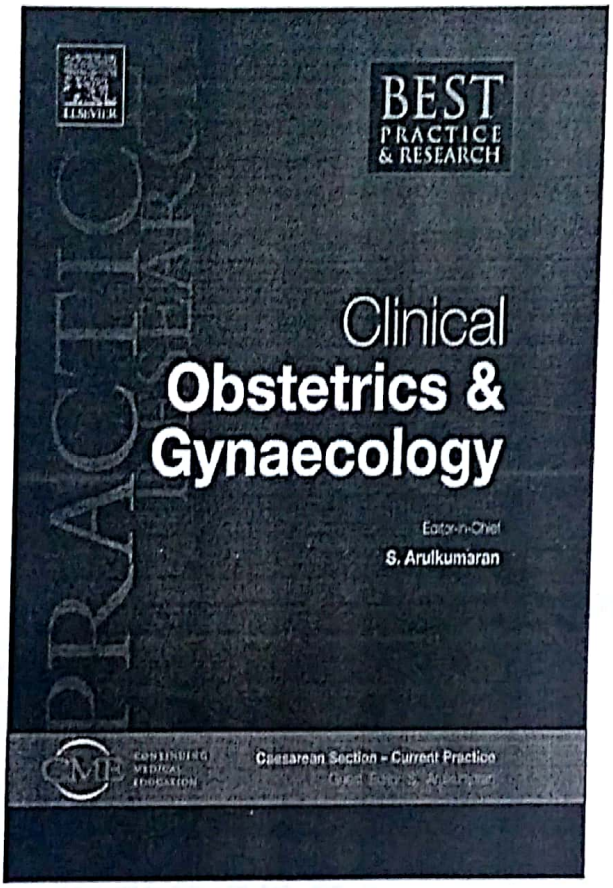

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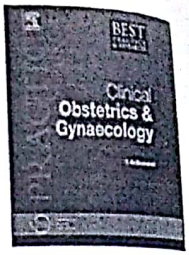

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Surgical techniques for performing caesarean section including CS at full dilatation

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Caesarean section (CS) is probably the most commonly performed procedure in obstetrics. Over the past two decades, caesarean delivery has become more commonly used throughout the world, and this increase has generated a number of controversial issues, including what constitutes a suitable indication and what is the proper surgical technique to perform a CS. Many aspects of the operation as it is commonly performed today are not based on randomised trials or techniques that have been proven to be superior by rigorous study, but instead are the culmination of many years of trial and error. This chapter presents the evidence on surgical techniques for performing CS, including CS at full dilatation.

Introduction

The current caesarean section (CS) rate worldwide is around 10–20%.[1] The indications for CS has also undergone a sea change, there being women who want an elective CS.[2,3] Over a period the surgical technique has also evolved and currently there is a wide range in the surgical techniques being used for performing CSs (evidence level 3) Tables 1 and 2.[3,99] The development of the modern caesarean operation has not been a recent accomplishment but instead it represents a series of innovations over many centuries of trial and error.

Legends and myths about the abdominal delivery of an infant appear in many cultures. One of the earliest Greek myths includes the birth of Aesculapius, who was cut from his mother's abdomen by

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Table 1
Levels of evidence.

Level evidence
1a Systematic review or meta-analysis of randomised controlled trials
1b At least one randomised controlled trial
2a At least one well-designed controlled study without randomisation
2b At least one well-designed quasi-experimental study, such as a cohort study
3 Well-designed non-experimental descriptive studies, such as comparative studies, correlation studies, case–control studies, and case series
4 Expert committee reports, or opinions and/or clinical experience of respected authorities

Apollo, Bacchus and Jupiter.[4] Legend holds that Julius Caesar was also delivered abdominally and the term 'caedare' (Latin verb) means to cut and the children born by post-mortem CSs were called 'caesones'.[5,6]

The earliest authenticated report of a child who survived caesarean birth is Gorgias in Sicily, 508 BC.[7] Gabert and Bey assessed the evolution of the CS by dividing its development into three eras: before 1500, between 1500 and 1877 and from 1878 until the present.[5] Before 1500, references are often clouded in mystery and misinformation. In 1500, Nufer reported to have performed the first successful 'modern' CS, with both the mother and the infant surviving. From 1878 to present, several modifications have been made. The earliest ones were the Porro operation followed by Sanger, etc.[7] Modifications included, not dissecting the uterine serosa, introduction of a silver wire to approximate the myometrium and the use of interrupted silk sutures on the serosal surface.[5] Preoperative antimicrobial preparation was introduced by Lister in 1876. Closure of the abdominal incision slowly evolved from allowing healing by secondary intention, to full closure of the abdominal wall. Johnson first described a lower-segment uterine incision in 1786.[5]

Indications

Indications for caesarean delivery vary depending on the clinical situation, the resources available and the physician's management techniques. There are no definitive algorithms and the decision remains a joint judgement between the physician and the patient, after carefully weighing the pros and cons of a caesarean delivery versus continued labour and/or operative or spontaneous vaginal delivery.

Consent

Consent should always be obtained after counselling. This should include at least indication and possible complications.

Technique

As noted in the historical review at the beginning of this chapter, the caesarean operation has undergone a number of technical changes. However, there are relatively few randomised trials to support many of the commonly used techniques.[8]

Table 2
Grading of recommendations.

Grade strength of evidence
A. Based directly based on level 1 evidence
B. Based directly on level 2 evidence or extrapolated from level 1 evidence
C. Based directly on level 3 evidence or extrapolated from level 1 or level 2 evidence
D. Based directly on level 4 evidence or extrapolated from level 1, level 2 or level 3 evidence

Preoperative evaluation

The preoperative assessment should include a full history and physical examination, past medical and surgical history and indication for CS. In the uncomplicated patient, no preoperative laboratory investigation is needed except for the routine labour and delivery admission investigations. In some cases, as indicated, preoperative consultation with an anaesthesiologist, physician or both should be considered.

Abdominal preparation

Although abdominal preparation and shaving the maternal abdomen the night before have been the norm in the past, but studies show that it actually increases the bacterial count.[9] The Centers for Disease Control and Prevention (CDC) recommends that hair not be removed unless it will interfere with the operation, and if hair is to be removed it is done immediately before the operation with electric clippers rather than shaving.[10] Placing the patient in the left lateral tilt position using either a hip wedge or an operative table with lateral tilt will help avoid uterine compression of the inferior vena cava and foetal bradycardia. Two randomised controlled trials (RCTs) have addressed the impact of abdominal drapes on the incidence of postoperative wound infection but not on infection due to blood spillage. One study described their use as an isolated intervention and found the incidence of postoperative wound infection to be unchanged (evidence level 1b).[11] The other RCT using drapes with repeat disinfection of the skin before closure failed to find any decrease (evidence level 1b).[12] Before the abdominal preparation, a Foley catheter should be placed to monitor urinary output intra-operatively and minimise the presence of the bladder in the operative field.

Skin incision

A number of skin incisions have been used in abdominal deliveries. The most frequently used is the Pfannenstiel incision followed by the midline vertical incision. Other skin incisions used include the Maylard, Cherney, right paramedian and the low transverse. In general, the skin incision should be determined based on maternal body habitus, clinical situation, time available to deliver the infant and skill of the surgeon Fig. 1.

Transverse incisions fall along the Langerhans' lines and therefore should create less pronounced scarring, risk of dehiscence and postoperative pain. Vertical incisions for CS are uncommon now (>1%) (evidence level 3).[3] Midline vertical incisions are generally more haemostatic and require less dissection and therefore, less time from incision to birth than transverse incisions. A meta-analysis of general surgical RCTs has compared midline, oblique and transverse incisions for their effect on postoperative pain, wound infection rates, incisional hernias and dehiscence.[13] Two RCTs ($n = 209$) compared midline and transverse incisions and found that the group with transverse incisions had lower pain scores and required less pethidine for analgesia ($p < 0.001$). Ten RCTs ($n = 3586$) reported on the incidence of wound infection and found no difference between the different types of incisions. Wound dehiscence and incisional hernias were reported in nine RCTs ($n = 2551$) and there was no difference detected (evidence level 1a).[13] A case–control study of 48 cases of fascial dehiscence after CS described risk factors for dehiscence using stepwise logistic regression and did not find transverse incisions to have a lower risk of dehiscence than vertical incisions (evidence level 3).[14] An observational study ($n = 89$) reported on women's perceptions of the cosmetic outcome of scar formation after either percutaneous or subcuticular sutures for CS with transverse sutures being more favoured (evidence level 2b).[15]

In Pfannenstiel after skin incision, there is transverse incision of the sheath, rectus muscles are separated bluntly and the parietal peritoneum is incised is the midline. Care must be taken not to cut the underlying rectus muscles and to avoid the transverse oblique muscle when incising the fascia. During this dissection, one must identify and ligate or electrocoagulate the perforating vessels between the rectus muscles and the anterior fascia. The posterior sheath should be opened high in the operative field to avoid injury to the maternal bladder. Once the peritoneal cavity is entered, the peritoneal incision is extended. In the moderately obese patient, a variation of the Pfannenstiel incision is

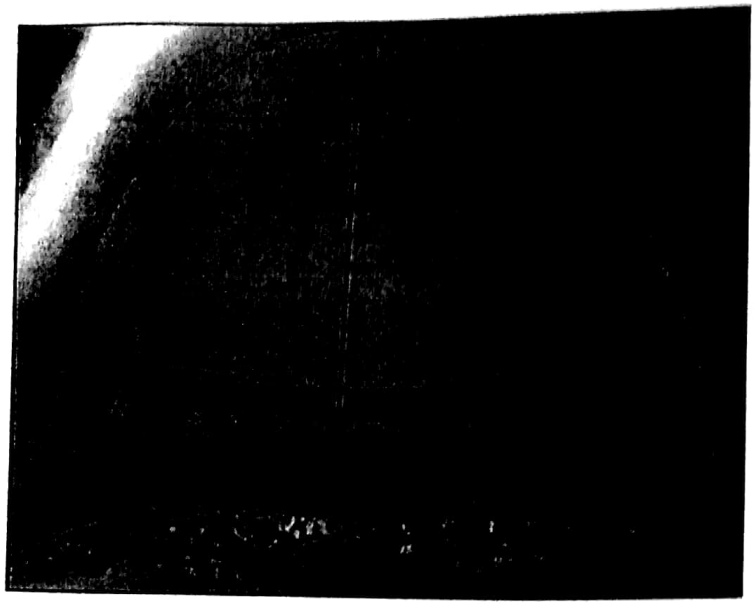

Fig. 1. Abdominal incisions (A - Pfannenstiel incision, B - Joel-Cohen incision and C - Midline vertical incision). A. The Pfannenstiel incision should be made in a curvilinear fashion approximately 2 cm above the pubic symphysis. B. The Joel-Cohen incision should be made in a linear fashion approximately 2–3 cm above the traditional placement of the Pfannenstiel incision. C. The midline vertical incision should be made in the midline and extend from just below the umbilicus to just above the symphysis pubis and may be continued around the umbilicus if more exposure is necessary. D. A right paramedian incision should be made several centimetres to the right side of the umbilicus and somewhat higher than the normal midline vertical incision. Usually, this incision is not recommended now.

performed several centimetres higher than the true Pfannenstiel to avoid placing the incision in the fold created by the abdominal pannus and thereby decreasing the rate of wound complications.

The Maylard and Cherney incisions differ from the Pfannenstiel incision in the manner in which the anterior rectus sheath and the rectus muscles are approached. With the Maylard incision, once the anterior rectus sheath is incised in a transverse fashion, the fascia is not dissected free from the underlying rectus muscles; instead, the inferior epigastric arteries are identified and ligated, and the rectus muscles are incised, usually with electrocautery to minimise bleeding. The Cherney incision is performed in the same manner as the Pfannenstiel and the Maylard incisions except that the rectus fascia is not entered; instead, the rectus muscles are cut free from the symphysis pubis at their tendinous insertion and reflected superiorly. The Joel-Cohen incision is performed in a transverse manner several centimetres above the location of a Pfannenstiel incision and is linear, not curvilinear. The fascia is not dissected off of the rectus muscles, and the peritoneum is entered transversely and bluntly.[16] Four RCTs have compared different transverse incisions for CS.[17,18] Two RCTs compared the Pfannenstiel incision with the Joel-Cohen incision. Both RCTs reported that the Joel-Cohen incision is associated with shorter operating time and reduced postoperative febrile morbidity (evidence level 1b).[19,20] Two RCTs compared Pfannenstiel with Maylard incisions and showed no difference in terms of operative and postoperative morbidity (evidence level 1b).[21,22]

Historically, the midline vertical skin incision has been the preferred incision for CS because of the speed and ease of entry into the peritoneal cavity. Currently, vertical incisions remain useful only in situations such as foetal bradycardia and in the morbidly obese patient. The incision is performed vertically from just below the umbilicus and extended to just above the symphysis pubis and can easily be extended around the umbilicus if exposure of the upper abdomen is required. When making a midline vertical incision, it is important to remember that the linea nigra may not represent the true midline. The incision is carried sharply down to the level of the rectus sheath, which is then incised sharply with the scalpel in a vertical direction. A right paramedian incision is useful in the morbidly obese patient in whom the abdominal pannus is grossly displaced when the patient is placed in the left lateral position. The advantages are that the incision can be continued perpendicular towards the floor of the operating room, with incision of the fascia approximately in the midline, resulting in better exposure for the delivery of the infant.

Recommendations: CS should be performed using a transverse abdominal incision as it is associated with less postoperative pain and an improved cosmetic effect compared with a midline incision [B].

The transverse incision of choice should be the Joel-Cohen incision; subsequent tissue layers are opened bluntly and, if necessary, extended with scissors and not a knife, because it is associated with shorter operating times and reduced postoperative febrile morbidity [A].

In patients undergoing repeat caesarean delivery, the abdominal scar may be revised. In the case of an emergency caesarean section, any scar revision should be performed at the time of abdominal closure. It is also important to remember that the choice of skin incision should be not dictated by the location of a previous scar.

No RCTs have addressed which instruments should be used for skin incision at CS. An RCT that included patients undergoing elective general surgical compared the 'one versus two scalpels technique' (the first scalpel for the skin and the second scalpel for deeper tissue) ($n = 277$) did not detect any difference in wound infection (evidence level 1b).[22] An experimental study showed that scalpels remained sterile after skin incision (evidence level 3).[23]Two general surgical RCTs comparing abdominal entry using a scalpel and electrocautery did not detect any difference in wound outcomes such as infection or strength. However the time required for the incision and blood loss was less with electrocautery (evidence level 1b).[24,25] Another RCT comparing incision using a surgical knife with diathermy at cholecystectomy ($n = 200$) showed that postoperative pain and need for analgesia was less in the diathermy group (evidence level 1b).[26]

Recommendation: The use of separate surgical knives to incise the skin and the deeper tissues at CS is not recommended because it does not decrease wound infection [B].

Bladder flap

Historically, the creation of a bladder flap was advocated before making any uterine incisions. This dissection serves two purposes: it allows better access to the lower uterine segment and it allows the bladder to be retracted out of the operative field. More recently, RCTs have noted that the omission of the bladder flap provides short-term advantages such as reduction of operating time and incision-delivery interval, reduced blood loss and need for analgesics. Long-term effects remain to be evaluated.[27]

Uterine incisions

There are three standard uterine incisions that can be performed for delivery of the foetus: low transverse, low vertical and classical. The specific type of uterine incision should be determined by the surgeon based on gestational age, lie of the foetus and any uterine anomalies. Any special incision must be documented and informed to the patient, as they have a bearing on future pregnancies.

The standard low-segment transverse incision accounts for 90% of all uterine incisions.[28] The low-transverse uterine incision should be made through the thin, non-contractile portion of the lower uterine segment in a curvilinear fashion. A low-vertical incision is made through the non-contractile lower uterine segment in a vertical fashion. Studies have shown that there is no increased risk of uterine rupture in either group as long as the incision remains primarily in the thin, lower-uterine segment.[29]The classical uterine incision is made through the contractile portion of the myometrium above the bladder reflection. Indications for this include inadequately developed lower uterine segment; abnormal foetal lie such as back-down transverse lie or myomas or uterine abnormalities distorting the uterus. Before making the incision, one should identify the round ligaments to properly orient the degree of dextrorotation of uterus and any malformations that might affect the placement of incision.

Intentional extension of the low-transverse incision is necessary in 1–2% of cases.[30] This can be performed by creating a low vertical incision in the midline, 'T-ing the uterine incision', or creating a vertical incision at the lateral aspect of the uterine incision, a 'J-extension'. These are commonly performed for malpresentations, poorly developed lower uterine segment or deep transverse arrest.[30] These extensions are associated with increased incidence of maternal blood loss, broad-ligament haematoma and uterine-artery laceration. Two RCTs have compared sharp versus blunt extension of the uterine incision at CS (evidence level 1b).[27,28] One RCT ($n = 945$) reports that sharp extension is

associated with greater estimated blood loss, greater change in haematocrit, incidence of post-partum haemorrhage and need for transfusion (evidence level 1b).[30] The other RCT ($n = 286$) found no difference (evidence level 1b).[27] This study was however underpowered to detect a difference in outcome.

The RCTs comparing sharp to blunt extension of the uterine incision do not report on incidence of trauma to the neonate; however, there are three descriptive studies report on the incidence of foetal lacerations at CS (evidence level 3). One study was from the UK (evidence level 3) and two of the studies were from the US.[31,32] The UK study reports an incidence of foetal lacerations of 1.5%, which is similar to the US studies (1.9% and 0.74%, respectively). The UK study reported that the incidence of lacerations was independent of type of CS (unplanned or planned), foetal presentation, cervical dilatation and operator grade. One US study reported that the incidence of lacerations increased to 6% with a non-cephalic presentation (evidence level 3).[33]

Recommendations: When there is a well–formed lower-uterine segment, blunt rather than sharp extension of the uterine incision should be used because it reduces blood loss, incidence of postpartum haemorrhage and the need for transfusion at CS [A].

Women who are having a CS should be informed that the risk of foetal lacerations is about 2% [C].

Stapling devices can be used during incision of the uterus to decrease the blood loss from the cut edges of the uterine wall. A systematic review that included four RCTs ($n = 526$ women) reported no difference in the total operating time between groups using and not using a stapling device.[34] Stapling devices increased the time to deliver the baby, but blood loss was less. There was no difference for other perinatal outcomes (evidence level 1a).

Delivery of the foetus

After the uterine incision has been made, the foetal membranes, if still intact, are ruptured with an Allis clamp. During baby delivery, adequate knowledge of foetal lie, presentation, station, degree of flexion and position of occiput is important. Adequate uterine incision and delivery by flexion maintaining an occipto-anterior position are principal. Using the right hand inserted below the head as a 'shoehorn', the head is levered out. If the foetus is in a non-cephalic presentation, leaving the membranes intact until the foetal feet or head can be moved into the uterine incision will increase the ease of delivery. When the foetus is in a cephalic presentation, delivery is performed by the surgeons placing their dominant hand into the uterine cavity and elevating the foetal head into the uterine incision. If the foetus is not in an occiput-anterior position, rotating the head into this position will allow the foetal neck to extend around the upper portion of the incised myometrium and more closely mimic the cardinal movements of vaginal delivery. Breech presentation should be delivered with the same care as in vaginal breech delivery.

Difficulty in baby deliveries:

1. Floating head: A high floating head may result in extension of the uterine wound and delay in delivering the infant. Any of the following manoeuvres may be used:
   –rotation of chin or occiput to the front and application of forceps,
   –Kielland forceps application (Warenski method) with traction on the foetal head as occipito transverse, then rotation to the occipito-anterior position and delivery by extension and
   –vacuum extraction.
2. Deeply impacted head:
   –Deepen the plane of anaesthesia, achieve uterine relaxation if the presenting part has been gripped tightly.
   –Head low position may help to disimpact the foetal head, along with upward pressure on the foetal shoulder by the operator.
   –The surgeon can place a hand in the lower-uterine segment in the standard fashion to cup and then disengage the foetal head. Care must be taken not to flex the wrist, because this often causes extension of the uterine incision caudally towards the bladder and vagina.
   –While the operator's hand is inserted to lever out the head, pressure by an assistant on the foetal shoulder and an attempt to bring the chin anterior can be made. This may be followed by use of one or both blades of obstetric forceps to deliver the head.

–If not delivered, an assistant can place a sterile, gloved hand into the vagina from the introitus and disengage the foetal head from below (increased maternal morbidity).
–If the arm or shoulder has been extruded from the uterine incision, extraction may be achieved by:
(i) Patwardhan's manoeuvre for delivery when the back is anterior - Delivery of one arm, opposite arm, trunk, one leg, the other leg and finally the head is in succession[35–37] and
(ii) Patwardhan's manoeuvre for delivery when the back is anterior - Delivery of one arm, the same side leg, buttock, opposite leg, the opposite arm and lastly the head is delivered[35–37]
–Lower vertical incision may be taken, especially if a constriction ring is suspected.

Once the foetal head is at the uterine incision, mild fundal pressure by the first assistant will encourage the expulsion of the foetal head from the uterus. At this point, the nares and mouth of the foetus should be suctioned, after checking for and reducing any nuchal cord. In special cases such as high floating head, rupture of membranes followed by suctioning of liquor and allowing vertex to descend to incision site, then flexion and delivery should be done.[36] Vacuum or short forceps can also be used. The use of forceps at CS has also been suggested as a method of easing delivery of the foetal head, particularly for preterm infants or when the lower segment of the uterus is poorly formed (evidence level 3).[38] In a small RCT ($n = 44$) of women undergoing planned repeat CS, the subjects were randomised to vacuum, forceps or manual delivery of the foetal head (evidence level 1b).[39] There was no difference between these groups in the incidence of extension of the uterine scar, maternal blood loss or neonatal outcomes. However, women in the vacuum group reported less pain. The trial is however underpowered to evaluate these outcomes (evidence level 1b).

Recommendations: Forceps should only be used at CS if there is difficulty delivering the baby's head. The effect on neonatal morbidity of the routine use of forceps at CS remains uncertain [C].

After the infant is delivered, the cord is doubly clamped and cut, and the infant is handed to the personnel assigned to care for the newborn. Suggested benefits of delayed cord clamping include decreased neonatal anaemia, better systemic and pulmonary perfusion and better breastfeeding outcomes. Possible harms are polycythaemia, hyperviscosity, hyperbilirubinaemia, transient tachypnoea of the newborn and risk of maternal foetal transfusion in Rhesus-negative women.[40] One RCT based in UK that randomised women having a vaginal birth to either early or delayed cord clamping ($n = 554$) showed no difference in the duration of cord adherence and neonatal or maternal outcomes (evidence level 1b).[41] Two RCTs have compared the likelihood of infant anaemia in preterm neonates delivered by CS (evidence level 1b).[42,43] One of the RCTs, from Germany ($n = 40$), reports that delayed cord clamping of 45 s results in a reduced need for packed cell transfusions during the first 6 weeks of life.[42] The second RCT from Australia ($n = 46$) found no difference.[43]

Use of uterotonics

Oxytocin is used to ensure uterine contraction, minimise delay in delivering the placenta, reduce intra-operative blood loss and prevent post-partum haemorrhage. Oxytocin has a direct relaxant effect on vascular smooth muscle and under normal circumstances there is a reflex tachycardia and increased cardiac output that accompanies the transient decrease in blood pressure.[44] Five RCTs have compared the use of different uterotonics such as oxytocin, oxytocin with ergometrine, misoprostol and prostaglandin F2a. One RCT ($n = 40$) compared oxytocin administered as an intravenous bolus of 5 IU compared with intramyometrial injection of 20 IU. The intramyometrial injection was associated with more hypotension (evidence level 1b).[45] Another RCT ($n = 321$) comparing different oxytocin infusion concentrations (20 vs. 160 IU l^{-1}) showed that the lower concentration group required additional uterotonics (39% vs. 19%, $p < 0.001$) with no difference in the incidence of hypotension (evidence level 1b).[46] One small RCT ($n = 40$) compared oxytocin to misoprostol orally and found no difference.[45] However, misoprostol has not been found to be as effective as oxytocin for preventing post-partum haemorrhage in large multicentred RCTs (evidence level 1b).[47] Another RCT ($n = 60$) compared prophylactic administration of intravenous oxytocin and intramyometrial prostaglandin and detected no difference in mean estimated blood loss (evidence level 1b).[48] Two published RCTs ($n = 694$; $n = 40$) have compared 100 μg carbetocin (longer half-life of 40 min) with an 8-h oxytocin infusion.[49,50] Only one RCT ($n = 57$) measured estimated blood loss

and there was no difference detected (evidence level 1b) while the other reported need for additional oxytocic(s).[49,50]

Recommendations: Oxytocin 5 IU by slow intravenous injection should be used at CS to encourage contraction of the uterus and to decrease blood loss [C].

The delivery of the placenta may be accomplished either by manual extraction or by awaiting spontaneous delivery. Nine RCTs have studied the effect of method of placental removal.[51] The methods of placental removal described in each of the RCTs are manual removal of the placenta compared to controlled cord traction or spontaneous separation of the placenta. Eight of the RCTs considered blood loss and endometritis and one RCT looked at foeto-maternal haemorrhage, which showed that foeto-maternal transfusion does not increase by manual removal of the placenta (evidence level 1b).[52–54] A meta-analysis of five of the RCTs that reported data for endometritis was undertaken, which showed an increased incidence of endometritis with manual removal of the placenta (evidence level 1a). In four of the six RCTs all women received prophylactic antibiotics. In one RCT no antibiotics were given[29] (evidence level 1b) and in the other there was variable use[57] (evidence level 1b). Meta-analysis of these showed no difference between manual removal and spontaneous separation of the placenta (evidence level 1b).[29,53–60] Three RCTs reported on the effect of changing gloves after manual removal of the placenta and found no difference in the likelihood of post-CS endometritis[57] (evidence level 1b).

Recommendations: At CS, the placenta should be removed using controlled cord traction and not manual removal as this reduces the risk of endometritis [A].

Once the placenta has been delivered, the uterus may be either exteriorised or left *in situ* to be repaired. Blood loss is not significantly different with either method.[61] Exteriorisation of the uterus allows better visualisation of the adnexal structures and increases the ease with which tubal ligation can be performed. Four RCTs compare exteriorisation to intraperitoneal repair.[58,59] All four RCTs report on blood loss and wound infection; however, this is measured differently across the trials (such as total units of blood transfused in each group, mean change in haematocrit per group, perioperative change in haemoglobin and mean drop in haemoglobin between the two groups). Three RCTs detected no difference in blood loss between the groups[58,59] (evidence level 1b), the fourth RCT detected a reduction in haemoglobin drop if the uterus is exteriorised. However, there was no difference in blood-transfusion rates or surgeon's estimates of blood loss[59] (evidence level 1b). The meta-analysis of this outcome showed no difference in rate of blood transfusion between the two groups (evidence level 1b). One RCT assessed nausea, vomiting, sensation of tugging and pain scores at the end of the procedure and found no difference between the two groups. However, two women in the exteriorised group had their epidural converted to general anaesthetic due to pain[59] (evidence level 1b). Daily pain scores were measured from day 1 to day 5 postoperatively. Pain scores were higher in the exteriorisation group on day 3[58,59] (evidence level 1b).

Recommendations: Intraperitoneal repair of the uterus at CS should be undertaken. Exteriorisation is not recommended as it is associated with more pain and does not improve operative outcomes such as haemorrhage and infection [A].

Uterine closure may be performed with either a single- or double-layer closure. In a single-layer closure, the surgeon should be careful to include all layers of incised myometrium, taking care to avoid including excess decidua and serosa. Single-layer closure using a running locking stitch has been shown to be associated with decreased operative time. A systematic review comparing single- versus two-layer suturing for closing the uterine incision at CS showed a shorter mean operating time of 5.6 min and fewer haemostatic sutures in the one-layer closure group (evidence level 1a).[62,63] In another RCT all the women had hysterography to determine integrity of the uterine scar 3 months after the CS (evidence level 1b).[64] In the case of two-layer closure, 82% had either a major or minor scar deformity and in one-layer closure scar deformity was lower (26%). The method of randomisation in this RCT is unclear and the clinical significance of the hysterography findings as an outcome measure is uncertain. One RCT ($n = 188$) found no difference in operating time (evidence level 1b) and the other ($n = 200$) found a decrease in operating time with single-layer closure of the uterus (evidence level 1b).[64,65] These four RCTs used slightly different methods of single-layer closure. None of the RCTs directly compared locked versus unlocked sutures. Concern about the use of single-layer closure of the uterus and scar rupture in future pregnancies have been raised by a cohort study ($n = 2142$) that reported an increase likelihood of uterine rupture in women who had had a single-layer closure of the

uterus[66](evidence level 2b). Follow-up of the women recruited in one of these RCTs has also been reported.[67]Length of labour, mode of birth, incidence of uterine scar dehiscence and other labour outcomes were not significantly different between those women who had had previous one- or two-layer closure[67](evidence level 2a). Closure of the uterus is currently being studied in a large UK RCT (CAESAR).[68]This study says that given the relatively low incidence of uterine rupture (0.4–0.6% for women undergoing a trial of labour vs. 0.2% for those having elective repeat caesarean) and dehiscence (1.1%), attempts to detect differences in these outcomes between different surgical techniques with adequate power is challenging.[69,70]It further states that one large observational study has looked at this outcome and found an association with previous single-layer uterine closure.[66]

Recommendations: The effectiveness and safety of single-layer closure of the uterine incision is uncertain. Except within a research context, the uterine incision should be sutured with two layers [B].

Chromic catgut has been the suture of choice for closure of the uterine incision by many obstetricians for a number of years. However, it is absorbed by phagocytosis and results in inflammation while synthetic absorbable suture, such as polyglycolic acid or polyglactin, is decomposed by hydrolysis with decreased inflammation, as well as increased suture strength.[66]

After the uterus is closed and has been returned to the peritoneal cavity, irrigation can be employed. Routine irrigation in low-risk populations does not reduce intrapartum or post-partum maternal morbidity.[67] Next, attention should be paid to ensure that the operative field is haemostatic, with special attention to the uterine incision and bladder flap and to the rectus muscles.

Closure of the peritoneum (visceral and parietal) has formed part of standard surgical practice and is aimed to restore anatomy, reapproximate the tissues and reduce infection by forming an anatomical barrier. A systematic review comparing non-closure with closure of the peritoneum at CS included four RCTs ($n = 1194$) (evidence level 1a).[71] Two RCTs compared closure to non-closure of both visceral and parietal peritoneum, one RCT compared closure to non-closure of the visceral peritoneum only and one RCT compared closure with non-closure of the parietal peritoneum only.[72–75] Overall, non-closure of the peritoneum saved operating time with no significant differences in postoperative morbidity, analgesic requirements or length of hospital stay (evidence level 1a).[75] All RCTs consistently found operating times to be less with non-closure while none reported long-term outcomes related to healing, scarring or implications for future surgery.

Recommendations: Neither the visceral nor the parietal peritoneum should be sutured at CS because this reduces operating time and the need for postoperative analgesia and improves maternal satisfaction [A].

Fascial closure in a Pfannenstiel incision is performed in a single layer with a synthetic absorbable suture. In patients who have undergone more than one laparotomy through the same scar or in patients who are at increased risk for fascial separation or dehiscence such as diabetic patients or on chronic corticosteroids, the use of a synthetic delayed absorbable suture such as polydioxanone may be preferable because of its ability to maintain suture strength for a longer period of time.[76] For the closure of a vertical fascial incision, a continuous, running, delayed, absorbable suture has been shown to be as effective as the Smead–Jones closure and reduced operating time without increasing morbidity. It is important to remember that a 10-mm zone of collagenolysis occurs surrounding the incision; therefore, sutures should be placed more than 1 cm from the fascial edge to achieve maximal wound strength.[77] The main outcome measures of a meta-analysis (15 RCTs) of 'methods for abdominal-wall closure in midline incisions in general surgical patients' ($n = 6566$) were incidence of hernia, dehiscence, infection, pain and suture sinus formation. Incisional hernias were less common with continuous, slowly absorbable sutures compared with continuous, rapidly absorbable sutures or non-absorbable sutures while wound pain and sinus formation were more common with non-absorbable sutures (evidence level 1a).[78] A meta-analysis of RCTs comparing mass versus layered closure of midline incisions in general surgical patients found less incisional hernias and dehiscence with mass closures (evidence level 1a).[79]

Recommendations: In the rare circumstances that a midline abdominal incision is used at CS, mass closure with slowly absorbable continuous sutures should be used [B].

The subcutaneous tissue may be closed with an absorbable suture or simply reapproximated by closure of the skin. Two RCTs randomised all women undergoing CS to suture or non-suture of the subcutaneous tissue space. One RCT found no difference in terms of wound infection or risk of wound

separation (evidence level 1b).[80] The other RCT reported suturing to be protective against wound separation; however, the method of randomisation and hence the quality of the RCT is not clear (evidence level 1b).

Recommendations: Routine closure of the subcutaneous tissue space should not be used, unless the woman has more than 2 cm subcutaneous fat, because it does not reduce the incidence of wound infection [A].

Five RCTs ($n = 1211$) have compared the routine use of superficial wound drains in CS to their selective use (evidence level 1b).[81] There was no significant difference in wound infection, formation of haematoma, duration of hospital stay or need for analgesia between the groups. In another study, group 1 had suture closure of subcutaneous tissue, group 2 had a subcutaneous closed suction drain and group 3 (control) had neither.[81,82] The use of subcutaneous drain was associated with reduced incidence of wound complications. This is a small trial and these findings could be due to chance (evidence level 1b).[82]

Recommendations: Superficial wound drains should not be used at CS because they do not decrease the incidence of wound infection or wound haematoma [A].

Skin closure may be accomplished by either a subcuticular stitch or staples. The subcuticular stitch has been associated with less immediate postoperative pain and more cosmetically appealing at 6 weeks when compared to the stapling device. A systematic review that includes one RCT ($n = 66$) compares subcuticular polyglycolic suture with staples for closure of a Pfannenstiel skin incision (evidence level 1b).[83] They found that women with wounds closed using staples had more postoperative pain and the cosmetic effect was less favourable (evidence level 2a).[84]

Recommendations: Obstetricians should be aware that the effects of different suture materials or methods of skin closure at CS are not certain [C].

Postoperative care

There is little literature to support any specific postoperative regimen in post-caesarean patients. In the first hour after CS, the patient should be monitored closely in a recovery area where urine output, pulse, blood pressure, respirations and any evidence of bleeding can be closely observed; if the patient remains stable and without complication, she may then be transferred to the post-partum ward. Once any nausea and vomiting has abated, the patient should be encouraged to take fluids orally, followed by solid food no later than the first postoperative day[15] Early ambulation should be encouraged as this will decrease the incidence of pulmonary complications such as atelectasis and facilitate removal of bladder catheters, therefore decreasing catheter-associated urinary tract infections. In the uncomplicated patient with adequate urine output, the catheter should be removed no later than the first postoperative day. Routine laboratory studies are probably unnecessary in most post-caesarean patients who have no unexpected symptoms. The wound should be cared for in the standard manner and staples can be removed on the fifth to seventh postoperative day depending on the incision.

Special situations

CS at full dilatation

Women in the second stage of labour may require caesarean delivery despite a fully dilated cervix. In the United States, an observational study by the National Institute of Child Health and Human Development (NICHD) Maternal Fetal-Medicine Units Network (MFMU) revealed that among a total of 11,981 primary caesarean deliveries in 13 participating centres across the US between January 1999 and December 2000, 2716 cases (22.7%) were performed in the second stage of labour[85] Several studies have also shown a decreasing trend of instrumental vaginal delivery and an increasing trend of CS in the second stage of labour.[86]

Timely second-stage CS reduces neonatal trauma, but whether it reduces birth asphyxia remains a debate.[87] For the mother, second-stage CS is associated with increased risk for surgical injury, including major haemorrhage, bladder trauma, extension tears of the uterine angle, broad-ligament haematoma, longer surgery time and hospital stay and increased postoperative fever.[88,89] In the

long run, there is evidence of possible involuntary subfertility and reduced likelihood of vaginal delivery in future.[8] Therefore, CS performed in the second stage of labour is not without risk and case selection is extremely important.

Indications

Failure to progress

In the *UK National Sentinel CS* audit report, of the 35% of CSs for singleton pregnancy performed for failure to progress in labour, 25% were done at full cervical dilation. In 55% of these cases, CS was performed without attempting instrumental vaginal delivery and where attempted, the failure rate was 35% for ventouse and 2% for forceps.[88] There is reluctance to use both types of instruments, because failure of both makes subsequent CS more difficult with impaction of the foetal head deep in the pelvis.

The following maternal and foetal risk factors are associated with increased chance of requiring second-stage CS for failure to progress:

1. maternal body mass index (BMI) above 30 kg m^{-2}.
2. station at ischial spines.
3. neonatal birth weight >4.0 kg.
4. foetal malposition at full dilatation – risk increased by nearly twofold for occiput-transverse and more than fourfold for occiput-posterior positions.[89]

Foetal macrosomia is an independent risk factor for failed ventouse and forceps delivery.

Breech presentation

For a term breech foetus, planned CS is safer than vaginal birth with respect to immediate neonatal outcomes.[90] The benefit of emergency caesarean delivery is less clear when a mother presents with an unexpected breech in advanced labour with full cervical dilatation. Undiagnosed breech presentations are more likely to deliver vaginally than those diagnosed antenatally, with comparable short-term neonatal outcomes.[91] Even when the estimated foetal weight is over 4 kg, only 2% of undiagnosed breech-presenting foetuses require CS at a fully dilated cervix. Nevertheless, women may be advised to undergo an emergency second-stage CS section by an obstetrician inexperienced in vaginal breech delivery.[88]

Second twin

There is an increasing rate of CS for delivery of the second twin after vaginal birth of the first twin.[92] Some of the common reasons are non-vertex presentation of the second twin, foetal distress, cord prolapse and placental abruption. It has been found that if the second twin is 25% larger than the first, the risk of caesarean delivery would be significantly increased.[93] After vaginal delivery of the first twin, the second twin's risk of hypoxia is five times greater.[93] It is estimated that two-thirds of these CSs are avoidable and are due to operator inexperience, such as the inability to perform internal version and breech extraction of a malpresenting second twin or poorly timed rupture of membranes leading to premature cervical contraction.[88]

Better training in instrumental delivery reduces unnecessary caesarean delivery in the second stage of labour.[88] A consensus statement by an American Congress of Obstetricians and Gynecologists taskforce has recommended the provision of improved training in operative vaginal delivery in the interest of reducing the caesarean delivery rate. When attempting vaginal instrumental delivery, one should avoid excessive pulls and a duration of <10 min instrumentation before resorting to CS for failed vaginal delivery.[94]

A pilot study has demonstrated foetal head engagement both dynamically and objectively in the second stage of labour by the use of intrapartum translabial ultrasound (ITU). During maternal pushing, three parameters were assessed by ITU: (1) descent (subjectively judged as 'yes' or 'no'); (2) whether the widest part was below the infrapubic line; and (3) head direction. Eleven of the 20 vacuum deliveries with the head-up sign (head pointing ventrally) and objective descent of the foetal head below the infrapubic line, both noted at the height of pushing, resulted in successful instrumental vaginal delivery. Lack of descent or lack of passage below the infrapubic line and horizontal or downward head

direction were poor prognostic signs. Therefore, ITU may have a role in helping to decide whether to have a trial of instrumental vaginal delivery or to proceed to second-stage CS directly.[95]

To conclude, second-stage CSs are not rare and could reduce birth trauma of instrumental delivery. On the other hand, second-stage CSs are not without risks. The key lies in the selection of cases for second-stage CSs, which rest on the awareness of clinical risk factors, better training, presence of experienced obstetricians on site and the potential of using ITU.

Perimortem CS

One of the first indications for CS was for the delivery of the foetus in the case of maternal death. In the event of maternal cardiac arrest with a viable foetus, CS should be initiated early, with the goal of delivering the foetus within 5 min of onset of cardiac arrest. This has been shown to allow neurologically intact survival of all infants delivered. Delivery after 5 min results in increasing neurologic sequelae in surviving infants. Immediate abdominal delivery accomplishes two goals in this setting: removal of the foetus from an extremely hostile uterine environment and increase of maternal blood return to the heart by relieving uterine pressure on the inferior vena cava.[97] It is important to remember that the performance of a perimortem caesarean delivery outside an operating room under non-sterile conditions is not likely to negatively impact maternal survival, because survival to discharge after a witnessed, in-hospital, cardiac arrest is only 3%.

Complications

Maternal mortality

As anaesthesia and operative techniques have improved, CS has become an increasingly safe and common procedure; however, the obstetrician must always bear in mind that it is still a major operative procedure and can be associated with significant mortality and morbidity. Maternal mortality after CS has been estimated to be between 5.81 and 6.1 per 100,000 procedures.[96] Common intra-operative complications include uterine haemorrhage and injury to either the urinary or the gastrointestinal tract. Uterine haemorrhage can be caused by atony, lacerations or retained placenta. Having a rational, well-thought-out approach in dealing with potential uterine atony will allow the obstetrician to address this complication in an effective and timely manner.

Urinary tract injuries

Injury to the urinary tract is a relatively rare. The incidences of bladder and ureteral injury are 0.3% and 0.1%, respectively.[97] Bladder injuries are more common with the use of Pfannenstiel incision and history of previous CS. The most common site for bladder injury is at the dome of the bladder. Laceration of the bladder should be evaluated by first ensuring that the trigone and ureters are not involved by direct visualisation of the ureters through a cystotomy incision. If the trigone is not involved and ureters are functioning, the cystotomy can be closed in two layers. Ureteral injury is less common than injury to the bladder. Evaluation of the ureters can be performed by performing a cystotomy in the dome of the bladder and passing an 8-French ureteral stent. If ureteral stents are not immediately available, 8-French paediatric feeding tubes can be used. Repair of ureteral injuries is performed as indicated by the level of the injury, and consultation intra-operatively with the appropriate specialist is warranted.

Gastrointestinal tract injury

Injury to the bowel at the time of CS is exceedingly rare, <1%.[97] The risk of bowel injury is increased in patients with previous abdominal surgery or adhesions. These injuries should be quickly identified and isolated to minimise contamination of the peritoneal cavity. Injury to the small bowel can be primarily repaired with a two-layer closure using silk or delayed absorbable suture, performed at 90° to the bowel lumen. Larger or multiple lacerations may require resection of a length of bowel.[94] Broad-spectrum antibiotics should be administered in cases of large bowel injury.

Wound infections

Wound infections occur at a rate of approximately 7% after CS when prophylactic antibiotics are not given and 2% with the use of prophylactic antibiotics.[97] These include endomyometritis, pelvic abscess, incisional abscess and cellulitis. The antibiotic of choice for each infection depends on the location of the infection and the suspected pathogen. The rate of uterine infection can be reduced to 5% or less with the use of prophylactic antibiotics given at the time of cord clamp.[98,99]

Conclusion

Over the past several decades the incidence of caesarean delivery has increased dramatically. Although the operation continues to become safer, the incidence of maternal mortality and morbidity is still higher than that of a vaginal delivery.[99] Continued efforts on the part of the obstetrician must be made to ensure that these are not performed for inappropriate indications. Continuing research is required to evaluate the techniques of the caesarean operation and the safety of elective, primary caesarean delivery.

Practice points

1. CS should be performed using a transverse abdominal incision as it is associated with less postoperative pain and an improved cosmetic effect compared with a midline incision [B].
2. The transverse incision of choice should be the Joel-Cohen incision; subsequent tissue layers are opened bluntly and, if necessary, extended with scissors and not a knife, because it is associated with shorter operating times and reduced postoperative febrile morbidity [A].
3. The use of separate surgical knives to incise the skin and the deeper tissues at CS is not recommended because it does not decrease wound infection [B].
4. When there is a well-formed lower uterine segment, blunt rather than sharp extension of the uterine incision should be used because it reduces blood loss, incidence of post-partum haemorrhage and the need for transfusion at CS [A].
5. Women who are having a CS should be informed that the risk of foetal lacerations is about 2% [C].
6. Forceps should only be used at CS if there is difficulty delivering the baby's head. The effect on neonatal morbidity of the routine use of forceps at CS remains uncertain [C].
7. Oxytocin 5 IU by slow intravenous injection should be used at CS to encourage contraction of the uterus and to decrease blood loss [C].
8. At CS, the placenta should be removed using controlled cord traction and not manual removal as this reduces the risk of endometritis [A].
9. Intraperitoneal repair of the uterus at CS should be undertaken. Exteriorisation is not recommended as it is associated with more pain and does not improve operative outcomes such as haemorrhage and infection [A].
10. The effectiveness and safety of single-layer closure of the uterine incision is uncertain. Except within a research context, the uterine incision should be sutured with two layers [B].
11. Neither the visceral nor the parietal peritoneum should be sutured at CS because this reduces operating time and the need for postoperative analgesia and improves maternal satisfaction [A].
12. In the rare circumstances that a midline abdominal incision is used at CS, mass closure with slowly absorbable continuous sutures should be used [B].
13. Routine closure of the subcutaneous tissue space should not be used, unless the woman has more than 2 cm subcutaneous fat, because it does not reduce the incidence of wound infection. Superficial wound drains should not be used at CS because they do not decrease the incidence of wound infection or wound haematoma [A].
14. Obstetricians should be aware that the effects of different suture materials or methods of skin closure at CS are not certain [C].

Research agenda

1. Research is needed to determine the effect of CS compared with vaginal birth for women with a preterm breech presentation that is diagnosed in the second stage of labour.
2. RCTs are required to determine the effectiveness of adhesive drapes at CS in reducing blood spillage and cross infection and improving safety for staff in the operating room.
3. RCTs are needed to evaluate the effectiveness of incisions made with diathermy compared with surgical knife in terms of operating time, wound infection, wound tensile strength, cosmetic appearance and women's satisfaction with the experience.
4. RCTs are needed to determine the effect of delayed cord clamping on neonatal outcomes including transient tachypnoea of the newborn and risk of maternal foetal transfusion in Rhesus-negative women for term and preterm births.
5. RCTs are required to determine the effectiveness of mass closure compared to layered closure of the abdominal wall incision at CS particularly for transverse abdominal incisions.
6. Research is required to assess the effect of the various surgical techniques for CS on future surgery such as repeat CS and the incidence of complications during future surgery such as hysterectomy and urogynaecological procedures.
7. RCTs are needed to determine the effect of wound drainage of postoperative morbidity especially in women more at risk of this outcome such as obese women.
8. RCTs are needed to determine the effect of staples compared to subcuticular sutures for skin closure at CS on postoperative pain and cosmetic appearance.
9. What is the most effective antibiotic to prevent maternal infectious morbidity post-CS when given prior to incision?

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