

# **Impact of surgeon annual volume on short-term maternal outcome in Cesarean Delivery**

Lior DRUKKER<sup>1</sup> MD, Yael HANTS<sup>2</sup> MD, Rivka FARKASH<sup>1</sup> MPH, Sorina GRISARU-GRANOVSKY<sup>1</sup> MD, Ori SHEN MD<sup>1</sup>, Arnon SAMUELOFF<sup>1</sup> MD and Hen Y. SELA<sup>1</sup> MD

From the Department of Obstetrics and Gynecology, Shaare Zedek Medical Center<sup>1</sup> and the Department of Obstetrics and Gynecology, Hadassah Medical Center<sup>2</sup>, the Hebrew University Medical School, Jerusalem, Israel

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## **Corresponding author**

Lior Drukker, MD

Department of Obstetrics and Gynecology,

Shaare Zedek Medical Center affiliated with the Hebrew University Medical School

Jerusalem 91031, Israel

E-mail: [drukker@szmc.org.il](mailto:drukker@szmc.org.il)

Phone: +972-2-655-5562

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## Condensation

Short Title: Obstetrician annual CD volume and maternal outcome

Condensation: Maternal composite morbidity is decreased as the volume of cesarean deliveries performed or supervised by obstetricians increases.~~Cesarean delivery performed by high annual volume obstetricians is associated with decreased maternal composite morbidity and shorter operative times~~

## Abstract

Background: The annual procedure volume is an accepted marker for quality of care and has been documented in various medical fields. Surgeon volume has been shown to correlate with morbidity and mortality in surgical and high risk medical procedures. Though cesarean delivery is one of the most common surgical procedures in the USA, the link between surgeon's annual cesarean delivery volume and maternal outcome has never been tested.

Objective: To evaluate the impact of surgeons' annual volume on short term maternal outcome in cesarean deliveries.

Study Design: Retrospective cohort study in a single tertiary center between 2006 and 2013. Cesarean deliveries were categorized into two groups based on the annual volume of cesarean delivery of the attending obstetrician. LOW group included low annual volume obstetricians, whose annual volume of cesarean delivery was lower than median. HIGH group comprised high annual volume obstetricians whose annual volume was median and above. ~~Data were collected for all cesarean deliveries; stillbirth and cesarean hysterectomy were excluded.~~ Further analyses were done for quartiles and for four clinical relevant groups according to the annual number of cesarean delivery performed/supervised by the attending (20 or less, 21-60, 61-120 and more than 120) ~~in regards to the primary outcome. Data were collected for all cesarean deliveries; stillbirth and cesarean hysterectomy were excluded.~~ The primary outcome was a composite adverse maternal outcome including one or more of the following: urinary or gastrointestinal tract injuries, hemoglobin drop > three gm/dL, blood transfusion, re-laparotomy, puerperal fever, prolonged maternal hospitalization and readmission. Secondary outcomes were operative times (skin incision to delivery and overall).

Results: A total of 11,954 cesarean deliveries were included, the median annual number of cesarean delivery performed/supervised ~~performed~~ by one obstetrician was 48. Unadjusted ~~bivariate~~ analysis suggested that HIGH group patients, had fewer urinary and gastrointestinal

~~tract~~-injuries 18/9278 (0.2%) vs. 16/2676 (0.6%),  $P < 0.001$ , less blood loss as measured by hemoglobin drop ~~greater than~~  $\geq$  three gm/dL 1053/9278 (11.5%) vs. 366/2676 (13.8%),  $P < 0.001$  and fewer cases of prolonged maternal hospitalization: 80/9278 (0.9%) vs. 39/2676 (1.5%),  $P = 0.006$ . The rate of blood transfusion, re-laparotomy, puerperal febrile morbidity and readmission to hospital did not differ between groups. Multivariable regression analysis showed that cesarean delivery ~~performed/supervised performed~~ by HIGH group resulted in a significantly lower composite adverse maternal outcome (15.8% vs. 18.9%, OR 0.86; 95% CI 0.78–0.95,  $p = 0.004$ ). This was primarily related to a decreased frequency of urinary and gastrointestinal ~~tract~~-injuries, lower likelihood of hemoglobin drop  $>$  three gm/dL and lower incidence of prolonged maternal hospitalization. ~~Both measures of o~~Operative times were significantly shorter for ~~HIGH group high annual volume obstetricians~~. ~~The e~~Composite adverse maternal outcome ranged from 21.8% in the lowest quartile (~~Q1~~), to 17.9% in Q2, to 17.4% in Q3, and 15.6% in Q4. With Q4 defined as the reference, Q3 had an OR of 1.14 95% CI[1.01-1.29],  $p = 0.029$ , Q2 had an OR 1.18 95% CI[1.02-1.36],  $p = 0.021$  and Q1 had an – OR 1.51 95% CI[1.14-1.99]–,  $p = 0.004$  for composite adverse maternal outcome. Composite adverse maternal outcome ranged from 21.5% in clinical group 1, to 17.5% in clinical group 2 to 17.9% in clinical group 3, and 15.2% in clinical group 4,  $p$  value=0.001). Cesarean delivery performed/supervised by clinical groups 2, 3 and 4 in compare to clinical group 1 were associated with a statistically significant risk reduction, (23%, 25% and 34% respectively).

Conclusion: Maternal composite morbidity is decreased as the volume of cesarean deliveries performed or supervised by obstetricians increases~~Cesarean delivery performed by high annual volume obstetricians is associated with decreased maternal composite morbidity and shorter operative times.~~

**Key words:** cesarean delivery outcome; obstetrician volume; annual cesarean delivery volume; workload; volume-outcome; surgical skills; maternal outcome; neonatal outcome; patient safety

## Introduction

The annual procedure volume is an accepted marker for quality of care and has been documented in various medical fields. Surgeon volume has been shown to be directly correlated with morbidity and mortality in surgical and high risk medical procedures.<sup>1-3</sup> It has been suggested that volume-outcome relationship is not always linear and that in some instances there appears to be a threshold.<sup>4</sup>

Cesarean delivery (CD) is one of the most common surgical procedures in the USA and worldwide.<sup>5</sup> Compared to vaginal delivery it is associated with increased maternal morbidity including hemorrhage, infection, damage to pelvic organs and increased readmissions.<sup>6</sup> In contrast to other surgical fields, there are no reports regarding the correlation between caregiver annual CD volume and outcome, while other factors of obstetric volume vs. outcome have been extensively studied. Examples of variables assessed include overall hospital delivery volume, timing of delivery and multiple other factors.<sup>7-17</sup> A nationwide study had found the provider delivery volume to be related to maternal complications, yet the study did not assess the risk of complications related to physician annual CD volume.<sup>18</sup> Physician annual volume has also been linked to the risk of CD.<sup>19</sup> A literature search using Mesh of "Cesarean Section" and outcome, clinical trials published in the English literature on humans between 1995 and 2015 using PubMed revealed 783 publications. These 783 publications titles were read by 2 authors (LD, HYS) and all relevant abstracts (n=35) and manuscripts (n=13) were read. We failed to find an answer to the question whether obstetricians annual CD volume impacts CD outcome.

We hypothesized that obstetricians who perform or supervise more CD have fewer maternal complications as well as shorter operative times. The purpose of our study was to explore whether CD outcomes differ when performed/supervised ~~performed~~ by low versus high annual CD volume obstetricians.

## Materials and Methods

We performed a retrospective cohort study of all CD births (defined as 24 weeks of gestation or more) in a single large tertiary center between January 2006 and December 2013. Stillbirths, cesarean hysterectomies and CD with missing crucial data defined as CD performed by residents only without attending obstetrician were excluded. Anonymized patient data were extracted from our computerized database including demographic parameters, procedures, and diagnoses all of which is updated during hospital admission.

The study protocol was approved by the IRB/Institutional Ethical Committee.

### Setting

Shaare Zedek Medical Center (SZMC) is a University affiliated medical center with a large obstetric service. The labor and delivery department consists of 12 delivery rooms with two operating rooms. There are roughly fifteen thousand deliveries annually with annual CD rate of 11% (national CD rate 19%).

All CD are performed either by an attending physician or by a resident supervised by a scrub attending. In elective CD cases surgery teams are assigned by the chair of the maternal fetal medicine division, based on medical and surgical history: usually the more complicated cases are assigned a more senior attending physician. Attending physicians performing CD are general obstetricians, maternal fetal medicine specialists, or other practitioners of OB/GYN subspecialties (Board certified OB/GYN) with privileges to perform/supervise CD, that were either on call, or performed CD on their private patients. Attending obstetricians who performed/supervised ~~performed~~ at least one CD during the study period were included in this study. Post-operative and postpartum care is routinely provided by residents that are postgraduate year one or 2 and are supervised by a maternal fetal medicine specialist when necessary. Decision regarding discharge is based on maternal medical status.

Any cutoff of number of CD ~~performed/supervised performed~~ annually by a single obstetrician would be arbitrary, and as our aim was to assess whether the high annual volume obstetrician had lower incidence of maternal complications, we decided initially to use the median as a cutoff. The overall median CD ~~performed/supervised performed~~ annually, based on all the attending physicians, was calculated. Median number of CD ~~performed/supervised performed~~ annually was determined for individual obstetricians and was used for group assignment. Physicians performing fewer than the median were defined as low volume obstetricians while those performing from the median and above were defined as high volume obstetricians. We assigned each CD to one of two groups: LOW group – CD was ~~performed/supervised performed~~ by a low volume obstetrician, and HIGH group – CD was ~~performed/supervised performed~~ by a high volume obstetrician. LOW group was chosen as the reference group for analysis. To avoid possible confounding by time, groups were assigned each year separately. All attending physicians' names were masked and replaced with random numbers to allow analysis to be performed blinded to the identity of the obstetrician.

As the median was an arbitrary cutoff, we decided to perform additional analysis according to quartiles, to assess whether there is an association between volume and outcome in terms of “more is better” and to determine the existence of a threshold. To this effect, we compared each quartile to its previous one. Based on the number of CDs performed/supervised monthly by an obstetrician we defined four clinically relevant groups (CG1, CG2, CG3 and CG4). These groups correspond to the number of CD performed/supervised annually by an obstetrician; 20 or less (CG1), 21-60 (CG2), 61-120 (CG3) and more than 120 CD (CG4). This roughly correlates with 1-2, up to 5, up to 10 and more than 10 CD a month.

~~Following a discussion we defined four clinical relevant numbers of CD performed annually by an obstetrician as 20 or less (CG1), 21-60 (CG2), 61-120 (CG3) and more than~~

~~120 CD (CG4). We came up with this annual number as we thought about a number of CD performed monthly by an obstetrician that roughly correlates with 1-2, up to 5, up to 10 and more than 10 CD a month.~~

Further analysis included experience of the surgeon as measured by years from residency graduation, and analysis without the outliers defined as obstetricians performing fewer than 10 CD per year or greater than 350 CD per year

#### Outcome measures:

Our primary outcome measure was a composite adverse maternal outcome representing the occurrence of one or more of the following: urinary and gastrointestinal tract injuries (i.e. incidental cystotomy, ureterotomy, ureter obstruction, or enterotomy), hemoglobin drop > three gm/dL (calculated between pre- and postoperative hemoglobin levels), representing double to triple the average blood loss during CD,<sup>20-21</sup> blood transfusion (one or more units packed red blood cells (PRBC)), re-laparotomy (within initial admission), puerperal febrile morbidity (defined as temperature of 100.4° F [38° C] or higher on any two of the first ten days after delivery, exclusive of the first 24 hours,<sup>22</sup> prolonged maternal hospitalization (length of stay > 10 days), readmission to hospital (within 42 days post-operatively<sup>23</sup>). Secondary outcomes were lengths of operative times: skin incision to delivery of the neonate and overall time from skin incision to skin closure.

#### Exposure:

The primary exposure variable was obstetrician annual CD volume. Univariate analysis was performed for categorical variables using the  $\chi^2$  or Fisher's exact tests. Continuous variables were compared using the Student's T-test or Mann-Whitney U-test. To evaluate the independent association between obstetrician annual CD volume and each outcome we conducted multivariate logistic regression modeling, adjusting for patient

demographic parameters and co-morbidities: maternal age, maternal education (greater than 12 years), parity, assisted reproduction techniques, hypertensive disorder, diabetes mellitus, multifetal gestation, placenta previa, gestational age, trial of labor after cesarean, intrapartum fever (temperature > 100.4° F (38° C)), second stage CD,<sup>24</sup> delivery during on-call hours,<sup>25</sup> and elective vs. urgent CD.<sup>26</sup> Each model was constructed in two blocks; first all potential confounders were assigned to the model using stepwise backward method. In the next step obstetrician annual CD volume was forced into the model using the "enter" method. Multiple linear regression models were used to investigate the relation of obstetrician annual CD volume with CD durations while controlling for the aforementioned potential confounders. Additional analysis was performed in order to assess whether there was a linear association between obstetrician's annual volume and composite adverse maternal outcome by dividing the group into four quartiles of volume and four clinically relevant groups (CG1-4). Odds ratio (OR) and 95% confidence intervals (CI) are reported. All tests are two-tailed; P value below 0.05 was considered statistically significant. Analyses were carried out using SPSS software package version 20.0 (IBM, Armonk, NY).

## Results

During the study period there were a total of 105,618 deliveries of which 12,280 (11.6%) were cesarean. We excluded 50 stillbirths (0.4%), 60 cases of cesarean hysterectomy (0.5%) and 216 cases that were missing crucial data (1.7%), for a total of 11,954 (97.3%) CD for analysis (Figure 1). The annual median number of attending obstetricians was 26 (range 22-34). Throughout the study period, the median number of CD performed/supervised ~~performed~~ annually by a single attending obstetrician was 48 (range 1-389); thus, CD performed/supervised ~~performed~~ by an obstetrician who performed/supervised ~~performed~~ fewer than 48 CD annually was assigned to LOW group; and CD performed/supervised

~~performed~~ by one of the physicians who performed/supervised ~~performed~~ 48 or more CD annually were assigned to HIGH group. In total, 2,676 (22.4%) CD were assigned to LOW group and 9,278 (77.6%) CD throughout the study period were assigned to HIGH group (Figure 2). The overall percentage of CD performed by the residents and supervised by the scrub attending was 37.3% (4567/12239), and it varied between years from 28.3% to 56.6%.

Maternal characteristics are presented in Table 1. Women with one previous CD or three or more previous CD were more likely to be operated on by a high annual volume obstetrician. Cesarean deliveries of nulliparas, CD during on-call hours and urgent CD were more likely to be performed/supervised ~~performed~~ by a low annual volume obstetrician. Maternal age, education, the incidence of three or more prior miscarriages, multifetal gestation, placenta previa, diabetes mellitus, and hypertensive disorders did not differ between groups.

Composite adverse maternal outcome was identified in 1966/11954 women (16.4%) of the total study population: 500/2676 occurred in women who were assigned to LOW group (18.9%) as compared to 1466/9278 of the women who were included in HIGH group (15.8%),  $p < 0.001$ . Detailed maternal adverse outcomes are shown in Table 2. Unadjusted bivariate analysis suggested that HIGH group patients, whose CD were performed/supervised ~~performed~~ by high annual volume obstetricians, had fewer urinary and gastrointestinal tract injuries 18/9278 (0.2%) vs. 16/2676 (0.6%),  $P < 0.001$ , less blood loss as measured by hemoglobin drop greater than three gm/dL 1053/9278 (11.5%) vs. 366/2676 (13.8%),  $P < 0.001$  and fewer cases of prolonged maternal hospitalization: 80/9278 (0.9%) vs. 39/2676 (1.5%),  $P = 0.006$ . The rate of blood transfusion, re-laparotomy, puerperal febrile morbidity and readmission to hospital did not differ between groups.

Cesarean deliveries performed/supervised ~~performed~~ by HIGH group were significantly shorter, both overall and from the time of skin incision to neonatal delivery time,

P<0.001 as shown in Table 3; however, the absolute median decrease in surgical times was one minute (6 vs. 7, P<0.001 and 30 vs. 31, P<0.001, respectively). Multiple linear models revealed that CD ~~performed/supervised performed~~ by high volume obstetrician were independently associated with shorter durations of skin incision to neonate delivery [-0.93 minutes, 95% CI (-0.66) – (-1.18), p<0.001] and skin incision to skin closure [-1.25 minutes, 95% CI (-0.28) – (-2.22), p=0.012].

The association between obstetrician annual CD volume and adverse outcome as derived from the multivariable logistic regression analysis is shown in Table 4. The following factors remained significantly less frequent among the HIGH group: urinary and gastrointestinal tract injuries, hemoglobin drop greater than 3 gm/dL and prolonged maternal hospitalization (OR 0.33, 95% CI 0.16-0.66, P=0.002, OR 0.85, 95% CI 0.74-0.96, P=0.01 and OR 0.59, 95% CI 0.40-0.87, P=0.008), respectively. Blood transfusion, re-laparotomy and puerperal febrile morbidity remained comparable between groups.

The incidence of composite adverse maternal outcome was significantly lower in the HIGH group compared to the LOW group (OR 0.83; 95% CI 0.74-0.93, P=0.001); this correlation remained statistically significant on separate analysis of primary and recurrent CD (OR 0.85; 95% CI 0.74-0.98, P=0.021 and OR 0.81; 95% CI 0.66-0.99, P=0.049, respectively).

#### Quartile analysis

Rate of composite adverse maternal outcomes was compared among quartiles. All quartiles included on average six surgeons, ranging in various years from 5-9(Q1), 4-10(Q2), 5-8(Q3) and 5-9(Q4). Number of CD ~~performed/supervised performed~~ in each quartile: Q1 (1-15), Q2 (16-48), Q3 (49-85), Q4 (86-398). The composite adverse maternal outcome ranged from 21.8% in the lowest quartile (Q1), to 17.9% in Q2, to 17.4% in Q3, and 15.6% in Q4. ~~(Figure 3).~~ With Q4 defined as the reference, Q3 had an OR of 1.14 95%CI[1.01-1.29] ,

p=0.029, Q2 had an OR 1.18 95%CI[1.02-1.36] , p=0.021 and Q1 had an – OR 1.51 95%CI[1.14-1.99] , p=0.004 for composite adverse maternal outcome. In order to assess whether the difference in outcomes was mostly driven by the high composite adverse maternal outcome in Q1, we compared Q1 and the other quartiles (Q2-4). This revealed that Q1 had a 21.8% (68/312) rate of composite adverse maternal outcome as opposed to 16.3% (1876/11487) with a p value of 0.01. Univariate analysis comparison between Q1 and Q2-4 revealed that the only factors within the composite that were significantly different were: hemoglobin drop of more than 3 gm/dl (16.1% vs. 11.9%, p=0.026) and re-laparotomy (within initial admission) (1.6% vs. 0.3%, p=0.04). Stepwise logistic regression revealed an OR of 1.5 for adverse maternal outcome between quartiles 1 and 4 (95% CI 1.14-1.99, p=0.004), and OR of 1.33 for adverse maternal outcome between Q1 and Q2-4 (95% CI 1.01-1.77, p=0.045).

To control for years of experience we added time from completion of residency to the model. This neither strengthened nor weakened our results: the OR for composite adverse maternal complication was 1.5 (95% CI 1.16-2.031, p=0.002). Each additional year of experience, had an independent protective effect from maternal complications of a 1% for each year (OR 0.99, 95% CI 0.99 0.98-.99, p=0.001). When outliers, defined as obstetricians performing fewer than 10 CD per year or greater than 350 CD per year were excluded, the results were unchanged.

#### Clinically relevant number of CD analysis

The proportion of CD ~~performed/supervised performed~~ by each CG was as follows: CG1 - 4.2%, CG2 - 23.6%, CG3 – 28.9% and 43.3% by CG4. The rate of composite adverse maternal outcome differed among groups (21.5%, 17.5%, 16.9% and 15.2% respectively, p value=0.001) (Figure 3). When CG1 was defined as the reference, multivariate regression analysis revealed that when CD was ~~performed/supervised performed~~ by CG2 there was a

risk reduction of 23% (95% CI [0.60-.98]), when CD was ~~performed/supervised performed~~ by CG3 there was a risk reduction of 25% (95% CI [0.58-.94]) and that when CD was ~~performed/supervised performed~~ by CG4 there was a risk reduction of 34% (95% CI [0.52-.82]).

## Comment

In the present study we show a correlation between attending annual CD volume and risk of adverse maternal outcome. We found that women whose CD was ~~performed/supervised performed~~ by an obstetrician performing more than the median annual number of CD sustained less composite adverse maternal outcome. Furthermore, the same correlation between volume of CD performed/supervised by the obstetrician and maternal outcome persisted when the volume of CD was divided into quartiles or clinical significant groups. Comparison between quartiles as well as between clinical groups revealed that there is no apparent threshold, rather that when CD are ~~performed/supervised performed~~ by a provider who ~~performs/supervise performs~~ more CD there are less maternal complications. The lower maternal complication rate associated with higher volume of CD was mostly driven by lower rates of excess blood loss, prolonged hospitalization, and gastrointestinal and or / urinary tract injuries. We also found that length of CD ~~performed/supervised performed~~ by high volume obstetricians is slightly shorter though most likely this lacks clinical significance. These differences remained statistically significant when analyzed in primary CD vs. repeat CD, when applying multiple logistic regression analysis, when the data were analyzed in quartiles and according to clinical groups, and when outliers were excluded.

It is possible that the beneficial impact of the surgeons' annual CD volume observed, was blunted due to several reasons:

Comparison of LOW group and HIGH group cases showed that those in HIGH group were more complicated surgical cases overall, i.e. they had higher rates of prior CD in general (46.3% vs. 36.9%,  $p<0.001$ ) and higher rates of three previous CD or more (9.4% vs. 5.6%,  $p<0.001$ ). This trend is due to our practice, which tends to assign more complex cases to high volume physicians. Yet women operated on by high annual volume attending obstetricians had less composite adverse maternal outcome and shorter operative times, while these more complex cases would, at least theoretically, be expected to exhibit more composite complications and longer operative times.

Whether 21.8% or 18.9% or 15.6% are an acceptable adverse maternal outcome rate is unknown. It is clear though that women who had CD ~~performed/supervised~~ ~~performed~~ by an obstetrician from HIGH group in comparison to LOW group had significantly lower short term adverse outcome by 16.5%. If the CD was ~~performed/supervised~~ ~~performed~~ by an obstetrician from the top quartile as compared to the lower one, short term adverse outcome rate was decreased by 28.8% and it also decreased by 34% from the higher clinical group to the lower clinical group. When attempting to define the biggest change between groups – quartiles, median and clinical groups, it seems that the biggest difference in adverse maternal outcomes exist between clinical group 1 and 2 – where women who had there CD performed/supervised by CG had 23% decrease in adverse maternal outcome.

Annual procedure volume is an accepted quality marker and is associated with better outcomes in various surgical procedures, and has been studied in obstetrics.<sup>1-3,11</sup> Although physician delivery volume was found to correlate with maternal complication rate,<sup>18</sup> individual annual CD volume was never studied in relation to procedure outcome. Several studies assessed the learning curve of CD, and demonstrated that by performing 20 CD, residents reach the flat part of the curve in regards to operation time.<sup>27-29</sup> One study found the ranking of residency program to be related to maternal complication.<sup>30</sup>

Risk of maternal complications is also related to surgeon experience: a retrospective study demonstrated that the risk of postoperative complications was higher when the CD was performed by a resident rather than an attending physician (OR = 2.4, 95% CI 1.2–4.8).<sup>31</sup> Furthermore, it seems that major obstetric hemorrhage occurs more frequently in women operated by junior as compared to senior obstetricians (19.6%, 164/835 vs. 13.1%, 153/1166).<sup>32</sup>

The rates of maternal complications of CD reported in this study are consistent with previous major publications: urinary and gastrointestinal tract injuries 0.18-0.48%,<sup>24</sup> blood transfusion 3.2%,<sup>33</sup> re-laparotomy 0.23-0.4%,<sup>34-36</sup> readmission to hospital 1.8%,<sup>23</sup> and a composite of selected maternal adverse outcomes 19.6-21.7%.<sup>24</sup>

### Strengths and limitations

Our study strengths include large number of CD and consistent method of real time data collection that was gleaned from electronic medical record. The weaknesses of the study include its retrospective nature and the fact that it is a single center with a relatively low CD rate; it is possible that at centers where the CD rate is higher, the annual median obstetrician CD number would be different. Our database lacks information on body mass index (BMI). Considering that obesity significantly contributes to surgical morbidity,<sup>37</sup> we tend to assign obese patients to high volume operators. It is possible that if this data was available, it would have strengthened the power of our results. Other limitations include lack of overall obstetrician experience, presence of adhesions and long term outcomes in the analysis. Furthermore, we had not dealt with cost of prolonged hospitalization or maternal complications.

Our study demonstrated a reduction in the short-term composite adverse maternal outcome in high volume operators. There is a small but significant difference in morbidity

between quartiles and the different clinical groups. As defining an acceptable threshold for maintaining surgical competence was beyond the scope of our study, we would caution the readers that establishing minimal volume requirements for performing CD is dependent on many local parameters not addressed in this work. Yet using clinical grouping and dividing providers into 4 CG based on their annual CD volume revealed that physicians who perform/supervise more than 20 CD annually have lower composite adverse maternal outcome. Our finding that the annual CD volume affects short term maternal outcomes is in line with literature, which supports the notion that the more experience the operator has, the lower the risk of complications. This important issue should be addressed in large multicenter studies where various rates of CD exist, as it has the potential to impact outcomes in a large proportion of deliveries.

In conclusion, we showed that in our setup, obstetricians with higher annual CD volume have lower composite adverse maternal outcome, as well as shorter operative times, even though they operate on more complex cases. It might be possible to identify a minimum number of procedures an obstetrician should perform or supervise annually to maintain CD competence and thereby reduce adverse maternal outcomes. Future studies should address the acceptable “adverse maternal outcome” rate as well as the minimum number of CD that needs to be performed/supervised ~~performed~~ by an individual provider and utilize the clinical group analysis and confirm or reject the finding that physicians who perform/supervise less than 20 CD annually have increased morbidity. ~~in order to achieve this goal, as well as to~~ Future studies should also evaluate long-term outcome differences in CD according to the annual volume of the caregiver.

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**Table 1** Maternal and neonatal demographic characteristics in 11,954 cesarean deliveries according to obstetricians' annual volume

	LOW group	HIGH group	
	CD	CD	
Characteristic	(n=2676)	(n=9278)	P
<b>Maternal characteristic</b>			
Maternal age (years)	31.0 ± 6.4	31.2 ± 6.3	0.08
AMA (>35years)	702 (26.2%)	2463 (26.5%)	0.75
Education (≥12 years)	2484 (95.7%)	8636 (95.7%)	0.94
Prior miscarriages ≥3	163 (6.1%)	575 (6.2%)	0.84
Previous CD	988 (36.9%)	4292 (46.3%)	<0.001
Previous CD ≥3	151 (5.6%)	869 (9.4%)	<0.001
Parity	3.2 ± 2.6	3.4 ± 2.6	<0.001
Nulliparous	916 (34.2%)	2592 (27.9%)	<0.001
<b>Gestation characteristic</b>			
Artificial reproductive techniques	409 (15.3%)	1073 (11.6%)	<0.001
Multifetal gestation	265 (9.9%)	889 (9.6%)	0.62
Placenta previa	44 (1.6%)	183 (2.0%)	0.27
Diabetes mellitus (pre and gestational)	260 (9.7%)	948 (10.2)	0.45
Gestational diabetes mellitus	218 (8.1%)	796 (8.6%)	0.48
Hypertensive disorder (chronic, gestational, preeclampsia)	169 (6.3%)	541 (5.8%)	0.35
Preeclampsia	128 (4.8%)	364 (3.9%)	0.05
<b>Labor characteristic</b>			
Gestational age (weeks)	38.0 ± 2.6	37.9 ± 2.6	0.001
Preterm <37 weeks	486 (18.2%)	1610 (17.4%)	0.33
Trial of labor after cesarean	244 (9.1%)	874 (9.4%)	0.64
Intrapartum fever >100.4° F (38°C)	79 (3.0%)	185 (2.0%)	0.003
CD during second stage	142 (5.3%)	462 (5.0%)	0.50

Cesarean delivery characteristic			
Elective	1418 (53.0%)	5777 (62.3%)	<0.001
Urgent	1258 (47%)	3501 (37.7%)	
General anesthesia	166 (6.2%)	574 (6.2%)	0.98
During on-call hours	1546 (57.8%)	4611 (49.7%)	<0.001
Urgent cesarean indication			
Dystocia	272 (21.6%)	746 (21.3%)	0.016
Non Reassuring fetal heart rate	629 (50.0%)	1614 (46.1%)	
Other	357 (28.4%)	1141 (32.6%)	

Data are mean  $\pm$  standard deviation; number (%); LOW group – CD ~~performed/supervised performed~~  
by low annual volume obstetrician; HIGH group – CD ~~performed/supervised performed~~-by high  
annual volume obstetrician

**Table 2** Adverse maternal outcomes according to obstetricians' annual CD volume

	LOW group	HIGH group	
Outcome	CD(n=2676)	CD(n=9278)	P
<b>Adverse maternal outcomes</b>			
Urinary and/or gastrointestinal tract injuries	16 (0.6%)	18 (0.2%)	<b>0.001</b>
Hemoglobin drop > 3 gm/dL	366 (13.8%)	1053 (11.5%)	<b>0.001</b>
Blood transfusion	112 (4.2%)	351 (3.8%)	0.34
Re-laparotomy	12 (0.4%)	29 (0.3%)	0.29
Puerperal febrile morbidity	48 (1.8%)	172 (1.9%)	0.84
Prolonged maternal hospitalization	39 (1.5%)	80 (0.9%)	<b>0.006</b>
Readmission to hospital	34 (1.3%)	89 (1.0%)	0.16
<b>Composite adverse maternal outcome</b>	500 (18.9%)	1466 (15.8%)	<b>&lt;0.001</b>

Data are number (%); LOW group – CD ~~performed/supervised performed~~ by low annual volume

obstetrician; HIGH group – CD ~~performed/supervised performed~~ by high annual volume obstetrician

**Table 3** Comparison of cesarean delivery operative times according to obstetricians' annual volume

	LOW group CD	HIGH group CD	
Operative time	(n=2676)	(n=9278)	P
<b>Skin incision to fetus delivery</b>			
All cesarean deliveries	7 (5 – 10)	6 (4 – 10)	<0.001
Primary cesarean deliveries	6 (4 – 9)	5 (3 - 8)	<0.001
Recurrent cesarean deliveries	9 (6 – 13)	8 (5-12)	<0.001
<b>Skin incision to skin closure</b>			
All cesarean deliveries	31 (25- 40)	30 (23 – 41)	<0.001
Primary cesarean deliveries	30 (25 – 37)	28 (21 – 37)	<0.001
Recurrent cesarean deliveries	36 (29 -48)	35 (25 - 46)	<0.001

Data are median minutes (interquartile range); **LOW group** – CD ~~performed/supervised~~ performed by low annual volume obstetrician; **HIGH group** – CD ~~performed/supervised~~ performed by high annual volume obstetrician

**Table 4** Multivariable regression of maternal outcomes in cesarean delivery according to obstetricians' annual volume<sup>1</sup>

Outcome <sup>1</sup>	LOW group		P
	CD	HIGH group CD	
	(n=2676)	(n=9278)	
Adverse maternal outcome			
Urinary and gastrointestinal tract injuries	1.00	0.33 (0.16 – 0.66)	0.002
Hemoglobin decrease > 3 gm/dL	1.00	0.85 (0.74 – 0.96)	0.01
Blood transfusion	1.00	0.92 (0.73 – 1.12)	0.36
Re-laparotomy	1.00	0.69 (0.35 – 1.36)	0.27
Puerperal febrile morbidity	1.00	1.01 (0.73 – 1.40)	0.95
Prolonged maternal hospitalization	1.00	0.59 (0.40 – 0.87)	0.008
Readmission to hospital	1.00	0.81 (0.54 – 1.21)	0.30
Composite adverse maternal outcome <sup>2</sup>	1.00	0.83 (0.74 – 0.93)	0.001

Data are odds ratio (95% confidence interval).

LOW group – CD performed/supervised ~~performed~~ by low annual volume obstetrician;

HIGH group – CD performed/supervised ~~performed~~ by high annual volume obstetrician

<sup>1</sup>Adjusted for: maternal age, education, parity, number of prior CD, maternal chronic or gestational disease, abnormal placentation, gestational age, TOLAC (trial of labor after cesarean), indication for CD: elective vs. urgent CD and birth weight.

<sup>2</sup>Composite adverse maternal outcome includes one or more: urinary and gastrointestinal tract injuries, hemoglobin decrease >3 gm/dL, blood transfusion, re-laparotomy, puerperal febrile morbidity, maternal prolonged hospitalization, and readmission to hospital.

## **Figure Legends**

**Figure 1:** Woman included in this study

**Figure 2:** Obstetrician annual cesarean delivery volume

**Figure 3:** Composite adverse maternal outcome by Obstetrician annual cesarean delivery workload quartile