Effect of surgeon case volume on major surgical complications for abdominal and laparoscopic radical hysterectomy for cervical cancer in China, 2004-2016: A retrospective cohort study

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May 19, 2022

Abstract

Abstract Objectives: To examine changes in surgeon volume over time and evaluate the influence of surgeon volume on complications of abdominal radical hysterectomy (ARH) and laparoscopic radical hysterectomy (LRH) for cervical cancer. Design: A retrospective cohort study. Setting: 42 hospitals in China. Population: 14536 patients undergoing ARH and 8148 patients underwent LRH. Methods: The influence of the surgeon volume of ARH and LRH on surgical complications was examined using multivariable logistic regression models. Main outcome measures: Intraoperative complications and postoperative complications. Results: In the ARH cohort, the mean surgeon case volume increased from 3.5 cases in 2004 to 8.7 cases in 2013 and then decreased to 4.9 cases in 2016. The number of surgeons performing LRH increased from 1 surgeon with 1 patient (mean cases=1) in 2004 to 183 surgeons who operated on 2,206 patients in 2016 (mean cases=12.1) ($P< 0.01$). In the ARH, patients treated by intermediate-volume surgeons had more postoperative complications (OR=1.55, 95% CI=1.11-2.15). In the laparoscopic surgery cohort, surgeon volume had no independent effect on intraoperative or postoperative complications (P=0.46; P=0.13). Conclusions: The performance of ARH by intermediate-volume surgeons is associated with an increased risk of postoperative complications. However, surgeon volume may have little effect on intraoperative or postoperative complications after LRH.

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Running title: Effect of surgeon case volume on complications during RH

Abstract

Objectives: To examine changes in surgeon volume over time and evaluate the influence of surgeon volume on complications of abdominal radical hysterectomy (ARH) and laparoscopic radical hysterectomy (LRH) for cervical cancer.

Design: A retrospective cohort study.

Setting: 42 hospitals in China.

Population: 14536 patients undergoing ARH and 8148 patients underwent LRH.

Methods: The influence of the surgeon volume of ARH and LRH on surgical complications was examined using multivariable logistic regression models.

Main outcome measures: Intraoperative complications and postoperative complications.

Results: In the ARH cohort, the mean surgeon case volume increased from 3.5 cases in 2004 to 8.7 cases in 2013 and then decreased to 4.9 cases in 2016. The number of surgeons performing LRH increased from 1 surgeon with 1 patient (mean cases=1) in 2004 to 183 surgeons who operated on 2,206 patients in 2016 (mean cases=12.1) ($P < 0.01$). In the ARH, patients treated by intermediate-volume surgeons had more postoperative complications (OR=1.55, 95% CI=1.11-2.15). In the laparoscopic surgery cohort, surgeon volume had no independent effect on intraoperative or postoperative complications (P=0.46; P=0.13).

Conclusions: The performance of ARH by intermediate-volume surgeons is associated with an increased risk of postoperative complications. However, surgeon volume may have little effect on intraoperative or postoperative complications after LRH.

Funding

The National Science and Technology Support Program of China (2014BAI05B03);

The Natural Science Fund of Guangdong Province (2015A030311024);

The Science and Technology Plan of Guangzhou (158100075).

They provided financial assistance that played an important role in the collection of data.

Keywords: cervical cancer; radical hysterectomy; cervical cancer; major complications

Clinical Trial Registration: ChiCTR1800017778,*http://www.chictr.org.cn/index.aspx*

Tweetable Abstract: The performance of ARH by intermediate-volume surgeons is associated with an increased risk of postoperative complications.

Word Count:

Abstract:238; Manuscript:3124

Introduction

Cervical cancer ranks as the fourth most frequently diagnosed cancer in women (570,000 cases)[1]. Radical hysterectomy with bilateral pelvic lymph node dissection is the recommended surgical treatment for women with early-stage disease[2]. Major complications during radical hysterectomy (RH) depend on many factors, such as patients characteristics, tumor characteristics, hospital medical resources, surgical approach[3], surgeon volume, and hospital volume[4]. Among these, the surgeon's volume has increasingly received attention[5].

Accumulative evidence to date has suggested that higher surgeon volume leads to improved perioperative outcomes for oncologic surgery, such as surgery for esophageal cancer[6], brain tumors[7], pancreatic cancer[8], bladder cancer[9], endometrial cancer[10], rectal cancer[11] and lung cancer[12]. However, some scholars argue that surgeon volume is not associated with complications[13,14]. Recognition of the volume-outcomes paradigm in high-risk cancer procedures has led to changes in practice. Consequently, some health systems are instituting a minimum surgeon volume standard for high-risk surgery, such as esophagectomy and lung resection[6,15]. Wright et al. demonstrated that women treated by high-volume surgeons had fewer postoperative medical complications and lower transfusion requirements after abdominal radical hysterectomy (ARH)[16]. To date, there are few studies that have investigated the association between surgeon volume and outcomes of laparoscopic radical hysterectomy (LRH) based on large population cohort, although there is a proportionate increase in LRH [17][17]. In addition, there is a paucity of data about surgeon volume in Asian populations.

The first objective of this population-based analysis is to explore the association between surgeon volume and complications after ARH and LRH. The second objective is to examine changes in the number of surgeons, mean surgeon case volume and the total number of cases of cervical cancer over time.

Methods

2.1 Data source

Data from the Major Surgical Complications of Cervical Cancer in China (MSCCCC) project database were utilized. The MSCCCC database is a multicenter retrospective database established to measure surgical quality. Approximately 97.5% of cases from the database could be matched to the cases in Chinese Clinical Cervical Cancer (FOUR-C) project (*http://www.chictr.org.cn/index.aspx*, ChiCTR1800017778). The MSCCCC database gathers hospitalization information for 36,543 patients from 42 hospitals in 14 provinces of China from 2004-2016 (updated of June 2020). The 42 hospitals consist of 32 general hospitals, 4 cancer centers and 6 women and children's hospitals (W&C hospitals)[17,18].

Using the discharge diagnosis of "cervical cancer" as the keyword or the International Classification of Diseases Tenth Revision code C53.9 for computerized search, specially-trained gynecologists abstracted data from medical records and the hospital information system. The documentation used for data extraction on complications included inpatient medical records for surgical treatment, postoperative adjuvant therapy records within 6 months, outpatient records, and readmission to the other department for complication treatment within 2 years[17,18]. The MSCCCC database collects data on patient demographics, clinical characteristics, and hospital factors. After completion of double data entry, data checking were carried out by two independent gynecologists to eliminate input errors and logic errors. Data masking was used to protect patient privacy. Ethical approval was obtained from Institutional Ethics Committee of Southern Medical University Nanfang Hospital (NFEC-2017-135).

2.2 Cohort identification

Women who underwent RH for cervical cancer between 2004 and 2016 were analyzed. The inclusion criteria were as follows: 1) the patient had been diagnosed stage IA1 with LVSI (lymphovascular space invasion) to stage IIB, according to the 2009 International Federation of Gynecology and Obstetrics (FIGO) staging system; 2) the patient underwent type B or C RH (Querleu and Morrow classification)[19] + pelvic lymphadenectomy (PLN) ± para-aortic lymphadenectomy (PALA); and 3) the patient underwent ARH or LRH. The exclusion criteria were as follows: 1) the patient was diagnosed with cervical cancer during pregnancy, was diagnosed with incidental cervical cancer after extrafascial hysterectomy or had a prior history of other malignancies; 2) the patient had an unknown lymphadenectomy status or did not undergo lymphadenectomy; 3) the patient underwent laparoscopic-assisted radical vaginal hysterectomy or robot-assisted RH; or 4) the patient had missing surgeon data or a missing date of operation.

2.3 Clinical and demographic characteristics

The demographic characteristics included age, year of surgery, urban-rural distribution, mode of delivery, and comorbidities. Clinical characteristics that were analyzed included FIGO stage, gross type of tumor, histological type, preoperative anticancer treatment, hysterectomy type and lymph node dissection. Other operation details include operative time and estimated blood loss.

The hospitals where patients were treated were characterized based on hospital function (general hospital, cancer center, or W&C hospital), region of the country (north, south, central, east, southwest, northwest or northeast), and city scale (first-tier, second-tier, and third-tier or below). The levels of urban economic development were as follows: first-tier cities > second-tier cities > third-tier cities.

2.4 Surgeon volume

We calculated the total volume of each surgeon. For each surgeon, annualized surgeon volumes were calculated as the total number of procedures that the surgeon performed divided by the number of years in which an individual surgeon contributed to at least one RH[10,16,20]. Patients were stratified into two cohorts based on the hysterectomy approach: ARH group or LRH group. Surgeon volume cutoff points were then selected to divide patients into approximately equal tertiles. Abdominal surgeon cutoff points were: low volume ([?] 8.1 procedures per year), intermediate volume (8.2-16.9 procedures per year), and high volume (>16.9 procedures per year). Laparoscopic surgeon cutoff points were: low volume ([?] 11.0 procedures per year), intermediate volume (11.1-20.0 procedures per year), and high volume (>20.0 procedures per year).

2.5 Outcomes

Complications were divided into intraoperative complications and postoperative complications. The intraoperative complications, which included ureteral injury, bladder injury, bowel injury, vascular injury, obturator nerve injury, and stomach injury, were recorded. Postoperative complications included bowel obstruction, pelvic hematoma, hemorrhage, vesicovaginal fistula, ureterovaginal fistula, ureteral fistula, rectovaginal fistula, venous thromboembolism and chylous leakage. We also recorded deaths from surgical complications.

Statistical analysis

The relationship between the number of surgeons and year was assessed by a non-parametric Spearman correlation test. Due to discontinuous data, one of the hospitals was not including in the graphs. Frequency distributions between categorical variables were compared using $\chi 2$ or the Fisher's exact test, and continuous variables were compared using a one-way analysis of variance. The median and interquartile range (IQR) of surgeon volume were also reported for each tertile. Binary logistic regression models were used to determine predictors of treatment by the intermediate and high volume (highest 2/3 volume) surgeons. Demographic, clinical, and hospital characteristics constituted independent variables. To examine the association between surgeon volume and outcome, we built binary logistic regression models including surgeon volume while adjusting for the other variables described above. The results are reported as odds ratios (ORs) and 95% confidence intervals (CIs). A value of $P < 0.05$ was considered statistically significant. All analyses were performed with the SPSS 23.0 statistical software package (SPSS, Inc., Chicago, IL, USA).

Results

3.1 Trends in the number of surgeons and patients

We identified a total of 22,684 patients, including 14536 (64.1%) patients who underwent ARH and 8148 (35.9%) patients who underwent LRH (Table 1). The number of surgeons performing ARH each year increased from 89 surgeons who operated on 313 patients in 2004 to 187 surgeons who operated on 1,294 patients in 2012 (P<0.01, r=0.99). However, the number of abdominal surgeons decreased to 122 surgeons with 594 patients in 2016 (P=0.20, r=-0.80). The mean surgeon case volume increased from 3.5 cases in 2004 to 8.7 cases in 2013 and then decreased to 4.9 cases in 2016 (Figure 1A). The number of surgeons performing LRH increased from 1 surgeon with 1 patient in 2004 to 183 surgeons who operated on 2,206 patients in 2016 (P<0.01, r=0.99). The mean number of surgeons performing LRH increased from 1 to 12.1 cases between 2004 and 2016 (Figure 1B).

3.2 Characteristics of the cohort

In the ARH cohort, the median volume of surgeons in the low-volume group was two (IQR 1.0-3.5) per year and rose to 30.9 (IQR 21.9-42.1) in the high volume group. Similarly, in the LRH cohort, the median volume of surgeons in the low-volume group was 2.3 (IQR 1.0-5.0) and increased to 27.8 (IQR 21.6-30.1) in the high-volume group (Table 2). In both the ARH and LRH cohorts, the operation time and bleeding loss for patients in the high-volume surgeon group were significantly lower than those for patients in the intermediate-volume and low-volume groups (P<0.001) (Table 2).

In the multivariable model of the ARH cohort, patients diagnosed in later years, patients living in rural areas, patients with a higher tumor stage (except stage IIB), patients with the endophytic or preclinical gross type, patients with preoperative radiotherapy, patients undergoing type C1 or C2 hysterectomy, patients undergoing surgery in a W&C hospital or cancer center, and patients undergoing surgery in a hospital of a first-tier city were more likely to be treated by high-volume or intermediate-volume surgeons (P<0.05) (Table 3).

Similarly, in the multivariable model of the LRH cohort, age > 60 years, later year of diagnosis, previous cesarean section, FIGO stage IIA2 and IIB, PLN+PALA, and type C1 and C2 hysterectomy were associated with treatment by a high-volume or an intermediate-volume surgeon (P<0.05). In addition, patients undergoing surgery in the cancer center, patients undergoing surgery in the hospital of a second-tier city, and patients undergoing surgery in the hospital of the southwest area were more likely to be treated by intermediate- or high-volume surgeons (P<0.05). Patients with the endophytic gross type, patients with neoadjuvant chemotherapy, and patients undergoing surgery in W&C hospitals were associated with treatment by a low-volume laparoscopic surgeon (P<0.05) (Table 3).

3.3 The impact of surgeon volume on complications

In the univariate analysis of the ARH group, the overall complication rates were 3.06% for women treated by low-volume surgeons, 3.42% for those treated by intermediate-volume surgeons, and 2.01% for those treated by high-volume surgeons (P<0.001) (Table 4). Compared with patients treated by intermediate-volume surgeons, those operated on by high-volume surgeons had fewer postoperative complications (2.87% vs. 1.69%, P<0.001), fewer ureteral injuries (0.45% vs. 0.16%, P=0.045), fewer bowel obstructions (1.28% vs. 0.61%, P=0.003), and fewer ureterovaginal fistulas (0.43% vs. 0.13%, P=0.006). There was no significant difference in the frequencies of other complications (P<0.05).

In the univariate analysis of the LRH group, patients treated by intermediate-volume surgeons had the highest ureterovaginal fistula rate (low vs. intermediate vs. high volume = 1.02% vs. 1.78% vs. 1.08%, P=0.02). The frequencies of the other complications among laparoscopic surgery cases were similar across the tertiles (P<0.05) (Table 4).

In the multivariable analysis of the ARH cohort, patients treated by intermediate-volume surgeons were more likely to experience postoperative complications than those treated by high-volume surgeons (OR=1.55, 95% CI=1.11-2.15). However, abdominal surgeon volume had no influence on overall complications or intraoperative complications (P>0.05). In the multivariable analysis of the LRH cohort, surgeon volume had no effect on overall complications, intraoperative complications or postoperative complications (P>0.05) (Table 5).

4.Discussion

4.1 Main findings

Our findings suggest that trends in the number of surgeons and mean surgeon case volume over time were different in ARH and LRH. In the ARH cohort, postoperative complication rates were higher among intermediate-volume surgeons, while patients treated by high-volume surgeons had lower postoperative complications. However, in the LRH cohort, surgeon volume had little effect on intraoperative and postoperative complications.

4.2 Interpretation

The trends in the number of surgeons and mean surgeon volume over time were differed between the two surgical approaches. From 2004 to 2016, the number of laparoscopic surgeons and mean surgeon case volume rose annually. This increasing acceptance of laparoscopic technique could be due to the short-term benefits of LRH, including a more cosmetically pleasing incision, less bleeding, less postoperative pain, and faster postoperative recovery. However, the opposite trend was observed in ARH cohort. The number of abdominal surgeons and mean surgeon case volume have been decreasing since 2013. In addition, it is noteworthy that categorical definitions of surgeon volume varied substantially among the different studies. In the study of Wright et al.[16], a high-volume surgeon and a low-volume surgeon were defined as a surgeon who performed more than 3.75 and less than 2.25 ARHs per year, respectively; but we defined the same terms as a surgeon who performed greater than 16.9 and less than or equal to 8.1 ARHs per year, respectively. The surgeon volume gap between the two groups was much larger than that of the study by Wright et al.. In addition, our results revealed a positive correlation between the number of surgeons and the number of patients. The increasing number of surgeons could effectively alleviate national disease stress. In patients with endometrial cancer in the United States, although there was a small increase in the overall number of patients per year, the surgical treatment of patients has been limited to a smaller number of surgeons[10]. They suggested that the increased complexity of treatment has resulted in fewer general gynecologists treating these women. Referral of women with endometrial cancer to gynecologic oncology subspecialists is recommended[21].

Our data demonstrated that the association between surgeon volume and complications for cervical cancer was complex. In the ARH cohort, the postoperative complication rate was higher for intermediate-volume surgeons than for high-volume surgeons (OR=1.55, 95%=1.11-2.15). However, the postoperative complication rate was found to be similar in the low-volume surgeon group and high-volume surgeon group (OR=1.38, 95%=0.97-1.96). This observation resembles that of Wright et al.[16]. Their results showed that the perioperative complication rate was highest in the intermediate-volume surgeon group compared with the low-volume and high-volume surgeon groups (low vs. intermediate vs. high= 2.9% vs. 6.7% vs. 1.8%, P<0.001). However, no direct comparisons between intermediate-volume surgeons group and other groups were performed in their study. We suppose that surgeon volume had an inverted U-shaped relationship with postoperative complications, rather than a simple linear relationship. Low-volume surgeons with limited experience and limited surgical opportunities performed surgery with utmost caution to prevent complications. The majority of high-volume surgeons benefited from the effect of sufficient learning curve and close cooperation with an experienced surgical team, which translates into a lower complication rate. One possible reason for highest postoperative complications in the intermediate-volume surgeon group could be that they were more lenient in their selection of patients. Patients treated by intermediate-volume surgeons had a higher frequency of FIGO stage IIB, more preoperative radiotherapy, and a higher frequency of PLA +PALA and type C2 hysterectomy. In the Laparoscopic Approach to Cervical Cancer (LACC) trial, ARH was associated with higher rates of disease-free survival and overall survival than minimally invasive radical hysterectomy among women with early-stage cervical cancer[22]. ARH therefore has re-emerged as a mainstream treatment for cervical cancer. We may need to pay more attention to the impact of the abdominal surgeon volume on complications.

In our laparoscopy surgery cohort, surgeon volume had no significant effects on intraoperative complications or postoperative complications. It appears that the effects of surgeon volume on radical hysterectomy complications of different surgical routes are different. Similar results have been reported in endometrial cancer. Among patients who underwent abdominal hysterectomy for endometrial cancer, increased surgical volume was associated with reductions in perioperative surgical complications and medical complications[23]. However, during laparoscopic hysterectomy, the surgeon volume appear to have little effect on perioperative morbidity for endometrial cancer[20]. A retrospective analysis of 1016 laparoscopic hysterectomies for benign gynecologic problems found that increasing the surgical volume could not reduce the rate of serious complications[24]. In addition, surgeon volumes in terms of different surgical procedures differentially affects surgical complication outcomes. This population-based study by Sheetz et al. demonstrated that the comparative safety of laparoscopic and open colectomy was influenced by surgeon volume, but the relationship was stronger for laparoscopy[25].

Numerous factors affects surgical experience. First, surgical experience was assessed and quantified by different metrics, such as annual surgeon volume (frequency), technique-specific volume, surgeon cumulative volume, and years of experience[11,26,27]. Yasunaga et al.[28] defined surgeon volume as the number of radical hysterectomies that each gynecologist had performed as an operating surgeon over his or her professional career. Their study showed that higher surgeon volume (greater than 200 procedures) was associated with a reduced incidence of postoperative urinary disorders. However, they did not mention the surgical route of radical hysterectomy. Second, surgical educators recognize that skill sets may transfer between operations[29]. Modrall et al[30]. defined the aggregate annual volume per surgeon of upper gastrointestinal operations as the "surrogate volume", including excision of esophageal diverticulum, gastrectomy, gastroduodenectomy, and repair of diaphragmatic hernia. Among surgeons with a low-volume esophagectomy experience, increasing the volume of surrogate operations improved the outcomes observed for esophagectomy. However, there has been little discussion about "surrogate surgery" in gynecological cancer surgery. It was uncertain whether surrogate operative experiences, such as experiences of extrafascial hysterectomy in benign disease and cytoreductive surgery in ovarian cancer, yield improvements in outcomes for radical hysterectomy. Third, the characteristics of the surgeons may have an effect on surgical experience, such as the age of the surgeon. Surgeon age [?] 51 and [?] 56 years may increase short- and long-term mortality after esophagectomy for cancer, and the highest surgical competence is achieved between 52 and 56 years of surgeon age[31]. The reason for the decreasing performance among older surgeons might be related to mental fatigue, poorer compliance with evidence-based medicine, and higher administrative positions leading to reduced surgical frequency[26].

4.3 Strengths and limitations

This population-based study is the first to examine changes in the number of surgeons and annual surgeon volume for cervical cancer over time, and to explore the association between surgeon volume and complications after ARH and LRH in China. First, a strength of our study is its large sample size. We reviewed 22,684 cases treated at 42 hospitals over a 13-year period so that data on the rare adverse events could be collected. Second, we also included clinical characteristics, such as FIGO stage, histology, preoperative treatment, hysterectomy type, and lymph node dissection type that may influence treatment outcome[17].

We also recognize several limitations to our findings. First, this study was a retrospective study in which the data were obtained from inpatient medical records or through readmission. Data on complications that may have occurred after discharge and have been treated by other hospitals, could not be obtained. Second, we divided the patients into tertiles based on annualized surgeon volumes, but the results of the present study could not translate into clinically meaning cutoff points. Third, although we considered a wide range of clinical characteristics and tumor characteristics, there might be other unmeasured confounding factors affecting complications, such as assistant surgeons[32], uterine size, downstream care, surgical instruments and management of complications. In addition, skill transference between LRH and ARH remains unclear. Fourth, our study only included patients from only 42 hospitals and the findings may not be representative of other areas in China.

Conclusion

In conclusion, patients treated by intermediate-volume surgeons may have more postoperative complications after ARH, while patients treated by high-volume surgeons had fewer postoperative complications. In the LRH cohort, surgeon volume appeared to have no significant predictive value for complications.

Acknowledgements

We are grateful to Min Hao (Department of Obstetrics and Gynecology, The Second Hospital of ShanXi Medical University), Wuliang Wang (Department of Obstetrics and Gynecology, The Second Affiliated Hospital of Zhengzhou University), Ying Yang (Department of Obstetrics and Gynecology, Xinqiao Hospital, Third Military Medical University), Shan Kang (Department of Obstetrics and Gynecology, The Forth Hospital of Hebei Medical University & The Tumor Hospital of Hebei Province), Bin Ling (Department of Obstetrics and Gynecology, China-Japan Friendship Hospital), Xinli Sun and Hongwei Zhao (Department of Gynecology, Shanxi Provincial Cancer Hospital), Yu Guo and Lihong Lin (Department of Gynecology, Anyang Tumor Hospital), Li Wang (Department of Gynecology, The Affiliated Tumor Hospital of Zhengzhou University), Weidong Zhao (Department of Gynecology and Oncology, Anhui Provincial Cancer Hospital), Yan Ni (Department of Obstetrics and Gynecology, The Yuncheng Central Hospital of Shanxi province), Donglin Li and Wentong Liang (Department of Obstetrics and Gynecology, Guizhou Provincial People‘s Hospital), Jianxin Guo (Department of Obstetrics and Gynecology, Daping Hospital, The Third Military Medical University), Xuemei Zhan and Mingwei Li (Department of Gynecology, Jiangmen Central Hospital), Weifeng Zhang (Department of Obstetrics and Gynecology, Ningbo Women & Children's Hospital), Peiyan Du (Department of Gynecological Oncology, Cancer Center of Guangzhou Medical University), Ziyu Fang (Department of Obstetrics and Gynecology, Liuzhou Workers' Hospital), Long Chen (Department of Obstetrics and Gynecology, Qingdao Municipal Hospital), Encheng Dai and Ruilei Liu (Department of Obstetrics and Gynecology, Linyi People's Hospital), Mubiao Liu and Yuanli He (Department of Obstetrics and Gynecology, Zhujiang Hospital, Southern Medical University), Jilong Yao and Zhihua Liu (Department of Obstetrics and Gynecology, Shenzhen Maternity & Child Healthcare Hospital), Xueqin Wang (Department of Obstetrics and Gynecology, The Fifth Affiliated Hospital of Southern Medical University), Yan Xu (Department of Obstetrics and Gynecology, Guangzhou Panyu Central Hospital), Ben Ma (Department of Obstetrics and Gynecology, Guangzhou First People's Hospital), Zhonghai Wang (Department of Obstetrics and Gynecology, Shenzhen Nanshan People's Hospital), Lin Zhu (Department of Gynecology, The Second Hospital of Shandong University), Hongxin Pan (Department of Obstetrics and Gynecology, the 3rd Affiliated Hospital of Shenzhen University, Luohu People's Hospital), Qianyong Zhu (Department of Obstetrics and Gynecology, No.153. Center Hospital of Liberation Army, Hospital No.988 of the Chinese People's Liberation Army Joint Support Force), Xiaohong Wang (Department of Obstetrics and Gynecology, Jinan City People's Hospital, Former Laiwu People's Hospital), Dingyuan Zeng and Zhong Lin (Department of Obstetrics and Gynecology, Maternal and Child Health Care Hospital of Liuzhou), Shaoguang Wang (Department of Obstetrics and Gynecology, Yantai Yuhuangding Hospital), Bin Zhu (Department of Obstetrics and Gynecology, Yiwu Maternal and Child Health Hospital), Anwei Lu (Department of Obstetrics and Gynecology, Maternal and Child Health Care Hospital of Guizhou Province), Mei Ji (Department of Obstetrics and Gynecology, the First Affiliated Hospital of Zhengzhou University), Qianqing Wang (Department of Obstetrics and Gynecology, Central Hospital Affiliated to Xinxiang Medical University), Zhumei Cui (Department of Gynecology, The Affiliated Hospital of Qingdao University Medical College), Biliang Chen (Department of Gynecology, Xijing Hospital of Air Force Medical University), Qinghuang Xie (Department of Gynecology, Foshan Women and Children Hospital), Qiubo Lv (Department of Gynecology, Beijing Hospital), Chang Liu (Department of Gynecology, the First Hospital of Lanzhou University), and Yi Zhang (Department of Gynecology, the First Hospital of China Medical University) for providing medical records.

Disclosure of Interests

All authors declare they have no relevant conflict of interest.

Contribution to Authorship

Cong Liang: Investigation, Methodology, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization; Weili Li: Supervision, Conceptualization; Xiaoyun Liu: Investigation, Resources; Hongwei Zhao: Investigation, Resources; Lu Yin: Investigation; Mingwei Li: Investigation, Resources; Yu Guo: Investigation, Resources; Jinghe Lang: Investigation; Xiaonong Bin: Validation, Formal analysis; Ping Liu: Conceptualization, Supervision, Project administration; Chunlin Chen: Conceptualization, Supervision, Project administration, Funding acquisition.

Details of Ethics Approval

Ethical approval was obtained from Institutional Ethics Committee of Southern Medical University Nanfang Hospital (NFEC-2017-135).

Funding

The National Science and Technology Support Program of China (2014BAI05B03);

The Natural Science Fund of Guangdong Province (2015A030311024);

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Legends

Figure 1. Numbers of patients and surgeons by year in abdominal surgery cohort (A); Numbers of patients and surgeons by year in laparoscopic surgery cohort (B).

Table 1. Schema of patient selection.

Table 2. Demographic and clinical characteristics of the abdominal and laparoscopic cohorts stratified by surgeon volume.

Table 3. Predictors of the high and intermediate volume surgeons.

Table 4. Unadjusted complications associated with radical hysterectomy for cervical cancer stratified by surgeon volume.

Table 5. Multivariable analysis of factors associated with complications.

Table 1. Schema of patient selection.

Variable	No. of patients
1.All patients diagnosed with cervical cancers, 2004-2016	36,543
2. Type B or C radical hysterectomy	31,581
3. Pelvic lymphadenectomy ± para-aortic lymphadenectomy	30,641
4. 2009 FIGO stage IA1 with LVSI to IIB	24,447
5. No pregnancy, incidental cervical cancer or previous malignant disease	24,350
6. Abdominal surgery or total laparoscopic surgery	23,409
7. Missing information of surgeon or date of surgery	22,684

Table 2. Demographic and clinical characteristics of the abdominal and laparoscopic cohorts stratified by surgeon volume.

Characteristic	Abdominal surgeon volume	Abdominal surgeon volume	Abdominal surgeon volume
	Low	Low	Intermediate
Patients	4837	33.3	4913
Surgeons	362		44
Annualized hospital volume	2.0 (1.0-3.5)	2.0 (1.0-3.5)	10.8 (9.1-12.5)
Age at surgery, years			
60	444	9.2	515
< 60	4393	90.8	4398
Year of diagnosis			
2004-2009	1736	35.9	1748
2010-2016	3101	64.1	3165
Urban-rural distribution			

Characteristic	Abdominal surgeon volume	Abdominal surgeon volume	Abdominal surgeon volume
Rural	2316	47.9	2988
Urban	1423	29.4	1539
Unknown	1098	22.7	386
Hospital function			
General hospital	3451	71.3	2893
Cancer center	1088	22.5	1626
W&C center	298	6.2	394
Region			
North	724	15.0	1292
South	1380	28.5	1095
Central	618	12.8	410
East	1490	30.8	1013
Southwest	307	6.3	335
Northwest	158	3.3	668
Northeast	160	3.3	100
City scale			
First-tier	773	16.0	745
Second-tier	2458	50.8	2885
Third-tier	1606	33.2	1283
Mode of delivery			
No delivery	49	1.0	57
Vaginal delivery	3684	76.2	4026
Cesarean delivery	253	5.2	291
Unknown	851	17.6	539
Comorbidity			
No	4526	93.6	4592
Yes	311	6.4	321
FIGO stage			
IA1+IA2	133	2.7	76
IB1	2288	47.3	2117
IB2	656	13.6	690
IIA1	679	14.0	680
IIA2	297	6.1	324
IIB	784	16.2	1026
Gross type			
Exophytic	2585	53.4	2854
Endophytic	276	5.7	316
Ulcerated	900	18.6	790
Endocervical	105	2.2	64
After conization	132	2.7	106
Preclinical carcinoma	342	7.1	414
Unknown	497	10.3	369
Histological types			
Squamous cell	4178	86.4	4326
Adenocarcinoma	450	9.3	397
Adenosquamous	113	2.3	92
Other subtypes	81	1.7	90
Unknown	15	0.3	8
Preoperative treatment			
No received	3457	71.5	3565

Characteristic	Abdominal surgeon volume	Abdominal surgeon volume	Abdominal surgeon volume
Neoadjuvant chemotherapy	1243	25.7	970
Preoperative radiotherapy	137	2.8	378
Lymph node dissection			
PLA	4651	96.2	4604
PLA+PALA	186	3.8	309
Hysterectomy types			
Type B	2852	59.0	2140
Type C2	1962	40.6	2719
Type C1	23	0.5	54
Operation time	232.8±64.8	232.8±64.8	205.0±55.4
Blood loss	499.2±363.1	499.2±363.1	470.3±375.14

Abbreviations: PLA, pelvic lymphadenectomy; PALA, para-aortic lymphadenectomy.

Table 3. Predictors of the high and intermediate volume surgeons.

	Abdominal cohort	**Abdominal cohort**	**Laparoscopic cohort**	**Laparoscopic coh**
	OR (95% CI)	**P value**	**OR (95% CI)**	**P value**
Age at surgery, years		0.16		0.002?¿?
60	Ref		Ref	
< 60	0.16 (0.79-1.04)	0.16	0.74 (0.61-0.90)	0.002
Year of diagnosis		<0.001		0.02
2004-2009	Ref		Ref	
2010-2016	1.55 (1.41-1.69)	<0.001	1.46 (1.06-2.01)	0.02
Urban-rural distribution		<0.001		0.08
Rural	Ref		Ref	
Urban	0.87 (0.80-0.96)	0.005	1.11 (0.97-1.27)	0.13
Unknown	0.51 (0.45-0.58)	<0.001	0.87 (0.72-1.08)	0.20
Hospital function		<0.001		<0.001
General hospital	Ref		Ref	
Cancer center	3.43 (3.06-3.86)	<0.001	1.82 (1.49-2.23)	<0.001
W&C center	1.55 (1.27-1.89)	<0.001	0.26 (0.20 -0.35)	<0.001
Region		<0.001		<0.001
North	Ref		Ref	
South	0.46 (0.39-0.54)	<0.001	4.90 (3.65-6.57)	<0.001
Central	0.91 (0.78-1.06)	0.24	2.10 (1.67-2.66)	<0.001
East	0.37 (0.32-0.42)	<0.001	0.35 (0.28-0.45)	<0.001
Southwest	1.06 (0.84-1.32)	0.64	82.85 (57.46-116.60)	<0.001
Northwest	3.30 (2.55-4.25)	<0.001	1.28 (0.88-1.87)	0.19
Northeast	0.22 (0.16-0.29)	<0.001	3.34 (1.70-6.57)	<0.001
City scale		<0.001		<0.001
First-tier	Ref		Ref	
Second-tier	0.71 (0.59-0.85)	<0.001	8.75 (6.32-12.12)	<0.001
Third-tier	0.37 (0.31-0.43)	<0.001	1.18 (0.89-1.56)	0.25
Mode of delivery		<0.001		0.004
No delivery	1.01 (0.68-1.49)	0.97	1.06 (0.57-1.98)	0.84
Vaginal delivery	Ref		Ref	
Cesarean delivery	1.06 (0.89-1.27)	0.51	1.36 (1.10-1.68)	0.005
Unknown	0.66 (0.59-0.74)	<0.001	1.33 (1.07-1.67)	0.01

	Abdominal cohort	**Abdominal cohort**	**Laparoscopic cohort**	**Laparoscopic coh**
Comorbidity		0.40		0.44
No	Ref		Ref	
Yes	0.93 (0.79-1.10)	0.40	1.09 (0.88-1.35)	0.44
FIGO stage		<0.001		<0.001
IA1+IA2	Ref		Ref	
IB1	1.44 (1.08-1.94)	0.015	1.16 (0.77-1.76)	0.48
IB2	1.54 (1.12-2.11)	0.008	1.46 (0.93-2.31)	0.10
IIA1	1.83 (1.34-2.49)	<0.001	1.42 (0.91-2.22)	0.12
IIA2	1.83 (1.31-2.56)	<0.001	2.62 (1.60-4.29)	<0.001
IIB	1.07 (0.77-1.48)	0.71	1.85 (1.13-3.03)	0.02
Gross type		<0.001		0.008
Exophytic	Ref		Ref	
Endophytic	2.09 (1.78-2.45)	<0.001	0.64 (0.48-0.86)	0.003
Ulcerated	0.87 (0.78-0.98)	0.018	1.16 (0.98-1.38)	0.08
Endocervical	0.55 (0.40-0.77)	<0.001	0.89 (0.56-1.42)	0.63
After conization	0.92 (0.70-1.19)	0.52	1.21 (0.85-1.70)	0.29
Preclinical carcinoma	1.41 (1.20-1.65)	<0.001	0.88 (0.72-1.08)	0.22
Unknown	0.73 (0.64-0.85)	<0.001	1.05 (0.87-1.28)	0.61
Histological types		0.021		0.97
Squamous cell	Ref		Ref	
Adenocarcinoma	0.89 (0.77-1.02)	0.10	1.06 (0.87-1.28)	0.56
Adenosquamous	0.81 (0.62-1.07)	0.14	1.00 (0.65-1.55)	0.98
Other subtypes	0.66 (0.49-0.90)	0.008	0.98 (0.64-1.48)	0.90
Unknown	0.75 (0.33-1.72)	0.50	0.89 (0.50-1.57)	0.68
Preoperative treatment		<0.001		<0.001
No received	Ref		Ref	
Neoadjuvant chemotherapy	0.81 (0.72-0.91)	<0.001	0.69 (0.57-0.82)	<0.001
Preoperative radiotherapy	1.91 (1.53-2.39)	<0.001	0.85 (0.58-1.26)	0.42
Lymph node dissection		0.99		0.04
PLA	Ref		Ref	
PLA+PALA	0.99 (0.81-1.23)	0.99	1.19 (1.01-1.40)	0.04
Hysterectomy types		<0.001		<0.001
Type B	Ref		Ref	
Type C2	1.74 (1.59-1.92)	<0.001	2.33 (1.98-2.74)	<0.001
Type C1	2.78 (1.63-4.73)	<0.001	3.59 (2.26-5.70)	<0.001

Abbreviations: PLA, pelvic lymphadenectomy; PALA, para-aortic lymphadenectomy.

Table 4. Unadjusted complications associated with radical hysterectomy for cervical cancer stratified by surgeon volume.

Outcome	Abdominal surgeon volume	Abdominal surgeon volume	Abdominal surgeon volume
	Low	Low	Intermediate
	N	%	N
Any 1 complication	148	3.06[a]	168
Intraoperative complication	27	0.56	32
Ureteral injury	15	0.31[ab]	22
Bladder injury	3	0.06	4
Bowel injury	0	0	2

Outcome	Abdominal surgeon volume	Abdominal surgeon volume	Abdominal surgeon volume
Vascular injury	9	0.18	2
Obturator nerve injury	0	0	2
Stomach	0	0	0
Postoperative complication	122	2.52[a]	141
Bowel obstruction	46	0.95[ab]	63
Pelvic hematoma	1	0.02	1
Hemorrhage	3	0.06	3
Vesicovaginal fistula	8	0.16	9
Ureterovaginal fistula	9	0.19 [ab]	21
Rectovaginal fistula	1	0.02	2
Ureteral	3	0.06	3
Venous thromboembolism	51	1.05	43
Chylous leakage	1	0.02	0
Other			
Death	0	0	0

Different letters on the shoulder mark indicate significant differences ($P < 0.05$), and the same letter or no letter indicates that the difference is not significant (P [?] 0.05).

Table 5. Multivariable analysis of factors associated with complications.

	Abdominal surgeon volume	Abdominal surgeon volume	Abdominal surgeon volume
	Low	Intermediate	High
Any 1 complication	3.06%	3.42%	2.01%
			1.20
			1.39
Intraoperative complication	0.56%	0.65%	0.33%
			0.46
			0.58
Postoperative complication	2.52%	2.87%	1.69%
			1.38
			1.55

The middle row for each complication class was adjusted for clinical and demographic factors, including age, year of diagnosis, urban-rural distribution, hospital function, region, city scale, mode of delivery, comorbidity, FIGO stage, gross type, histological type, preoperative treatment, lymph node dissection, and hysterectomy type reported, with the odds ratio (95% CI) of low vs. high volume. The bottom row for each complication class is adjusted for the factors mentioned above, with the odds ratio (95% CI) of intermediate vs. high volume.

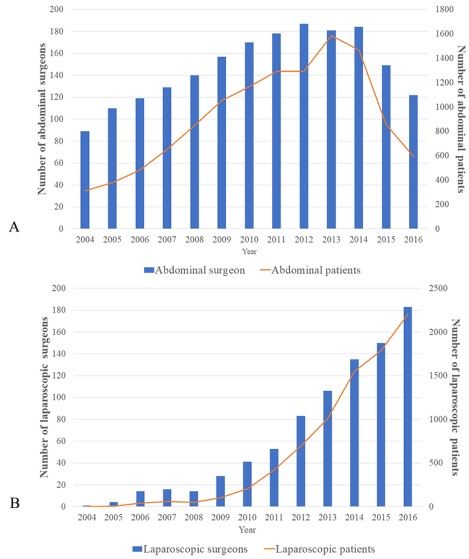

Figure 1. Numbers of patients and surgeons by year in abdominal surgery cohort (A); Numbers of patients and surgeons by year in laparoscopic surgery cohort (B).