Review

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Cesarean section one hundred years 1920–2020: the Good, the Bad and the Ugly

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Abstract: In present-day obstetrics, cesarean delivery occurs in one in three women in the United States, and in up to four of five women in some regions of the world. The history of cesarean section extends well over four centuries. Up until the end of the nineteenth century, the operation was avoided because of its high mortality rate. In 1926, the Munro Kerr low transverse uterine incision was introduced and became the standard method for the next 50 years. Since the 1970's, newer surgical techniques gradually became the most commonly used method today because of intraoperative and postpartum benefits. Concurrently, despite attempts to encourage vaginal birth after previous cesareans, the cesarean delivery rate increased steadily from 5 to 30–32% over the last 10 years, with a parallel increase in costs as well as short- and long-term maternal, neonatal and childhood complications. Attempts to reduce the rate of cesarean deliveries have been largely unsuccessful because of the perceived safety of the operation, short-term postpartum benefits, the legal climate and maternal request in the absence of indications. In the United States, as the cesarean delivery rate has increased, maternal mortality and morbidity have also risen steadily over the last three decades, disproportionately impacting black women as compared to other races. Extensive data on the prenatal diagnosis and management of cesarean-related abnormal placentation have improved outcomes of affected women. Fewer data are available however for the improvement of outcomes of cesarean-related gynecological conditions. In this review, the authors address the challenges and opportunities to research, educate and change health effects associated with cesarean delivery for all women.

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Introduction

Cesarean section (CS), avoided for its alarming mortality rate over a little more than a century ago, is now the mode of delivery for one in three women in the United States [1] and up to four in five women in some other places in the world [2]. Its long recorded history reflects evolving surgical opinion through the ages addressing bleeding, infection, pain, sutures and, most recently, hospitalization time and cost savings.

History

The origin of the term cesarean section has been exhaustively investigated. Interestingly, historians have rejected the assertion that Julius Caesar was brought into the world by this means and concluded that the operation does not derive its name from his birth. Instead, they argue that the operation, in Roman law, was codified by King Numa Pompilius (715–673 BC) to be performed upon women dying within the last few weeks of pregnancy. The *Lex Regia*, as it was originally called, was changed to *Lex Caesarea* during Julius Caesar's reign and the procedure itself became known as the cesarean operation. The procedure was used to remove from a dead or dying mother a child, either alive or dead, through an incision in the abdominal and uterine walls. In ancient times, the operation was performed by the patient herself, her husband, sow gelders, barbers, midwives, surgeons or by tribal natives. A variety of instruments were used, ranging from razors to axes. Primitive abdominal deliveries also occurred spontaneously during difficult labor or accidentally, as gored lacerations of a woman by horned animals for example. Interestingly, some women reportedly survived [3].

The documented history of CS extends well over four centuries. From as early as the sixteenth century, the operation was occasionally resorted as a post-mortem

effort in the hope to save the life of a child after the death of the mother. In the seventeenth and eighteenth centuries, accounts of CSs resulting in live births highlighted the possibility of performing the operation on live women. During this period of time, after the uterine incision and the removal of the child, the uterine walls were not sutured, relying instead upon contractions and retraction to control hemorrhage. Most women perished from hemorrhage or infection; the maternal mortality following the procedure was reported to be between 52.5 and 100% and the operation was avoided at all cost.

The nineteenth century's remarkable progress in science and medicine introduced cesarean section for obstructed labor as possible, albeit still risky. In 1876, recognizing infection rather than hemorrhage as the primary cause of mortality, Italian obstetrician Eduardo Porro described his method of amputating the body of the pregnant uterus and stitching the cervical stump as a mode of delivery [4]. In 1882, gynecologist Max Sänger described the use of a double layer of sutures to close the vertical uterine incision to preserve the uterus after delivery and introduced approximation of the peritoneal edges [5]. The operation was designated "conservative cesarean section" in contra-distinction to the hysterectomy of the Porro method. Although the conservative operation brought about a significant reduction in maternal mortality, the results were limited by possible infection. However, the importance of Sänger's work was recognized, becoming the standard for the classical operation today.

For improved results, in the beginning of the twentieth century and in the absence of antibiotics, an extraperitoneal cesarean approach was reported as well as several modifications to existing techniques for women with long labors or possible infections. The selection of patients and the specific choice of operation, in addition to the use of antiseptic technique in abdominal surgery, reduced maternal mortality to 1–2%, particularly when done at an appointed time before labor (or shortly after its onset) and on uninfected women. In the 1920s, as the diminution in maternal mortality continued to improve and the procedure was widely published, uterine rupture during labor, hemorrhage and infection emerged as the key challenges.

Since future conception was possible after a conservative CS, successful repeated CSs were reported upon the same individual. In subsequent pregnancies, the occurrence of uterine rupture through the site of a previous classical incision after a failed attempt at vaginal birth led to the dictum "Once a cesarean, always a cesarean" [6]. Such a belief was debated and thought to be erroneous with the absence of scar tissue by gross and histopathology of the site of a previous CS, even in the presence of a shallow vertical furrow in the external and internal surfaces of the anterior uterine wall. Intra-abdominal adhesions were frequently formed between the uterus and abdominal wall along with omental and intestinal adhesions. Abnormal adherence of the placenta was diagnosed in rare instances by firm and extensive adhesion of the placenta, confirmed by absent decidua and deep chorionic villi invasion into the myometrium [7, 8].

Evolution of cesarean surgical technique

1920–1970

The Sänger technique consisted of interrupted deep sutures that were placed through the thickness of the myometrium, avoiding the decidua. The superficial muscular layer and peritoneum are brought together by a continuous suture. Then, the parietal peritoneum, muscles, fascia, and skin are closed in separate layers [5]. Popularity of the classical Sänger operation continued for the next 40 years until obstetrical surgeon John Martin Munro Kerr introduced in 1926 his method of double closure of the lower uterine segment [9, 10]. The Kerr incision, also referred to as Pfannenstiel–Kerr in recognition of the German gynecologist who invented the abdominal incision in 1900, [11] featured the creation of a bladder flap in the lower uterine segment, double layer closure of the uterine incision, emphasis not to include the decidua in the uterine closure, re-approximation of the bladder flap, and re-approximation of the parietal peritoneum. This lower segment method was then generally regarded as the most important of the various cesarean operations and is regarded as the most significant advance in obstetrical care. The popularity of the operation remained unchallenged and became the operation of choice thereafter, as it reduced the dangers of both hemorrhage and infection.

During this time, maternal mortality steadily decreased to near 1% in most major hospitals in the US, and the fetal salvage rate increased as well. This period showed an increasing perfection of surgical technique as well as the introduction of blood banks, aseptic techniques, and antibiotics. The classical and low flap operations were performed equally in number from 1937 to 1944. From the 1950s on however, the lower segment method was universally taught to all residents in training, in all major universities, and described in all major teaching textbooks. It was generally accepted by all obstetricians as the best method of delivery for mother and baby when facing obstetrical

complications requiring immediate interventions. With the advance of antimicrobial drugs, the extraperitoneal operation was rarely performed. The drawback was mainly the limitation of the operative field and the inevitable extension into the peritoneal cavity, the integrity of which was being protected. The classical section was performed only for specific indications such as placenta previa and severe abruptio placentae. The overall incidence of CS in the US rose from 2.5 to 5.1% from 1932 to 1963, then to 8% in 1970, as the perinatal mortality plummeted from 9.8 to 2.9% and maternal mortality from 1.8 to 0.04% [12].

1970–2020

In the 1970s, an upsurge in the CS rate was observed, justified on the basis of maternal and fetal results and safety improvement. The rate, from 5.5% of deliveries in 1970 to 16.5% in 1980, [13] continued to increase until appearing to have stabilized around 31–32% in the US in 2019 [1]. New developments of surgical techniques, or modifications to existing ones, challenged the predominantly practiced Pfannenstiel–Kerr technique [9, 11]. Blunt dissection of the abdominal incision and parietal peritoneum advanced by Joel-Cohen [14] was later combined with blunt uterine incision as the cornerstone of a new generation of cesarean techniques, including the Misgav–Ladach [15, 16] and the modified Misgav–Ladach [17] methods. The numerous steps adopted since 1926 were now modified to include one or two layer uterine closure, limited to no approximation of peritoneal layers. When compared to the Pfannenstiel–Kerr method, the new techniques offered the benefits of shorter operating time, less blood loss, shorter hospitalization and recovery time, diminished postoperative pain, and reduced cost [18, 19]. These findings led to the exclusive teaching of the newer techniques in large medical centers, in the US and abroad, and created a new generation of obstetricians who practice them exclusively. The former procedure has been replaced by much fewer steps and shortened the operative time. These steps do not include the management of the endometrium or decidua in the uterine closure, be it in single or double layer closure. The American College of Obstetricians and Gynecologists and other governing bodies who advocate for the autonomy of physicians in the selection of their preferred techniques have endorsed the safety of these new techniques for post-partum outcomes [20]. The utility of peritoneal closure has been challenged and mostly abandoned [21]. Currently there is a lack of data on the impact of these contemporaneous techniques on subsequent pregnancies and long term maternal outcomes [22, 23].

Long-term obstetrical complications

Abnormal placentation

The observed increase in abnormal placentation linearly related to the number of CSs seems a recent phenomenon. The rising cesarean delivery rate and the perceived safety to perform increasing numbers of cesareans coincide with a parallel growing insurgence of abnormal placentation. Cesarean delivery (CD) increased dramatically from 5.8% in 1970 to 31.9% in 2016, [24] contributing to an increasing incidence of placenta previa (PP), placenta accreta (PA), and cesarean scar pregnancy (CSP). The emergence of these long term conditions, years after the preceding CD, resulted in a dramatic rise in maternal mortality and morbidity. The maternal mortality rate increased from 7.2 deaths per 100,000 live births in 1987 [25] to a high of 17.4 deaths per 100,000 in 2018 [26]. In modern obstetrics, PA and PP account for a large percentage of maternal morbidity and mortality, accounting for 1.7% of all maternal deaths in the United States [27, 28]. It is estimated that if the CD rate continues to rise, by 2020 there will be an additional 6,236 cases of PP, 4,504 cases of PA cases and 130 maternal deaths annually [29].

Earlier observational studies described the prevalence of PA to be 1 in 4,000 deliveries in the 1970s, [30] 1 in 2,500 deliveries in the 1980s, [31] and more recently, 1 in 533 in 2002 [32]. A recent study found the overall rate of PA in the US was closer to 1 in 272 live births for women with a birth-related hospital discharge diagnosis [33]. A number of studies have documented a strong association between PP and previous CD with the incidence of PA. The risk is significantly increased when both factors are present. Clark concluded that a woman with one prior cesarean and a PP has a 24% risk of PA. The risk increases to 67% with four or more CSs and a PP [34]. Silver and many others have also reported an increase in PA with the number of previous CDs. In women with PP and prior CDs, the risk of PA is 11% after one procedure, 40% after two procedures and 61% after three procedures [35]. Systematic reviews and meta-analysis of PP and PA have emphasized the prevalence and incidence of PP complicated by PA, and found evidence of regional variation [36, 37].

The term placenta accreta spectrum (PAS) refers to the range of abnormal adherence of the placental trophoblast to the uterine wall, invasion into and through it. It was formerly known as morbidly adherent placenta. Since the introduction of CSP in 1978, its frequency has continued to trend upward, coinciding with the rise in the CD rate. Its

true incidence is unknown, likely because the condition is underreported or underdiagnosed [38]. The estimated incidence of CSP is 1 in 1,688 normal pregnancies [39].

CSP and PAS are considered to be manifestations of the same spectrum of abnormal implantation with similar histopathological features of a pregnancy implanted in the scar of a previous CS [40]. CSP and PAS are associated with considerable morbidity such as severe hemorrhage, uterine rupture, peripartum hysterectomy, organ injury, intensive care admission, prolonged hospitalization and even death. PAS is the most common indication for both hysterectomy associated with CD and peripartum hysterectomy. From 1969 to 2009, the peripartum hysterectomy rate in a setting of previous CD increased from 27 to 57%, as PA as the indication increased significantly from 5.4 to 46.5% [41]. PA was noted to be the indication for peripartum hysterectomy in 33–50% of cases in reviewed studies [42]. PA, first described in 1937, occurs after manual removal of the placenta, endometritis or uterine curettage [43]. Today, it is primarily the result of uterine scar as a result of damage to the endometrium-myometrium interface of the uterine wall secondary to cesarean delivery [44].

The technique of CS has evolved over time, and has particularly stabilized over the past 50 years. However, cesareans remain a high risk procedure despite the advances in surgical procedures, anesthesia techniques, blood banking and antibiotic therapy. The procedure can lead to short-term and long-term health effects for both women and children. Every woman who has a CD increases her risk of these unintended consequences. Joel-Cohen introduced a technique of entry in the abdomen emphasizing blunt dissection [14]. Several modifications of his technique became more popular than that used in the Pfannenstiel–Kerr era [15–17]. This leads to education of providers who strive to improve the perceived short term benefits without consideration of potential long-term consequences.

Uterine rupture

Uterine rupture is a rare but potentially fatal complication of a subsequent pregnancy following a previous CS. It can happen before or during labor and is often associated with the need for emergency CS, excessive bleeding, expulsion of the placenta and or fetus into the abdomen, hysterectomy or uterine repair. The newborn is often distressed, requiring admission to a neonatal intensive care unit. The incidence of uterine rupture varies according to clinical circumstances and is reported to be between 0.5 and 4% [45]. Uterine rupture is more prevalent after attempting vaginal birth after two prior CSs, increasing accordingly the risk of cesarean hysterectomy. Uterine scar dehiscence is more common, but rarely results in life-threatening maternal and fetal complications [46]. Uterine suture technique has been implicated in the outcome of trial of labor after a CS with no differences found between the single or double layer closure techniques [47]. The incidence of uterine rupture is likely to increase with increasing CDs. The understanding of the diversity of uterine closure techniques among individual obstetricians may assist the investigation.

Long-term gynecological complications

The relative safety of CD in current obstetrical practice focuses on short-term, rather than long term maternal outcomes. However, after a CD, women are at an increased risk for a variety of chronic gynecological conditions. These include surgical adhesions, pain, infertility or sub-fertility, irregular bleeding, painful intercourse, painful menses and endometriosis [48–51]. These chronic conditions often require intensive follow-up evaluation or surgical intervention by laparotomy or endoscopic exploration using hysteroscopy, laparoscopy or robotic assistance [52, 53]. These procedures carry additional risks for complications related to unforeseen difficulties.

Chronic pain

There are few studies published regarding the risk of developing chronic pain in women after CD. Sun et al., described the challenges of predicting pain after CD [54]. Other investigators highlight the potential role of surgical technique on the risk of pain. Emergency CD, selection of abdominal incision, closure versus non closure of the visceral or peritoneal incision, and uterine closure technique may lead to nerve entrapment, pelvic adhesions, uterine scar defects and endometriosis, and may influence the likelihood of pain [55–58]. The risk of pain is greater with an increasing number of CDs. Women with multiple repeat CDs carry substantially additional risks of organ injuries at the time of surgery. The occurrence of cesarean scar endometriosis is unknown. However, it often presents as cyclic abdominal pain and incisional mass favoring a Pfannenstiel incision more than a midline vertical incision [50].

Pelvic adhesions

Very few published data exist on the etiology of pelvic and abdominal adhesions after CD. As with pain, surgical technique appears to influence the likelihood of post-cesarean adhesion formation. In non-pregnant women, adhesions are often associated with chronic pain and infertility [59]. At delivery, pregnant women are often faced with difficult repeat CDs, organ injury, severe blood loss and increased operating time [35].

Fertility

There are very few studies in which the authors assessed the effect of CD on infertility or subfertility. Pelvic adhesions might interfere with tubal function and patency. Cesarean scar defects have been related to infertility. Surgical intervention with laparoscopy, hysteroscopy or both combined has been successful in restoring fertility [60].

Irregular bleeding

The incidence of cesarean uterine scar defect or "niche" is increasing simultaneously with the resulting long-term gynecological sequelae which include dysmenorrhea, irregular uterine bleeding, subfertility [61, 62] as well as abnormal placentation in subsequent gestations [63]. Tanos summarized five studies assessing niche symptoms in 5,123 patients. He reported 65% of patients presented with uterine bleeding, 46.2% with chronic pelvic pain, 52% with dysmenorrhea, 71.5% with infertility and 24.2% with dyspareunia [46]. Long-term studies on the effect of uterine closure techniques on these unintended gynecological and reproductive symptoms are much needed.

Neonatal morbidity

There is emerging evidence that neonates born by CS may experience altered immune development, reduced intestinal microbiome, late childhood obesity and asthma [64–67]. Continuing investigation is needed to further strengthen the evidence [68]. Adverse perinatal events in women with previous cesareans are primarily related to prematurity and related complications [69, 70]. Compared to infants born vaginally, infants born by CD are more likely to have respiratory symptoms and to need NICU care [71].

Healthcare-associated costs

Cesarean health care costs are often discussed as significant benefits of various surgical techniques used over the past five decades. These costs usually take into account short-term benefits but do not include long-term complications, which are often overlooked as side effects of CD. Yet the management of women affected with PA and subsequent maternal and neonatal morbidity can create a significant financial burden to the health care system. Mogos et al. reported a higher mean cost, per hospitalization, of inpatient care after adjustment for inflation, translating into over $115 million in additional inpatient expenditures relative to non-PA affected deliveries from 2001 to 2011 [33]. Furthermore, the additional costs associated with gynecological evaluations and antenatal consultations in relation to niche and abnormal placentation need to be studied as well.

Reducing cesarean section rates

"Healthy People 2020," the United States federal prevention agenda for building a healthier nation, has established a goal of reducing cesareans for first time births to 24.7% or less for low-risk females [72]. However, the relative safety and the short-term benefits of CD often encourage obstetricians not to deliberate before performing a CD. The potentially associated long-term risks, often unknown to the mothers-to-be, are rarely considered and discussed before surgery. In the absence of medical necessity, some pregnant women choose an elective cesarean birth in part because of lack of knowledge of potential risks and for fear of pain and pelvic floor dysfunction. Women need to be educated about the short- and long-term potential risks of a cesarean birth to both mother and infant. Avoiding a CD and trying a vaginal birth after a previous CS are the most recommended approaches to reduce the risk of PAS and should therefore be encouraged.

In a 1914 lecture and again in 1916, Edward Cragin reported on the risks of vaginal birth in women who previously had been delivered by CS and said "once a cesarean, always a cesarean." [6]. Cragin was predicting the near certainty of repeat CS in a group of women who failed to deliver vaginally after several days in active labor. At that time, rickets and pelvic deformity were prevalent, oxytocin for augmentation of labor was nonexistent, there were no blood banks or antibiotics, and surgery was dangerous. The primary CS was undertaken to save the life of a debilitated mother. In those days, fetal distress was not an indication for CS; the

fetal stethoscope was used only to confirm a living fetus, and fetal monitoring did not exist. This is the basis in large part for half a century of obstetricians and hospitals refusing to let women attempt natural labor after a CS. Through the 1960s in the United States, changes in the management of labor kept the CS rate low. Operative vaginal delivery with forceps, use of oxytocin, vaginal delivery of breeches, and fetal monitoring by auscultation alone [73, 74] contributed to a reduced rate of 4–6%. Reconsideration of Cragin's paradigm led to studies supporting the relative safety of a trial of labor after a low transverse incision CD (TOLAC) [75–77]. Despite reports with larger numbers of patients supporting the relative safety of a trial of labor after CS, the US CS rate continued to rise, going from 5% in 1970 [78] to 20% in 1996, to 31% by 2006, and staying around 32% in the years since [1, 24].

From 1989 to 1996, the increase in trials of labor after CD was reflected in an increased vaginal birth after cesarean (VBAC) rate (VBAC per 100 women with a prior CD) from 18.9 to 28.3%, [35] resulting in a decline in the total CS rate from 25 to 20.7% in 1996 [79]. In the mid-1990s, this substantial reduction in the CS rate was challenged by various published reports describing uterine ruptures and associated neonatal and maternal complications [80]. These risks and the professional liability climate dissuaded practicing obstetricians from recommending VBAC. By 2006, the trend of VBAC was reversed and the rate had decreased to 8.5%, resulting in a dramatic increase in the total CD rate to 31.1% [79, 81, 82]. In some hospitals, policies have restricted or banned TOLAC altogether [83]. There are a number of reasons for this.

Clinical and social reasons account for the current cesarean rate in the US. First, CS is among the safest and most prevalent surgeries performed in the US. There were 1,208,176 cesareans performed in 2018, and 21.7% of a total of 31.9% were primary [84]. In addition, there is no consensus on the clinical criteria for a primary CS in labor, nor for repeat CSs [85]. A request for a cesarean birth for convenience, patient perceptions of social status, and fear of pelvic anatomic disturbance contribute to the cesarean rate. Pregnancies resulting from fertility treatments generate intense pressure in favor of a cesarean birth. As CS became an extremely safe and common operation, concurrently electronic fetal monitoring became the standard of care for all patients, and the focus shifted to the fetus. This generated enormous financial awards based on misunderstanding of the role of intrapartum hypoxia as a cause of cerebral palsy. Vaginal delivery of breeches was abandoned and the use of forceps and vacuum declined as any adverse outcome for the newborn became indefensible in a lawsuit which would similarly result in massive monetary awards for alleged malpractice. The proper management of labor and standardized interpretation of fetal monitoring have long been advocated in the challenge to reduce the CS rate, without much success. The United States CD rate has remained in the 30–32% range for the past 10 years. Other interventions, including mandatory second opinion and the implementation of strict guidelines have been shown to safely reduce the cesarean birth rate [86, 87]. Despite growing pressure to decrease the rate of CSs, experts do not anticipate a significant drop for at least 15 years. However, as there is greater recognition of the participation of midwives, doulas and other continuous support during labor, we hope for a decrease in cesarean birth [88–90].

We suggest the following steps which might limit cesarean births and obtain the best outcomes:

(1) Uniform criteria for diagnosing fetal jeopardy in labor using fetal monitoring.
(2) Diagnosing dystocia by standardized criteria.
(3) Using oxytocin for induction of labor and stimulation of arrested labor in a defined protocol.
(4) Extensive training, including simulation in operative vaginal delivery of vertex presentations [91, 92].
(5) Extensive training, including simulation in vaginal delivery of breech presentations [93].
(6) Developing ultrasound pelvimetry to supplement clinical evaluation of the pelvis prior to operative vaginal delivery, a new concept based on now obsolete X-ray pelvimetry.
(7) Participation of midwives and continuous labor support.
(8) Counseling patients requesting primary or repeat CS regarding risks and suggesting a limit to three, recognizing progressively increasing risks [94].
(9) Employing proper surgical technique to minimize complications at subsequent pregnancies.
(10) Malpractice law reform.

Maternal mortality/morbidity and disparate racial outcomes

CDs carry overall higher rates of maternal mortality and morbidity than vaginal deliveries [95, 96]. Clark reported 8–10 times higher maternal mortality risk for CD compared with vaginal birth [97]. These rates stand out particularly in the United States when compared to other westernized nations [98]. US maternal mortalities rose from 7.2 deaths per 100,000 live births in 1987 [25] to 17.4 deaths per 100,000 live births in 2018, resulting in the death of 658 women [26] for that year. Racial and ethnic disparities are a

significant factor in these higher mortality rates. Black and African American women are three to four times more likely to die during childbirth than women in all other racial and ethnic groups. The most recently published statistics for 2018 identified 17.4 deaths per 100,000 live births. The rate for black women (37.1) was 2.5–3.1 times the rates for white (14.7), and Hispanic (11.8) women [26, 99]. The rate of severe maternal morbidity has also increased in recent years and had affected more than 50,000 American women in 2014 [100]. Racial and ethnic disparities are also substantially prevalent in severe maternal morbidity. From 1997 to 2014, the prevalence of severe maternal morbidity increased by 170% in each racial/ethnic group studied and was highest in black women (1.63%), and lowest in white women (0.84%) [101]. Maternal comorbidities, including hypertension, diabetes, obesity and cesarean birth are frequently identified as significant contributors to the growing morbidity [102, 103] Racial and ethnic disparities in both maternal mortality and morbidity involved cesarean birth. These disparities, which extend farther back in time, were highlighted in a trend analysis from 1935, the inception of Title V of the Social Security Act, to 2007 [104].

Recognizing the multifactorial character of this discrepancy, improving health care outcomes for women of color begins with equitable, high-quality health care services which take into account co-morbid health conditions and socio-economic status, and foremost the need for respect, dignity and communication in providing care. The recognition of individual and structural racism on maternal health is crucial to reducing maternal deaths and improving outcomes for women of color. Racial disparity and its impact on the health care of black women have led to the creation in New York State of the Taskforce on Maternal Mortality and Disparate Racial Outcomes. Similar taskforces have been established throughout the United States to provide and implement recommendations to address the multiple factors, including racial bias and institutional barriers, which compromise health leading to poorer outcomes for black women.

Future directions: cesarean surgical techniques

Currently investigators have focused on the increasing prevalence of PAS; its prenatal diagnosis, epidemiology, and on various approaches towards optimizing maternal outcomes [63, 105, 106]. Research focusing on identifying and preventing novel risk factors in addition to CD may further decrease the severe morbidities and economic burden associated with PA [33]. There are no studies of cesarean surgical techniques and maternal long-term outcomes. Recommendations have been made by several investigators to determine whether a modification of surgical techniques can lower the incidence of abnormal implantation in subsequent pregnancies [107]. The study of a specific "endometrium-free double closure technique," or EFCT, showed no evidence of abnormal placental implantation irrespective of the number of subsequent pregnancies when the technique was used [108]. EFCT addresses prevention and offers a surgical approach which has the potential to reduce PAS and CSP, as conditions diagnosed long after the prior cesarean birth. When EFCT is combined with peritoneal closure, unlike previously published data, preliminary review suggests that a reduction in incidence of debilitating conditions, such as infertility, chronic pelvic pain, irregular bleeding, dyspareunia and dysmenorrhea is possible.

Uterine closure technique appears to influence the origin of niche formation, which concludes its ultimate shape with healing [108]. In this report, the needle placement through both the endometrium and myometrium leads to the presence of endometrium at the superficial level of the uterine closure and gives rise to the origin of uterine scar defect or "niche." [109]. Uterine scar defect and damaged endometrium have long been implicated in the pathophysiology of CS related abnormal placentation [63, 106]. This emerging research paves the way for continuing investigation of the role of cesarean technique, in particular of the endometrium or decidua, on remote obstetrical and gynecological conditions seen in women with prior CDs. Hence, Sholapurkar advised focused research on the finer details of surgical technique to identify and formulate preventive strategies [61]

Individual cesarean techniques are not monitored by any local or national bureaus, even as related long-term risks and complications are skyrocketing. There are neither protocols nor standard techniques for the performance of a CD. At present, the operation relies completely on individual autonomy and preference. The American College of Obstetricians and Gynecologists(ACOG) along with other governing bodies have clearly stated that "a physician should perform her or his technique as it makes no differences in short-term maternal outcomes." [110–112]. Vast circumstances shape the choice of individual physician technique. The type of practice (private solo or group), faculty group practice, hospital employees, insurance plan (in and out of network), and patient preference are all factors contributing to cost and operating time. This leaves some obstetricians to complete the operation in the shortest possible timeframe, while others take longer. The lack

of surgical standardization, although not yet studied, is most likely a contributing factor to unintended chronic adverse effects after a CD. A call to action is in order to standardize the steps necessary for the most optimal outcomes. The ensuing challenge to physician autonomy will be necessary to effectuate change for the benefit of women's health and safety. It may become necessary to evaluate individual provider and institutional performance nationwide, as well as to monitor complications by an independent committee to include midwives, nurses and doulas, along with operating room technicians, doctors and governmental agents to implement safety parameters and risk-reducing methods.

Video-documentation of CSs is currently being used for research purposes to examine the impact of technique on a repeat CS [108]. It is used to record and compare surgical techniques at a prior cesarean with intra-abdominal findings at the time of a subsequent CD. In the same individual patient, it is found to be instrumental for transparency, education, documentation and for preparation of a subsequent operation, including repeat CS [109]. The establishment of a central platform for videos of CS should be considered as a shared learning experience for all obstetrical surgeons. Video documentation may also be an added resource of documentation to the CS operative report. The narrative report, as it is currently used for documentation in the form of handwritten, typed, or multiple choice template, often misses important finer details that may help understand or predict risks of future pregnancy outcomes.

Conclusions

For the past hundred years there has been a continuing evolution of the role of cesarean births in obstetrics. CSs remain the most common operation performed in women of childbearing age in the world, accounting for one in three American women, and is the leading cause of maternal mortality and morbidity in the US. The operation can be life-saving for the fetus, the mother, or both in rare cases. Before the recommendation of a CS and prior to its performance however, the justification including potential risks and benefits should be provided to the patient and discussed. Potential injuries should refer to both maternal and fetal risks. The most catastrophic maternal risks are uterine rupture, excessive blood loss that may result in hysterectomy or transfusion, injury to neighboring organs (bladder or bowel), and thromboembolic disease. The risk of infant injury is low but not absent. The maternal morbidities may be in great part avoided, with greater awareness during the performance of the operation of the ultimate goal of returning uterine function to normal physiology. To a large extent, obstetricians hold the solution to the reduction of cesarean-related complications in their hands. The increasing performance of CS should never be regarded as the simplest means to solve most obstetrical difficulties. The relationship of a prior CS and subsequent conditions remotely connected necessitate further studies of various techniques and the adoption of specific surgical features to improve long term outcomes.

Cesarean morbidity has predominantly focused on short, rather than long-term maternal risks and outcomes. Women undergoing a cesarean birth are at increased risk of a variety of chronic and life-threatening conditions. These conditions increase with the increasing number of CDs. In the non-pregnant state, these include pain, adhesions, irregular bleeding and infertility. The pregnancy related risks include CSP and PAS, which represent the most deadly maternal complications in obstetrics. Increasing attention recently has addressed alterations in the infant microbiota induced by CS compared with vaginal birth, with long term consequences for obesity, and immune disorders such as asthma, allergy and atopic dermatitis.

Over the past 100 years, evolution of cesarean techniques has made it possible to reduce maternal morbidity and mortality. Despite this decline however, black women continue to experience substantially increased risks of both maternal mortality and morbidity compared to white women. These disparities have been challenging to the health care system and represent inequities in access to high-quality obstetrical care.

Surgical techniques have been implicated to influence the likelihood of all long term complications. Emerging studies have shown sparing the endometrium in the uterine closure may influence a reduction in abnormal placentation in subsequent pregnancies. A most recent study related the origin of cesarean scar defect to the technique of uterine closure after a cesarean birth. The authors stressed the significant impact of the location of the endometrium during closure of the uterine incision. Further studies are needed to find the optimal surgical techniques that may reduce cesarean scar defects, which is considered the prevailing factor in abnormal placental implantation. The risk of chronic maternal morbidities is intricately woven in surgical techniques. Video documentation of individual providers' technique may offer a precise understanding of the diversity of surgical techniques in use. This promises to eliminate the subjective assessment of complications in research studies. The autonomy of physician for surgical technique selection must also be reassessed in favor of a more structured, standardized

optimal cesarean technique to curb these long-term maternal complications. Identification of all patients undergoing a cesarean birth and subsequent follow-up would create a registry and database for tracking and a statistic-driven understanding of complications related to CDs. These steps could potentially lead to the discovery of the association between surgical technique and related complications.

Of equal importance, patients must be educated about the risks of a cesarean birth as part of pregnancy education, and providers must factor long term risks in the decision to perform a CD. The education of women about the short and long term potential risks of a CD to both mother and infant is vital for the success of this mission. The optimal cesarean technique will also create an opportunity to level the playing field, where no particular racial or ethnic group will suffer from disparate reduction of cesarean-related complications. One hundred years later, our mission continues as we pursue a twenty first century solution to the alarming rate of obstetrical hemorrhage, peripartum hysterectomy, maternal mortality and racial inequity for health care.

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