# Cesarean Section: The Evidence-Based Technique, Complications, and Risks

14

Michael Stark, Michel Odent, Andrea Tinelli, Antonio Malvasi, and Eric Jauniaux

## 14.1 Introduction

At the time when endoscopy prevails as well as new techniques, such as natural orifice surgery and telesurgery, the cesarean section (CS) might become in the future the only indicated laparotomy. Therefore, it is of utmost importance to evaluate its methodology, which should be based on evidence.

In any surgical method, complications do happen, and cesarean section is no different. The most important thing in order to avoid unnecessary complications is the prevention. It means to avoid unnecessary operation, as each operation needs a correct indication. This chapter will deal with different aspects of cesarean section, historical, technical, and physiological aspects which will bring into light not just how to perform but also when to perform in case of correct indication. This knowledge will prevent unnecessary complications and morbidity, both to the mother and to the newborn.

M. Stark (✉)
The New European Surgical Academy, Berlin, Germany

ELSAN Hospital Group, Paris, France
e-mail: mstark@nesacademy.org

M. Odent
Primal Health Research Centre, London, UK

A. Tinelli, MD, PhD
Department of Obstetrics and Gynaecology, Division of Experimental Endoscopic Surgery, Imaging, Technology and Minimally Invasive Therapy, Vito Fazzi Hospital, Lecce, Italy

Laboratory of Human Physiology, Moscow Institute of Physics and Technology (State University), Dolgoprudny, Moscow Region, Russia

A. Malvasi, MD
Department of Obstetrics and Gynaecology, Santa Maria Hospital, GVM Care and Research, Bari, Italy

The International Translational Medicine and Biomodelling Research Group, Department of Applied Mathematics, Moscow Institute of Physics and Technology (State University), Moscow, Russia

E. Jauniaux
Academic Department of Obstetrics and Gynaecology, Institute for Women's Health, London, UK

## 14.2 Historical Perspective

There is no doubt that cesarean section (CS), together with advances in anesthesia and access to blood transfusions and antibiotics, contributed to declining maternal mortality rates since the Second World War.

Since then, the rising percentage of CS worldwide has been associated with complications such as placenta accreta as rarely seen before [1]. The CS is now the most commonly performed major operation around the world and the first surgical procedure performed independently by residents/trainees in obstetrics-gynecology in the Western world [2]. In most countries, the rise in the frequency of CS is a relatively recent phenomenon. Prior to the 1980s, the rates of CS were generally less than 10 %, but now in most countries this is well above the 10–15 % ideal rates as proposed by the WHO in order to optimize maternal and perinatal health [3–5]. By contrast, in the rural areas of many developing countries, CS remains well below 10 %, and there is no doubt that if substantial reductions in maternal and perinatal mortality are to be achieved, universal availability of life-saving interventions such as CS needs to be matched with comprehensive emergency care and overall improvements in the quality of maternal and neonatal health care [6, 7].

Until the nineteenth century, CS was a surgical procedure of last resort performed to save the baby's life and nearly always resulting in the death of the mother due to intra- and postoperative hemorrhage or secondary infections [8]. It is only when surgeons started to suture the uterus after surgery, using sutures made of silver wire as described by the American gynecologist James Marion Sims (1813–1883), that maternal mortality rates following CS started to improve [3, 5, 6]. In the early 1880s, two German obstetricians, Ferdinand Adolf Kehrer (1837–1914) and Max Saenger (1853–1903), both independently developed a new uterine closure method by advocating a two-layer uterine closure [8]. They also advocated for the first time the use of antisepsis and stressed the importance of not delaying surgery.



A. Malvasi et al. (eds.), *Management and Therapy of Late Pregnancy Complications*, DOI 10.1007/978-3-319-48732-8_14

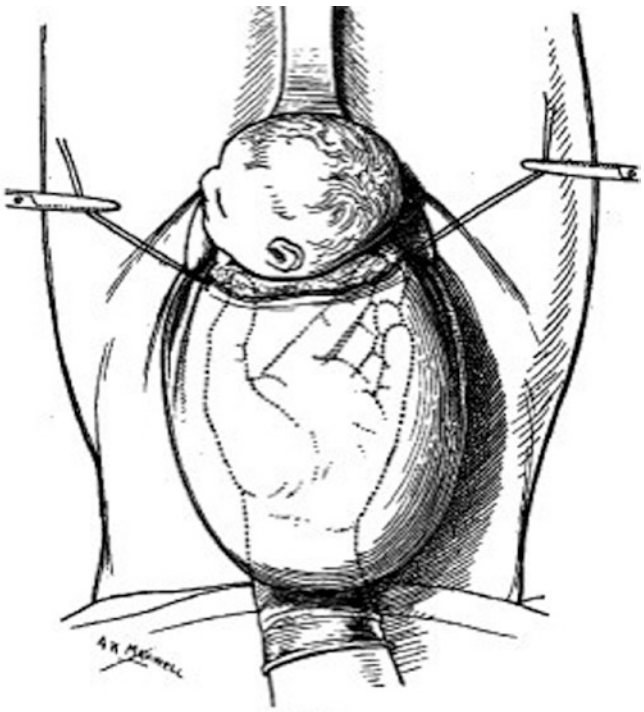


**Fig. 14.1** Diagram of a low-segment cesarean delivery based on Munro Kerr description (From Munro Kerr [12])

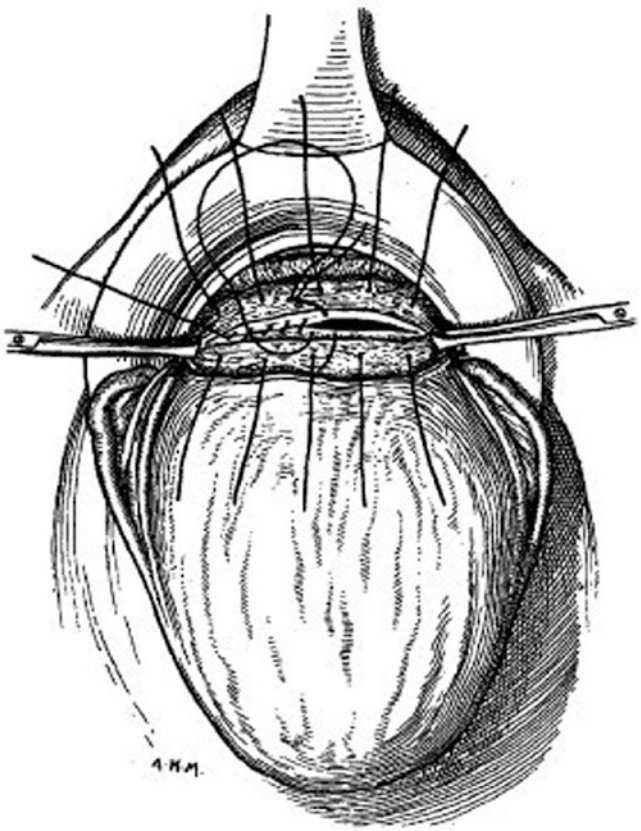


**Fig. 14.2** Diagram showing the double-layer closure of the uterine incision based on Munro Kerr [12])

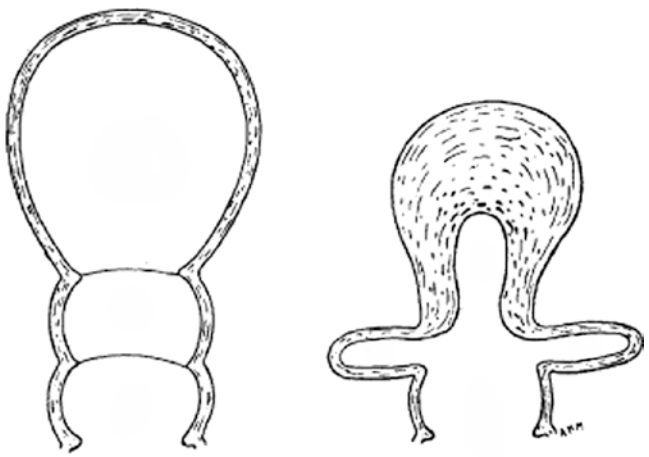


**Fig. 14.3** Diagram comparing the uterus during labor [1] and 24 h after delivery. *A* Corpus uteri. *B* Lower segment. *C* Cervix (From Munro Kerr [12])

Significant advances in the twentieth century were marked by the widespread adoption of the transverse low-segment uterine incision over the "classical" vertical corpus uteri approach. Several surgeons including Kehrer had performed the transverse incision in the nineteenth century, but this only became widespread following strong support by John Martin Munro Kerr (1868–1960), who was professor of obstetrics midwifery at the University of Glasgow from 1927 to 1934. Fluent in German and French, Munro Kerr spent a number of years after his graduation in Germany, Austria, and Ireland studying obstetrics and gynecology in Berlin, Vienna, and Dublin. Appointed as visiting surgeon at the Glasgow Royal Maternity Hospital in 1900, he published to great success the book *Operative Midwifery* in 1908, popularizing the lower-segment CS in preference to the classical operation (Figs. 14.1 and 14.2).

The advantages of this "Kehrer-Kerr" technique were less hemorrhage, less infection, and a reduced risk of uterine rupture during subsequent trials of vaginal delivery [9, 10]. These changes made the operation safer, ensuring that most mothers survived the surgical procedure and facilitated its wider use in clinical obstetric practice around the world.

Munro Kerr was also the first to combine the low transverse uterine opening described by Kehrer and the suprapubic transverse skin incision as described by Hermann Johannes Pfannenstiel (Figs. 14.1, 14.2, and 14.3).

Pfannenstiel (1862–1909) was a German gynecologist who, in 1900, described a transverse suprapubic incision method for genitourinary surgery [9] with the aim to decrease the risks of incisional hernia associated with the vertical abdominal incision. In 1921, *The Journal of Obstetrics and Gynaecology of the British Empire* published a special issue on CS, and as we will see later, the transverse incision was modified and improved by Sydney Joel-Cohen. The manuscript entitled "The results of a

collective investigation into caesarean sections performed in Great Britain and Ireland from the year 1911 to 1920 inclusive" is of particular interest [11–13]. This historical audit, the first of its kind, was commissioned by the British Medical Association to Munro Kerr and analyzed by Eardley Lancelot Holland (1880–1967) from the London Hospital. As noted by the authors, "the analysis of the large material is robbed of a certain amount of completeness by the absence of details in many cases." Nevertheless, the data analysis of 4,197 cesarean deliveries indicated that the main indication was "pelvic contraction" (80 %). CS performed for this indication was associated with a 4.1 % maternal mortality mainly due to general peritonitis. Data on fetal and infant mortality were available in 3,378 cases and identified an overall perinatal mortality of 7.5 %.

In 1931, 1,000 deliveries in Germany were evaluated of which 21 (2.1 %) were delivered by CS, most of them due to cephalopelvic disproportion. The mortality rate was 19 % [14].

Most prominent obstetricians and gynecologists at the time opposed the use of the Pfannenstiel abdominal incision because it required more dissection and access to the uterus took more time than using the vertical incision. Overall, surgeons preferred the vertical (midline) abdominal incision because it also enabled a wide space when delivering the baby and better access to the pelvis and lower abdomen. Interestingly, the vertical opening of the abdomen was still the main technique used in the 1970s, although it was known from the beginning of the twentieth century to be associated with higher rates of long-term postoperative complications such as wound dehiscence and abdominal incision hernia and cosmetic issues compared to the transverse skin incision [8, 10]. The midline vertical abdominal incision is still considered faster for entry into the abdomen, and a recent prospective cohort study comparing transverse and vertical skin incision for emergency cesarean delivery found that delivering the baby is 1 min quicker using the vertical incision but that the total median operative time is longer by 3–4 min [15].

Delivering the baby by the Misgav-Ladach CS, which will be described later, is even shorter than the longitudinal incision [16].

Surgeons who are not familiar with this method can still use the longitudinal incision in case of an emergency or in special circumstances. Similarly, the classical vertical uterine incision should only be used in rare cases of very early preterm birth (23–25 weeks) or the delivery of conjoined twins. In developing countries where visibility may not be as optimized and operating time may be more of a pressing concern, the classical vertical incision is still commonly used [3, 6, 7].

There are now scores of possible different methodological variations of performing CS, if one includes the many different ways of opening the skin, the rectus sheath, the peritoneum, and the myometrium and of closing the uterus, the peritoneum, and the subcutaneous tissue [17–19]. In addition for the closure of the different layers, there is the possibility of using different suture materials in a continuous locked or unlocked manner, interrupted sutures, or staples. Although it is now an overall safe procedure, CS can be associated with a variety of immediate and long-term complications for both mother and baby. Considering the rapid increase in the number of CS worldwide, these complications have become an important and often unrecognized iatrogenic issue in obstetrics and gynecology [3]. Some of these anomalies have now become so common that they are reviewed in individualized chapters (see Chaps. 12, 14, 15, and 17).

## 14.3 The Evidence-Based CS

The method described here is the result of long years' experience, accompanied by comparative, retrospective, and prospective studies. This technique was subject to scores of comparative studies, and without any exception, all showed benefits over different traditional methods which were compared to it.

Local traditions were and continue until today to be the main cause for a surgeon to adhere to one or the other of the described methods, definitely concerning the abdominal incision. It is interesting to note that the first comparative study, showing benefits to the transverse incision concerning scar dehiscence, was done only 74 years after Pfannenstiel's first publication [20].

In 1972, Sydney Joel-Cohen published his book *Abdominal and Vaginal Hysterectomy* [21], in which he suggested cutting the fascia above the plica arcuata. At this level the fascia does not adhere to the muscle and moves freely over it. This is probably the reason that, when this approach was compared to the Pfannenstiel incision, when all other parameters of the operation were similar, significantly lower febrile mobility resulted [22]. This is most likely due to lack of trauma to the tissues, when detaching the fascia from the muscle became superfluous.

As we have seen, the uterine wall continued to be opened longitudinally until John Martin Munro Kerr presented his low-segment transverse CS in September 1921, arguing that in this way less dehiscence would occur in the next pregnancies [23]. The density of the muscular fibers in the body of the uterus is much more abundant than in the lower segment where the connective tissue prevails. Otherwise the cervix would not be able to open when the upper part is contracting. More damage is done to the muscle tissue the higher the uterus is cut open. The mean actomyosin content of the uterus is significantly greater than that of the cervix (7.54 vs. 3.72 mg/gm) ($P = 0.01$) [24].

Embryologically, each Mullerian duct is surrounded by the urogenital ridge mesenchyme that gives rise to the fibromuscular wall of the uterus (endometrial stroma and myometrium) and to comparable connective tissue and muscle layers of the oviduct, cervix, and upper vagina [25], hence

the difference in the histology between the body of the uterus and the cervix. Despite being considered as one organ, the cervix and the uterus have different structures and function. Their histology is different; the endocervix and the endometrium have different characters; the body of the uterus is covered with peritoneum, which is not the case in the cervix; and during labor, the uterus contracts, while the cervix widens and relaxes. We will see later that these differences take part in the decision in where to perform the opening of the uterus.

In the years to come, the prevailing CS contained the following steps: opening the abdominal wall in a longitudinal or transverse incision, opening the peritoneum transversely or longitudinally, packing the abdomen with abdominal towels, opening the uterus above the bladder plica, or separating the bladder, pushing it down, and opening the lower segment transversely, delivering the baby and the placenta, contracting the uterus, suturing the uterus with two layers, suturing the visceral peritoneum when applicable, removing the abdominal towels and cleaning the abdomen, closing the parietal peritoneum, closing the fascia continuously or with single stitches, suturing the subcutaneous tissue, and closing the skin intradermally or with single stitches [26].

At the point where the scalpel touches the skin, all surgical history and culture should be present.

However, each surgical procedure is composed of many, sometimes hundreds, of movements, each one of them has its own history and rationale. Many of these steps are based on local traditions established by opinion leaders in their specialties and countries, and their charismatic influence prevailed in following years. Every single surgical step should be carefully examined for its necessity and, if found so, for the most optimal way to perform it, as even very trivial steps might be significant. It is important to use an evidence-based CS to avoid unnecessary complications.

Therefore, many surgical methods were never subject to comparative studies, and in many hospitals, traditional steps prevail despite the existence of data showing the unnecessity or existing disadvantages. The same applies also to the indications for CS. The very fact that there are such large differences in the rate of CS, even in different hospitals in the same country or even the same city, demonstrates that there are still no standardized indications. It has been shown that with simple measurements the CS rate was reduced dramatically without any ill effects on the outcome of newborns [27].

### 14.3.1 The Positioning of the Parturient

Today, most CSs are performed using an epidural or spinal anesthesia or combination of both. After anesthesia is administered, the patient should be placed on the operation table with her legs closed. This will prevent tension on the fascia while it is being sutured. The arms of the parturient should not be extended outward in order to prevent neurological damage; this is especially the case when general anesthesia is used [28].

For optimal access to the lower segment of the uterus, and in order to avoid the use of abdominal packs, a Trendelenburg position should be used [29].

After the bladder is emptied with the catheter and the abdomen has been cleaned and covered, the planned site of the incision should be marked. This can be done by pinching or with a pencil, respecting the Langer skin lines [30]. Following these lines will result with an optimal scar. The level of the incision should be drawn in a straight line 3 cm below an imaginary line connecting both spinae iliacae anteriores superiores. The Langer lines become clear when the lateral aspect of the scar is pushed away from the midline. Therefore, marking the planned incision should be done while stretching the skin laterally. In case this line is not clearly marked before stretching the skin, there is a risk that the scar will not be symmetrical and wider on one of the ends.

### 14.3.2 The Positioning of the Surgeon

For ergonomical reasons the right-handed surgeon should stand on the right side of the parturient. When delivering the baby, the more sensitive right hand can easily estimate the needed force to extract the baby, thereby creating less risk for unnecessary extension of the incision of the uterus, avoiding unnecessary extra bleeding. Later, when stitching the uterus, the tip of the needle will point away from the bladder, thus protecting it.

### 14.3.3 The Surgical Technique

The first incision is done along the marked Langer lines very superficially, cutting only through the cutis (Fig. 14.4). The

**Fig. 14.4** First incision, cutting only through the cutis

location is 3 cm below an imaginary line which connects both spinae iliacae anteriores superiores.

This step usually does not require any hemostasis as there are no large blood vessels close to the cutis.

In the midline, where there are anatomically no significant blood vessels, the incision is deepened transversely until the fascia is reached. Then a transverse incision of 2–3 cm is made in the fascia, exposing the recti muscles underneath (Fig. 14.5).

Now a straight scissor with rounded tips is taken in hand.

One tip of the scissors is placed below and the other above the fascia, while the tips of the scissors are opened to about 3 mm (Fig. 14.6). The scissors are pushed toward the assistant, opening the fascia as much as is necessary as estimated by the size of the baby and then repeating this step backward toward the surgeon.

Following this step, the fascia is now open between the straight blood vessels and the muscles. The surgeon inserts both index fingers below the fascia and stretches its leaflets caudally and cranially (Fig. 14.7).

**Fig. 14.5** In the midline, the incision is deepened, cutting the fascia, exposing the muscles underneath

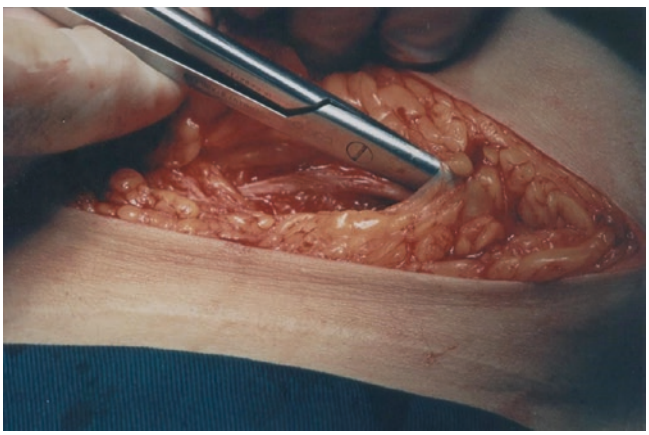


**Fig. 14.6** Round-tipped scissors, one tip above and one tip below the fascia pushed laterally as far as necessary

This enables the assistant to insert an index and middle finger below the recti muscles.

The surgeon does the same from his or her side. Now, both, the surgeon and the assistant, pull the muscles laterally, together with the fat tissue and blood vessels as much as needed, again depending on the size of the baby (Fig. 14.8).

Once in a while, more force is needed to pull the muscles laterally, as might happen by repeat operations with fibrosis of the subcutaneous tissues or by overweight women. In this case, four fingers (two fingers from each hand) should be used by both the surgeon and the assistant. The placement of the four fingers should not be next to each other, but one over the other.

Blood vessels have lateral sway, but do not have length elasticity. When both hands are pulling the opening, there is a natural tendency that the hands will move apart, thereby risking blood vessel tearing.

Abdominal packs should not be used, as their usage causes adhesions. The abrasive effect of introducing packs will produce mesothelial trauma which becomes a stimulus for inflammation, followed by adhesions to adjacent surfaces [31, 32].

Not using abdominal packs also ensures that they will not be forgotten inside the abdominal cavity.

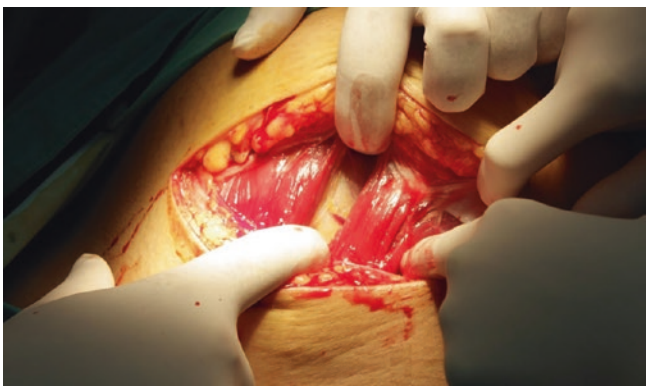


**Fig. 14.7** The fascia is pushed up and down which enables both the surgeon and the assistant to place their fingers below the muscles

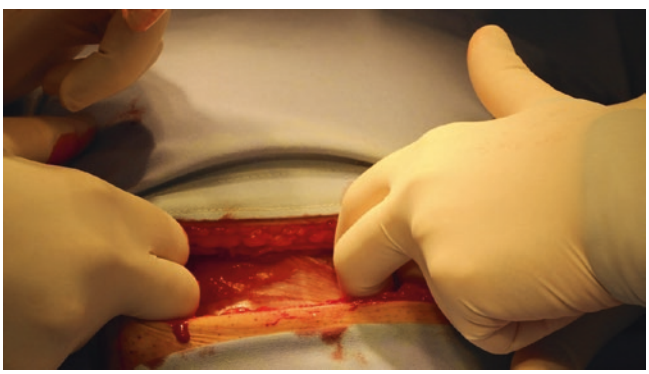


**Fig. 14.8** Both the surgeon and the assistant pulling the recti muscles laterally, together with the blood vessels as far as necessary

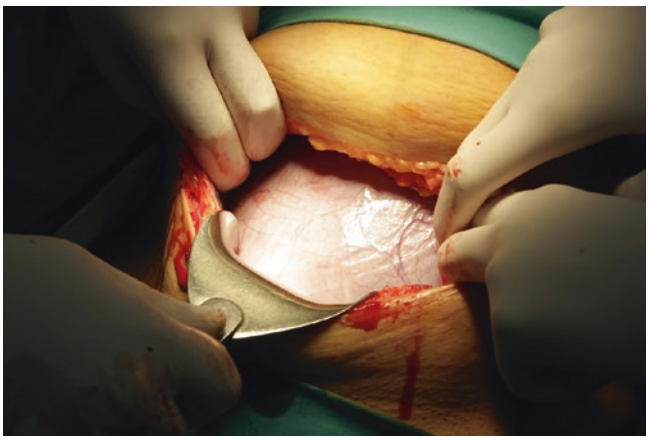


**Fig. 14.9** A hand speculum pulls the lower part of the incision to expose the plica

The bladder plica should be cut open using a scalpel; in order to expose the plica, a hand speculum should be used, pulling the lower part of the incision down (Fig. 14.9).

Cutting the visceral peritoneum should always be done from the lateral aspects of one side toward the midline and then from the lateral aspect of the other side toward the midline, until it reaches the point where the other side was reached. The reason is that, if it is done the whole way in one direction, there is a risk of cutting into the intestines, as it is difficult to observe clearly the cutting edge of the scalpel. The plica can now be pushed down using two index fingers.

As mentioned, Munro Kerr suggested opening the uterus in its lower segment [33]. In the lower segment, the amount of the fibrous tissue is more dense than in the uterine body. Therefore, the lower the opening in the uterus, the less damage to the myometrium occurs.

Using a scalpel in the exposed lower segment, a transverse incision of about 2–3 cm is done carefully and gently. It is not necessary to complete the incision to the whole thickness of the cervix as this might cut the head or face of the baby which can happen if the membranes have already ruptured and the woman is in active labor, and therefore the lower segment is thin. The final internal part can be penetrated by pushing with one finger through the cut.

Planned CS should be ideally done after the onset of spontaneous contractions. The initiation of labor starts with the initiative of the baby [34, 35].

In predelivery CS one can find not just a thick lower segment, but also maternal breasts which are not yet ready for breastfeeding. There are also other good reasons to avoid pre-labor CS. A recent large cohort study has found that prior pre-labor cesarean delivery was associated with more than twofold significantly increased risk of placenta previa in the following delivery [36]. By contrast, the 20 % increased risk of placenta previa associated with prior intrapartum cesarean delivery was found to be not significant.

The optimal way to complete the opening of the lower segment of the uterus is to extend the initial opening by extension using two fingers (the thumb of the right hand of a right-handed surgeon pushing away and the index finger pulling toward the surgeon). Doing so, the lower segment will open along its natural fibers, which become transverse when it develops, therefore causing minimal bleeding. Cutting with a sharp instrument, like scissors, does not respect the natural anatomy and results with excessive bleeding.

Delivering the baby in vertex position happens while inserting the right hand of the surgeon into the uterus and encircling the head of the baby and then directing the head upward, while slight fundal pressure is allowed. As the right hand has its sensitivity, usually no overextension of the uterine opening will occur, and therefore no unnecessary bleeding happens.

After clamping, drawing blood, and cutting the umbilical cord, the placenta should ideally be delivered spontaneously by assisting through mild traction of the umbilical cord, rather than by manual extraction [37].

Thereafter the uterus should be exteriorated, as in this position it is easier to suture the uterus, to contract it in order to avoid extra bleeding, and also to easily inspect both ovaries.

There are different ways to suture the lower segment. Many of them originate from the already mentioned local traditions. Some surgeons prefer to suture first the angles, followed by two layers of sutures, usually continuously, but sometimes with single stitches to the first or second layer.

The uterus quickly contracts in the first hours after surgery, and after 6 weeks, the uterus returns to its size before the pregnancy. The quick involution results also in shrinkage of the lower segment of the uterus. The sutures are unable to contract along with the uterus, and in a short time after the surgery, they will begin to loosen over the opening line. The aim of the suture is to secure hemostasis in the first postoperative hours. Suture material creates foreign body reaction, and the more of them used, the more marked and longer the reaction, prolonging the healing process. Therefore the less suture material used, the better the healing.

In order to close the uterine wall with the most minimal amount of suture material possible, it is best to use a big needle which will enable closure of the opening and safe hemostasis (Fig. 14.10).

For this reason, it is recommended to use at least an 80 mm needle with an absorbable 1 m-long suture, PGA USP size 1, done continuously. The reason for using a long suture is that it enables placing the knot not at the most lateral aspect of the opening but allows one to go back one or two times in the direction of the midline. Knots placed at the end of the opening might loosen, which will cause bleeding.

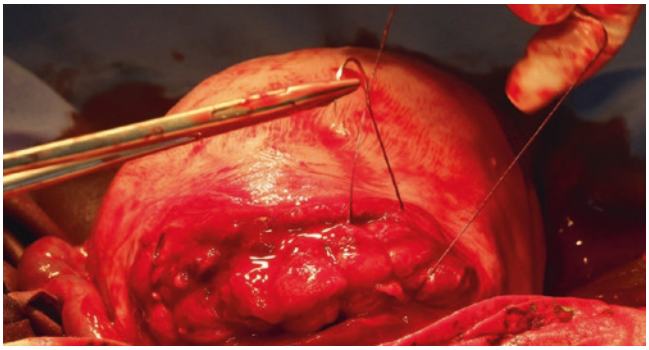


**Fig. 14.10** The uterus is closed with one layer only, using a big needle

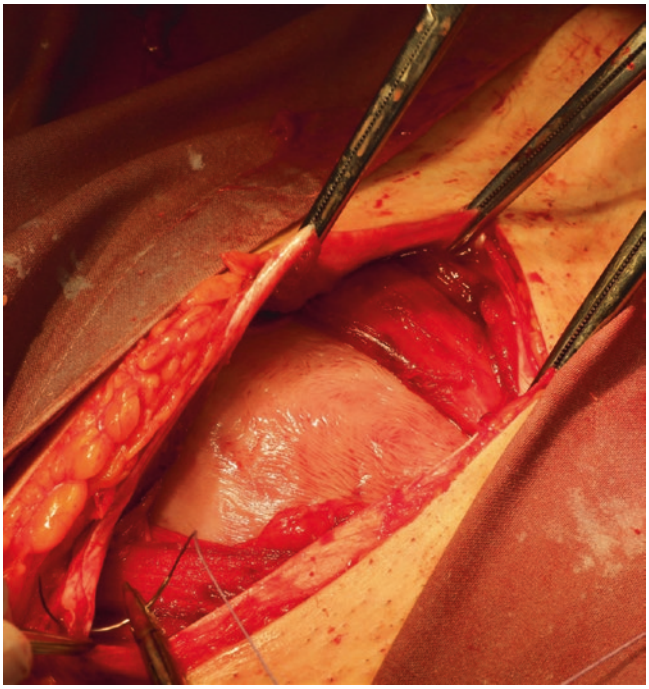


**Fig. 14.11** The fascia is closed continuously and the first knot is under the fascia to avoid irritation to the subcutaneous tissue

There is no point whatsoever for a second layer as long as hemostasis is achieved.

It is not surprising that the dehiscence of previous uterine sutured with one layer is less frequent than those with two layers [38], and a double-layer closure of the cesarean uterine incision does not increase residual myometrium thickness compared to single-layer closure [39].

As no abdominal packs are used, blood clots should be removed with the palm of the hand, and fluid blood will anyhow be absorbed naturally by the peritoneum in a short time, as has been known for many years [40].

The uterus is then repositioned into the abdomen. As long as the uterus is exteriorated, the mechanical tension might disguise active bleeding. Therefore, when the uterus is positioned back into the abdomen, the lower segment should be inspected to ensure that there is no bleeding. Bleeders should be treated with targeted single stitches. There is no justification for a second layer in case of single-sight bleeding.

The abdomen should never be closed before checking the blood pressure of the woman as in low blood pressure bleeding cannot be identified and might occur later when the blood pressure rises. As a rule, the abdomen should not be closed unless blood pressure is normal.

In 1980, Harold Ellis from the Westminster Hospital in London demonstrated that when the peritoneum is left open, a new one will form in short time from the coelom cells underlying the muscles [41].

Unlike the skin, the peritoneum cannot heal by end-to-end approximation. If the peritoneum is left open, a new one will be formed without adhesions.

Our group started leaving the peritoneum open already in 1983. Ten years later, we could compare the rate of adhesions in repeated CS in women who were operated on in the first CS, leaving the peritoneum open and with those in which both peritoneum layers were sutured. In the group where the peritoneum was left open, there was significantly less adhesions [42]. The guidelines of the Royal College advise leaving both peritoneal layers open during closure [43]. In 600 repeated operations, adhesions were found in 7 (11.3 %, in women where the peritoneum was left open during the previous operation) and 22 (35.5 %, in cases where the peritoneum was sutured) [44].

As the peritoneum is left open, just the fascia and the skin must be closed.

Similar to the uterus, there are many variations about how to close the fascia; many of them based on local traditions. Anatomically the fascia was opened above the plica arcuata, and therefore we will find two layers in this level on the lateral sides which should be stitched together. In order to facilitate the stitching, a straight Pean is placed in order to laterally hold both layers, and two other Peans are placed three-fourths of the way toward the assistant (Fig. 14.11).

Knots cause local reaction and irritation. Therefore it is advised to place the lateral initial stitch underneath the fascia. This is done by starting the first stitch from inside to outside, taking both layers together, then from outside to inside.

The first knot is placed below the fascia. The suturing now moves with the needle from inside to outside in continuation through the whole layer. It is advised that the suturing will start at the side of the surgeon toward the assistant. If it is done so, the assistant will hold both of the Peans on the side and lift the fascia, thus guiding the surgeon. The Peans should be held close enough to each other in order to enable suturing without tension, but at the same time, open enough to enable the surgeon to see the underlying structure and to

**Fig. 14.12** Skin closure, intracuticular

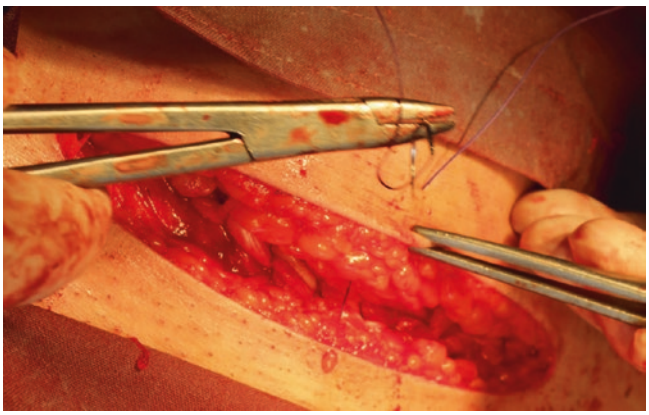


**Fig. 14.13** Skin closure, with single Donati stitches, which enables good drainage

avoid damage to intra-abdominal structures. Once the suture reaches the two lateral Peans, the assistant should remove them and elevate the Pean next to his or her side. In this way, the surgeon, holding the suture material with the left hand, is able to control the needed tension.

There is still no convincing evidence concerning the optimal way to close the skin. Some surgeons prefer using intracuticular suturing which looks at first sight more aesthetic (Fig. 14.12).

However to use this method means subcutaneous sutures are needed. Any sutures and knots are reason for foreign body reaction, and therefore we recommend the use of single Donati silk sutures with a cutting skin needle, and the less placed sutures, the less risk for subcutaneous seromas or hematomas (Fig. 14.13).

The amount of the sutures has to do directly with the experience of the surgeon. Well-trained surgeons can achieve excellent results by using three stitches only, provided they use a big skin needle, where the lateral stitches can be removed after 48 h, resulting in immediate disappearance of local abdominal pain, and the midline suture should be removed after 5 days. The reason that the removal of the lateral stitches will immediately reduce the amount of pain is due to the fact that the skin will swell in reaction to the trauma but the sutures cannot expand with it. As a result there is a constant pinching feeling until the removal of the stitch.

Thereafter, the uterus should be contracted again manually, and the abdominal incision should be covered with a pad which should be replaced 3–4 h after surgery as the wide sutures enable blood to drain from the wound.

### 14.3.4 Postoperative Treatment

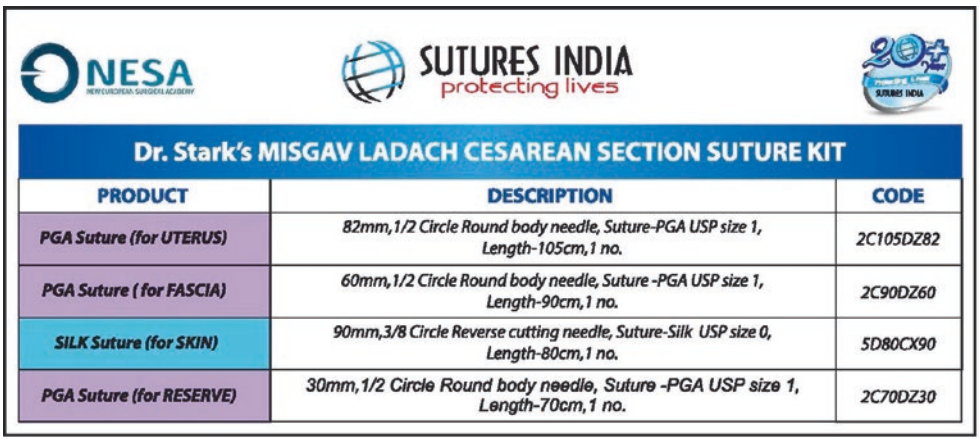
Early mobilization is the most optimal way to avoid the complications of vein thrombosis and therefore should be encouraged. CS is a significant risk factor for thromboembolism [45]. Early mobilization can be enhanced by good postoperative pain treatment and removal of the catheter as early as possible. One should encourage early drinking which helps the self-assurance of the mother and function of her intestines [46].

One of the major problems concerning comparison of different surgical methods is the lack of standardization. Different surgeons, even in the same departments, are often using different variations. Therefore, without standardization of the surgical method in use, it will be impossible to compare the outcomes and standardization is the basis for the ability to compare different methods and even comparison between different surgeons and institutions [47].

## 14.4 World Literature and Meta-analysis Pitfalls

Since the first publications concerning the evidence-based CS, retrospective and prospective studies have been done extensively. Comparative studies were made concerning febrile mobility, complications, need for painkillers, and cost. Without any exception, all the studies show benefits of the described operation over other methods in use. However, it is interesting to note that nearly each one of these publications finds benefits in different details, sometimes concerning the febrile mobility and at other times concerning the use of painkillers. Obviously the reason for this is that despite the meticulous description of the method [48, 49], local traditions still prevail, and certain variations are used which influence the outcome. Therefore it is of utmost importance to standardize the surgical method and prospective studies, always to compare two methods which will be repeatedly the same [50]. The reason we need a large number of patients in prospective studies is due to the individual variations in the operated mothers. We try to stratify studies according to age,

**Fig. 14.14** The designed CS kit




weight, number of previous operations, birth weight of the baby, etc. and are using sophisticated statistical methods to find the significant differences. The surgical steps, however, should not vary, and therefore it is important to define them and to use also the right sequence and way of performance. It is important to use a standardized set of instruments as different instruments might result in variant reaction of the tissues; at the same time, it is important to use standard needles and suture material. The size of the needle, for example, which is used for suturing the uterus, will define the amount of foreign material left behind. Using short sutures will need extra ties and starting again with new suture and a new tie; these are causing local reaction. It is recommended to use an 80 mm round-body needle with 1 m long suture (PGA USP size 1). Same for the suturing of the fascia, a 60 mm half-circle round-body needle with a PGA USP size 1 suture and, for the skin, a 90 mm 3/8 circle reverse cutting needle, suture silk USP size 0, are recommended. This combination of sutures proved to be the most optimal with the least movement needed and in favor of standardization; a CS surgical kit was produced (Fig. 14.14).

Using standardized surgical methods and a standardized set of surgical instruments, as well as suture material, next to standardized routines concerning usage of bladder catheter, antibiotics, painkiller routines and mobilization, and hydration routines, is the only way to enable reliable comparison between different surgical procedures.

## 14.5 The Future of In-Labor Non-emergency CS

The best way to prevent CS complication is to avoid doing them whenever possible and, in case they have to be done in non-emergency situations, to find their most optimal timing. Even among professionals, it is still frequent to confuse elective and pre-labor CS. It is also frequent to confuse emergency and in-labor CS. Where the responses by the fetal physiological reactions are concerned, it appears today that the main differences are between pre-labor CS and all the other ways of birth. Our objective is to make the concept of "in-labor non-emergency CS" familiar. We will emphasize that it is possible to plan an in-labor CS and also to decide and perform before the stage of emergency "in-labor CS."

### 14.5.1 Other Reasons to Avoid In-Labor Emergency CS

In order to avoid unnecessary complications, it is important to understand that CS performed in emergency situations are associated with non-favorable short-term outcomes. Many times, such CS are performed when there are already signs of fetal distress, after a long period of pharmacological influence. We must also take into account that emergency CS are often performed in a hurry and very often are associated with non-favorable technical conditions. Furthermore, they are associated with negative long-term complications. According to an American study, women with a full-term second-stage CS have a significant increased rate of subsequent premature births (13.5 %) compared to a first-stage CS (2.3 %) and to the overall national rate (7–8 %) [51]. The same authors have demonstrated that a prolonged second stage of labor alone does not increase the risk of premature birth in following pregnancies. One plausible interpretation is that in case of CS during the second stage of labor, the location of the hysterotomy on the low segment is different from what it is otherwise [52].

This overview of the negative effects of both pre-labor and last-minute emergency CS suggests that the optimal kind of CS is the one performed during labor, before the stage of a real emergency. Until now, the concepts of "planned in-labor CS" and "in-labor non-emergency CS" have not been subject for epidemiological studies. In a multicentered randomized controlled trial about breech presentation at term, only two options were considered: planned pre-labor CS and planned

vaginal route [53]. In the extensive Scottish retrospective cohort study of adverse outcomes in childhood, "planned CS delivery" was in fact synonymous with pre-labor CS. It is noticeable that, in this cohort, children born by planned (pre-labor) CS were more likely to develop type 1 diabetes than those born by "emergency" CS or by the vaginal route. The differences were highly significant, even after adjustment for potential confounders, including maternal type 1 diabetes [54]. This data about an autoimmune disorder indicates the need for further studies of the risks of dysregulations of the immune system in relation to "birth without labor." There is a need, in particular, for a new generation of studies focusing on the risk factors for IgE-mediated atopic syndromes.

### 14.5.2 Toward New Obstetrical Strategies

On the day when the concept of "in-labor non-emergency CS" becomes familiar, the doors will be opened toward simplified binary strategies, with two basic scenarios: either the birth process is straightforward by the vaginal route or it appears difficult and an in-labor CS before the stage of emergency is considered the best option. Before such simplified strategies become realistic, the history of obstetrics will have to go through several steps. One of these steps will be via studies regarding the long-term side effects of the different medications used during labor. Although there are serious theoretical reasons to reconsider the widespread use of synthetic oxytocin and epidural analgesia, we have not been able to rely, until now, on a large amount of hard data. However, in this new framework, we can already mention valuable studies of the effects of epidural analgesia and synthetic oxytocin, on the initiation and quality of breastfeeding [55, 56]. We can also mention studies looking at risk factors for autism in the perinatal period: while they are based on a great diversity of research protocols in different countries, they all reach similar conclusions about labor induction and labor augmentation [57–61]. The emergence of this new generation of studies (collected in the database "www.primalhealthresearch.com") is already offering reasons to use medications during birth with renewed caution, particularly for labor induction and labor augmentation.

The main step toward the advent of simplified strategies will be an understanding of the process of parturition challenging the effects of thousands of years of tradition and cultural conditioning. This is realistic in the light of modern physiology. From this perspective, the birth process appears as an involuntary process under the control of archaic brain structures. As a general rule, one does not try to help an involuntary process. The point is to identify possible inhibitory factors. From a practical perspective, the key word is *protection*. Several physiological concepts clearly indicate the factors that can negatively interfere with the process of parturition. The concept of adrenaline-oxytocin antagonism is essential where mammals in general are concerned: mammals postpone the delivery when releasing emergency hormones of the adrenaline family. Although this concept is well established, in practice it is not always taken into account, as if it were not perfectly assimilated.

The evolution worked in the direction of continuation of generations with as little complications as possible. Many of the complications which happen during labor or CS are iatrogenic in nature. It is important to stress that each maneuver during childbirth or performance for CS should be well indicated. It seems that the active management of labor did not answer expectations, even if the rate of CS was reduced [62].

### 14.5.3 The Concept of Neocortical Inhibition

When considering the case of human birth, the focus should be on the concept of neocortical inhibition, a key to understanding human nature in general. We should keep in mind that some human abilities are usually obscured by neocortical activity. There has been until now a lack of interest in this essential particularity of our species. Human parturition is better understood if introduced in the framework of functions usually obscured by neocortical activity. A first example is offered by olfactory abilities. An ingenious experiment has explored the human sense of smell after neocortical disinhibition by alcohol consumption [63]. Another example is offered by the human swimming abilities: the capacity to adapt to immersion and have coordinated swimming movements when submerged disappears around the age of 3 or 4 months, when the neocortex is reaching a certain degree of maturity [64].

When the concept of neocortical inhibition is understood and taken into account, it is easy to challenge the assumption that mechanical factors are the main reasons for difficult births in our species. In fact, the mechanical factors are undoubtedly overestimated, since there are women with no morphological particularities who occasionally give birth quickly without any difficulty. There are anecdotes of women who give birth before realizing that they are in real labor. There are in particular countless anecdotes of teenagers who, at the end of a hidden or undiagnosed pregnancy, just go to the toilet and give birth within minutes. These facts alone suggest that the main reasons for difficult human births are not related to the shape of the body. The best way to clarify the nature of the specifically human handicap during the period surrounding birth is to consider the case of civilized modern women who have given birth through an authentic "fetus ejection reflex" [65]. It is exceptionally rare in the context of socialized birth. The birth is suddenly preceded by a very short series of irresistible, powerful, and highly effective uterine contractions without any room for

voluntary movement. The important point is that when the "fetus ejection reflex" is imminent, women are obviously loosing neocortical control. They become indifferent to what is happening around them. They forget what they have previously learned. They forget their plans. They behave in a way that, in other situations, would be considered unacceptable regarding a civilized woman. For example, they dare to scream or to swear. There are anecdotes of women who have bitten a person perceived as intrusive. Women in hard labor can find unexpected, complex, asymmetrical postures usually involving bending forward. Such scenarios clearly indicate the solution. Nature found to make birth possible in our species: reduced neocortical control. This essential aspect of birth physiology in our species offers an ideal perspective to reach the simple conclusion that a laboring woman needs to be *protected* against all possible stimulants of her neocortex. Since language is a major stimulant, silence appears as a basic need that is culturally ignored or underestimated after thousands of years of socialization of childbirth. In this respect, rational language and language expressing questions have particularly powerful effects.

Light has not been scientifically studied as a powerful cortical stimulant until recent advances regarding the functions of melatonin, the "darkness hormone." However, the long history of blinds and curtains is the confirmation of deep-rooted transcultural empiric knowledge that is pushing us, today, to switch off electric lights in order to reduce neocortical activity during sleeping time. Recent studies of the interactions inside the triad oxytocin-melatonin-GABA offer a promising avenue for research. It is already understood that the GABA(A) receptors mediate the effects of melatonin on neocortical activity [66, 67]. Until now, the interactions between the oxytocin and the GABA systems in the perinatal period have been mostly studied in the framework of the shift of the effects of GABA at the end of fetal life, when this primary excitatory neurotransmitter becomes inhibitory [68]. When considering the effects of melatonin, and therefore light, on human parturition, we have to deviate from the concept of neocortical inhibition and refer to recent advances regarding peripheral effects. It is now established that there are melatonin receptors in the human myometrium and that melatonin is synergistic with oxytocin to enhance contractility of human myometrial smooth muscle cells [69–74]. Today melatonin appears as an important hormonal agent in human parturition. This is confirmed by the significant amount of melatonin in the blood of neonates, except those born by pre-labor CS. The importance of these findings appears clearly when the protective antioxidative properties of melatonin are taken into account. In the age of electric lights, the reasons to improve our understanding of melatonin release and melatonin properties are obvious. It is already well established that short-wavelength light (in practice "blue" light) is the most melatonin suppressive. This is an important fact, since it is the kind of light typically emitted by devices such as televisions, computer screens, cellphones, and even lamps in conventional delivery rooms. It is probable that, when birth physiology is better understood, the practical implications of these recent scientific advances will be seriously considered. Until now preliminary practical implications have been limited to attempts to facilitate shift work and also to facilitate the initiation of sleep through the use of amber glasses that block blue light [75, 76]. Can we imagine a time when it will be considered rational to give birth by candle light? Can we imagine a time when women familiar with the use of amber glasses when in front of computer screens will also use such glasses when in labor? After mentioning language and light, we might summarize the most important points by emphasizing that all attention-enhancing situations are stimulants of neocortical activity. This is the case of feeling observed: it implies that one of the basic needs of a laboring woman is privacy. The perception of a possible danger is another example of an attention-enhancing situations: it implies that a laboring woman needs to feel secure. We can notice that similar conclusions can be reached when using the concept of adrenaline-oxytocin antagonism as a starting point.

### 14.5.4 Predictive Scores and Tests

As a primary objective, reducing the rates of CS is dangerous. The effect is an increased prevalence of difficult births by the vaginal route with an increased need for pharmacological assistance [77]. The first step should be a renewed understanding of the basic needs of laboring women inspired by the physiological perspective: only this perspective can induce a paradigm shift after thousands of years of socialization of childbirth. According to our deep-rooted dominant cultural conditioning, a woman needs cultural interferences to give birth: this is the "helping-guiding-managing-coaching-supporting paradigm." From the perspective of modern physiology, the keyword is "protection" (of an involuntary process). Such a paradigm shift is the prerequisite for the advent of simplified binary strategies based on the concept of in-labor non-emergency CS. When simplified binary strategies become realistic, there will be new reasons to associate clinical judgements with predictive scores and tests. An American study of predictive scores took into account 11 variables in order to identify, within 2 h after admission, risk factors that place at term nulliparous women in labor at risk for CS. The population was divided into quintiles, in which the lowest risk group had a 5 % incidence and the highest risk group had an 88 % incidence of CS. The objective of this study was clearly to reduce the potential morbidity of long labor or failed operative vaginal delivery [78]. Interestingly it takes also about 2 h to decide, through the "birthing pool test," if an in-labor

non-emergency CS is the optimal option when the first stage is not straightforward. This test is based on the simple fact that when a woman in hard labor enters the birthing pool and is immersed in water at body temperature, a spectacular progress in the dilation is supposed to occur in an hour or two [79]. If the already well-advanced dilation remains stable in spite of water immersion, privacy (no camera!), and dim light, one can conclude that there is no reason for procrastination. It is wiser therefore to perform a CS immediately [80]. In the age of simplified techniques of CS, there are renewed reasons for simplified obstetrical strategies which will reduce, when followed, the rate of neonatal and maternal complications.

## 14.6 Complications

We have emphasized that the best way to avoid complications related to CS is to avoid unnecessary operations, and understanding the physiology is a key factor. An extremely low percentage of CS is not necessarily an indication for quality, and an extremely high rate is not necessarily a sign of overuse. The population in each hospital is different, not just because of the existence or nonexistence of intensive care units for the mother and newborn, but also due to the population living in the area, their general health, age by first delivery, and many other factors. Therefore, artificially defining an optimal rate of CS will miss the point. It should be individualized, and each single case should be discussed, and the decision to perform CS, except in extreme emergencies, should be consulted with another obstetrician or during the daily staff meeting where applicable.

Even when a CS is indicated for a justified reason, the timing of the operation is critical. We know today that it is optimal to perform an indicated CS after labor has started. The lower segment develops which has influence on the amount of bleeding and easiness to open the uterus; the chance of the baby to be mature is higher, as the baby is the one signaling the mother when to start contractions and the mother is ready to start breastfeeding [81]. There are also surgical aspects which are more favorable when contractions have already started due to fact that when the lower segment develops, it is surgically easier to open the uterus in a location with less muscular tissue and more fibrous tissue. This will secure a stronger scar and lower the risk of dehiscence in following deliveries.

Pre-labor CS is a risk factor for respiratory difficulties during the neonatal period, and the risks are dependent on the gestational age: differences in the quality of the respiratory functions are detectable when comparing pre-labor births at 38 and 39 weeks [82]. The roles of maternal and fetal stress hormones are well known. The effects of maternal corticosteroids on fetal lung maturation are already known and have had practical implications for several decades. Labor implies the action of beta-endorphins (releasers of prolactin, which participate in lung maturation) [83]. Labor also implies the release of the fetal noradrenaline, which is one of the main factors responsible for lung maturation.

The negative effects of stress deprivation of babies born by pre-labor CS are underestimated. For example, it has been demonstrated that, under the effect of noradrenaline, the sense of smell reaches a high degree of maturity at birth among these babies than those delivered naturally. The principle of a Swedish study was to expose babies to an odor for 30 min shortly after birth and then to test them for their response to this odor (and also to other odors) at the age of 3 or 4 days [84].

Since the concentrations of noradrenaline had been evaluated, it was possible to conclude that fetal noradrenaline released during labor is involved in the maturation of the sense of smell. We must emphasize the paramount role of the sense of smell immediately after birth. The fact that the sense of smell is a main guide toward breastfeeding was already recognized in the 1970s [85, 86].

It has also been shown that it is mostly through the sense of smell that the newborn baby can identify its mother (and, to a certain extent, that the mother can identify her baby). There has recently been an accumulation of data multiplying the reasons for waiting, whenever possible, for the onset of labor before performing a CS. Many unexpected differences have been demonstrated through human studies regarding the effects of CS births according to their timing. Among such studies, we must mention the evaluation of adiponectin concentration in cord blood of healthy babies born at term. The concentration of this agent involved in fat metabolism is significantly lower after pre-labor CS compared with in-labor CS or vaginal route [87]. These data suggest a mechanism according to which stress deprivation at birth might be a risk factor for obesity in childhood and adulthood. We must also give great importance to data regarding the milk microbiome. There are significant differences between the milk of mothers who gave birth by pre-labor CS and those who gave birth by in-labor CS or the vaginal route [88]. These results suggest that there are other factors than the operation per se that can alter the process of microbial transmission to milk. Similar differences were found by a Canadian study of the gut flora of 4-month-old babies [89]. Joanna Holbrook and her team, in Singapore, suggest interpretations for these surprising data. They collected fecal samples from 75 babies at the age of 3 days, 3 weeks, 3 months, and 6 months (and they evaluated the degree of adiposity at 18 months). It appears that, apart from the route of birth and exposure to antibiotics, a shortened duration of pregnancy tends to delay the maturation of the gut flora, 1 week more or less in the duration of pregnancy is associated with significant differences, and a pre-labor CS implies the association of all the known factors

that can delay the maturation of the gut flora. This study is all the more important since it also reveals that a delayed maturation of the gut flora is a risk factor for increased adiposity at the age of 18 months [90].

In the framework of human studies, we may include also evaluations of the concentrations of melatonin in the cord blood. Melatonin levels proved to be low after pre-labor births [91]. This is an important point, since melatonin has protective antioxidative properties. Furthermore, it confirms that the "darkness hormone" is involved in the birth process. This is one of the reasons why the role of melatonin during labor is a topical issue, at a time when we are learning about a synergy between its uterine receptors and oxytocin receptors. In general, a baby born after a pre-labor CS is physiologically different from others. For example, babies born before the start of labor tend to have a lower body temperature than others during the first 90 min [92]. In spite of possible interspecies differences, we must learn from animal experiments suggesting that the stress of labor influences brain development. Such is the case of studies demonstrating that the birth process in mice triggers the expression of a protein (uncoupled protein 2) that is important for the hippocampus development [93]. The hippocampus in *Homo sapiens* is a major component of the limbic system. It has been compared to an "orchestra conductor" directing brain activity. It has also been presented as a kind of physiological GPS system, helping to navigate while also storing memories in space and time: the work of three scientists who studied this important function of the hippocampus has been recognized by the award of the 2014 Nobel Prize in physiology and medicine. This is also the case of studies with rats suggesting that oxytocin-induced uterine contractions reverse the effects of the important neurotransmitter gamma-aminobutyric acid (GABA): this primary excitatory neurotransmitter becomes inhibitory [94]. If uterine contractions affect the neurotransmitter systems of rats during an important phase of brain development, it is not improbable that the same happens in humans.

Other reasons to avoid pre-labor CS will present in the future. It seems that the prevalence of lateral (Fig. 14.15) or central placenta previa (Fig. 14.16) is significantly increased only in the case of a pregnancy following a pre-labor CS [95]. There is already an accumulation of data confirming the negative effect of pre-labor CS on breastfeeding, particularly at the phase of initiation of lactation [96, 97]. Toward the end of the pregnancy, major anatomical changes happen. The lower segment of the uterus develops and the wall in the lower aspect of the uterus becomes thinner. Optimally, during CS, the uterus should be open after pushing down the bladder. As we stressed before, the histology of the lower segment is different than the body of the uterus, and one of the differences is the prevalence of more fibrous tissue and less muscle. Therefore, performing CS after the initiation of contractions will enable the opening of the uterus in a segment with less muscle and with a thinner wall. This will result with easy extension of the opening which, as we described, can be done by using two fingers (the thumb of the right hand pushing away and the index finger pulling toward the surgeon). This maneuver results with less bleeding and is much easier than opening the lower segment during pre-labor CS. This enables suturing the uterus with one layer, which proved to be beneficial, not just due to less suture material and therefore less foreign body reaction which could result in a weak scar, but also in avoiding complications related to bleedings and unnecessary extra stitches which might cause damage to the urine bladder (Fig. 14.17) and occasionally even to the ureters and fistulae [98, 99].

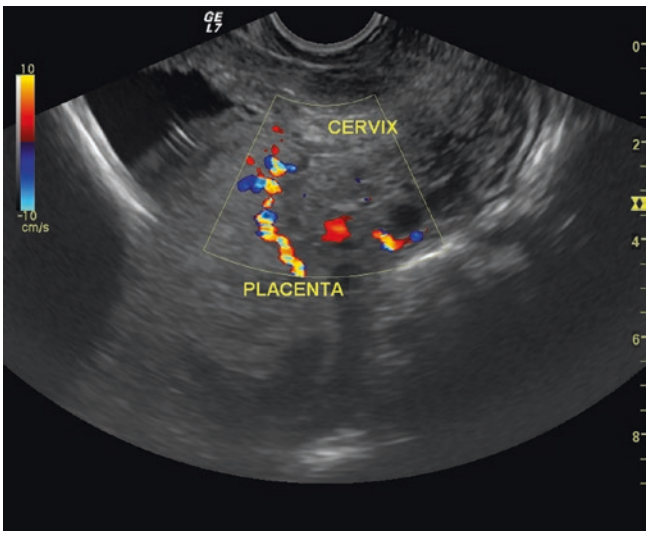



**Fig. 14.15** A transvaginal ultrasonographic scan of lateral placenta previa

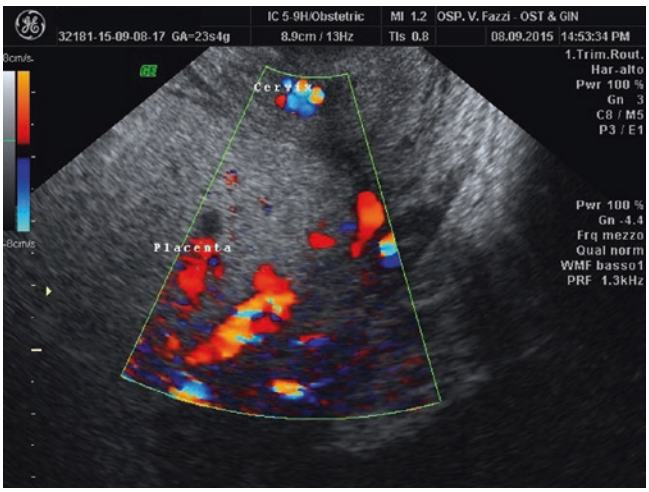



**Fig. 14.16** A transvaginal ultrasonographic scan of central placenta previa with accretism

**Fig. 14.17** A complication during cesarean section: the accidental damage to the urine bladder, with the leakage of the catheter from the bladder

### 14.6.1 The Short-Term Complications of CS

Short-term complications of delivery include all maternal or neonatal complications from birth up to 42 days after delivery. Complications such as intra- and postpartum hemorrhage (PPH) are more frequent during and after emergency CS and in women with a preexisting condition such as hypertension and diabetes, women with multiple gestation pregnancy (MGP), or women presenting with a low-lying placenta [17, 100]. These risk factors also increase the need for cesarean delivery [17, 19, 101, 102]. New risks factors such as maternal obesity and advanced maternal age (AMA) are now established risk factors for CS and can explain in part the some of the rapid increase in the CS rates worldwide [103–109]. Obese primiparous women and multiparous women with no previous cesarean delivery have similarly increased adjusted RRs for intrapartum cesarean delivery (relative risk (RR) 1.64 and RR 1.66, respectively) [106]. Induced labor is a significant risk factor for delivery by CS (adjusted odds ratio 2.2) in obese women [104]. A recent retrospective cohort study of all women ($n$ = 1,346,889) delivering singleton births in the state of California between 2007 and 2012 has shown that the CS rates increase from 30.5 % at 20–34 years to 40.5 % at 35–39 years, 47.3 % at 40–44 years, 55.6 % at 45–49 years, and 62.4 % at >50 years [108]. Similar increased rates (35–39 years, 25.9 %, RR = 1.25; 40–44 years, 30.9 %, RR = 1.45; 45–49 years, 35.7 %, RR = 1.59; and ⩾50 years, 60.7 %, RR = 2.44) were also found in a Washington State population-based cohort study of 78,880 births to mothers 25 years and older with singleton births [109]. Nulliparous women age ≥50 years were significantly more likely to experience an intrapartum cesarean delivery (RR, 2.61) [108].

Factors such as obesity combine risks of intrapartum and postpartum complications for both mother and newborn in particular when associated with gestational diabetes and fetal macrosomia [17, 105, 107]. MGP increases the risk of CS due to a higher incidence of fetal malpresentation, also in case of fibroids (Fig. 14.18a, b), and placenta previa and CS in these cases are associated with a higher rate of intra- and postoperative complications [17, 101]. Women requiring cesarean delivery for early preterm births (23–27 weeks) are at higher risks of hemorrhage, infection, and intensive care unit admission, in particular when a classic CS delivery is performed [110].

#### 14.6.1.1 Maternal Complications

Serious maternal complications are defined as hemorrhage leading a blood loss ≥1,500 mL, blood transfusion, or hysterectomy for hemorrhage, infection including endometritis, wound dehiscence, or wound infection requiring antibiotics, reopening, or unexpected procedure, admission to intensive care unit (ICU), or death [100]. The management of PPH is described in other chapters.

Overall excessive bleeding is more common in CS for MGP, placenta previa, placenta previa accreta (Fig. 14.19); in grand multiparous women, following a long and dystocic labor, at full dilation; and in cases of fibroids [17, 100, 101] (Fig. 14.20), and obstetricians need to be prepared to manage potential PPH in these high-risk cases.

Women undergoing CS have a fivefold to 20-fold greater risk for infection and infectious complications compared with a vaginal birth, and infectious complications that occur after cesarean deliveries are an important cause of maternal morbidity and are associated with an increase in hospital stay [111]. Infectious complications following CS include high fever, wound infection, endometritis (most common complications of CS), and urinary tract infection.

Rarely, there can also occasionally be life-threatening infectious complications such as pelvic abscess, septicemia, and septic shock, necrotizing fasciitis, and septic pelvic vein thrombophlebitis. Obese women have a twofold–fourfold increase in infectious postoperative complications, including primary infectious outcome and wound infection [107]. The most important source of microorganisms responsible for

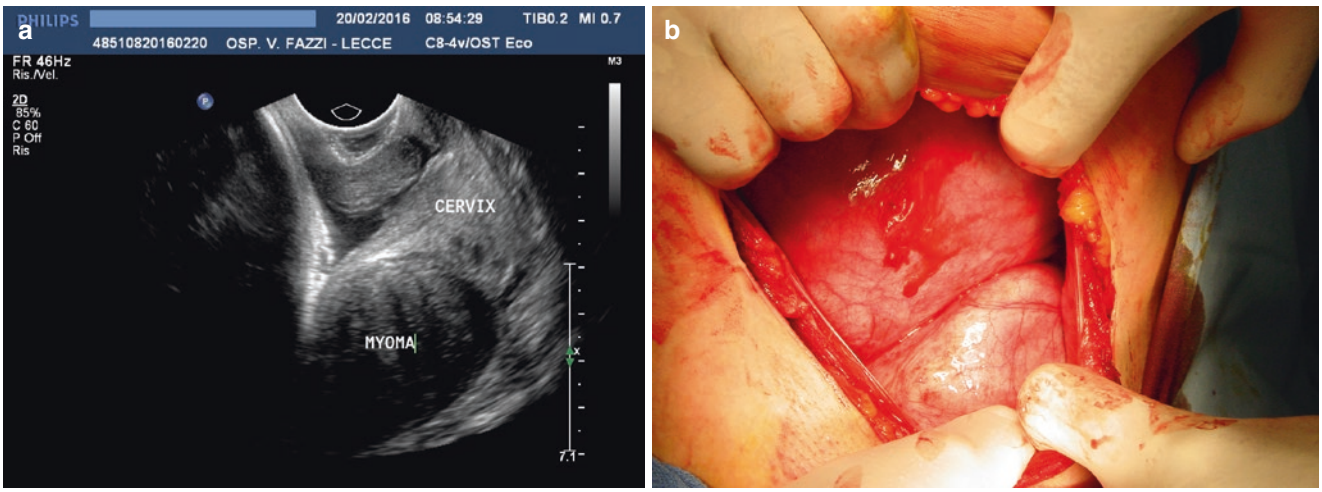



**Fig. 14.18** (**a**) Transvaginal ultrasonographic scan showing a posterior cervical fibroid at 36 weeks of pregnancy. (**b**) Intraoperative image of a large cervical fibroid during cesarean section


**Fig. 14.19** A transvaginal ultrasonographic scan showing an anterior placenta previa in a patient at 31 weeks of gestation, operated by an urgent cesarean section. During operation, patient was hysterectomized for placenta accreta

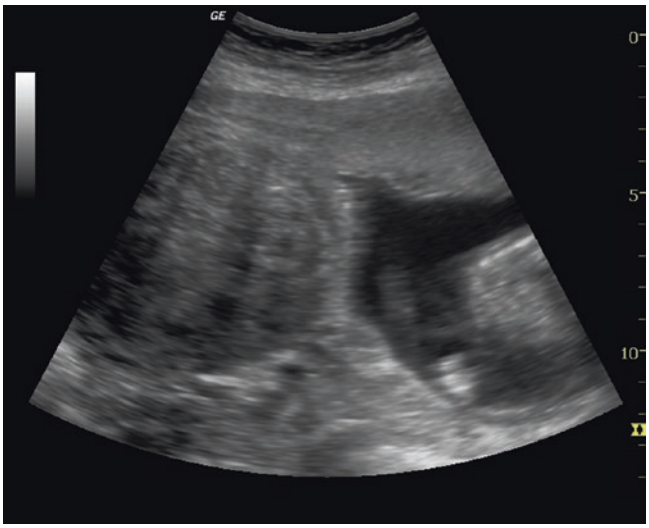



**Fig. 14.20** A transabdominal ultrasonographic scan showing a lateral fibroid of 10 cm in diameter in a patient at 26 weeks of pregnancy

post-cesarean section infection is the genital tract, particularly if the membranes are ruptured [111]. Pathogens isolated from infected wounds and the endometrium include *Escherichia coli* and other aerobic gram-negative rods, group B streptococcus and other streptococcus species, *Enterococcus faecalis*, *Staphylococcus aureus* and coagulase-negative staphylococci, anaerobes, *Gardnerella vaginalis*, and genital mycoplasmas. The use of prophylactic antibiotics before skin incision decreases in women undergoing cesarean section reduces the incidence of wound infection, endometritis, and serious infectious complications by 60–70 % [17, 19, 111].

The skin layer can be repaired by subcuticular stitch (immediately below the skin layer) or an interrupted stitch (individual stitches) or with skin staples. In theory, staples are attractive because there is less chance of bacterial migration into the wound, and the capillaries in the subcuticular layer are not damaged during placement of the clips [17]. A recent meta-analysis has shown that closure of the transverse skin incision with suture significantly decreases wound morbidity, specifically wound separation, without significant differences in pain, patient satisfaction, or cosmesis [112].

Vascular thromboembolism (VTE) is the leading cause of maternal death in developed countries. Risk factors are also the puerperal period, CS, immobility, obesity, advanced age, and parity. The incidence of DVT was reported at 0.17 % and that of pulmonary embolism (PE) at 0.12 % in women undergoing cesarean birth [19, 100]. Operative

injuries are uncommon and include uterine lacerations, bladder injury (Fig. 14.21), ureteral injury, and gastrointestinal tract injury (Fig. 14.22) [19].

Multiple repeat CS and cesarean delivery at full dilation increase the risks of serious maternal morbidity, and the risks increase with the number of previous cesarean deliveries [17].

Although CS is the most common operation among obstetricians and gynecologists, it should be considered as a major surgery and should not be done without the presence of an experienced obstetrician. The complications involved are unpredictable and hemorrhages are an extremely actual risk. Complications can happen in any stage of the surgery, starting with the skin incision, injury to the blood vessels and muscles, damage to the intestines and bladder, and injuries to the newborn. Knowledge of anatomy and physiology is of utmost importance, and any complication should be immediately recognized and taken care of. Once in a while, intraoperative consultation with a general surgeon or urologist is necessary. Calling for assistance is not a sign of weakness; on the contrary, it shows responsibility and maturity.

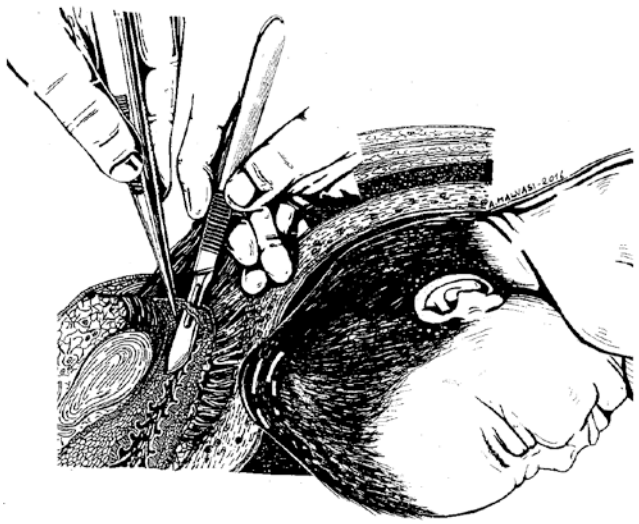


**Fig. 14.21** An accidental bladder injury

**Fig. 14.22** An accidental gastrointestinal tract injury

#### 14.6.1.2 Neonatal Complications

The main complication of preterm CS is a higher rate of neonatal intensive care unit (NICU) admission. Neonatal adverse events are more frequent with elective cesarean delivery performed at 38 than 39 weeks of gestation and at 37 weeks compared to 38 and 39 weeks of gestation [113–115]. The difference between 38 and 39 weeks seems to be significantly smaller than previously anticipated, and a recent randomized controlled multicenter open-label trial found no significant reduction in neonatal admission rate after CS scheduled at 39 weeks compared with 38 weeks of gestation [116].

As shown previously, the maternal skin microbiome, the oral flora, and the breast milk microbiome have also an important role in the development of the human immune system [117]. The physiological changes that occur during pregnancy may disrupt this balanced ecosystem and predispose women to a potentially pathogenic microbiota. Infant colonization sets the stage for the adult microbiome [118]. The intestinal flora of the children born by CS contains less bifidobacteria and is similar to the intestinal flora found in diabetic individuals [117, 119]. Premature and/or very low birth weight (VLBW) neonates are at greater risk for marked dysbiosis of the gut microbiome and are at greater risks of late-onset neonatal sepsis and necrotizing enterocolitis [117]. Maternal obesity and prenatal exposure of antibiotics are additional risk factors for these complications [105, 110, 120, 121]. Prophylactic antibiotics are now routinely given to all women undergoing elective or non-elective CS and are beneficial for women [17, 111] with no obvious consequences for the term newborn. The passage of a single dose of prophylactic antibiotic during a cesarean delivery through the breast milk is thought to be minimal.

Direct injury, i.e., skin cut to the newborn (Fig. 14.23), is uncommon at CS but may be unreported and vary with the experience of the operator and the technique used (Fig. 14.24). There are no epidemiologic data available on accidental cut skin during CS and their short-term impact. Bone fractures in neonates are rare, but can occur during CS, and case of bilateral humerus fracture and other orthopedic complications have been reported [122–124].

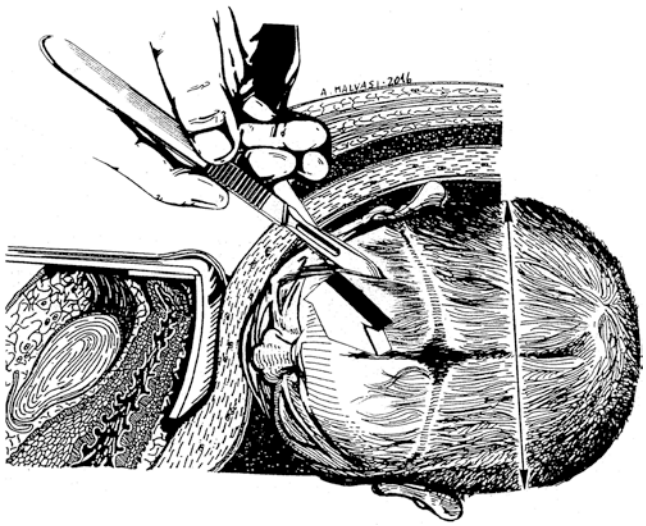



**Fig. 14.23** Accidental skin cut to the newborn during cesarean section

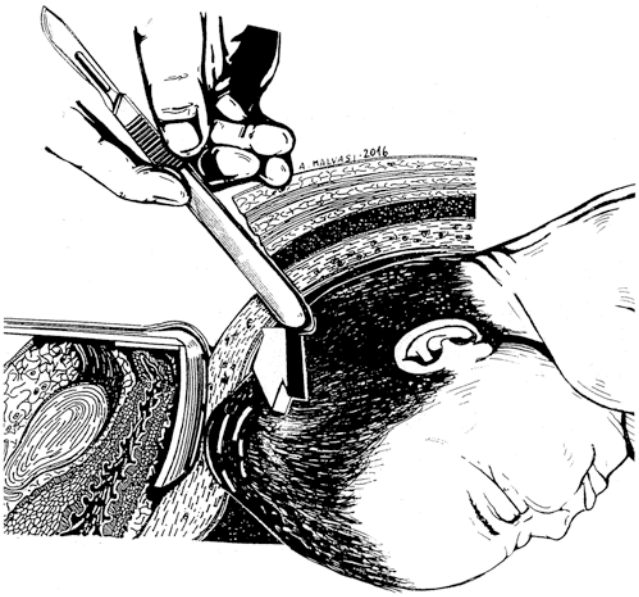



**Fig. 14.24** A safety technique used by surgeon during the opening of the myometrium, performed with the scalpel taken from the handle

## 14.6.2 Long-Term Complications

A cesarean delivery requires cutting and opening of the skin and underlying fat tissue, the muscular sheet, the peritoneum, and the uterine muscle including the myometrial-endometrial junction zone. All these layers need to go through the healing process afterward, which will vary depending on the type of tissue involved and requires hemostasis, inflammation, proliferation, and remodeling. For a wound to heal effectively, these phases should be accomplished fully and in the right sequence. Scarring is considered abnormal when fibrosis is excessive or suboptimal.

### 14.6.2.1 Keloids

Surgical wounds alter the skin's fibrotic structure, thereby producing scar tissue with significant functional impairments [125]. Keloids and hypertrophic scars are generally characterized by abnormally proliferative scar tissue. Keloids are benign, fibroproliferative lesions that represent abnormal healing resulting in excessive fibrosis, which can occur in all skin types with a higher frequency in black women. Keloids have a different clinical course than do hypertrophic scars. Optimal prevention and treatment of these abnormal wound healing process remain undefined, but they may be surgically corrected. Other measures such as intralesional corticosteroid or verapamil injection, pressure therapy, cryotherapy, and other topical treatments such as topical gel sheeting may be useful [126, 127], but most have not been tested in randomized controlled trials (RCT). Many surgeons remove keloids in subsequent CS; however, mostly the keloids form again. The best way to deal with keloids and at least to minimize their appearance is to remove them, not beyond their borders, but very near to the inner border, leaving minimal keloid tissue and then closing the skin as keloid does not produce another keloid. It will result in a much thinner scar than the previous one.

### 14.6.2.2 Adhesions

Most of the long-term complications related to CS are related to the development of postoperative adhesions [125]. Recent data suggest that the formation of adhesions is caused by the organization of a fibrin matrix, which takes place during the coagulation process facilitated by suppression of fibrinolysis [128]. Adhesions develop more frequently and with increasing severity with each repeat cesarean. Around 40 % of women develop adhesions following the primary cesarean delivery, and nearly 70 % of those have adhesions at the second surgery [129]. Of those who did not develop adhesions after the primary CS, almost 40 % have adhesions at the third surgery. Overall, a woman presenting with adhesions at her second cesarean has a 1.88-fold risk for adhesions at her third cesarean.

The complications related to adhesions are diverse in nature and clinical consequences, varying from emergency reoperations for small bowel obstruction to chronic pelvic pain. In the context of reproduction, pelvic adhesions are also associated with increasing maternal morbidity for subsequent cesarean deliveries, such as bladder injury and/or the need for hysterectomy and increased delivery interval time [17, 125]. However, the association between CS, adhesions, and infertility has been controversial. A recent retrospective cohort study of 224,024 women delivered by CS has provided strong evidence that there is no or only a slight effect of CS on future fertility [130]. The clinical and social circumstances leading to the CS have a greater effect on future fertility than the CS itself. Similarly a population-based

study of 52,498 women has provided further corroboration of previous studies that have reported reduced childbearing subsequent to cesarean section in comparison with vaginal delivery [131]. However, the authors were unable to measure prepregnancy body mass index, weight gain during pregnancy, and prior infertility, which would have been reduced selection bias. Also, it is unclear whether it is more likely that women could not conceive or whether they actively chose to avoid further childbearing.

It appears that adhesion formation may be reduced with closure of the peritoneum and double-layer closure of the uterine incision, although whether this reduction has clinical significance remains uncertain [17]. Uterine adhesions can now be diagnosed during pelvic ultrasound examination. The typical features include fusion of the uterine tissue with surrounding tissue, acute uterine retroflexion, and lack of uterine mobility. Ultrasound features of pelvic adhesions are found in more than a third of women with a history of CS, and they are associated with chronic pelvic pain [132]. Adhesions in the vesicouterine pouch were the most common, and increasing number of CSs (OR 3.4) and a postoperative wound infection (OR 11.7) increase the likelihood of adhesions developing in the anterior pelvic compartment.

Although adhesions might cause several clinical manifestations, they probably are a group of their own. In a prospective study, women were asked to describe their clinical symptoms prior to the next operation and the surgeons which were not aware of the questionnaire results described the amount and location of the adhesions found. No connection was found between the clinical symptoms presented after CS and with the location and amount and severity of adhesions, as found in the subsequent operation [133].

#### 14.6.2.3 CS Defects

Musculature in mammals cannot be functionally repaired and does not heal by regenerating muscle fibers, but by forming "foreign" substances including collagen [125]. The resulting scar tissue is weaker, less elastic, and more prone to injury than the intact muscle. Experiments in mice have indicated that differences in regenerative ability translate into histological, proliferative, and functional differences in biomechanical properties of the scarred myometrium after CS [134]. These results could explain wide individual variations observed in uterine healing after CS (Fig. 14.25).A uterine CS defect (CSD) or "niche" is a tethering of the endometrium that can serve as a reservoir for intermenstrual blood and fluid and can be associated with clinical gynecological symptoms such as postmenstrual spotting and dysmenorrhea [135]. Approximately 30 % of women with a niche report spotting at 6–12 months after their CS. Other reported symptoms in women with a niche are dysmenorrhea, chronic pelvic pain, and dyspareunia. A CSD may range from a small defect of the superficial myometrium (Fig. 14.26) to clear

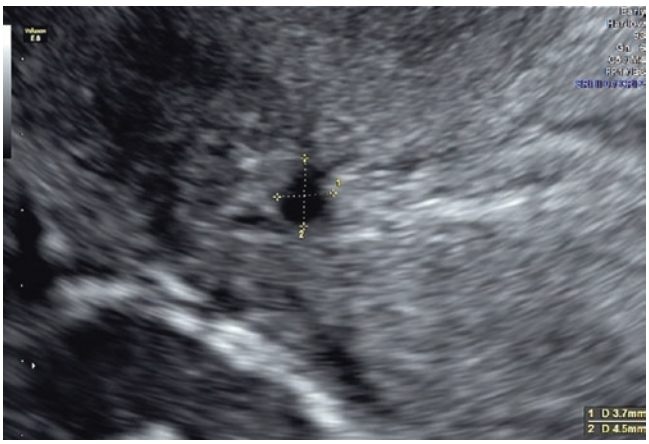



**Fig. 14.25** Transvaginal ultrasound view of the of the lower uterine segment in a 7-week pregnant woman 18 months after a previous emergency CS. Note a small scar defect in the superficial myometrium at the junction between the lower segment and the cervix

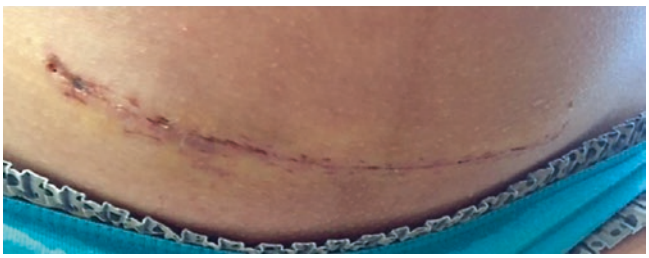


**Fig. 14.26** Image of a minor scar dehiscence associated with a skin infection 2 weeks after an emergency CS

loss of substance with a direct communication between the endometrial cavity and the visceral serosa.The relationship between the size of the CSD and the clinical symptoms, uterine position, and number of previous CS has been evaluated in many different studies [136–139]. Possible factors that could play a role in niche development include a very low incision through cervical tissue, inadequate suturing technique during closure of the uterine scar, surgical interventions that increase adhesion formation, or patient-related factors that impair wound healing or increase inflammation or adhesion formation [135].

The main issue of a previous CS scar is the risk of scar deficiency/separation, during the next pregnancy and delivery [140]. This is increased in women with a retroflexed uterus, in those who have undergone multiple CS, and after cesarean delivery in advanced labor [136–139]. A recent retrospective cohort study has shown that uterine scar dehiscence in a previous pregnancy is a potential risk factor for preterm delivery, low birth weight, and peripartum hysterectomy in the following pregnancy [141]. The other and much more serious complications of a previous CS are implantation of clinically detectable pregnancy into a scar (scar ectopic pregnancy) and an abnormally invasive placenta (AIP) or

placenta accreta in a subsequent pregnancy (Chap. 12). Scar ectopic pregnancies are still very rare [142], but the rise in AIP corresponds temporally to rising CS rates with recent US epidemiological studies indicating an overall incidence of PA of 1 in 533 deliveries or an OR of 1.96 after one CS [1, 143]. It has been estimated that if the CS rate continues to rise as it has in recent years, by 2020, there will be an additional 6,236 placentae previae, 4,504 PAs, and 130 maternal deaths annually [144]. As both complications are associated with severe maternal morbidity and significant mortality from very early in pregnancy, an accurate early prenatal diagnosis of this condition is pivotal to avoid catastrophic complications such as uterine rupture, massive vaginal bleeding, and placenta previa/accreta, which might lead to hysterectomy [143]. Uterine scar surgical repair could prevent recurrent cesarean scar ectopic pregnancies [145] and also prevent AIP in subsequent pregnancies, but this concept remains unproven.

#### 14.6.2.4 CS-Induced Disorders of Placentation

The decidual defect following a uterine scar may have an adverse effect on early implantation by creating conditions for preferential attachment of the blastocyst to scar tissue and facilitating abnormally deep invasion of the extravillous trophoblast leading to AIP, but it may also lead to impaired placentation if the uterine tissue around the scar is compromised and does not allow a sufficient blood supply to the placenta. A recent study of the uterine circulation in women with a previous CS has shown that the uterine artery resistance is increased and the volume of uterine blood flow is decreased as a fraction of maternal cardiac output compared to women with a previous vaginal birth [146]. These data suggest a possible relationship between of a poorly vascularized uterine scar area and an increased in the resistance to blood flow in the uterine circulation with a secondary impact on placental implantation.

Large epidemiologic studies have shown that women who have had a previous CS are at increased risk of unexplained stillbirth in the second pregnancy [147, 148]. The etiology behind the higher rates of unexplained stillbirth in subsequent pregnancies after cesarean delivery remains unknown, but it could be explained by the increased prevalence of placenta abruption, which may be, in turn, a consequence of impaired placentation [125].

Epidemiological studies have also indicated that a cesarean delivery is associated with increased risks of placenta previa and abruption in the subsequent pregnancies [36, 149–153]. The risk of previa is higher with increasing number of prior cesarean deliveries [149].

By contrast, the 20 % increased risk of previa associated with prior intrapartum cesarean delivery was found to be not significant. A recent meta-analysis of five cohorts and 11 case-control studies published between 1990 and 2011 has indicated that after a cesarean delivery, the calculated summary odds ratios (OR) are 1.47 for placenta previa and 1.38 for placental abruption [151]. The increased incidence of placenta previa and placenta abruption after a previous CS supports the concept of a biological dysfunction of the lower-segment myometrium secondary to damage of the corresponding uterine area by previous lower-segment CS scar [125].

**Conclusion**

The aim of this chapter was not just to summarize possible complications, but also to explain our vision toward a reduction in the rate of CS complications by providing insights into the physiology of the late pregnancy, hence the understanding when is the most optimal time to perform the operation, and by introduction of the most reasonable way to conduct the surgery which is based on evidence resulting from several comparative studies. Any CS should follow a solid indication, and in case there is one, a predelivery CS should be avoided unless in an emergency. It is important that the physiological changes occurring to the mother following CS will be as similar as possible to those happening in natural childbirth.

## References

1. Jauniaux E, Jurkovic D (2012) Placenta accreta: pathogenesis of a 20th century iatrogenic uterine disease. Placenta 33:244–251
2. Madsen K, Grønbeck L, Rifbjerg Larsen C, Østergaard J, Bergholt T, Langhoff-Roos J, Sørensen JL (2013) Educational strategies in performing cesarean section. Acta Obstet Gynecol Scand 92:256–263
3. Jauniaux E, Grobman WA (2016) Caesarean section: introduction to the "world's no.1" surgical procedure. In: Jauniaux E, Grobman W (eds) A textbook of caesarean section. Oxford University Press, Oxford, pp 1–8
4. Pasko D, Subramaniam A, Tita ATN (2016) The epidemiology of caesarean section. In: Jauniaux E, Grobman W (eds) A textbook of caesarean section. Oxford University Press, Oxford, pp 37–48
5. Jauniaux E (2016) Caesarean deliveries: what has changed over the last century. BJOG 123(3):438
6. Walker J (2016) Caesarean section: a global perspective. In: Jauniaux E, Grobman W (eds) A textbook of caesarean section. Oxford University Press, Oxford, pp 191–200
7. Lewis G, Regan L, Morroni C, Jauniaux E (2016) Improving global maternal health: challenges and opportunities. In: Gabbe SG, Niebyl JR, Simpson SL, Galan H, Goetzl L, Landon M, Jauniaux E, Berghella V, Grobman B (eds) Obstetrics: normal and problem pregnancies, 7th edn. Elsevier, Philadelphia (In press)
8. West MJ, Irvine LM, Jauniaux E (2016) Caesarean section: from antiquity to the 21st century. In: Jauniaux E, Grobman W (eds) A textbook of caesarean section. Oxford University Press, Oxford, pp 9–24
9. Chassar MJ (1956) Munro Kerr's operative obstetrics, 6th edn. Bailliere, Tindall and Cox, London
10. Baskett TF, Calder AA, Arulkumaran S (2007) Munro Kerr's operative obstetrics: centenary edition. Elsevier, Philadelphia, pp 91–123

11. Pfannenstiel HJ (1900) Uber die Vortheile des Suprasymphysaren Fascienquerschnitts fur die Gynakologischen Koliotomien, Zugleich ein Beitrag zu der Indikatiosstellung der Operationswege. Samml Klin Vortr 268:1735–1756
12. Munro Kerr JM (1921) The lower uterine segment incision in conservative caesarean section. J Obstet Gynaecol Br Emp 28:475–487
13. Holland E (1921) The results of a collective investigation into caesarean sections performed in Great Britain and Ireland from 1911 to 1920 inclusive. J Obstet Gynaecol Br Emp 28:358–446
14. Stark L (1931) Auswertung von 1000 Anstaltsgeburten. Monatschrift für Geburtshilfe und Gynäkologie. Bd. LXXXIX. Heft 3
15. Wylie BJ, Gilbert S, Landon MB, Spong CY, Rouse DJ, Leveno KJ et al (2010) Comparison of transverse and vertical skin incision for emergency cesarean delivery. Obstet Gynecol 115:1134–1140
16. Hudić I, Bujold E, Fatušić Z, Skokić F, Latifagić A, Kapidžić M, Fatušić J (2012) The Misgav-Ladach method of cesarean section: a step forward in operative technique in obstetrics. Arch Gynecol Obstet 286 (5):1141–6. doi:10.1007/s00404-012-2448-6. Epub 2012 Jul 3
17. Jauniaux E, Berghella V (2016) The modern caesarean section. In: Jauniaux E, Grobman W (eds) A textbook of caesarean section. Oxford University Press, Oxford, pp 49–68
18. Stark M, Jauniaux E (2016) The Misgav Ladach caesarean section. In: Jauniaux E, Grobman W (eds) A textbook of caesarean section. Oxford University Press, Oxford, pp 69–76
19. Berghella V, Mackeen AD, Jauniaux E (2016) Cesarean delivery. In: Gabbe SG, Niebyl JR, Simpson JL, Galan H, Goetzl L, Landon M, Jauniaux E, Berghella V, Grobman B (eds) Obstetrics: normal and problem pregnancies, 7th edn. Elsevier, Philadelphia (In press)
20. Mowat J, Bonnar J (1971) Abdominal wound dehiscence after cesarean section. BMJ 2:256
21. Joel-Cohen S (1972) Abdominal and vaginal hysterectomy. New techniques based on time and motion studies. William Heinemann Medical Books, London, p. 170
22. Stark M, Finkel AR (1994) Comparison between the Joel-Cohen and Pfannenstiel incisions in cesarean section. Eur J Obstet Gynaecol Reprod Biol 53:121–122
23. Dunn PM (2008) Professor Munro Kerr (1868–1960) of Glasgow and caesarean delivery. Arch Dis Child Fetal Neonatal Ed 93(2):F167–F169
24. Rorie DK, Newton M (1967) Histologic and chemical studies of the smooth muscle in the human cervix and uterus. Am J Obstet Gynecol 99(4):466–469
25. Kurita T, Nakamura H (2008) Embryology of the uterus. In: Aplin JD, Fazleabas AT, Giudice LC (eds) Endometrium. Informa UK Ltd, London, pp 1–18
26. Xavier P, Ayres-De-Campos D, Reynolds A et al (2005) The modified Misgav-Ladach versus the Pfannenstiel-Kerr technique for cesarean section: a randomized trial. Acta Obstet Gynecol Scand 84(9):878–882
27. Reynolds A, Ayres-de-Campos D, Costa MA et al. (2004) Influence of three organisational measures on the cesarean section rate in a tertiary care University Hospital. [Article in Portuguese]. Acta Med Port 17(3):193–8. Epub 2004 Jun 30
28. Dhuner K (1950) Nerve injuries following operations: a survey of cases occurring during a six year period. Anesthesiology 11:289–289
29. Aschemann D, Krettek C (2005) Lagerungstechniken im Operationsbereich. Springer, Berlin
30. Gibson T (1978) Karl Langer (1819–1887) and his lines. Br J Plast Surg 31(1):1–2
31. Down RH, Whitehead R, Watts JM (1980) Why do surgical packs cause peritoneal adhesions? Aust N Z J Surg 50(1):83–85
32. Down RH, Whitehead R, Watts JM (1979) Do surgical packs cause peritoneal adhesions? Aust N Z J Surg 49(3):379–382
33. Hewitt JJM (1961) Munro Kerr. J Obstet Gynaecol Br Emp 68:510–514
34. Schwartz J, McMillen IC (2001) Fetal hypothalamus-pituitary-adrenal axis on the road to parturition. Clin Exp Pharmacol Physiol 28(1–2):108–112
35. Brooks AN, Challis Jr (1988) Regulation of the hypothalamic-pituitary-adrenal axis in birth. Can J Physiol Pharmacol 66(8):1106–1112
36. Downes KL, Hinkle SN, Sjaarda LA, Albert PS, Grantz KL (2015) Prior Prelabor or intrapartum cesarean delivery and risk of placenta previa. Am J Obstet Gynecol 212:669.e1–669.e6
37. Duff P (2010) A simple checklist for preventing major complications associated with cesarean delivery. Obstet Gynecol 116(6):1393–1396
38. Hudić I, Fatušić Z, Kamerić L et al (2010) J Matern Fetal Neonatal Med 23(10):1156–1159
39. Bennich G, Rudnicki M, Wilken-Jensen C et al (2015) Impact of adding a second-layer to a single unlocked closure of Cesarean uterine incision: a randomized controlled trial. Ultrasound Obstet Gynecol. doi:10.1002/uog.15792
40. Pritchard JA, Weisman R Jr (eds) (1957) The absorption of labeled erythrocytes from the peritoneal cavity of humans. J Lab Clin Med 49(5):756–761
41. Ellis H (1980) Internal overhealing: the problem of intraperitoneal adhesions. World J Surg 4(3):303–306
42. Stark M (1993) Clinical evidence that suturing the peritoneum after laparotomy is unnecessary for healing. World J Surg 17(3):419
43. Royal College of Obstetrics and Gynaecology (2002) Peritoneal closure guideline no. 15. RCOG, London
44. Nabhan AF (2008) Long-term outcomes of two different surgical techniques for cesarean. Int J Gynaecol Obstet 100 (1):69–75. Epub 1 Oct 2007
45. Seeho SK, Nippita TA, Roberts CL et al (2015) Venous thromboembolism prophylaxis during and following caesarean section: a survey of clinical practice. Aust N Z J Obstet Gynaecol 21:164–167
46. Guedj P, Eldor J, Stark M (1991) Immediate postoperative oral hydration after caesarean section. Asia Oceania J Obstet Gynaecol 17(2):125–129
47. Stark M, Gerli S, Renzo GC (2009) The importance of analyzing and standardizing surgical methods. J Minim Invasive Gynecol 16(2):122–125. doi:10.1016/j.jmig.2008.11.005
48. Stark M (1994) Technique of cesarean section: Misgav Ladach method. In: Popkin DR, Peddle LJ (eds) Women's health today. Perspectives on current research and clinical practice. Proceedings of the XIV World Congress of Gynaecology and Obstetrics, Montreal. Parthenon Publishing group, New York, pp 81–85
49. Holmgren G, Sjöholm L, Stark M (1999) The Misgav Ladach method for cesarean section: method description. Acta Obstet Gynecol Scand 78(7):615–621
50. Stark M, Gerli S, Renzo GC (2009) The importance of analyzing and standardizing surgical methods. J Minim Invasive Gynecol 16(2):122–125
51. Levine LD, Sammel MD, Hirshberg A, et al (2015) Does stage of labor at time of cesarean affect risk of subsequent preterm birth? Am J Obstet Gynecol 212(3):360.e1–7
52. Levine LD, Srinivas LK (2016) Length of second stage of labor and preterm birth in a subsequent pregnancy. Am J Obstet Gynecol 214(4):535.e1–4. pii: S0002-9378(15)02224-3
53. Hannah ME, Hannah WJ et al (2000) Planned caesarean section versus planned vaginal birth for breech presentation at term: a randomised multicentre trial. Lancet 356:1375–1383

54. Black M, Battacharya S et al (2015) Planned cesarean delivery at term and adverse outcomes in childhood health. JAMA 314(21):2271–2270
55. Beilin Y, Bodian C, Weiser J et al (2005) Effect of labor epidural analgesia with and without fentanyl on infant breast-feeding: a prospective, randomized, double-blind study. Anesthesiology 103(6):1211–1217
56. Marin Gabriel M, Olza Fernandez I, Malalana Martinez AM et al (2015) intrapartum synthetic oxytocin reduce the expression of primitive reflexes associated with breastfeeding. Breastfeed Med 10(4):209–213
57. Hattori R, Desimaru M, Nagayama I, Inoue K (1991) Autistic and developmental disorders after general anaesthetic delivery. Lancet 337:1357–1358
58. Glasson EJ, Bower C, Petterson B et al (2004) Perinatal factors and the development of autism. Arch Gen Psychiatry 61:618–627
59. Stein D, Weizman A, Ring A, Barak Y (2006) Obstetric complications in individuals diagnosed with autism and in healthy controls. Compr Psychiatry 47(1):69–75
60. Gregory SG, Anthropolos R, Osgood CE et al (2013) Association of autism with induced or augmented childbirth in North Carolina Birth Record (1990–1998) and Education Research (1997–2007) databases. JAMA Pediatr 167(10):959–966
61. Weisman O, Agerbo E, Carter CS et al (2015) Oxytocin-augmented labor and risk for autism in males. Behav Brain Res 284:207–212
62. O'Driscoll K, Foley M, MacDonald D (1984) Active management of labor as an alternative to cesarean section for dystocia. Obstet Gynecol 63(4):485–490
63. Endevelt-Shapira Y, Shushan S, Roth Y, Sobel N (2014) Disinhibition of olfaction: human olfactory performance improves following low levels of alcohol. Behav Brain Res 272C:66–74
64. Mc Graw MB (1939) Swimming behavior of the human infant. J Pediatr 15:485–490
65. Odent M (1987) The fetus ejection reflex. Birth 14:104–105
66. Wang F, Li J et al (2003) The GABA(A) receptor mediates the hypnotic activity of melatonin in rats. Pharmacol Biochem Behav 74(3):573–578
67. Wang F, Zou D et al (2003) The role of melatonin receptor and GABAA receptor in the sleeping time prolonged by melatonin in mice. Zhongguo Ying Yong Sheng Li Xue Za Zhi 19(4):402–405
68. Tysio R, Nsardou R et al (2014) Oxytocin-mediated GABA inhibition during delivery attenuates autism pathogenesis in rodent offspring. Science 343(6171):675–679
69. Cohen M, Roselle D, Chabner B et al (1978) Evidence for a cytoplasmic melatonin receptor. Nature 274:894–895
70. Sharkey JT (2009) Melatonin regulation of the oxytocin system in the pregnant human uterus. Electronic Theses, Treatises and Dissertations. Paper 1791. http://diginole.lib.fsu.edu/etd/1791
71. Olcese J, Beesley S (2014) Clinical significance of melatonin receptors in the human myometrium. Fertil Steril 102(2):329–335
72. Schlabritz-Loutsevitch N, Hellner N, Middendorf R et al (2003) The human myometrium as a target for melatonin. J Clin Endocrinol Metab 88(2):908–913
73. Sharkey JT, Puttaramu R, Word RA, Olcese J (2009) Melatonin synergizes with oxytocin to enhance contractility of human myometrial smooth muscle cells. J Clin Endocrinol Metab 94(2):421–427
74. Sharkey J, Cable C, Olcese J (2010) Melatonin sensitizes human myometrial cells to oxytocin in a PKCa/ERK-dependent manner. J Clin Endocrinol Metab 95(6):2902–2908
75. Kayumov L, Casper RF, Hawa RJ et al (2005) Blocking low-wavelength light prevents nocturnal melatonin suppression with no adverse effect on performance during simulated shift work. J Clin Endocrinol Metab 90(5):2755–2761
76. Burkhart K, Phelps JR (2009) Amber lenses to block blue light and improve sleep: a randomized trial. Chronobiol Int 26(8):1602–1612
77. Odent MR (2004) Making sense of rising caesarean section rates: reducing caesarean section rates should not be the primary objective. BMJ 329(7476):1240
78. Wilkes PT, Wolf DM et al (2003) Risk factors for cesarean delivery at presentation of nulliparous patients in labor. Obstet Gynecol 102(6):1352–1357
79. Odent M (1983) Birth under water. Lancet 2:1476–1417
80. Odent M (2004) The birthing pool test. In: Odent M. The caesarean. Free Association Books, London, pp 103–104
81. Condon JC, Jeyasuria P, Faust JM, Mendelson CR (2004) Surfactant protein secreted by the maturing mouse fetal lung acts as a hormone that signals the initiation of parturition. Proc Natl Acad Sci U S A 101(14):4978–4983. Epub 2004 Mar 25
82. Glavind J, Uldbjerg N (2015) Elective cesarean delivery at 38 and 39 weeks: neonatal and maternal risks. Curr Opin Obstet Gynecol 27(2):121–127
83. Hauth JC, Parker CR Jr, MacDonald PC et al (1978) A role of fetal prolactin in lung maturation. Obstet Gynecol 51(1):81–88
84. Varendi H, Porter RH, Winberg J (2002) The effect of labor on olfactory exposure learning within the first postnatal hour. Behav Neurosci 116(2):206–211
85. Odent M 1977 The early expression of the rooting reflex. Proceedings of the 5th International Congress of Psychosomatic Obstetrics and Gynaecology, Rome. Academic Press, London, pp 1117–1119
86. Odent M (1978) L'expression précoce du réflexe de fouissement. Les cahiers du nouveau-né 1–2:169–185
87. Hermansson H, Hoppu U, Isolauri E (2014) Elective caesarean section is associated with low adiponectin levels in cord blood. Neonatology 105:172–174
88. Cabrera-Rubio R, Collado MC, Laitinen K et al (2012) The human milk microbiome changes over lactation and is shaped by maternal weight and mode of delivery. Am J Clin Nutr 96(3):544–518
89. Azad MB, Konya T, Maugham H, et al (2013) Gut microbiota of healthy Canadian infants: profiles by mode of delivery and infant diet at 4 months. CMAJ 185(5):385–394
90. Dogra S, Sakwinska O, Soh S et al (2015) Dynamics of infant gut microbiota are influenced by delivery mode and gestational duration and are associated with subsequent adiposity. MBio 6(1):e02419–e02414
91. Bagci S, Berner AL et al (2012) Melatonin concentration in umbilical cord blood depends on mode of delivery. Early Hum Dev 88(6):369–373
92. Christensson K, Siles C et al (1993) Lower body temperature in infants delivered by caesarean section than in vaginally delivered infants. Acta Paediatr 82(2):128–131
93. Simon-Areces J, Dietrich MO, Hermes G et al (2012) Ucp2 induced by natural birth regulates neuronal differentiation of the hippocampus and related adult behavior. PLoS One 7(8):e42911
94. Tyzio R, Cossart R, Khalilov I et al (2006) Maternal oxytocin triggers a transient inhibitory switch in GABA signaling in the fetal brain during delivery. Science 314:1788–1792
95. Downes KL, Hinkle SN, Sjaarda LA, et al (2015) Prior prelabor or intrapartum cesarean delivery and risk of placenta previa. Am J Obstet Gynecol. http://www.ajog.org/article/S0002-9378(15)00005-8
96. Prior E, Santhakumaran S, Gale S et al (2012) Breastfeeding after cesarean delivery: a systematic review and meta-analysis of world literature. Am J Clin Nutr 95(5):1113–1135
97. Zanardo V, Savolna V, Cavallin F et al (2012) Impaired lactation performance following elective cesarean delivery at term: role of maternal levels of cortisol and prolactin. J Matern Fetal Neonatal Med 25(9):1595–1598

98. Tsivian M Jr, Tsivian M, Sidi AA, Tsivian A (2012) Ureterovesico-cervical fistula following a caesarean section: a unique case report. Int Urogynecol J 23 (11):1639–1641. doi:10.1007/s00192-012-1748-5. Epub 2012 Apr 18
99. Kazoń M, Kossakowski JS, Proniewski J (1981) Case of ureterocervical fistula as a result of cesarean section. [Article in Polish]. Ginekol Pol 52(2):183–187
100. Steer PJ (2016) Prevention and management of post-operative caesarean section. In: Jauniaux E, Grobman W (eds) A textbook of caesarean section complications. Oxford University Press, Oxford, pp 117–128
101. Jauniaux ERM (2012) Multiple gestation pregnancy after assisted reproductive technology. In: Jauniaux ERM, Risk RMB (eds) Pregnancy after assisted reproductive technology. Cambridge University Press, Cambridge, pp 82–92
102. Qin JB, Wang H, Sheng X, Xie Q, Gao S. Assisted reproductive technology and risk of adverse obstetric outcomes in dichorionic twin pregnancies: a systematic review and meta-analysis. Fertil Steril. 2016. Epub ahead of print
103. Papachatzi E, Paparrodopoulos S, Papadopoulos V, Dimitriou G, Vantarakis A (2016) Pre-pregnancy maternal obesity in Greece: a case-control analysis. Early Hum Dev 93:57–61
104. Vinturache A, Moledina N, McDonald S, Slater D, Tough S (2014) Pre-pregnancy Body Mass Index (BMI) and delivery outcomes in a Canadian population. BMC Pregnancy Childbirth 14:422
105. Sullivan EA, Dickinson JE, Vaughan GA, Peek MJ, Ellwood D, Homer CS, Knight M, McLintock C, Wang A, Pollock W, Jackson Pulver L, Li Z, Javid N, Denney-Wilson E, Callaway L (2015) Australasian Maternity Outcomes Surveillance System (AMOSS). Maternal super-obesity and perinatal outcomes in Australia: a national population-based cohort study. BMC Pregnancy Childbirth 15:322
106. Her M, Ray C, Blondel B, Goffinet F, Zeitlin J (2015) The risk of prelabor and intrapartum cesarean delivery among overweight and obese women: possible preventive actions. Am J Obstet Gynecol 212:241.e1–241.e9
107. Stamilio DM, Scifres CM (2014) Extreme obesity and postcesarean maternal complications. Obstet Gynecol 124:227–232
108. Osmundson SS, Gould JB, Butwick A, Yeaton-Massay A, El-Sayed YY (2016) Labor outcome at extremely advanced maternal age. Am J Obstet Gynecol 214(3):362
109. Richards MK, Flanagan MR, Littman AJ, Burke AK, Callegari LS (2016) Primary cesarean section and adverse delivery outcomes among women of very advanced maternal age. J Perinatol. Epub ahead of print J Perinatol 36(4):272–277
110. Reddy UM, Rice MM, Grobman WA, Bailit JL, Wapner RJ, Varner MW, Thorp JM Jr, Leveno KJ, Caritis SN, Prasad M, Tita AT, Saade GR, Sorokin Y, Rouse DJ, Blackwell SC, Tolosa JE (2015) Eunice Kennedy Shriver National Institute of Child Health and Human Development Maternal-Fetal Medicine Units Network. Serious maternal complications after early preterm delivery (24–33 weeks' gestation). Am J Obstet Gynecol 213:538.e1–538.e9
111. Smaill FM, Grivell RM (2014) Antibiotic prophylaxis versus no prophylaxis for preventing infection after cesarean section. Cochrane Database Syst Rev 10:CD007482
112. Mackeen AD, Schuster M, Berghella V (2015) Suture versus staples for skin closure after cesarean: a metaanalysis. Am J Obstet Gynecol 212:621.e1–621.10
113. Choissi G, Lai Y, Landon MB, Spong CY, Rouse DJ, Varner MW, Caritis SN, Sorokin Y, O'Sullivan MJ, Sibai BM, Thorp JM, Ramin SM, Mercer BM (2013) Eunice Kennedy Shriver National Institute of Child health and Human Development (NICHD) Maternal-Fetal Medicine Units (MFMU) Network. Timing of delivery and adverse outcomes in term singleton repeat cesarean deliveries. Obstet Gynecol 121:561–569
114. Robertson E, Lissauer T (2016) Perinatal outcome of neonates born by caesarean section. In: Jauniaux E, Grobman W (eds) A textbook of caesarean section. Oxford University Press, Oxford, pp 145–158
115. Glavind J, Uldbjerg N (2015) Elective cesarean delivery at 38 and 39 weeks: neonatal and maternal risks. Curr Opin Obstet Gynecol 27:121–127
116. Glavind J, Kindberg SF, Uldbjerg N, Khalil N, Møller AM, Mortensen BB, Rasmussen OB, Christensen JT, Jørgensen JS, Henriksen TB (2013) Elective caesarean section at 38 weeks versus 39 weeks: neonatal and maternal outcomes in a randomised controlled trial. BJOG 120:1123–1132
117. Odent M, Jauniaux E (2016) Caesarean section and human evolution. In: Jauniaux E, Grobman W (eds) A textbook of caesarean section. Oxford University Press, Oxford, pp 175–190
118. Sherman MP, Zaghouani H, Niklas V (2015) Gut microbiota, the immune system, and diet influence the neonatal gut-brain-axis. Pediatr Res 77:127–135
119. Gregory KE, LaPlante RD, Shan G, Kumar DV, Gregas M (2015) Mode of birth influences preterm infant intestinal colonization with bacteroides over the early neonatal period. Adv Neonatal Care 15:386–393
120. Mueller NT, Whyatt R, Hoepner L, Oberfield S, Dominguez-Bello MG, Widen EM, Hassoun A, Perera F, Rundle A (2015) Prenatal exposure to antibiotics, cesarean section and risk of childhood obesity. Int J Obes (Lond) 39:665–670
121. Mueller NT, Bakacs E, Combellick J, Grigoryan Z, Dominguez-Bello MG (2015) The infant microbiome development: mom matters. Trends Mol Med 21:109–117
122. Cebesoy FB, Cebesoy O, Incebiyik A (2009) Bilateral femur fracture in a newborn: an extreme complication of cesarean delivery. Arch Gynecol Obstet 279:73–74
123. Kamaci S, Danisman M, Marangoz S (2014) Neonatal physeal separation of distal humerus during cesarean section. Am J Orthop (Belle Mead NJ) 43:E279–E281
124. Canpolat FE, Köse A, Yurdakök M (2010) Bilateral humerus fracture in a neonate after cesarean delivery. Arch Gynecol Obstet 281:967–969
125. Jauniaux E, Jurkovic D (2016) Long-term complications after caesarean section. In: Jauniaux E, Grobman W (eds) A textbook of caesarean section. Oxford University Press, Oxford, pp 129–144
126. Wang R, Mao Y, Zhang Z, Li Z, Chen J, Cen Y (2016) Role of verapamil in preventing and treating hypertrophic scars and keloids. Int Wound J. Epub ahead of print Int Wound J 13(4):461–468
127. Bleasdale B, Finnegan S, Murray K, Kelly S, Percival SL (2015) The use of silicone adhesives for scar reduction. Adv Wound Care (New Rochelle) 4:422–430
128. Hellebrekers BW, Kooistra T (2011) Pathogenesis of postoperative adhesion formation. Br J Surg 98:1503–1516
129. Herzberger EH, Alon H, Hershko-Klement A, Ganor-Paz Y, Fejgin MD, Biron-Shental T (2015) Adhesions at repeat cesarean delivery: is there a personal impact? Arch Gynecol Obstet 292:813–818
130. Gurol-Urganci I, Cromwell DA, Mahmood TA, Meulen JH, Templeton A (2014) A population-based cohort study of the effect of cesarean section on subsequent fertility. Hum Reprod 29:1320–1326
131. Kjerulff KH, Zhu J, Weisman CS, Ananth CV (2013) First birth caesarean section and subsequent fertility: a population-based study in the USA, 2000–2008. Hum Reprod 28: 3349–3357
132. Moro F, Mavrelos D, Pateman K, Holland T, Hoo WL, Jurkovic D (2015) Prevalence of pelvic adhesions on ultrasound examination in women with a history of cesarean section. Ultrasound Obstet Gynecol 45:223–228

133. Stark M, Hoyme UB, Stubert B, Kieback D, Renzo GC (2008) Post-cesarean adhesions – are they a unique entity? J Matern Fetal Neonatal Med 21(8):513–516
134. Buhimschi CS, Zhao G, Sora N, Madri JA, Buhimschi IA (2010) Myometrial wound healing post-cesarean delivery in the MRL/MpJ mouse model of uterine scarring. Am J Pathol 177:197–207
135. Vervoort AJ, Uittenbogaard LB, Hehenkamp WJ, Brölmann HA, Mol BW, Huirne JA (2015) Why do niches develop in Caesarean uterine scars? Hypotheses on the aetiology of niche development. Hum Reprod 302:695–702
136. Ofili-Yebovi D, Ben-Nagi J, Sawy E, Yazbek J, Lee C, Gonzalez J, Jurkovic D (2008) Deficient lower-segment cesarean section scars: prevalence and risk factors. Ultrasound Obstet Gynecol 31:72–77
137. Wang CB, Chiu WW, Lee CY, Sun YL, Lin YH, Tseng CJ (2009) Cesarean scar defect: correlation between cesarean section number, defect size, clinical symptoms and uterine position. Ultrasound Obstet Gynecol 34:85–89
138. Osser OV, Jokubkiene L, Valentin L (2009) High prevalence of defects in cesarean section scars at transvaginal ultrasound examination. Ultrasound Obstet Gynecol 34:90–97
139. Osser OV, Valentin L (2011) Clinical importance of appearance of cesarean hysterotomy scar at transvaginal ultrasonography in nonpregnant women. Obstet Gynecol 117:525–532
140. Miller ES, Grobman WA (2016) Trial of labour caesarean. In: Jauniaux E, Grobman W (eds) A textbook of caesarean section. Oxford University Press, Oxford, pp 159–174
141. Baron J, Weintraub AY, Eshkoli T, Hershkovitz R, Sheiner E (2014) The consequences of previous uterine scar dehiscence and cesarean delivery on subsequent births. Int J Gynaecol Obstet 126:120–122
142. Jurkovic D, Knez J, Appiah A, Farahani L, Mavrelos D, Ross JA (2016) Surgical treatment of cesarean scar ectopic pregnancy: efficacy and safety of ultrasound-guided suction curettage. Ultrasound Obstet Gynecol 47(4):511–517
143. Jauniaux E, Bhide A, Wright JD (2016) Placenta accreta. In: Gabbe SG, Niebyl JR, Simpson JL, Galan H, Goetzl L, Landon M, Jauniaux E, Berghella V, Grobman B (eds) Obstetrics: normal and problem pregnancies, 7th edn. Elsevier, Philadelphia (In press)
144. Solheim KN, Esakoff TF, Little SE, Cheng YW, Sparks TN, Caughey AB (2011) The effect of cesarean delivery rates on the future incidence of placenta previa, placenta accreta, and maternal mortality. J Matern Fetal Neonatal Med 24:1341–1346
145. Ben Nagi J, Ofili-Yebovi D, Sawyer E, Aplin J, Jurkovic D (2006) Successful treatment of a recurrent cesarean scar ectopic pregnancy by surgical repair of the uterine defect. Ultrasound Obstet Gynecol 28:855–856
146. Flo K, Widnes C, Vårtun Å, Acharya G (2014) Blood flow to the scarred gravid uterus at 22–24 weeks of gestation. BJOG 121:210–215
147. O'Neill SM, Kearney PM, Kenny LC, Khashan AS, Henriksen TB, Lutomski JE, Greene RA (2013) Caesarean delivery and subsequent stillbirth or miscarriage: systematic review and meta-analysis. PLoS One 8:e54588
148. Moraitis AA, Oliver-Williams C, Wood AM, Fleming M, Pell JP, Smith G (2015) Previous caesarean delivery and the risk of unexplained stillbirth: retrospective cohort study and meta-analysis. BJOG 122:1467–1474
149. Wu S, Kocherginsky M, Hibbard JU (2005) Abnormal placentation: twenty-year analysis. Am J Obstet Gynecol 192:1458–1461
150. Getahun D, Oyelese Y, Salihu HM, Ananth CV (2006) Previous cesarean delivery and risks of placenta previa and placental abruption. Obstet Gynecol 107:771–778
151. Klar M, Michels KB (2014) Cesarean section and placental disorders in subsequent pregnancies – a meta-analysis. J Perinat Med 42:571–583
152. Vintzileos AM, Ananth CV, Smulian JC (2015) Using ultrasound in the clinical management of placental implantation abnormalities. Am J Obstet Gynecol 213:S70–S77
153. Siver BM (2015) Abnormal placentation: placenta previa, vasa previa and placenta accreta. Obstet Gynecol 126:654–668