrhages occur more commonly in infants delivered by vacuum, compared to normal spontaneous deliveries or forceps-assisted deliveries[27,28]. However, the hemorrhage is transient with no apparent long-term developmental or any ophthalmological consequences[29].

Neonatal jaundice

Like retinal hemorrhages, neonatal jaundice has been reported to occur more commonly with vacuum-assisted delivery than forceps or normal spontaneous vaginal deliveries. Nonetheless, it is important to remember that there is no difference between the two operative vaginal delivery techniques when comparing significant jaundice (i.e. hyperbilirubinemia) requiring phototherapy.[30]

Cephalohematoma

A cephalohematoma is a collection of serosanguinous fluid that accumulates under the periosteum of the skull bones, resulting from compression of the presenting part of the fetal head. It is clear that more cephalohematomas occur with operative vaginal delivery than forceps or normal spontaneous vaginal deliveries. The reported incidence of cephalohematomas ranges between 1 and 25%, with an average of approximately 12%[12,23]. However, the clinical significance of the cephalohematoma is minimal. This is because the bleed is confined within the boundaries of the periosteum, limiting the amount of blood that can accumulate in this potential space. Clinically, the edema associated with the cephalohematoma will not cross the suture lines and thus can be differentiated from the more serious complication, the subgaleal hemorrhage. Typically, cephalohematomas resolve within several days, but large ones may take up to several weeks, with no specific therapy required[31].

Subgaleal hemorrhage

On the other hand, a subgaleal hemorrhage is a potentially life-threatening complication of vacuum deliveries and

must be clinically differentiated from a cephalohematoma. A subgaleal hemorrhage is formed by ruptured emissary veins that bleed into the potential space between the scalp aponeurosis, or galea aponeurotica, and the periosteum of the cranial bones. Unlike the cephalohematoma, suture lines do not limit this potential space, thus infants can lose up to 80% of their blood volume into this potential space. Infants may present with symptoms of hypovolemic shock, in addition to the diffuse and dependent swelling of the cranium. The reported incidence of subgaleal hemorrhages is slightly less than 1%[23], but the mortality rate associated with this lesion approaches 25%[32], if untreated. Therefore, it is important that every infant who undergoes a vacuum-assisted delivery receives directed attention to the scalp at periodic intervals to detect evidence of diffuse swelling. This means that the cap placed on most of the neonates born in the USA, to retain body heat, must be removed periodically. In addition, the delivering physician should notify the care-provider of the neonate that a vacuum was used to perform the delivery, so that appropriate follow-up can be made. It should be remembered that subgaleal hemorrhages may not become clinically evident for hours to several days after the delivery[32,33].

WHICH CUP AND WHY?

There are two general categories of vacuum cup: the rigid, mushroom-shaped cups patterned after the original Malmstrom cup; and the soft, bell- or trumpet-shaped cups (Table 2). The original metal cups were reprimanded for being too cumbersome to assemble and too insulting to the fetal scalp. The soft, bell- or trumpet-shaped cups were criticized for being more likely to fail to achieve vaginal delivery and more likely to become detached (pop-off)[23]. The soft cups were touted for causing less fetal and maternal trauma, but the follow-up studies comparing the two types of cup showed that the soft cups may reduce the number of transient or superficial scalp effects, but they did not change the rate of serious complications (e.g. subgaleal hemorrhage) and there were no differences in Apgar scores, cord pH, neurological outcomes, or maternal genital tract trauma[23].

The majority of fetal complications associated with the use of vacuums are caused by misplacement of the cup, not unlike the fetal complications associated with the use of forceps. Thus, it appears that the material of the cup is less important, as long as it allows the operator to place it over the flexion point.

Although the soft cups have generally been better received in the USA, it is important to realize that the combined and centrally located vacuum port and traction stem limits their maneuverability. The operator is unable to move the soft cup more than 1–3 cm laterally or posteriorly, because the stem and height of the cup comes into contact with the maternal tissue. When the infant is at the outlet in an occiput-anterior (OA) position with minimal to no asynclitism, the flexion point lies near the introitus and is accessible by any cup on the market, including the soft cups. However, when there is significant asynclitism, the infant is in the low to mid-pelvis, or is malpositioned (occiput-posterior (OP) or occiput-transverse (OT)), there are only a few select cups on the market that can be properly placed in a flexing median application. Two companies have produced what appear to be the plastic equivalents of the Bird posterior cup (Omni-cup, Kiwi, Clinical Innovations, Murray, UT; M-select cup, Mityvac, Cooper Surgical, Trumbull, CT, USA). Like the Bird posterior cup, these cups can be used in all fetal positions because of their low profile and innovative design, and allow greater maneuverability within the birth canal.

METHOD OF TRACTION

Not unlike traction applied with forceps, correct traction in the axis of the pelvis should be followed while conducting a vacuum delivery. The traction should be applied at the onset of a contraction and maintained smoothly for the duration thereof, with maternal expulsive efforts. Traction efforts should be discontinued between contractions, or if an audible hiss is heard, representing a loss of vacuum. Constant encouragement should be offered to the mother to bear down during the contraction. In addition, the practitioner should inform her of the progress

Table 2 Classification and use of vacuum delivery cups

Soft cups – Indicated for outlet and low OA $< 45^\circ$ assisted deliveries	• Kiwi ProCup and Kiwi OmniCup • Silc, Gentle Vac, and Secure Cups • Silastic, Reusable and Vac-U-Nate cups • Standard MityVac and Soft Touch cups
Rigid 'anterior' cups – Indicated for outlet and low OA $< 45^\circ$ assisted deliveries	• M-Style MityVac cup • Flex cup • Malmstrom, Bird and O'Neil cups
Rigid 'posterior' cups – Indicated for OA $> 45^\circ$, OP and OT assisted deliveries	• Kiwi OmniCup • M-Select Mityvac cup • Bird and O'Neil Posterior cups

OA, occiput-anterior; OP, occiput-posterior; OT, occiput-transverse (adapted from Vacca A. Vacuum assisted delivery; improving patient outcomes and protecting yourself against litigation. *Suppl OBG Manag* 2004:S1–12 with permission)

being made. Conscious effort should be made to avoid any rotating or side-to-side movements, which only increase the incidence of the so-called 'cookie-cutter' lacerations and sudden cup detachments.

In an attempt to encourage correct pelvic-axis traction, a kneeling or seated position is recommended. This position encourages the operator to apply traction in a downward direction and achieve axis traction and progressive descent of the presenting part by maintaining the flexion point on or just behind the axis of the pelvis. Vacca states: 'this position is particularly important when vacuum extraction is attempted before the fetal scalp is visible at the introitus. For low extractions when the scalp is visible or when the head has descended to the outlet, the direction of traction will change progressively in an upward direction until the standing position becomes more appropriate'[34]. It is important to recall that the pelvis and birth canal are situated like a stovetop pipe – the superior portion sits nearly 90° in relation to the inferior portion and this direction should be followed when performing a vacuum delivery. One of the most common mistakes in vacuum deliveries is to direct the traction anteriorly, too soon. This tends to occur because the cup is positioned approximately 6 cm anterior to the BPD (the largest diameter of the fetal head) and once the cup is seen at the introitus, practitioners begin upward traction. Unfortunately, this force is absorbed by the pubic ramus of the mother because the largest diameter, the BPD, has not cleared the maternal pelvis. Thus, the downward traction should be continued slightly longer than anticipated, until the BPD has cleared the maternal pelvis.

With the pulling hand, the operator should maintain a 'finger-tip' position, holding the traction bar in the slightly flexed distal interphalangeal joints with the palm of the hand opened and facing upwards. Sufficient traction for the delivery of the infant can be generated in most cases simply by flexing the fingers that are holding the bar. It is also good practice for the operator to 'tuck' the elbow into the side of the body to help prevent pulling more forcefully with the arm[35].

In the past, a 'three-pull' rule has generally been promoted for conducting operative vaginal deliveries. This was implemented to prevent an excessive number of tractions applied to the fetal scalp and in hopes of reducing complications. However, what is the rush with assisted deliveries if the fetus and mother are tolerating the procedure and progress is being made? In their description of the active management of labor, O'Driscoll and colleagues divided the second stage of labor into two phases[35]. The first is the *descent phase*, in which the fetus traverses through the birth canal to the pelvic floor. The second is the *perineal phase*, which is from the pelvic floor to the delivery of the fetus. Utilizing this concept, attempting to decrease the incidence of pelvic floor injury and acknowledging the increase in regional anesthesia, Vacca suggested a 'three-plus-three-pull rule' when conducting a vacuum-assisted delivery[34]. Vacca maintains that three pulls for the descent phase and three pulls for the perineal phase are acceptable provided that some progress is observed with each pull and that the traction force is not excessive. This method allows the perineum to accommodate the fetal head and may avoid perineal tears or episiotomy extensions.

AUTOROTATION

It is often stated that one cannot rotate an infant with the vacuum. In fact, many have been taught that the only way to deliver an OP (or OT) infant is to pull them out directly OP or rotate them with specialized forceps (e.g. Kiellands). However, it has been shown that if the vacuum cup is placed in a flexing median application – 3 cm anterior to the posterior fontanelle along the sagittal suture – 90% or more of these infants will rotate and deliver in an OA position with normal axis traction[15,34]. This apparent anomaly is made possible by encouraging the optimal diameters of the fetal head to align with the maternal pelvis. It is important to remember that during the process of normal labor the majority of infants enter the pelvis in OP to OT positions, yet 90% of infants are delivered in an OA position. This occurs through the well-known cardinal movements of labor – one of which is internal rotation. Internal rotation occurs during the normal process of labor rotating the fetus from an OT position to an OA position (90% of the time) and an OP position (about 10% of the time). This movement encourages the smallest diameter of the infant's head to present to the maternal pelvis and allow passage with the least amount of force. This process should also take place when assisting the infant with the vacuum – the desire is to realign the asynclitic and/or deflexed fetal head with the maternal pelvis. This encourages the optimal diameters of the fetal head to traverse the birth canal with the least amount of force. Thus, the rotation that occurs is an 'autorotation' process, not a forced one. No attempt should be made to physically rotate the cup on the infant's head because this leads to a greater propensity for lacerations and cup detachments.

KNOWING WHEN TO ABANDON THE PROCEDURE

Although established rules are rarely absolute in the world of medicine, it is important to be aware of guidelines associated with abandoning a vacuum procedure, to decrease the incidence of serious injuries. This is not to imply that all injuries can be avoided; in fact, some injuries may occur prior to the cup being placed[4,5]. However, it is important to realize that using correct techniques and

being willing to abandon the procedure when 'normal' progress is not achieved, can significantly reduce the incidence and severity of injuries. Defining 'normal' progress is the difficult task, but the following guidelines, which have been created after an extensive literature review, should function as a template for clinicians performing vacuum-assisted deliveries.

An adequately trained operator should abort the procedure if no descent of the fetal scalp and skull occur after two tractions or the delivery is not achieved after 'three-plus-three tractions', as described above. It is important to realize that, when descent does not occur, it rarely is due to lack of traction force – the majority of successful vacuum deliveries require 25 lb (11.25 kg) or less.[34] In fact, the main cause of lack of descent with traction is malplacement of the cup (a paramedian and/or deflexing application), poorly directed traction or cephalopelvic disproportion.

Cup detachments or pop-offs were once thought of as a safety mechanism of the vacuum device. This notion originated from earlier forceps studies by Wylie revealing that up to 75 lb (33.75 kg) of force could be applied to the infant's head during a forceps delivery[36]. However, the vacuum detaches from the infant's scalp long before that amount of force can be applied to the infant's head. In laboratory studies, the vacuum detached at a maximum force of approximately 40 lb (18 kg)[37], making it appear 'safer' than forceps. Therefore, practitioners began thinking that the detachment or pop-off prevented them from applying excessive force to the infant's scalp. What they did not realize was that the sudden loss of pressure that occurs during the detachment is a predisposing factor for many of the major complications (subgaleal and intracranial hemorrhages)[27,38]. In addition, as the rate of pop-offs increases, so does the rate of scalp abrasions, lacerations and edema[15,26]. If the traction force required to overcome resistance to descent is greater than the adhesive force of the cup, detachment will occur, regardless of how well the cup is designed or where the cup is placed. For this reason, it is important to minimize the traction force and the number of detachments. Other possible causes of cup detachment that should be considered include poor axis traction, faulty equipment or inadequate vacuum pressure and large caput succedaneums (with soft cups). If one detachment occurs, a thorough evaluation of cup placement and whether or not maternal tissue may have been trapped under the cup should take place prior to considering a second application. It should be remembered that correct cup placement and traction directed along the axis of the pelvis should prevent the majority of detachments.

Arbitrary time limits ranging from 15 min[15] to 45 min[39] have been suggested for vacuum delivery as a protective measure for the fetus against prolonged or excessive traction. However, recent literature has demonstrated that, with efficient uterine contractions and good maternal expulsive efforts, almost all vacuum-assisted deliveries can be completed within 15 min[34] and, if one reaches the 20-min time limit, the procedure should be abandoned unless delivery is imminent.

Finally, one should be wary of attempting forceps delivery after a failed vacuum delivery. The literature has shown that sequential use of instrumental delivery carries a significantly higher neonatal morbidity than when a single instrument is used[40,41]. The ACOG cautions against this technique, but does not list it as an absolute contraindication[6]. The technique has an increased relative risk and thus should rarely be used. It should be limited to cases at the outlet when forceps are considered safe and vacuum failed, owing to inexperience or technical failure. Most importantly, one should always be willing to abandon the procedure and move directly to cesarean section without hesitation.

CONCLUSIONS

The future of vacuum-assisted deliveries will depend on the willingness of practitioners to be trained and to train those who come after them. The use of simulation models, like those being used to train physicians in the management of shoulder dystocia[42], should be implemented in operative delivery training efforts as well. Vacuum-assisted delivery is a good alternative to forceps or a Cesarean section in stalled labor, when used correctly. Placement of the cup over the flexion point is key to presenting the smallest diameter of the fetal head to the maternal pelvis, thus reducing the amount of force required to conduct the delivery. Correct cup selection is also important, especially in the malrotated or asynclitic infants. One should be encouraged to utilize a maneuverable vacuum cup with a low profile that allows correct cup placement (flexing median) in nearly all infants. Axis traction in line with the maternal pelvis is also of the utmost importance and should be stressed when training new physicians. Finally, being willing to abandon the procedure if one of the noted limits is reached, should also serve as a safety measure. If these guidelines are implemented, the success rate of vacuum delivery should increase, the complications decrease, and the litigation associated with assisted deliveries should also decrease. The problems with many of the current studies are that they are retrospective, have short follow-up intervals and confounding factors, and often lack randomization. Therefore, further research is needed to determine the ideal method of instrumental delivery in various clinical settings, especially focusing on the long-term effects of operative vaginal deliveries on the pelvic floor.

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