

Supplementary file 1: Details of data processing and methods

Medical information

In 2009 the Beijing Municipal Health Commission Information Center established a Beijing Inpatient Medical Record Face Sheet Database (BIMRFSD) for collecting the face sheets of medical records from all inpatients. A total of 108 midwifery hospitals in 16 districts and counties in Beijing (excluding the military and armed police-affiliated hospitals) transmitted the face sheets of medical records to the BIMRFSD. Data in the BIMRFSD are coded according to the International Classification of Diseases (ICD-10 and ICD-9-CM).

In this study, the ICD-9-CM/ICD-10 code of surgical operation and discharge diagnosis were used to determine whether the parturient gave birth by CS and the indications for CS. In this way, the coding quality of medical records face sheets directly affects the research results. The coding quality control system of medical records face sheets of newly opened hospitals is not perfect. Midway closed hospitals are likely to have serious medical quality problems and internal management problems, which affect the medical records face sheets coding quality. Hospitals with few deliveries are usually loosely organized, and often have no fixed midwives or obstetricians, which affect the quality of medical records face sheets. Thus, the inclusion criteria for the hospitals were (1) a monthly

average delivery volume of ≥ 200 and (2) continuous monthly reporting of medical record face sheets for hospitalized childbirths from 2012 to 2017. The data from 28 midwifery hospitals in the city of Beijing met the requirements including 17 tertiary and 11 secondary hospitals. The inclusion criteria for cases were hospitalized deliveries of babies at gestational ages ≥ 28 weeks from January 1, 2012 to December 31, 2017. Cases were identified using the BIMRFSD of the Beijing Municipal Health Commission Information Center.

The face sheets of medical records from a total of 747,918 women (accounting for 60% of the deliveries in Beijing during the same period) met the inclusion criteria. The data were sorted by professional biostatisticians. Data processing included 1) data preprocessing: all data were deduplicated and standardized, and invalid data were excluded; 2) data detection: we examined 138 fields item by item for integrity and standardization, and cases with missing data were excluded; 3) data analysis: after sorting, screening, and outlier detection, cases with logical errors and outliers were excluded. We removed 13,998 cases with invalid data, missing data, outlier data, or logical errors, ultimately resulting in a total of 733,920 women in the study cohort.

Medical information (including delivery year, delivery institution, administrative division code, maternal age, marital status, employment, payment method, discharge diagnosis, surgical operation, and neonatal outcome) was extracted from the medical records face sheets. When extracting the information, the Beijing Municipal Health Commission Information Center removed the private information such as the name and contact information. The medical record number served as the unique identification code used for each case. When the data collection and verification were completed, the medical record number was replaced by a digital serial number.

Classification and ordering of complications

Using ICD-10 and ICD-9-CM, deliveries from 2012 to 2017 were classified and grouped according to six complications: (1) scarred uterus, including a history of CS and/or hysteromyomectomy; (2) double/multiple-fetus pregnancy; (3) fetal malposition, including breech position, foot presentation, or transverse position; (4) dystocia-related factors, including pelvic abnormalities (pelvic stenosis or pelvic deformity), macrosomia, abnormal labor, relative cephalopelvic disproportion, persistent posterior occipital position, and persistent transverse occipital position; (5) fetal distress, including fetal distress due to fetal heart type and/or amniotic fluid type; (6) complications and comorbidities of pregnancy, including placental abruption, placenta previa, vascular previa, eclampsia, preeclampsia, uterine cavity infection, amniotic fluid embolism, cardiac insufficiency, malignant tumor, and severe hepatitis. Deliveries with two or more complications were assigned to a single diagnostic classification, and we referred to the hierarchical order designed by Anderson and Selma^[13,14]: 1) scarred uterus; 2) double/multiple- fetus pregnancy; 3) fetal malposition; 4) dystocia-related factors; 5) fetal distress; and 6) complications and comorbidities of pregnancy. Thus, a delivery with diagnoses of both fetal distress and dystocia-related factors would be assigned to the category “dystocia-related factors,” while scarred uterus superseded all other diagnoses.

There were some CS deliveries without medical indications. These cases were classified as “no medical indications”—i.e., cesarean deliveries with no indications with respect to the above six categories. Diagnoses of older nullipara, oligohydramnios, vaginitis, genital HPV-positivity, IVF protocol participation, and gestational diabetes were not considered indications for CS.

Evaluation indicators

The cesarean section rate (CSR) = cesarean deliveries/total deliveries \times 100%, and the indication-specific CSR = cesarean deliveries for a stated complication/total deliveries \times 100%. For the average annual percent change (AAPC), the weighted average of the annual percentage change of a variable in a specified period was used to summarize the overall trend of the variable over time. The indication contribution ratio = (indication-specific CSR_x – indication-specific CSR_y)/|CSR_x – CSR_y|, and reflected the influence of a specific indication on the change in the CSR. A negative value indicated that the parameter was beneficial to the decline in CSR, and a positive value indicated that it increased CSR.

Statistical analysis

R software (<http://www.r-project.org>) and SPSS v. 20.0 software (IBM Corporation, Armonk, NY, US). was employed to sort and analyze the data. The measurement data are expressed as $\bar{x} \pm sd$ and analysis of variance (single-factor ANOVA) was used for comparisons among groups. Numerical counts are expressed by frequency and rate. The Pearson χ^2 test was used for comparisons between groups. We used the Joinpoint Regression Program (Version 4.9.0.0) of the National Cancer Institute website (<https://surveillance.cancer.gov/joinpoint/>) to perform joinpoint regression analysis and calculate variable AAPCs and 95% confidence intervals (CIs). In the joinpoint regression model, year was the independent variable and the variable under investigation was the dependent variable. In this study, the total number of pregnant women (733,920) served as the standard population. The age-adjusted

CSR from 2012 to 2017 was calculated according to the age composition ratio of the standard population. AAPC and 95% CI of age-adjusted CSR from 2012 to 2017 were further calculated.

Supplementary file 2. Cesarean rate* by age of the mother and age-adjusted cesarean rate: 28 hospitals in Beijing, 2012–2017

Year	Age of mother						All ages	Age-adjusted cesarean rate
	Under 20 years	20–24 years	25–29 years	30–34 years	35–39 years	40 years and over		
2017	18.0 (39/217)	27.8 (1,557/5,609)	33.7 (14,309/42,450)	42.0 (21,681/51,636)	54.4 (14,503/26,683)	63.5 (2,758/4,340)	41.9 (54,847/130,935)	39.5 (51,719/130,935)
2016	18.1 (50/276)	26.3 (2032/7,739)	31.6 (19,111/60,526)	40.7 (22,416/55,100)	53.6 (11,008/20,544)	64.7 (1,828/2,827)	38.4 (56,445/147,012)	38.0 (55,865/147,012)
2015	15.2 (65/428)	27.3 (1,919/7,036)	34.0 (12,032/35,355)	42.3 (15,901/37,547)	56.0 (7,996/14,287)	67.3 (1,471/2,186)	40.7 (39,384/96,839)	40.0 (387,36/96,839)
2014	19.7 (106/539)	31.3 (3,741/11,955)	35.7 (22,740/63,778)	42.2 (22,590/53,511)	57.5 (7,312/12,706)	68.8 (1,345/1,955)	40.0 (57,834/144,444)	41.1 (59,366/144,444)
2013	21.4 (133/621)	35.1 (4,070/11,599)	41.8 (18,199/43,545)	47.0 (18,249/38,854)	63.5 (5,974/9,411)	69.4 (1,194/1,720)	45.2 (47,819/105,750)	46.4 (49,068/105,750)
2012	24.6 (168/684)	36.8 (4,576/12,433)	44.4 (20,342/45,828)	48.8 (19,509/39,963)	65.2 (5,532/8,488)	72.5 (1,120/1,544)	47.0 (51,247/108,940)	48.6 (52,945/108,940)
Trend χ^2	11.896	373.671	2,147.173	672.143	482.735	56.970	1,341.779	4297.478
<i>P</i>	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
AAPC (95% CI)	-6.4 (-13.7–	-6.6 (-10.5–	-6.3 (-10.1–-2.3)	-3.3 (-5.9–-0.7)	-4.0 (-6.0–-2.0)	-2.5 (-3.1–	-2.9 (-6.7–0.9)	-4.6 (-7.5–-1.7)
(%)	1.4)	-2.7)				-2.0)		
<i>P</i>	0.084	0.010	0.013	0.025	0.005	<0.001	0.100	0.012

*Cesarean rate = number of cesarean deliveries per 100 deliveries in a specified group.

Data are presented as % (*n/N*).

Supplementary file 3. Percentage of all deliveries (vaginal and cesarean) with specified complications in 28 hospitals in Beijing, 2012–2017.

Complications	2017	2016	2015	2014	2013	2012	2012–2017 AAPC (95%CI)	Percent change, 2012 to 2017
Total with one or more complications	52.8 (69,090/130,935)	48.4 (71,111/147,012)	49.5 (47,896/96,839)	47.1 (68,089/144,444)	49.2 (52,002/105,750)	48.9 (53,225/108,940)	1.1 (−1.3–3.5)	+8.0
Scarred uterus	19.8 (25,966/130,935)	14.6 (21,522/147,012)	13.3 (12,855/96,839)	8.5 (12,340/144,444)	7.2 (7,635/105,750)	6.5 (7,028/108,940)	26.2 (18.6–34.2)	+204.6
Double/multiple-fetus	1.8 (2,314/130,935)	1.6 (2,392/147,012)	2.0 (1,940/96,839)	1.6 (2,285/144,444)	1.6 (1,694/105,750)	1.5 (1,610/108,940)	3.3 (−3.1–10.1)	+20.0
Fetal malposition	3.5 (4,596/130,935)	3.7 (5,459/147,012)	4.0 (3,887/96,839)	4.3 (6,146/144,444)	4.4 (4,610/105,750)	4.3 (4,704/108,940)	−4.5 (−6.9–2.1)	−18.6
Dystocia-related factors	9.7 (12,722/130,935)	10.6 (15,519/147,012)	11.3 (10,945/96,839)	13.9 (20,040/144,444)	15.5 (16,379/105,750)	16.1 (17,510/108,940)	−10.5 (−13.1– −7.9)	−39.8
Fetal distress	10.2 (13,403/130,935)	10.4 (15,229/147,012)	11.1 (10,794/96,839)	12.0 (17,285/144,444)	13.1 (13,845/105,750)	13.7 (14,889/108,940)	−6.2 (−7.5–4.9)	−25.5
Complications and comorbidities of pregnancy	7.7 (10,089/130,935)	7.5 (10,990/147,012)	7.7 (7,475/96,839)	6.9 (9,993/144,444)	7.4 (7,821/105,750)	6.9 (7,474/108,940)	2.0 (−0.5–4.6)	+11.6

Data are presented as % (*n/N*).

Supplementary file 4. Number of cesarean deliveries per 100 deliveries with stated complication at 28 hospitals in Beijing from 2012 to 2017

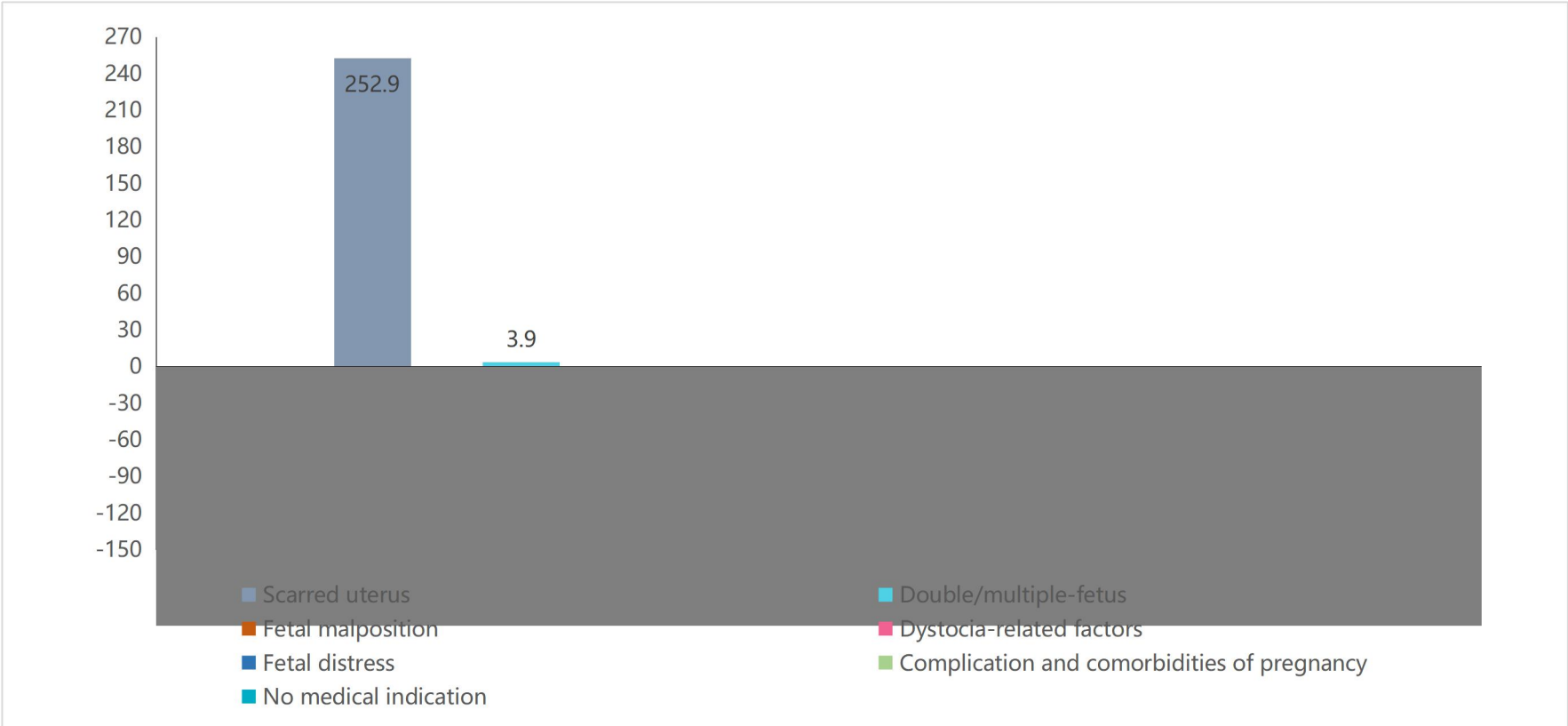
Complications	2017	2016	2015	2014	2013	2012	2012–2017	Percent change, 2012 to 2017
							AAPC (95% CI) (%)	
Scarred uterus	96.2 (24,989/2,5966)	95.2 (20,487/21,522)	94.8 (12,190/12,855)	95.7 (11,811/12,340)	95.6 (7,317/7,653)	96.2 (6,760/7,028)	–0.1 (–0.5–0.4)	0
Double/multiple fetus	83.0 (1,920/2,314)	83.2 (1,990/2,392)	86.4 (1,677/1,940)	86.1 (1,967/2,285)	88.0 (1,490/1,694)	88.0 (1,416/1,610)	–1.3 (–2.0–0.6)	–5.7
Fetal malposition	95.4 (4,386/4,596)	95.9 (5,234/5,459)	95.7 (3,719/3,887)	96.2 (5,912/6,146)	97.0 (4,472/4,610)	96.5 (4,541/4,704)	–0.3 (–0.5–0.1)	–0.9
Dystocia-related factors	69.6 (8,859/12,722)	70.6 (10,957/15,519)	74.1 (8,110/10,945)	76.2 (15,261/20,040)	81.1 (13,280/16,379)	83.6 (14,631/17,510)	–3.8 (–4.6–3.0)	–16.7
Fetal distress	36.5 (4,894/13,403)	38.1 (5,805/15,229)	39.2 (4,226/10,794)	36.9 (6,380/17,285)	44.0 (6,096/13,845)	46.4 (6,910/14,899)	–4.4 (–8.0–0.6)	–21.3
Complications and comorbidities of pregnancy	43.5 (4,385/10,089)	46.2 (5,082/10,990)	48.1 (3,593/7,475)	53.7 (5,369/9,993)	60.1 (4,703/7,821)	62.6 (4,681/7,474)	–7.5 (–9.0–5.9)	–30.5

Data are presented as % (*n/N*).

Supplementary file 5. Partition of 2012–2017 cesarean section rates (cesarean deliveries for stated complication per 100 total deliveries) and changes in rates for selected complications at 28 hospitals in Beijing.

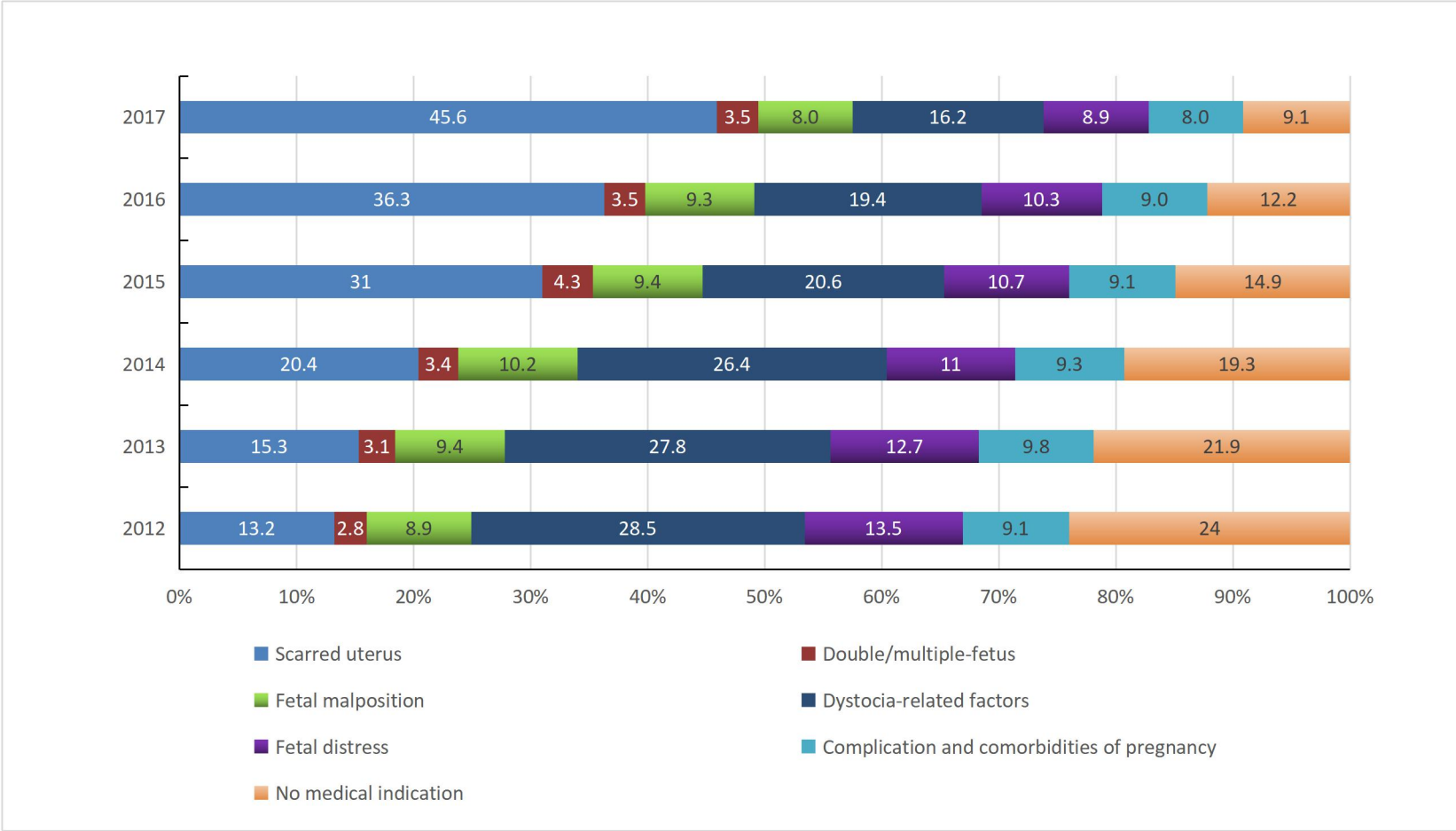
Complications	2017	2016	2015	2014	2013	2012	2012–2017	Change from 2012 to 2017	
	Rate	Rate	Rate	Rate	Rate	Rate	AAPC (95% CI)	Rate	Percent distribution
Total	41.9	38.4	40.7	40.0	45.2	47.0	−2.9 (−6.7–0.9)	−5.1	−100.0
Scarred uterus	19.1	13.9	12.6	8.2	6.9	6.2	26.2 (19.0–33.9)	+12.9	+252.9
Double/multiple fetus	1.5	1.4	1.7	1.4	1.4	1.3	2.6 (−3.1–8.7)	+0.2	+3.9
Fetal malposition	3.3	3.6	3.8	4.1	4.2	4.2	−4.9 (−6.9–−2.8)	−0.9	−17.6
Factors related to dystocia	6.8	7.5	8.4	10.6	12.6	13.4	−13.8 (−16.5–−11.0)	−6.6	−129.4
Fetal distress	3.7	3.9	4.4	4.4	5.8	6.3	−10.4 (−14.4–−6.3)	−2.6	−51.0
Pregnancy complications/comorbidities	3.3	3.5	3.7	3.7	4.4	4.3	−5.6 (−8.2–−2.9)	−1.0	−19.6
No medical indication	4.1	4.7	6.1	7.7	9.9	11.3	−19.4 (−21.6–−17.1)	−7.2	−141.2

Supplementary file 6



Indication-contribution ratio for each category of cesarean-section indication

Supplementary file 7



Changes in the constituent ratios of cesarean-section indications in Beijing from 2012 to 2017.