OBSTETRICS

Evidence-based surgery for cesarean delivery: an updated systematic review

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The objective of our systematic review was to provide updated evidence-based guidance for surgical decisions during cesarean delivery (CD). We performed an English-language MEDLINE, PubMed, and COCHRANE search with the terms, cesarean section, cesarean delivery, cesarean, pregnancy, and randomized trials, plus each technical aspect of CD. Randomized control trials (RCTs) involving any aspect of CD technique from Jan. 1, 2005, to Sept. 1, 2012, were evaluated to update a previous systematic review. We also summarized Cochrane reviews, systematic reviews, and metaanalyses if they included additional RCTs since this review. We identified 73 RCTs, 10 metaanalyses and/or systematic reviews, and 12 Cochrane reviews during this time frame. Recommendations with high levels of certainty as defined by the US Preventive Services Task Force favor pre-skin incision prophylactic antibiotics, cephalad-caudad blunt uterine extension, spontaneous placental removal, surgeon preference on uterine exteriorization, single-layer uterine closure when future fertility is undesired, and suture closure of the subcutaneous tissue when thickness is 2 cm or greater and do not favor manual cervical dilation, subcutaneous drains, or supplemental oxygen for the reduction of morbidity from infection. The technical aspect of CD with high-quality, evidence-based recommendations should be adopted. Although 73 RCTs over the past 8 years is encouraging, additional well-designed, adequately powered trials on the specific technical aspects of CD are warranted.

Key words: cesarean delivery, evidence-based medicine, randomized controlled trials, systematic review

Cesarean delivery (CD) is the most common major surgery performed and the 1.3 million women who undergo this operation per year in the United States face substantially increased risks of maternal morbidity and mortality compared with women who deliver vaginally.[1-3]

Previously, Berghella et al[4] summarized 150 randomized clinical trials (RCTs) published from 1960 to 2004 and made evidence based recommendations for each step of CD using US Preventive Services Task Force (USPSTF) definitions. Utilizing similar criteria as their review, our objective was to update and summarize the current body of literature regarding each technical step of CD.

Materials and methods

This review was modeled on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[5] We performed an English-language MEDLINE, PubMed, and COCHRANE database search with the terms, cesarean section, cesarean delivery, cesarean, pregnancy, and randomized trials plus each technical aspect of the operation (eg, lateral tilt, skin cleansing). Because the literature search for previous publication on this topic ended on Dec. 31, 2004, we searched from Jan. 1, 2005, to Sept. 1, 2012.[4]

Each abstract was evaluated by 2 authors (J.D.D. and H.M.F.); all pertinent references from the manuscripts were obtained and reviewed. We included RCTs that reported clinical outcomes. Metaanalyses and Cochrane and systematic reviews were included only if there were additional RCTs performed in our 2005-2012 time frame. After review, evidence-based recommendations using terminology defined by the USPSTF (Table 1)[6] were reported as changed, unchanged, or new compared with the original manuscript. If, in the previous review, a CD technique was assigned a USPSTF grade A or B (technique is recommended) and no new studies were added during our 2005-2012 time frame, we did not change the grade assigned by Berghella et al.[4] If, however, we deemed a new study (or studies) compelling enough (alone or in combination) to alter the grade, we did so by consensus of all the authors.

Results

From 5361 abstracts retrieved by our search, we identified 73 RCTs, 10 meta-analyses or systematic reviews, and 12 Cochrane reviews since Jan. 1, 2005. All technical aspects of CD with evidence-based recommendations and levels of certainty are summarized in Table 2. Additional techniques with RCTs since the review by Berghella et al[4] include the following items: thromboprophylaxis, preoperative vaginal cleaning, indwelling bladder catheterization, Misgav-Ladach

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TABLE 1
Standard recommendation language and quality of evidence according to the method outlined by the USPSTF[6]

Grade	Definition	Suggestions for practice
A	The USPSTF recommends the service. There is high certainty that the net benefit is substantial.	Offer or provide this service.
B	The USPSTF recommends the service. There is high certainty that the net benefit is moderate or there is moderate certainty that the net benefit is moderate to substantial	Offer or provide this service.
C	Note: The following statement is undergoing revision. Clinicians may provide this service to selected patients, depending on individual circumstances. However, for most individuals without signs or symptoms, there is likely to be only a small benefit from this service.	Offer or provide this service only if other considerations support the offering or providing the service in an individual patient.
D	The USPSTF recommends against the service. There is moderate or high certainty that the service has no net benefit or that the harms outweigh the benefits.	Discourage the use of this service.
I	The USPSTF concludes that the current evidence is insufficient to assess the balance of benefits and harms of the service. Evidence is lacking, of poor quality, or conflicting, and the balance of benefits and harms cannot be determined.	If the service is offered, patients should understand the uncertainty about the balance of benefits and harms.
Level of certainty	Description	
High	The available evidence usually includes consistent results from well-designed, well-conducted studies in representative primary care populations. These studies assess the effects of the preventive service on health outcomes. This conclusion is therefore unlikely to be strongly affected by the results of future studies.	
Moderate	The available evidence is sufficient to determine the effects of the preventive service on health outcomes, but confidence in the estimate is constrained by such factors as: • The number, size, or quality of individual studies. • Inconsistency of findings across individual studies. • Limited generalizability of findings to routine primary care practice. • Lack of coherence in the chain of evidence. As more information becomes available, the magnitude or direction of the observed effect could change, and this change may be large enough to alter the conclusion.	
Low	The available evidence is insufficient to assess effects on health outcomes. Evidence is insufficient because of: • The limited number or size of studies. • Important flaws in study design or methods. • Inconsistency of findings across individual studies. • Gaps in the chain of evidence. • Findings not generalizable to routine primary care practice. • Lack of information on important health outcomes. More information may allow estimation of effects on health outcomes.	

USPSTF, US Preventive Services Task Force.

Dahlke. Evidence-based cesarean delivery. Am J Obstet Gynecol 2013.

technique, supplemental oxygen, self-retaining retractors, additional uterine atony prophylaxis measures, placental drainage, manual cervical dilation, and elective appendectomy.

Preoperative preparation

Prophylactic antibiotics

Prophylactic antibiotic regimens comparing single-dose antibiotics with extended-spectrum coverage have been evaluated in 3 new RCTs.[7-9] Specifically, randomized trials using ampicillin/sulbactam,[7] triple antibiotic (ampicillin, gentamicin, and metronidazole),[8] and penicillin and cephalothin[9] did not demonstrate improved outcomes compared with standard cephalosporin prophylaxis. Thus, prophylaxis with a single dose of ampicillin or first-generation cephalosporins, such as cefazolin, should be administered in all women undergoing CD[5,10] (recommendation: A; level of certainty: high; Table 1; unchanged).

Timing of antibiotic administration (preoperative vs after cord clamp) has been evaluated in 4 new RCTs[11-14] and 1 metaanalysis.[15] Two trials[11,14] did not show a difference in maternal morbidity from infection, whereas 2 trials[12,13] demonstrated a significant decrease in maternal morbidity from infection when antibiotics were given preoperatively with no increase in neonatal complications. A metaanalysis of 5 RCTs noted that preoperative administration (15-60

TABLE 2
Evidence-based recommendations for CD

CD technical aspect (comment)	Recommendation[a]	Level of certainty[a]	References
Prophylactic antibiotics			
Yes (all CD)	A	High	7-10,102
Type (ampicillin or first-generation ceph)	A	High	101,103
Administration (systemic)	A	High	101
Multiple doses (NR)	D	High	101
Timing (preskin incision)	A[b]	High[b]	11-15,103-105
Thromboprophylaxis[b]	I[b]	Low[b]	16-18
Lateral tilt	I	Low	106-110
Skin cleansing (CHG or iodine)	I	Low	111,112
Preoperative vaginal preparation (iodine)[b]	B[b]	Moderate[b]	20-22
Supplemental oxygen (NR)[b]	D[b]	High[b]	29,30
Indwelling bladder catheter[b]			
None[b]	C[b]	Moderate[b]	23-26
Immediate or 24-h removal[b]	C[b]	Moderate[b]	27
Adhesive drape (NR)	D	Moderate	113,114
Skin incision			
Type (Pfaanenstiel or Joel-Cohen)	C	Moderate	31-36,115-123
Length	I	Low	123
Second scalpel (NR)	D	Moderate	124
Subcutaneous incision	I	Low	
Fascial incision	I	Low	
Rectus muscle cutting (NR)	D	Moderate	125
Dissection of fascia off rectus	I	Low	37
Opening of peritoneum	I	Low	
Self-retaining retractors[b]	I[b]	Low[b]	41
Bladder flap development (NR)	D	Moderate[b]	38-40,126
Uterine incision			
Type (transverse)	B	Moderate	127,128
Stapling device (NR)	D	Moderate	129-131
Expansion (blunt, cephalad-caudad[b])	A	High[b]	42-44,132,133
Instrumental delivery	I	Low	134,135
Prevention of postpartum hemorrhage			
Oxytocin or placebo (oxytocin[b])	B[b]	High[b]	136
Infusion rate (10-40 IU over 4-8 h)[b]	B[b]	High[b]	46,47,49
Carbetocin or oxytocin	C	Moderate	45,50,137,138
Miso plus oxytocin or oxytocin only (oxytocin)[b]	D[b]	Moderate[b]	51-55
Oxytocin or tranexamic acid[b]	B[b]	Moderate[b]	48,56,57

Dahlke. Evidence-based cesarean delivery. Am J Obstet Gynecol 2013. *(continued)*

TABLE 2
Evidence-based recommendations for CD *(continued)*

CD technical aspect (comment)	Recommendation[a]	Level of certainty[a]	References
Placental removal			
Spontaneous or manual (spontaneous)	A	High	139-145
Glove change (NR)	D	Moderate	139
Placental drainage[b]	I[b]	Moderate[b]	58
Uterine exteriorization (surgeon preference[b])	C	High[b]	59-66,142,146-150
Cleaning of uterus	I	Low	
Cervical dilation (NR)[b]	D[b]	High[b]	67-70
Closure of uterine incision[b]			
Undesired fertility (1-layer)[b]	A[b]	High[b]	44,72,75,151,152
Desired fertility[b]	C	Moderate	
Decidua/serosa incorporation	I	Low	
Continuous or interrupted (continuous)	B	Moderate	153
Elective appendectomy (NR)[b]	D[b]	Moderate[b]	73
Intraabdominal irrigation			
Saline (NR[b])	D[b]	Moderate[b]	74,154
Peritoneal closure	C[b]	Moderate[b]	75-84,155-165
Rectus muscles reapproximation	I	Low	
Technique of fascial closure			
Running or locked (running, unlocked)	I	Low	
Sharp or blunt needles (blunt)[b]	A[b]	Moderate[b]	84,85,166
Irrigation of subcutaneous tissue	I	Low	
Subcutaneous tissue[b]			
≥2 cm thickness[b]			
Closure or nonclosure (closure)[b]	A[b]	High[b]	167-175
Closure or drain (closure)[b]	A[b]	High[b]	75,87
Closure or drain plus closure (closure only)[b]	A[b]	High[b]	88
Closure of skin			
Staples or subcuticular suture	C[b]	Moderate[b]	89-96,176,177

Parentheses indicate the preferred technique. Other recommendations are from Berghella et al.[4]

CD, cesarean delivery; *Ceph*, cephalosporin; *CHG*, chlorhexidine gluconate; *Miso*, misoprostol; *NR*, not recommended; *TA*, tranexamic acid.

[a] See Table 1 for recommendation and level of certainty definitions; [b] Indicates changed or new recommendations based on this review.

Dahlke. Evidence-based cesarean delivery. Am J Obstet Gynecol 2013.

minutes prior to skin incision) significantly reduced the risk of postpartum endometritis (4% vs 8.8%, relative risk [RR], 0.47; 95% confidence interval [CI], 0.26−0.85) and total morbidity from infection (7.2% vs 14.3%, RR, 0.50; 95% CI, 0.33−0.78), with no significant effect on suspected neonatal sepsis (RR, 1; 95% CI, 0.70−1.42), proven sepsis (RR, 0.93; 95% CI, 0.45−1.96), or neonatal intensive care unit admissions (RR, 1.07 95% CI, 0.51−2.24).[15] These trials support preoperative prophylactic antibiotic administration before all CDs (recommendation: A; level of certainty: high; Table 1; changed).

Thromboprophylaxis

Thromboprophylaxis during CD was not previously reviewed. No clinical trials using compression stockings and/or pneumatic compressions stockings have been conducted nor has there been a comparison of these modalities to heparin. Three RCTs (total n = 267) have evaluated the efficacy of unfractionated heparin[16] or low-molecular-weight heparin.[17,18] Given that the risk of CD-associated venous thromboembolism (VTE) is estimated to be 0.23%,[19]

TABLE 3
Summary of general CD operative techniques

Variable	PKM	JCM	MLM	MMLM
Skin incision	Pfannenstiel[a]	Joel-Cohen[b]	Joel-Cohen[b]	Pfannenstiel[a]
Subcutaneous layer closure	Sharp dissection	Blunt dissection	Blunt dissection	Blunt dissection
Fascia opening	Sharp extension	Blunt extension	Blunt extension	Blunt extension
Peritoneal opening	Sharp entry	Blunt entry	Blunt entry	Blunt entry
Uterine incision	Sharp superficial, then blunt entry	Sharp superficial, then blunt entry	Sharp superficial, then blunt entry	Sharp superficial, then blunt entry
Placenta removal	Manual	Spontaneous	Manual	Spontaneous
Uterine closure	Single layer, interrupted	Single layer, interrupted	Single layer, running	Single layer, running
Peritoneal closure	Closed	Not closed	Not closed	Closed
Fascia closure	Interrupted	Interrupted	Continuous	Continuous
Subcutaneous closure	Not sutured	Not sutured	Not sutured	Not sutured
Skin closure	Continuous suture	Continuous suture	Mattress sutures	Continuous suture

CD, cesarean delivery; *JCM*, Joel-Cohen method; *MLM*, Misgav-Ladach method; *MMLM*, Modified Misgav-Ladach method; *PKM*, Pfannenstiel-Kerr method.

[a] Pfannenstiel skin incision is slightly curved, 2-3 cm or 2 fingers above the symphysis pubis, with the midportion of the incision within the shaved area of the pubic hair; [b] Joel-Cohen incision is straight, 3 cm below the line that joins the anterior superior iliac spines, slightly more cephalad than Pfannenstiel.

Modified from Hofmyr,[36] Naki,[31] and Xavier.[34] Some studies report slight variations to these techniques.

Dahlke. Evidence-based cesarean delivery. Am J Obstet Gynecol 2013.

these trials are collectively underpowered to provide recommendation guidance (recommendation I; level of certainty: low; Table 1; new).

Preoperative vaginal preparation

This type of surgical preparation has been evaluated in 2 RCTs[20,21] and a Cochrane review.[22] In a trial of more than 300 women undergoing nonemergent cesarean section, additional vaginal povidone-iodine scrub in addition to standard abdominal preparation resulted in a lower incidence of postcesarean endometritis (7-14.5%; adjusted odds ratio [OR], 0.44; 95% CI, 0.19−0.99) but not in postoperative fever or wound infection.[20] Another RCT of 300 women using a composite infectious morbidity (postoperative fever, endometritis, sepsis, readmission, wound infection, or complication) as its primary outcome noted a nonstatistically significant decrease (6.5-9%; RR, 0.55; 95% CI, 0.26−1.11) in the vaginal cleansing arm.[21] In a Cochrane review of 4 trials (n = 1198 women), vaginal preparation immediately before cesarean delivery significantly reduced the incidence of postcesarean endometritis (9.4-5.2%; RR, 0.57; 95% CI, 0.38−0.87), especially in women with ruptured membranes (15.4-1.4%; RR, 0.13; 95% CI, 0.02−0.66).[22] Given these findings, preoperative vaginal preparation with povidone-iodine scrub should be considered prior to CD (recommendation: B; level of certainty: moderate; Table 1; new).

Indwelling bladder catheterization

The use or nonuse of an indwelling bladder catheterization at the time of CD was evaluated in 2 RCTs.[23,24] A recent metaanalysis[25] of these trials and 1 prospective nonrandomized control trial (NRCT)[26] was notable for a decreased incidence of urinary tract infection in the uncatheterized group (0.5% vs 5.7%; RR, 0.08; 95% CI, 0.01−0.64[23,24]; 0.6% vs 6.0%, RR, 0.10; 95% CI, 0.02−0.57[26]) and no difference in urinary retention between groups (2 of 345 vs 0 of 345; RR, 5.00; 95% CI, 0.24−103.18[23,24]; 2 of 344 vs 0 of 50; RR, 0.74; 95% CI, 0.04−15.18[26]). Another RCT comparing immediate or 24 hour removal of an indwelling catheter found no significant differences in postoperative urinary retention and a nonsignificant lower incidence of positive urine culture 72 hours postoperatively in the immediate removal group (8.1% vs 11.2%; $P = .489$).[27] Given the low incidence of bladder or ureteral injury reported in the literature (bladder 1.4 of 1000 CD and ureteric injury 0.27 of 1000 CD[28]), these trials were underpowered to detect a difference in these outcomes. In the one study that reported it, operative time was similar in both groups.[24] These findings suggest not placing or early removal of indwelling bladder catheters may be considered during CD (recommendation: C; level of certainty: moderate; Table 1; new).

Supplemental oxygen

Supplemental oxygen for the prevention of CD morbidity from infection has been described in 2 RCTs. Both studies randomized patients to either 2 L of oxygen by nasal cannula during CD only (standard care) or 10 L of oxygen by nonrebreather mask (intervention group) during and for 2 hours after CD,[29,30] and neither trial reported a reduction in morbidity from infection among groups and thus cannot be recommended (recommendation: D; level of certainty: high; Table 1; new).

Intraoperative techniques

Skin incision type

This has been evaluated in the context of general approaches to CD (Pfannenstiel, Joel-Cohen, Misgav-Ladach, modified Misgav-Ladach). These methods are summarized in Table 3 and incorporate multiple components, making assessment of each individual CD technique impossible. Four RCTs comparing Misgav-Ladach–based procedures with Pfannenstiel techniques noted improved operating times and possible cost savings in the former with minimal difference in maternal morbidity.[31-34] A Cochrane review[35] and metaanalysis[36] of 14 trials (n = 2906) noted significantly improved short-term outcomes (less blood loss, less fever, lower duration of postoperative pain) in those techniques using Joel-Cohen–based surgical methods with insufficient data on neonatal or long-term morbidity or mortality (recommendation: C; level of certainty: moderate; Table 1; unchanged).

Dissection of fascia off the rectus muscles

This has been evaluated in one small RCT (n = 120).[37] Nondissection of the inferior rectus fascia was associated with lower decline of pre- and postsurgical hemoglobin levels (−1.2 g/dL vs −1.6 g/dL, $P = .05$) and less pain as determined by the visual analog scale (23 vs 30, $P = .03$). Outcomes such as surgical time and degree of difficult delivery of the fetus were not evaluated (recommendation: I; level of certainty: low; Table 1; unchanged).

Bladder flap

The bladder flap development vs no development has been studied in 2 additional RCTs,[38,39] and closure versus nonclosure of the bladder flap visceral peritoneum has been studied in one RCT.[40] In a trial of 258 women, omission of the bladder flap at primary and repeat CD shortened incision-to-delivery time but did not increase intraoperative or postoperative complications (estimated blood loss, change in hemoglobin level, postoperative microhematuria, postoperative pain, hospital days, endometritis, or urinary tract infection).[38] In a trial of 620 women undergoing CD, visceral peritoneal closure of the bladder flap increased postpartum urinary frequency and/or incontinence, but these symptoms disappeared without treatment within 6 months.[40] Routine bladder flap development and/or visceral peritoneal closure do not appear to provide any immediate advantage during CD, but trials have been underpowered to assess morbidity such as bladder injury and adhesion formation (recommendation: D; level of certainty: moderate; Table 1; changed).

Self-retaining retractors

These were evaluated in one feasibility trial of 231 women during CD.[41] Moreover, this study was not powered to assess any meaningful outcomes such as operative times or surgical site infection reduction (recommendation: I; level of certainty: low; Table 1; new).

Expansion of uterine incision

The expansion of uterine incision has been studied in 2 additional RCTs[42,43] and further summarized in a Cochrane review.[44] Blunt expansion remains preferred to sharp expansion of the uterine incision with decreased maternal morbidity as measured by estimated blood loss and decrease in hemoglobin.[42] In a well-designed trial of more than 800 women comparing blunt, transversal vs blunt, cephalad-caudad expansion, unintended extension (defined as any irregularity in the wound edge that required anything more than the standard uterine closure), and blood loss of more than 1500 mL was significantly higher in the transversal expansion group (7.4% vs 3.7%; $P = .03$, and 2.0% vs 0.2%; $P = .04$, respectively).[43] Thus, blunt cephalad-caudad expansion of the uterine incision is recommended (recommendation: A; level of certainty: high; Table 1; changed).

Prevention of postpartum hemorrhage

The prevention of postpartum hemorrhage using oxytocin infusion, oxytocin bolus, misoprostol, carbetocin, and tranexamic acid has been studied in combination or individually in 13 RCTs since 2005.[45-57] There is no standardized dose of oxytocin infusion used in these trials, thus making direct comparison difficult. Doses of continuous oxytocin infusion ranged from 10 to 40 IU in 1 L crystalloid over 4-8 hours and oxytocin intravenous boluses ranging from 0.5 to 5 IU over 30 minutes in these trials. Two RCTs[47,48] favored continuous intravenous infusion only, whereas 1 trial[49] found additional benefit from routine oxytocin bolus. These studies suggest that oxytocin infusion (10-40 IU in 1 L crystalloid over 4-8 hours) is effective in uterine atony prevention, with unknown benefit from oxytocin bolus. (recommendation: B; level of certainty: high; Table 1; changed).

Misoprostol in combination or in lieu of oxytocin infusion has been evaluated in 5 RCTs.[51-55] Misoprostol (200-800 μg rectal or sublingual) alone was similar in estimated blood loss (EBL) and the need for additional uterotonics as continuous oxytocin infusion in 4 trials.[51-54] Side effects of shivering, pyrexia, and metallic taste in the misoprostol group was noted in up to 57% of women and unique to this group. In another trial, misoprostol plus routine oxytocin infusion reduced the need for additional uterotonic agents during CD (43% vs 26%; RR, 1.3; 95% CI, 1.10–1.50).[55] Misoprostol is not superior to oxytocin in uterine atony prevention with increased side effects of maternal shivering and pyrexia (recommendation: D; level of certainty: moderate; Table 1; new).

Tranexamic acid (10 mg/kg intravenously prior to incision) is an antifibrinolytic and hemostatic agent, and 3 new RCTs have evaluated its use in decreasing blood loss in CD.[48,56,57] In these trials, tranexamic acid significantly decreased intraoperative and postpartum blood loss (100-200 mL). In one trial, the EBL of greater than 1000 mL and the need for additional uterotonics was significantly lower in the tranexamic acid group (2.1% vs 5.8%; RR, 2.7; 95% CI, 1.1–6.3; and 8.5% vs 14.5%; RR, 1.7; 95% CI, 1.1–2.6, respectively)[48] (recommendation: B; level of certainty: moderate; Table 1; new).

Carbetocin, an oxytocin agonist administered in a single dose (100 μg

intravenously after delivery) has been compared with oxytocin in 2 additional RCTs. Although women allocated to Carbetocin required fewer additional oxytocic agents, there was no significant differences between groups in major postpartum hemorrhage, blood transfusion, or fall in hemoglobin[45,50] (recommendation: C; level of certainty: moderate; Table 1; unchanged).

Placental drainage

Placental drainage, the act of allowing fetal blood to egress both passively and actively by milking the umbilical cord after the cord is clamped and cut, has been evaluated in 1 RCT. In 86 women, placental drainage was associated with a significant decrease in fetomaternal transfusion as measured by a postpartum positive Kleihauer-Betke test (6.8% vs 33%; RR, 0.2; 95% CI, 0.065−0.65).[58] However, given the small sample size of the trial, there is insufficient evidence to justify this technique (recommendation: I; level of certainty: low; Table 1; new).

Uterine exteriorization

Uterine exteriorization for hysterotomy repair has been evaluated in 7 additional RCTs[59-65] and summarized in a metaanalysis.[66] When analyzing the pooled data including 3183 women, febrile complications and surgical time were similar between uterine exteriorization and intraabdominal repair. Thus, the decision to exteriorize the uterus should be guided by provider preference (recommendation: C; level of certainty: high; Table 1; changed).

Cervical dilation

After placental removal, either manually or via the use of surgical instruments, cervical dilation has been evaluated in 3 RCTs[67-69] and a Cochrane review (n = 735).[70] There was no difference in morbidity from infection between groups, and hematometra was not assessed in these trials (recommendation: D; level of certainty: high; Table 1; new).

Closure of the uterine incision

Closure of the uterine incision with single- vs double-layer closure has been compared in 1 RCT,[71] 1 metaanalysis,[72] and 1 updated Cochrane review.[44] In the largest randomized trial of CD techniques undertaken to date (n = 3033), participants were randomized to 2 of 3 of the following techniques: single- vs double-layer uterine closure, peritoneal closure vs nonclosure, and liberal vs restrictive subsheath drainage.[74] All of the short-term outcomes including morbidity from infection (primary outcome), surgery duration, pain, the need for blood, hospital readmission, breast-feeding, and transfusion were no different between the groups. The role of a single- vs double-layer closure for reducing a subsequent uterine rupture remains controversial. The evidence that 2-layer closure reduces this risk is derived from cohort or case-control studies in which women were not randomly allocated to 1- or 2-layer closure. Therefore, definitive recommendations regarding subsequent uterine rupture risk are not possible in women with desired future fertility (recommendation: C; level of certainty: moderate; Table 1; changed). In women with undesired fertility, there does not appear to be any benefit of a 2-layer uterine closure (recommendation: A; level of certainty: high; Table 1; changed).

Elective appendectomy

Elective appendectomy during CD performed by the obstetrician/gynecologist has been studied in 1 small RCT.[73] In this trial (n = 93), coincidental appendectomy was associated with a significant increase in operative time by approximately 8 minutes ($P = .03$) with no increase in febrile morbidity (recommendation: D; level of certainty: moderate; Table 1; new).

Intraabdominal irrigation

Intraabdominal irrigation with normal saline before abdominal closure has been evaluated in 1 RCT.[74] The rate of intraoperative nausea was significantly increased (OR, 1.62; 95% CI, 1.15−2.28) in the intraabdominal irrigation group with no difference in estimated blood loss, operating time, intrapartum complications, hospital stay, return of gastrointestinal function, or infectious complications (recommendation: D; level of certainty: moderate; Table 1; unchanged).

Peritoneal closure

Peritoneal closure vs nonclosure has been evaluated in 7 additional RCTs,[71,75-80] 2 metaanalyses,[81,82] and 1 systematic review.[83] Some trials focused specifically on parietal or visceral peritoneum closure, whereas others reported both together. In one recent RCT of 533 women undergoing primary CD randomized to closure vs nonclosure, 50 women in the nonclosure group and 47 women in the closure group were subsequently evaluated intraoperatively at a repeat cesarean.[76] The presence and severity of adhesions were comparable among both groups (60% vs 51%, $P = .31$). In contrast, a metaanalysis including 4423 women retrospectively evaluated intraabdominal adhesion formation among 3 different CD surgical techniques.[81] Of note, these trials were not evaluating peritoneal closure alone, but a subset (n = 1161) of women underwent CD with techniques similar in all steps except closure (Misgav-Ladach) or nonclosure (modified Misgav-Ladach) of the peritoneum. In this cohort, there was an increased risk of intraabdominal adhesions in the nonclosure group (OR, 4.69; 95% CI, 3.32−6.62). Surgeons must balance the advantage of nonclosure in regard to less postoperative fever, less operating time, and reduced hospital stay and understand that limited data suggest parietal peritoneal closure may decrease the risk of future adhesions (recommendation: C, level of certainty: moderate; Table 1; changed).

Sharp vs blunt needles

Sharp vs blunt needles for the closure of tissue layers during CD has been evaluated in 1 additional RCT[84] and 1 Cochrane review.[85] In the RCT, the use of blunt needles was found to significantly reduce the overall risk of glove perforation (7.2% vs 17.5%; RR, 0.66; 95% CI, 0.49−0.89). The Cochrane review analyzed 10 RCTs involving 2961 participating surgeons comparing the usage of blunt needles with sharp needles but was not limited to CD.[85] In the

4 studies focusing on abdominal closure, the use of blunt needles reduced the number of percutaneous exposure incidents (1.3% vs 5.8%; RR, 0.31; 95% CI, 0.14−0.68), translating into an estimated 1 glove perforation prevented for every 6 operations.[85] Blunt needles are effective in reducing needle stick injuries and should be routinely available, accessible, and routinely used in all CDs (recommendation: A; level of certainty: moderate; Table 1; changed).

Subcutaneous closure vs drain

Subcutaneous closure vs drain has been evaluated in 1 RCT[71] and included in a recent metaanalysis.[86] Liberal vs restricted use of subcutaneous drains was not associated with a decrease in morbidity from infection (16% vs 18%; RR, 1.08; 95% CI, 0.92−1.27).[71] A metaanalysis evaluating 6 randomized trials showed that prophylactic drainage was not associated with decreased wound infection (OR, 1.15; 95% CI, 0.70−1.90), hematoma (OR, 1.05; 95% CI, 0.33−3.30), or seroma (OR, 0.44; 95% CI, 0.14−1.43).[86] Subcutaneous closure with or without a drain when the thickness is greater than 4 cm was evaluated in 1 RCT and found no difference in wound morbidity between groups (RR, 1.3; 95% CI, 0.8−2.1).[87] Suture closure of subcutaneous tissue thickness of 2 cm or greater is recommended (recommendation: A; level of certainty: high; Table 1; unchanged), whereas the subcutaneous drain placement, regardless of tissue thickness, does not appear to offer any additional benefit in reducing wound morbidity (recommendation: D; level of certainty: high; Table 1; changed).

Skin closure

Skin closure using staples or subcuticular suture has been evaluated in 5 recent RCTs[88-92] and summarized in 2 metaanalysis[93,94] and 1 Cochrane review.[95] Trials differed in both suture material used for closure and primary outcomes. In a review of 5 RCTs and 1 prospective cohort study, staple closure (n = 803) was associated with a 2-fold higher risk of wound infection or separation compared with subcuticular suture closure (n = 684) (13.4% vs 6.6%; pooled OR, 2.06; 95% CI, 1.43−2.98).[94] In contrast, a recent Cochrane review of 8 trials (n = 1665) concluded that wound complications and cosmetic outcomes were similar among both groups.[95] Given the conflicting data, it is uncertain whether sutures or staples are superior, making a definitive recommendation difficult (recommendation: C; level of certainty: moderate; Table 1; changed).

TABLE 4
Recommended cesarean delivery techniques

Cesarean delivery techniques	Recommendations with high level of certainty[a]
Recommended	
Prophylactic antibiotics	Single dose, ampicillin or first-generation cephalosporin 15-60 min prior to incision
Expansion of uterine incision	Blunt, cephalad-caudad direction
Prevention of PPH	Oxytocin infusion (10-40 IU in 1 L crystalloid over 4-8 h)
Placental removal	Spontaneous
Uterine exteriorization	Surgeon preference
Uterine closure	One-layer if future fertility undesired
Subcutaneous closure	Suture closure if ≥2 cm
Not recommended	
Supplemental oxygen	Does not reduce morbidity from infection
Cervical dilation	Does not reduce morbidity from infection
Subcutaneous drain	Does not reduce wound morbidity

PPH, postpartum hemorrhage.

[a] See Table 1. The available evidence usually includes consistent results from well-designed, well-conducted studies in representative primary care populations. These studies assess the effects of the preventive service on health outcomes. This conclusion is therefore unlikely to be strongly affected by the results of future studies.

Dahlke. Evidence-based cesarean delivery. Am J Obstet Gynecol 2013.

Comment

Worldwide, cesarean delivery is the most frequent major operation performed. Therefore, it is imperative that surgeons who perform the operation use techniques that have been shown to minimize maternal morbidity and mortality. Fortunately, several aspects of the surgery are supported by evidence with a high level of certainty as defined by the USPSTF: previously, Berghella et al[4] identified 5 such technical aspects, and the newer trials reviewed herein now support 10 such CD techniques (Table 4).

We acknowledge that our review has some limitations. Our recommendations are constrained by the specific questions the various RCTs asked. Indeed, many of these questions were narrowly focused on short-term outcomes or outcomes of arguable clinical importance. Most of the trials were not blinded and across trials, interventions, techniques, and outcomes were somewhat heterogeneously defined. Despite these shortcomings, one benefit of using USPSTF terminology is that both a recommendation and the level of certainty based on the quality of evidence can be assigned for each CD technique and communicated among clinicians and researchers.

Several important technical aspects of CD have not been sufficiently evaluated. Specifically we believe trials that evaluate means of reducing CD-associated VTE and hemorrhage are urgently needed. In the United States, 10.9% of maternal deaths are associated with VTE.[96] It has been estimated that the risk of CD-associated VTE is at least 0.23%[19] or approximately 1 in 400 surgeries, a rate that is twice that associated with vaginal delivery.[97] However, it remains unclear whether pharmacological or mechanical

measures (or both) should be routinely utilized to reduce the risk of CD-associated VTE. With the former, iatrogenic hemorrhage is a concern, and both are costly. We estimate that a definitive trial powered to detect a 50% reduction (0.25-0.125%) in CD-associated VTE using 1 of these methods VTE would require approximately 40,000 participants equally divided in a control or intervention group (2-tailed $\alpha = 0.05$, $\beta = 0.2$). Although a trial of this magnitude would be daunting, it is worth bearing in mind that 1.3 million CDs are performed each year in the United States alone. Thus, a trial of 40,000 participants would require 3% of these surgeries.

Similar to VTE, postpartum hemorrhage accounts for an appreciable proportion (11.9%) of pregnancy-related maternal death in the United States.[96] Additionally, 2-3% (approximately 40,000 each year) of all women in the United States who undergo CD require a blood transfusion.[98] Therefore, evaluating methods for minimizing CD-associated blood loss should remain a research priority. Specifically, interventions whose primary outcome is a reduction in blood transfusions seem to be in order. For example, we estimate a trial powered to detect a 50% reduction (3-1.5%) in blood transfusion for a given intervention (eg, tranexamic acid) would require 3400 participants equally divided in a control or intervention group (2-tailed $\alpha = 0.05$, $\beta = 0.2$).

Finally, whether the technique of 2-layer closure of the hysterotomy at the time of CD lowers the risk of subsequent uterine rupture is a question that has not been answered or adequately assessed in women randomized to 1- or 2-layer closure. Fortunately, in the CAESAR collaborative, more than 3000 women were randomized to 1- or 2-layer uterine closure,[71] and the recently completed international study of cesarean section techniques (CORONIS collaborative)[99] randomized almost 16,000 women to this technical aspect of CD. Long-term follow-up of these large trials is planned and may offer the best opportunity to answer this long-standing question (personal communication, chief investigator, Peter Brocklehurst).

The cesarean delivery technique has certainly evolved since it was first described in the medical literature in 1610 AD[100] and will undoubtedly continue to be refined with subsequent decrease in morbidity. As results from well-designed, Consolidated Standards of Reporting Trials (CONSORT) compliant RCTs provide evidence suggesting best surgical practices that minimize surgical morbidity, it is incumbent on clinicians to adopt evidence-based techniques when performing and teaching CD. ■

REFERENCES

1. Centers for Disease Control and Prevention. National Center for Health Statistics: vital statistics. Available at: http://www.cdc.gov/nchs/vitalstats.htm. Accessed Oct. 1, 2012.

2. Hall MJ, DeFrances CJ, Williams SN, Golosinskiy A, Schwartzman A. National Hospital Discharge Survey: 2007 summary. Natl Health Stat Report 2010;29:1-20:24.

3. Boyle A, Reddy UM. Epidemiology of cesarean delivery: the scope of the problem. Semin Perinatol 2012;36:308-14.

4. Berghella V, Baxter JK, Chauhan SP. Evidence-based surgery for cesarean delivery. Am J Obstet Gynecol 2005;193:1607-17.

5. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. J Clin Epidemiol 2009;62:1006-12.

6. US Preventive Service Task Force. Available at: www.uspreventiveservicestaskforce.org. Accessed Oct. 5, 2012.

7. Ziogos E, Tsiodras S, Matalliotakis I, Giamarellou H, Kanellakopoulou K. Ampicillin/sulbactam versus cefuroxime as antimicrobial prophylaxis for cesarean delivery: a randomized study. BMC Infect Dis 2010;10:341.

8. Alekwe LO, Kuti O, Orji EO, Ogunniyi SO. Comparison of ceftriaxone versus triple drug regimen in the prevention of cesarean section infectious morbidities. J Matern Fetal Neonatal Med 2008;21:638-42.

9. Rudge MV, Atallah AN, Peracoli JC, Tristao Ada R, Mendonca Neto M. Randomized controlled trial on prevention of postcesarean infection using penicillin and cephalothin in Brazil. Acta Obstet Gynecol Scand 2006;85:945-8.

10. Alfirevic Z, Gyte GM, Dou L. Different classes of antibiotics given to women routinely for preventing infection at caesarean section. Cochrane Database Syst Rev 2010;10:CD008726.

11. Thigpen BD, Hood WA, Chauhan S, et al. Timing of prophylactic antibiotic administration in the uninfected laboring gravida: a randomized clinical trial. Am J Obstet Gynecol 2005;192:1864-8; discussion 1868-71.

12. Sullivan SA, Smith T, Chang E, Hulsey T, Vandorsten JP, Soper D. Administration of cefazolin prior to skin incision is superior to cefazolin at cord clamping in preventing post-cesarean infectious morbidity: a randomized, controlled trial. Am J Obstet Gynecol 2007;196:455.e1-5.

13. Witt A, Doner M, Petricevic L, et al. Antibiotic prophylaxis before surgery vs after cord clamping in elective cesarean delivery: a double-blind, prospective, randomized, placebo-controlled trial. Arch Surg 2011;146:1404-9.

14. Macones GA, Cleary KL, Parry S, et al. The timing of antibiotics at cesarean: a randomized controlled trial. Am J Perinatol 2012;29:273-6.

15. Costantine MM, Rahman M, Ghulmiyah L, et al. Timing of perioperative antibiotics for cesarean delivery: a metaanalysis. Am J Obstet Gynecol 2008;199:301.e1-6.

16. Hill NC, Hill JG, Sargent JM, Taylor CG, Bush PV. Effect of low dose heparin on blood loss at caesarean section. Br Med J (Clin Res Ed) 1988;296:1505-6.

17. Burrows RF, Gan ET, Gallus AS, Wallace EM, Burrows EA. A randomised double-blind placebo controlled trial of low molecular weight heparin as prophylaxis in preventing venous thrombolic events after caesarean section: a pilot study. BJOG 2001;108:835-9.

18. Gates S, Brocklehurst P, Ayers S, Bowler U. Thromboprophylaxis and pregnancy: two randomized controlled pilot trials that used low-molecular-weight heparin. Am J Obstet Gynecol 2004;191:1296-303.

19. Lindqvist P, Dahlback B, Marsal K. Thrombotic risk during pregnancy: a population study. Obstet Gynecol 1999;94:595-9.

20. Starr RV, Zurawski J, Ismail M. Preoperative vaginal preparation with povidone-iodine and the risk of postcesarean endometritis. Obstet Gynecol 2005;105(5 Pt 1):1024-9.

21. Haas DM, Pazouki F, Smith RR, et al. Vaginal cleansing before cesarean delivery to reduce postoperative infectious morbidity: a randomized, controlled trial. Am J Obstet Gynecol 2010;202:310.e1-6.

22. Haas DM, Morgan Al Darei S, Contreras K. Vaginal preparation with antiseptic solution before cesarean section for preventing postoperative infections. Cochrane Database Syst Rev 2010;3:CD007892.

23. Nasr AM, El Bigawy AF, Abdelamid AE, Al-Khulaidi S, Al-Inany HG, Sayed EH. Evaluation of the use vs nonuse of urinary catheterization during cesarean delivery: a prospective, multicenter, randomized controlled trial. J Perinatol 2009;29:416-21.

24. Ghoreishi J. Indwelling urinary catheters in cesarean delivery. Int J Gynaecol Obstet 2003;83:267-70.

25. Li L, Wen J, Wang L, Li YP, Li Y. Is routine indwelling catheterisation of the bladder for caesarean section necessary? A systematic review. BJOG 2011;118:400-9.

26. Senanayake H. Elective cesarean section without urethral catheterization. J Obstet Gynaecol Res 2005;31:32-7.

27. Onile TG, Kuti O, Orji EO, Ogunniyi SO. A prospective randomized clinical trial of urethral catheter removal following elective cesarean delivery. Int J Gynaecol Obstet 2008;102:267-70.
28. Rajasekar D, Hall M. Urinary tract injuries during obstetric intervention. Br J Obstet Gynaecol 1997;104:731-4.
29. Scifres CM, Leighton BL, Fogertey PJ, Macones GA, Stamilio DM. Supplemental oxygen for the prevention of postcesarean infectious morbidity: a randomized controlled trial. Am J Obstet Gynecol 2011;205:267.e1-9.
30. Gardella C, Goltra LB, Laschansky E, et al. High-concentration supplemental perioperative oxygen to reduce the incidence of postcesarean surgical site infection: a randomized controlled trial. Obstet Gynecol 2008;112:545-52.
31. Naki MM, Api O, Celik H, Kars B, Yasar E, Unal O. Comparative study of Misgav-Ladach and Pfannenstiel-Kerr cesarean techniques: a randomized controlled trial. J Matern Fetal Neonatal Med 2011;24:239-44.
32. Gedikbasi A, Akyol A, Ulker V, et al. Cesarean techniques in cases with one previous cesarean delivery: comparison of modified Misgav-Ladach and Pfannenstiel-Kerr. Arch Gynecol Obstet 2011;283:711-6.
33. Belci D, Kos M, Zoricic D, et al. Comparative study of the "Misgav Ladach" and traditional Pfannenstiel surgical techniques for cesarean section. Minerva Ginecol 2007;59:231-40.
34. Xavier P, Ayres-De-Campos D, Reynolds A, Guimaraes M, Costa-Santos C, Patricio B. The modified Misgav-Ladach versus the Pfannenstiel-Kerr technique for cesarean section: a randomized trial. Acta Obstet Gynecol Scand 2005;84:878-82.
35. Mathai M, Hofmeyr GJ. Abdominal surgical incisions for caesarean section. Cochrane Database Syst Rev 2007;1:CD004453.
36. Hofmeyr JG, Novikova N, Mathai M, Shah A. Techniques for cesarean section. Am J Obstet Gynecol 2009;201:431-44.
37. Kadir RA, Khan A, Wilcock F, Chapman L. Is inferior dissection of the rectus sheath necessary during Pfannenstiel incision for lower segment caesarean section? A randomised controlled trial. Eur J Obstet Gynecol Reprod Biol 2006;128:262-6.
38. Tuuli MG, Odibo AO, Macones GA. Utility of the bladder flap at cesarean delivery: a randomized controlled trial. Obstet Gynecol 2012;120:709.
39. Malvasi A, Tinelli A, Guido M, et al. Effect of avoiding bladder flap formation in caesarean section on repeat caesarean delivery. Eur J Obstet Gynecol Reprod Biol 2011;159:300-4.
40. Shahin AY, Hameed DA. Does visceral peritoneal closure affect post-cesarean urinary symptoms? A randomized clinical trial. Int Urogynecol J 2010;21:33-41.
41. Theodoridis TD, Chatzigeorgiou KN, Zepiridis L, et al. A prospective randomized study for evaluation of wound retractors in the prevention of incision site infections after cesarean section. Clin Exp Obstet Gynecol 2011;38:57-9.
42. Sekhavat L, Dehghani Firouzabadi R, Mojiri P. Effect of expansion technique of uterine incision on maternal blood loss in cesarean section. Arch Gynecol Obstet 2010;282:5-479.
43. Cromi A, Ghezzi F, Di Naro E, Siesto G, Loverro G, Bolis P. Blunt expansion of the low transverse uterine incision at cesarean delivery: a randomized comparison of 2 techniques. Am J Obstet Gynecol 2008;199:292.e1-6.
44. Dodd JM, Anderson ER, Gates S. Surgical techniques for uterine incision and uterine closure at the time of caesarean section. Cochrane Database Syst Rev 2008;3:CD004732.
45. Borruto F, Treisser A, Comparetto C. Utilization of carbetocin for prevention of postpartum hemorrhage after cesarean section: a randomized clinical trial. Arch Gynecol Obstet 2009;280:707-12.
46. King KJ, Douglas MJ, Unger W, Wong A, King RA. Five unit bolus oxytocin at cesarean delivery in women at risk of atony: a randomized, double-blind, controlled trial. Anesth Analg 2010;111:1460-6.
47. Sheehan SR, Montgomery AA, Carey M, et al. Oxytocin bolus versus oxytocin bolus and infusion for control of blood loss at elective caesarean section: double blind, placebo controlled, randomised trial. BMJ 2011;343:d4661.
48. Butwick AJ, Coleman L, Cohen SE, Riley ET, Carvalho B. Minimum effective bolus dose of oxytocin during elective caesarean delivery. Br J Anaesth 2010;104:338-43.
49. Gungorduk K, Yildirim G, Asicioglu O, Gungorduk OC, Sudolmus S, Ark C. Efficacy of intravenous tranexamic acid in reducing blood loss after elective cesarean section: a prospective, randomized, double-blind, placebo-controlled study. Am J Perinatol 2011;28:233-40.
50. Attilakos G, Psaroudakis D, Ash J, et al. Carbetocin versus oxytocin for the prevention of postpartum haemorrhage following caesarean section: the results of a double-blind randomised trial. BJOG 2010;117:929-36.
51. Chaudhuri P, Banerjee GB, Mandal A. Rectally administered misoprostol versus intravenous oxytocin infusion during cesarean delivery to reduce intraoperative and postoperative blood loss. Int J Gynaecol Obstet 2010;109:25-9.
52. Owonikoko KM, Arowojolu AO, Okunlola MA. Effect of sublingual misoprostol versus intravenous oxytocin on reducing blood loss at cesarean section in Nigeria: a randomized controlled trial. J Obstet Gynaecol Res 2011;37:715-21.
53. Eftekhari N, Doroodian M, Lashkarizadeh R. The effect of sublingual misoprostol versus intravenous oxytocin in reducing bleeding after caesarean section. J Obstet Gynaecol 2009;29:633-6.
54. Vimala N, Mittal S, Kumar S. Sublingual misoprostol versus oxytocin infusion to reduce blood loss at cesarean section. Int J Gynaecol Obstet 2006;92:106-10.
55. Hamm J, Russell Z, Botha T, Carlan SJ, Richichi K. Buccal misoprostol to prevent hemorrhage at cesarean delivery: a randomized study. Am J Obstet Gynecol 2005;192:1404-6.
56. Movafegh A, Eslamian L, Dorabadi A. Effect of intravenous tranexamic acid administration on blood loss during and after cesarean delivery. Int J Gynaecol Obstet 2011;115:224-6.
57. Sekhavat L, Tabatabaii A, Dalili M, Farajkhoda T, Tafti AD. Efficacy of tranexamic acid in reducing blood loss after cesarean section. J Matern Fetal Neonatal Med 2009;22:72-5.
58. Leavitt BG, Huff DL, Bell LA, Thurnau GR. Placental drainage of fetal blood at cesarean delivery and feto maternal transfusion: a randomized controlled trial. Obstet Gynecol 2007;110:608-11.
59. Orji EO, Olaleye AO, Loto OM, Ogunniyi SO. A randomised controlled trial of uterine exteriorisation and non-exteriorisation at caesarean section. Aust N Z J Obstet Gynaecol 2008;48:570-4.
60. Siddiqui M, Goldszmidt E, Fallah S, Kingdom J, Windrim R, Carvalho JC. Complications of exteriorized compared with in situ uterine repair at cesarean delivery under spinal anesthesia: a randomized controlled trial. Obstet Gynecol 2007;110:570-5.
61. Nafisi S. Influence of uterine exteriorization versus in situ repair on post-Cesarean maternal pain: a randomized trial. Int J Obstet Anesth 2007;16:135-8.
62. Coutinho IC, Ramos de Amorim MM, Katz L, Bandeira de Ferraz AA. Uterine exteriorization compared with in situ repair at cesarean delivery: a randomized controlled trial. Obstet Gynecol 2008;111:639-47.
63. Ozbay K. Exteriorized versus in situ repair of the uterine incision at cesarean delivery: a randomized controlled trial. Clin Exp Obstet Gynecol 2011;38:155-8.
64. Doganay M, Tonguc EA, Var T. Effects of method of uterine repair on surgical outcome of cesarean delivery. Int J Gynaecol Obstet 2010;111:175-8.
65. Ezechi OC, Kalu BK, Njokanma FO, Nwokoro CA, Okeke GC. Uterine incision closure at caesarean section: a randomised comparative study of intraperitoneal closure and closure after temporary exteriorisation. West Afr J Med 2005;24:41-3.
66. Walsh CA, Walsh SR. Extraabdominal vs intraabdominal uterine repair at cesarean delivery: a metaanalysis. Am J Obstet Gynecol 2009;200:625.e1-8.
67. Ahmed B, Abu Nahia F, Abushama M. Routine cervical dilatation during elective cesarean section and its influence on maternal morbidity: a randomized controlled study. J Perinat Med 2005;33:510-3.
68. Tosun M, Sakinci M, Celik H, et al. A randomized controlled study investigating the necessity of routine cervical dilatation during

elective cesarean section. Arch Gynecol Obstet 2011;284:85-9.
69. Gungorduk K, Yildirim G, Ark C. Is routine cervical dilatation necessary during elective caesarean section? A randomised controlled trial. Aust N Z J Obstet Gynaecol 2009;49:263-7.
70. Liabsuetrakul T, Peeyananjarassri K. Mechanical dilatation of the cervix at non-labour caesarean section for reducing postoperative morbidity. Cochrane Database Syst Rev 2011; 11:CD008019.
71. Caesarean section surgical techniques: a randomised factorial trial (CAESAR)*. BJOG 2010;117:1366-76.
72. Roberge S, Chaillet N, Boutin A, et al. Single- versus double-layer closure of the hysterotomy incision during cesarean delivery and risk of uterine rupture. Int J Gynaecol Obstet 2011;115:5-10.
73. Pearce C, Torres C, Stallings S, et al. Elective appendectomy at the time of cesarean delivery: a randomized controlled trial. Am J Obstet Gynecol 2008;199:491.e1-5.
74. Viney R, Isaacs C, Chelmow D. Intra-abdominal Irrigation at cesarean delivery: a randomized controlled trial. Obstet Gynecol 2012;120:708.
75. Anteby EY, Kruchkovich J, Kapustian V, Gdalevich M, Shenhav S, Gemer O. Short-term effects of closure versus non-closure of the visceral and parietal peritoneum at cesarean section: a prospective randomized study. J Obstet Gynaecol Res 2009;35:1026-30.
76. Kapustian V, Anteby EY, Gdalevich M, Shenhav S, Lavie O, Gemer O. Effect of closure versus nonclosure of peritoneum at cesarean section on adhesions: a prospective randomized study. Am J Obstet Gynecol 2012;206:56.e1-4.
77. Shahin AY, Osman AM. Parietal peritoneal closure and persistent postcesarean pain. Int J Gynaecol Obstet 2009;104:135-9.
78. Komoto Y, Shimoya K, Shimizu T, et al. Prospective study of non-closure or closure of the peritoneum at cesarean delivery in 124 women: impact of prior peritoneal closure at primary cesarean on the interval time between first cesarean section and the next pregnancy and significant adhesion at second cesarean. J Obstet Gynaecol Res 2006;32:396-402.
79. Malomo OO, Kuti O, Orji EO, Ogunniyi SO, Sule SS. A randomised controlled study of non-closure of peritoneum at caesarean section in a Nigerian population. J Obstet Gynaecol 2006;26:429-32.
80. Zareian Z, Zareian P. Non-closure versus closure of peritoneum during cesarean section: a randomized study. Eur J Obstet Gynecol Reprod Biol 2006;128:267-9.
81. Shi Z, Ma L, Yang Y, et al. Adhesion formation after previous caesarean section-a meta-analysis and systematic review. BJOG 2011;118:410-22.
82. Cheong YC, Premkumar G, Metwally M, Peacock JL, Li TC. To close or not to close? A systematic review and a meta-analysis of peritoneal non-closure and adhesion formation after caesarean section. Eur J Obstet Gynecol Reprod Biol 2009;147:3-8.
83. Bamigboye AA, Hofmeyr GJ. Non-closure of peritoneal surfaces at caesarean section—a systematic review. S Afr Med J 2005;95:123-6.
84. Sullivan S, Williamson B, Wilson LK, Korte JE, Soper D. Blunt needles for the reduction of needlestick injuries during cesarean delivery: a randomized controlled trial. Obstet Gynecol 2009;114(2 Pt 1):211-6.
85. Parantainen A, Verbeek JH, Lavoie MC, Pahwa M. Blunt versus sharp suture needles for preventing percutaneous exposure incidents in surgical staff. Cochrane Database Syst Rev 2011;11:CD009170.
86. Hellums EK, Lin MG, Ramsey PS. Prophylactic subcutaneous drainage for prevention of wound complications after cesarean delivery—a metaanalysis. Am J Obstet Gynecol 2007;197: 229-35.
87. Ramsey PS, White AM, Guinn DA, et al. Subcutaneous tissue reapproximation, alone or in combination with drain, in obese women undergoing cesarean delivery. Obstet Gynecol 2005;105(5 Pt 1):967-73.
88. Rousseau JA, Girard K, Turcot-Lemay L, Thomas N. A randomized study comparing skin closure in cesarean sections: staples vs subcuticular sutures. Am J Obstet Gynecol 2009;200:265.e1-4.
89. Basha SL, Rochon ML, Quinones JN, Coassolo KM, Rust OA, Smulian JC. Randomized controlled trial of wound complication rates of subcuticular suture vs staples for skin closure at cesarean delivery. Am J Obstet Gynecol 2010;203:285.e1-8.
90. Cromi A, Ghezzi F, Gottardi A, Cherubino M, Uccella S, Valdatta L. Cosmetic outcomes of various skin closure methods following cesarean delivery: a randomized trial. Am J Obstet Gynecol 2010;203:36.e1-8.
91. Tan PC, Mubarak S, Omar SZ. Absorbable versus nonabsorbable sutures for subcuticular skin closure of a transverse suprapubic incision. Int J Gynaecol Obstet 2008;103:179-81.
92. de Graaf IM, Rengerink KO, Wiersma IC, Donker ME, Mol BW, Pajkrt E. Techniques for wound closure at caesarean section: a randomized clinical trial. Eur J Obstet Gynecol Reprod Biol 2012;165:47-52.
93. Clay FS, Walsh CA, Walsh SR. Staples vs subcuticular sutures for skin closure at cesarean delivery: a metaanalysis of randomized controlled trials. Am J Obstet Gynecol 2011;204:378-83.
94. Tuuli MG, Rampersad RM, Carbone JF, Stamilio D, Macones GA, Odibo AO. Staples compared with subcuticular suture for skin closure after cesarean delivery: a systematic review and meta-analysis. Obstet Gynecol 2011;117:682-90.
95. Mackeen AD, Berghella V, Larsen ML. Techniques and materials for skin closure in caesarean section. Cochrane Database Syst Rev 2012;11:CD003577.
96. Berg CJ, Callaghan WM, Syverson C, Henderson H. Pregnancy-related mortality in the United States, 1998-2005. Obstet Gynecol 2010;116:1302-9.
97. James AH, Jamison MG, Brancazio LR, Myers ER. Venous thromboembolism during pregnancy and the postpartum period: incidence, risk factors, and mortality. Am J Obstet Gynecol 2006;194:1311-5.
98. Rouse DJ, MacPherson C, Landon M, et al. Blood transfusion and cesarean delivery. Obstet Gynecol 2006;108:891-7.
99. CORONIS collaborative. International study of caesarean section surgical techniques: a randomised factorial trial. Available at: https://www.npeu.ox.ac.uk/coronis. Accessed Nov. 5, 2012.
100. Boley JP. The history of caesarean section. CMAJ 1991;145:319-22.
101. Alfirevic Z, Gyte GM, Dou L. Different classes of antibiotics given to women routinely for preventing infection at caesarean section. Cochrane Database Syst Rev 2010;10: CD008726.
102. Smaill FM, Gyte GM. Antibiotic prophylaxis versus no prophylaxis for preventing infection after cesarean section. Cochrane Database Syst Rev 2010;1:CD007482.
103. Cunningham FG, Leveno KJ, DePalma RT, Roark M, Rosenfeld CR. Perioperative antimicrobials for cesarean delivery: before or after cord clamping? Obstet Gynecol 1983;62: 151-4.
104. Gordon HR, Phelps D, Blanchard K. Prophylactic cesarean section antibiotics: maternal and neonatal morbidity before or after cord clamping. Obstet Gynecol 1979;53:151-6.
105. Wax JR, Hersey K, Philput C, Wright MS, Nichols KV, Eggleston MK. Single dose cefazolin prophylaxis for postcesarean infections: before vs after cord clamping. J Matern Fetal Neonatal Med 1997;6:61-5.
106. Clemetson CA, Hassan R, Mallikarjuneswara VR, Wallace G. Tilt-bend cesarean section. Obstet Gynecol 1973;42:290-8.
107. Crawford JS, Burton M, Davies P. Time and lateral tilt at caesarean section. Br J Anaesth 1972;44:477-84.
108. Downing JW, Coleman AJ, Mahomedy MC, Jeal DE, Mahomedy Y. Lateral table tilt for caesarean section. Anaesthesia 1974;29:696-703.
109. Cluver C, Novikova N, Hofmeyr GJ, Hall DR. Maternal position during caesarean section for preventing maternal and neonatal complications. Cochrane Database Syst Rev 2010;6:CD007623.
110. Carbonne B, Benachi A, Leveque ML, Cabrol D, Papiernik E. Maternal position during labor: effects on fetal oxygen saturation measured by pulse oximetry. Obstet Gynecol 1996; 88:797-800.
111. Edwards PS, Lipp A, Holmes A. Preoperative skin antiseptics for preventing surgical wound infections after clean surgery. Cochrane Database Syst Rev 2005.
112. Magann EF, Dodson MK, Ray MA, Harris RL, Martin JN, Morrison JC. Preoperative skin preparation and intraoperativepelvic

irrigation: impact on post cesarean endometritis and wound infection. Obstet Gynecol 1993;81:922-5.
113. Cordtz T, Schouenborg L, Lauren K, Daugaard HO, Buur K, Munk Christensen B. The effect of incision plastic drapes and redisinfection of operation site on wound infection following caesarean section. J Hosp Infect 1989;13:267-72.
114. Ward HRG, Jennings OGN, Potgieter P, Lombard CJ. Do plastic adhesive drapes prevent post caesarean wound infection? J Hosp Infect 2001;47:230-4.
115. Ayers JW, Morley GW. Surgical incision for cesarean section. Obstet Gynecol 1987;70:706-8.
116. Franchi M, Ghezzi F, Balestreri D, Beretta P, Maymon E, Miglierina M. A randomized clinical trial of two surgical techniques for cesarean section. Am J Perinatol 1998;15:589-94.
117. Franchi M, Ghezzi F, Raio L, DiNaro E, Miglierina M, Agosti M. Joel-Cohen or Pfannenstiel incision at cesarean delivery: does it make a difference? Acta Obstet Gynecol Scand 2002;81:1040-6.
118. Kerr JMM. The technique of cesarean section, with special reference to the lower uterine segment. Am J Obstet Gynecol 1926;12:729-34.
119. Mathai M, Ambersheth S, George A. Comparison of two transverse abdominal incisions for cesarean delivery. Int J Gynecol Obstet Gynecol 2002;78:47-9.
120. Mowatt J, Bonnar J. Abdominal wound dehiscence after cesarean section. BMJ 1971;2:256-7.
121. Stark M, Chavkin Y, Kupfersztain C, Guedj P, Finkel AR. Evaluation of combinations of procedures in cesarean section. Int J Gynaecol Obstet 1995;48:273-6.
122. Berthet J, Peresse JF, Rosier P, Racinet C. Comparative study of Pfannestiel's incision and transverse abdominal incision in gynecologic and obstetric surgery. Presse Med 1989;18:1431-3.
123. Finan MA, Mastrogiannis DS, Spellacy WN. The "Allis" test for easy cesarean delivery. Am J Obstet Gynecol 1991;164:772-5.
124. Hasselgren PO, Hagberg E, Malmer H, Saljo A, Seeman T. One instead of two knives for surgical incision: does it increase the risk of postoperative wound infection? Arch Surg 1984;119:917-20.
125. Giacalone PL, Daures JP, Vignal J, Herisson C, Hedon B, Laffargue F. Pfannenstiel versus Maylard incision for cesarean delivery: a randomized controlled trial. Obstet Gynecol 2002;99:745-50.
126. Hohlagschwandtner M, Ruecklinger E, Husslein P, Joura EA. Is the formation of a bladder flap at cesarean necessary? A randomized trial. Obstet Gynecol 2001;98:1089-92.
127. Dargent D, Audra G, Noblot G. Utilization de la pince POLY CS 57 pour l'operation cesarienne. Un essai randomise [in French]. J Gynecol Obstet Biol Reprod (Paris) 1990;18:961-2.
128. Lao TT, Halpern SH, Crosby ET, Huh C. Uterine incision and maternal blood loss in preterm caesarean section. Arch Gynecol Obstet Gynecol 1993;252:113-7.
129. Hoskins IA, Ordorica SA, Frieden FJ, Young BK. Performance of cesarean section using absorbable staples. Surg Gynecol Obstet 1991;172:108-12.
130. Van Dongen PWJ, Nijhuis JG, Jongsma HW. Reduced blood loss during caesarean section due to a controlled stapling technique. Eur J Obstet Gynecol Reprod Biol 1989;32:95-102.
131. Villeneuve MG, Khalife S, Marcoux S, Blanchet P. Surgical staples in cesarean section: a randomized controlled trial. Am J Obstet Gynecol 1990;163:1641-6.
132. Magann EF, Chauhan SP, Bufkin L, Field K, Roberts WE, Martin JN. Intra-operative haemorrhage by blunt versus sharp expansion of the uterine incision at caesarean delivery: a randomised clinical trial. BJOG 2002;109:448-52.
133. Rodriguez AI, Porter KB, O'Brien WF. Blunt versus sharp expansion of the uterine incision in low-segment transverse cesarean section. Am J Obstet Gynecol 1994;171:1022-5.
134. Bofill JA, Lencki SG, Barhan S, Ezenagu LC. Instrumental delivery of the fetal head at the time of elective repeat cesarean: a randomized pilot study. Am J Perinatol 2000;17:265-9.
135. Majoko F, Gardener G. Trial of instrumental delivery in theatre versus immediate caesarean section for anticipated difficult assisted births. Cochrane Database Syst Rev 2012;10:CD005545.
136. Munn MB, Owen J, Vincent R, Wakefield M, Chestnut DH, Hauth JC. Comparison of two oxytocin regimens to prevent uterine atony at cesarean delivery: a randomized controlled trial. Obstet Gynecol 2001;98:386-90.
137. Boucher M, Horbay GLA, Griffin P, Deschamps Y, Desjardins C, Schulz M. Double-blind, randomized comparison of the effect of carbetocin and oxytocin on intraoperative blood loss and uterine tone of patients undergoing cesarean section. J Perinatol 1998;18:202-7.
138. Dansereau J, Joshi AK, Helewa ME, Doran TA, Lange IR, Luther ER. Double-blind comparison of carbetocin versus oxytocin in prevention of uterine atony after cesarean section. Am J Obstet Gynecol 1999;180:670-6.
139. Atkinson MW, Owen J, Wren A, Hauth JC. The effect of manual removal of the placenta on post-cesarean endometritis. Obstet Gynecol 1996;87:99-102.
140. Chandra P, Schiavelo HJ, Kluge JE, Holloway SL. Manual removal of the placenta and postcesarean endometritis J. Reprod Med 2002;47:101-6.
141. Lasley DS, Eblen A, Yancey MK, Duff P. The effect of placental removal method on the incidence of postcesarean infections. Am J Obstet Gynecol 1997;176:1250-4.
142. Magann EF, Dodson MK, Allbert JR, McCurdy CM, Martin RW, Morrison JC. Blood loss at the time of cesarean section by method of placental removal and exteriorization versus in situ repair of the uterine incision. Surg Gynecol Obstet 1993;177:389-92.
143. Magann EF, Washburne JF, Harris RL, Bass JD, Duff WP, Morrison JC. Infectious morbidity, operative blood loss, and length of the operative procedure after cesarean delivery by method of placental removal and site of uterine repair. J Am Coll Surg 1995;181:517-20.
144. McCurdy CM, Magann EF, McCurdy CJ, Slatzman AK. The effect of placental management at cesarean delivery on operative blood loss. Am J Obstet Gynecol 1992;167:1363-7.
145. Notelovitz M, Dalrymple D, Grobbelaar B, Gibson M. Transplacental haemorrhage following caesarean section. S Afr J Obstet Gynaecol 1972;10:28-30.
146. Edi-Osagie ECO, Hopkins RE, Ogbo V, Lockhat-Clegg F, Ayeko M, Akpala WO. Uterine exteriorisation at caesarean section: influence on maternal morbidity. BJOG 1998;105:1070-8.
147. Hershey DW, Quilligan EJ. Extraabdominal uterine exteriorization at cesarean section. Obstet Gynecol 1978;52:189-92.
148. Jacobs-Jokhan D, Hofmeyr GJ. Extra-abdominal versus intraabdominal repair of the uterine incision at caesarean section. Cochrane Database Syst Rev 2004;4:CD000085.
149. Magann EF, Dodson MK, Harris RL, Floyd RC, Martin JN, Morrison JC. Does method of placental removal or site of uterine incision repair alter endometritis after cesarean delivery? Infect Dis Obstet Gynaecol 1993;1:65-70.
150. Wahab MA, Karantzis P, Eccersley PS, Russell IF, Thompson JW, Lindow SW. A randomised, controlled study of uterine exteriorisation and repair at caesarean section. BJOG 1999;106:913-6.
151. Hauth JC, Owen J, Davis RO. Transverse uterine incision closure: one versus two layers. Am J Obstet Gynecol 1992;167:1108-11.
152. Lal K, Tsomo P. Comparative study of single layer and conventional closure of uterine incision in cesarean section. Int J Gynaecol Obstet 1988;27:349-52.
153. Hohlagschwandtner M, Chalubinski K, Nather A, Husslein P, Joura EA. Continuous vs interrupted sutures for single-layer closure of uterine incision at cesarean section. Arch Gynecol Obstet 2003;268:26-8.
154. Harrigill KM, Miller HS, Haynes DE. The effect of intraabdominal irrigation at cesarean delivery on maternal morbidity: a randomized trial. Obstet Gynecol 2003;101:80-5.
155. Bamigboye AA, Hofmeyr GJ. Closure versus non-closure of the peritoneum at caesarean section. Cochrane Database Syst Rev 2003;4:CD000163.
156. Chanrachakul B, Hamontri S, Herabutya T. A randomized comparison of postcesarean section pain between closure and non closure of peritoneum. Eur J Obstet Gynecol Reprod Biol 2002;101:31-5.

157. Galaal KA, Krolikkowski A. A randomized controlled study of peritoneal closure at cesarean section. Saudi Med J 2000;21:759-61.
158. Grundsell HS, Rizk DEE, Kumar MR. Randomized study of nonclosure of peritoneum in lower segment cesarean section. Acta Obstet Gynecol Scand 1998;77:110-5.
159. Hojberg K, Aagaard J, Laursen H, Diab L, Secher NJ. Closure versus non-closure of peritoneum at cesarean section—evaluation of pain. Acta Obstet Gynecol Scand 1998;77:741-5.
160. Hull DB, Varner MW. A randomized study of closure of the peritoneum at cesarean delivery. Obstet Gynecol 1991;77:818-21.
161. Irion O, Luzuy F, Beguin F. Non closure of the visceral and parietal peritoneum at cesarean section: a randomised controlled trial. BJOG 1996;103:690-4.
162. Nagele F, Karas H, Spitzer D, Staudach A, Karasegh S, Beck A. Closure or non closure of the visceral peritoneum atcaesarean delivery. Am J Obstet Gynecol 1996;1996:1366-70.
163. Pietrantoni M, Parsons MT, O'Brien WF, Collins E, Knuppel RA, Spellacy WN. Peritoneal closure or non-closure at cesarean. Obstet Gynecol 1991;77:293-6.
164. Rafique Z, Shibli KU, Russell LF, Lindow SW. A randomised controlled trial of the closure or non-closure of peritoneum at caesarean section: effect on post-operative pain. BJOG 2002;109:694-8.
165. Roset E, Boulvain M, Irion O. Nonclosure of the peritoneum during cesarean section: long term follow-up of a randomized controlled trial. Eur J Obstet Gynecol Reprod Biol 2003;8:40-4.
166. Parantainen A, Verbeek JH, Lavoie MC, Pahwa M. Blunt versus sharp suture needles for preventing percutaneous exposure incidents in surgical staff. Cochrane Database Syst Rev 2011;11:CD009170.
167. Allaire AD, Fisch J, McMahon MJ. Subcutaneous drain vs. suture in obese women undergoing cesarean delivery: a prospective, randomized trial. J Reprod Med 2000;45:327-31.
168. Anderson ER, Gates S. Techniques and materials for closure of the abdominal wall in caesarean section. Cochrane Database Syst Rev 2004;4:CD004663.
169. Cetin A, Cetin M. Superficial wound disruption after cesarean delivery: effect of the depth and closure of subcutaneous tissue. Int J Gynecol Obstet Gynecol 1997;57:17-21.
170. Chelmow D, Huang E, Strohbehn K. Closure of the subcutaneous dead space and wound disruption after cesarean delivery. J Matern Fetal Neonatal Med 2002;11:403-8.
171. Chelmow D, Huang E, Strohbehn K. Closure of the subcutaneous dead space and wound disruption after cesarean delivery. J Matern Fetal Neonatal Med 2002;11:403-8.
172. DelValle GO, Combs P, Qualls C, Curet LB. Does closure of camper fascia reduce the incidence of post-cesarean superficial wound disruption? Obstet Gynecol 1992;80:1013-6.
173. Loong RLC, Rogers MS, Chang AMZ. A controlled trial on wound drainage in caesarean section. Aust N Z J Obstet Gynecol 1988;28:266-9.
174. Magann EF, Chauhan SP, Rodts-Palenik S, Bufkin L, Martin JN, Morrison JC. Subcutaneous stitch closure versus subcutaneous drain to prevent wound disruption after cesarean delivery: a randomized clinical trial. Am J Obstet Gynecol 2002;186:1119-23.
175. Naumann RW, Hauth JC, Owen J, Hodgkins PM, Lincoln T. Subcutaneous tissue approximation in relation to wound disruption after cesarean delivery in obese women. Obstet Gynecol 1995;85:412-6.
176. Alderdice F, McKenna D, Dorman J. Techniques and materials for skin closure in caesarean section. Cochrane Database Syst Rev 2003;2:CD003577.
177. Frishman GN, Schwartz T, Hogan JW. Closure of Pfannenstiel skin incisions: staples vs subcuticular suture. J Reprod Med 1997;42:627-30.