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Urological complications in women undergoing surgery for placenta accreta spectrum disorders: systematic review and meta-analysis

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Short title: Urological complication in placenta accreta spectrum

Keywords: Placenta accreta spectrum disorders; urological complication; hysterectomy; Cesarean section

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process which may lead to differences between this version and the [Version of Record](#). Please cite this article as doi: [10.1002/uog.26299](https://doi.org/10.1002/uog.26299)

CONTRIBUTION

What are the novel findings of this work?

The present systematic review provides a comprehensive evaluation of the incidence of urologic complications associated with surgery for PAS. Patients placenta percreta and those requiring an emergent delivery had the highest incidence of urologic complications, mainly cystotomy.

What are the clinical implications of this work?

The high prevalence of urologic of women with PAS disorders highlight the need for a multidisciplinary approach of these anomalies in centres with high expertise in surgical management of PAS.

ABSTRACT

Objective: To report the occurrence of urologic complications in women undergoing surgery for placenta accreta spectrum (PAS) disorders.

Methods: Medline, Embase and Cochrane databases were searched electronically up to 1st of November 2022. Studies reporting cohort on surgical management and outcome of PAS. Two independent reviewers performed the data extraction using a predefined protocol and assessed the risk of bias using the Newcastle-Ottawa scale for observational studies, with difference agreed by consensus. The primary outcome was the overall occurrence of urologic complications in women undergoing surgery for PAS. Secondary outcomes were overall cystotomy, intentional cystotomy, unintentional cystotomy, ureteral damage, ureteral fistula, vesicovaginal fistula. All these outcomes were explored in the overall population of patients undergoing hysterectomy for PAS disorders. In addition, we performed sub-group analyses according to the severity of PAS at histopathology (placenta accreta/increta and percreta), type of intervention (planned vs emergency), ureteral stent placing and number of cases per year. Random-effect meta-analyses of proportions were used to analyze the data.

Results: Sixty-two studies were included. Urologic complications occurred in 15.29% (95% CI, 13.0-17.2) of cases. Cystotomy complicated 13.02% (95% CI, 9.2-17.3) of surgical operations. Intentional cystotomy was required in 5.58% (95% CI, 2.7-9.3) of cases while damage to the bladder occurred in 7.40% (95% CI, 4.3-11.2) of cases. Urologic complications occurred in 19.36% (95% CI, 16.3-22.7) of cases undergoing hysterectomy and 12.22% (95% CI, 7.5-17.8) of those having conservative treatment. In the sub-group analyses, urologic complications occurred in 9.42% (95% CI, 5.4-14.4) of women with placenta accreta-increta and 38.52% (95% CI, 21.6-57.0) of those described as placenta percreta and were mainly represented by cystotomy (5.53% (95% CI, 0.6-15.1) in women with placenta accreta increta

and 21.97% (95% CI, 15.4-45.5) in the placenta percreta subgroup). Urologic complications occurred in 15.44% (95% CI, 8.1-24.6) during planned procedures and in 24.61% (95% CI, 13.0-38.5) during emergency intervention. The incidence of urologic complications was similar to that reported in the primary analysis in studies reporting >10 cases per year.

Conclusions: Patients undergoing surgery for PAS disorders are at high-risk of urologic complications, mainly cystotomy. The incidence of these complications is higher in patients described as having a placenta percreta at birth and in case of emergency surgical intervention. The high heterogeneity highlights the need to use standardized protocols for the diagnosis of PAS to identify prenatal imaging signs associated with a risk of urologic morbidity at delivery.

INTRODUCTION

Placenta accreta spectrum (PAS) disorders encompass an heterogeneous group of conditions which occurs when the gestational sac implants and the definitive placenta develops within a uterine scar area^{1,2}. The incidence of PAS disorders has significantly increased over the past decade, mainly because of the increasing cesarean delivery (CD) rates, and is now estimated to complicate approximately 1 in 1000 deliveries^{1,2}. The prevalence of PAS is directly linked to the number of prior CD and thus countries with high CD and fertility rates have the highest rate of PAS and associated maternal morbidity and mortality³⁻⁵.

Patients with PAS at birth are at high risk of hemorrhagic complications, in particular when PAS is not suspected before birth^{6,7}. Over 90 % of patients with PAS at birth also present with a low-lying/placenta previa, extended remodeling of the lower uterine segment and increased vascularization of the placental bladder interface and surrounding pelvic tissue, further increasing the risks of complications during surgical delivery⁷⁻⁹. Distortion of the normal pelvic anatomy with the presence of large bladder-uterovaginal anastomoses, bulging of the part of the placenta into the bladder or laterally into the parametrium and thick pelvic adhesions increase the risks of ureteral and bladder unintentional damage¹⁰⁻¹². The incidence of urologic complications is also increased when intentional cystotomy is required due of a lack of a cleavage between the anterior wall of the uterus and the posterior bladder.

The incidence of urologic complication in pregnancies complicated by PAS disorders has not been evaluated. Small sample size of published cohort studies, absence of stratification for the type of surgery, and major variations in surgical protocols between centres limits the estimation of the risk of urologic complication associated with the surgical management of PAS. The objective of this systematic review and meta-analysis is to review the available

literature to identify the incidence of urologic complications and impact of the type of surgical procedure and placement of stents in patients with PAS disorders.

Accepted Article

METHODS

Protocol, eligibility criteria, information sources and search

This review was performed according to a priori designed protocol recommended for systematic reviews and meta-analysis^{13,14}. Medline, Embase, Cinahl and Clinicaltrials.gov databases were searched electronically up to 1st of November 2022 (Table S1). The search protocol was designed *a priori* and registered on PROSPERO (CRD42022383373). The overall search strategy was inclusive of MeSH headings for “placenta accreta, placenta increta, placenta percreta, abnormally invasive placenta and morbidly adherent placenta” which were combined with terms including “urologic complications, bladder damage and ureteral damage”. Title, abstracts and full-text were independently assessed by the authors for content, data extraction and analysis. Additional relevant studies were identified from reference lists of reviews and editorials and by hand-searching key journals and websites. All search results were combined in a reference database. Duplicates were removed by hand. The search was limited to articles published in English. Prisma guidelines were followed¹⁵.

Study selection, data collection and data items

The inclusion criteria were patients undergoing surgery for PAS.

The primary outcome was the overall incidence of urologic complications in women undergoing surgery for PAS.

The secondary outcomes included:

- Cystotomy (overall)
- Intentional cystotomy
- Unintentional cystotomy
- Ureteral damage

- Ureteral or bladder fistula

All these outcomes were explored in the overall population of women undergoing surgery for PAS. Sub-group analyses were performed according to the type of surgical procedure (hysterectomy or conservative techniques), planned or emergency intervention, grade of PAS and the number of cases performed by the authors per year (≥ 10 per year)

Study selection and risk of bias

Only full-text articles were considered eligible for inclusion; case reports, conference abstracts, and case series with < 10 cases were also excluded to avoid publication bias.

Two independent investigators (AL, ST) selected studies in two stages. The abstracts of all potentially relevant papers were individually examined for suitability. Papers were only ruled out at this stage if they obviously did not meet the inclusion criteria. The remainder were obtained in full text and were independently assessed for content, data extraction and analysis. Disagreements between the two original reviewers were resolved by discussion with the third investigator (FDA). Full text copies of those papers were obtained. Study characteristics and surgical outcomes were extracted using a predesigned data extraction protocol. If more than one study was published on the same cohort with identical endpoints, the report containing the most comprehensive information on the population was included to avoid overlapping populations.

Two independent reviewers (AL, ST) undertook the quality assessment with difference agreed by consensus. Quality assessment of the included studies was performed using the Newcastle-Ottawa Scale (NOS) for case-control and cohort studies. According to NOS, each study is judged on three broad perspectives: the selection of the study groups; the comparability of the groups; and the ascertainment of the outcome of interest. Assessment of the selection of

a study includes the evaluation of the representativeness of the exposed cohort, selection of the non-exposed cohort, ascertainment of exposure and the demonstration that the outcome of interest was not present at the start of study. Assessment of the comparability of the study includes the evaluation of the comparability of cohorts based on the design or analysis. Finally, the ascertainment of the outcome of interest includes the evaluation of the type of the assessment of the outcome of interest, length and adequacy of follow-up. According to NOS a study can be awarded a maximum of one star for each numbered item within the Selection and Outcome categories. A maximum of two stars can be given for Comparability¹⁶.

Statistical analysis

Analyses were conducted using the StatsDirect software version 2.7.9 (StatsDirect, Ltd, Altrincham, Cheshire, UK). Random effects model of proportions were used to analyse the data. Tests for funnel plot asymmetry were not used when the total number of publications included for each outcome was less than ten. In this case, the power of the tests is too low to distinguish chance from real asymmetry¹⁷.

Statistical heterogeneity was assessed with the Cochran's Q-test and the I^2 statistic (the proportion of variation in study estimates because of heterogeneity rather than sampling error). A value of 0% indicates no observed heterogeneity, whereas I^2 values of $\geq 50\%$ indicate a substantial level of heterogeneity. A fixed effect model was used when I^2 values were $<50\%$; conversely a random effect model was used when I^2 values were $\geq 50\%$ ¹⁷.

RESULTS

The initial search provided with 847 articles, 749 were excluded as the reported outcomes were not relevant, leaving 97 studies which were obtained for full text review. An additional 35 articles were excluded after full review leaving 62 articles for the systematic review¹⁸⁻⁷⁹ (Table 1, Figure 1, Table S2).

The results of the quality assessment of the included studies using NOS scale tool are presented in Table 2. The included studies showed an overall good score regarding the selection and comparability of the study groups, and for ascertainment of the outcome of interest. Their major limitations were the retrospective design and lack of stratification of the analysis according to type of intervention, prenatal diagnosis, and surgeons' experience.

Synthesis of results

The primary analysis included 11618 patients undergoing surgery for PAS. Urologic complications was found in 15.29% (95% CI, 13.0-17.2) of cases. Most of the studies did not specifically report the type of urologic morbidity. Cystotomy was reported 13.02% (95% CI, 9.2-17.3) of surgical operations. Intentional cystotomy was performed in 5.58% (95% CI, 2.7-9.3) of cases whereas unintentional damage to the bladder was found in 7.40% (95% CI, 4.3-11.2) of cases. 2.45% (95% CI, 1.4-3.9) of patients had ureteral damage and 1.44% (95% CI, 0.9-2.2) ureteral or vesicovaginal fistulas (Table 3).

In the subgroup of patients undergoing hysterectomy for PAS at birth, urologic complications were reported in 19.36% (95% CI, 16.3-22.7) of the cases, mainly due to cystotomy (17.05% (95% CI, 14.1-20.3)). Intentional cystotomy was performed in 8.69% (95% CI, 4.8-13.6) of cases whereas unintentional opening of the bladder occurred in 9.27% (95% CI, 5.2-14.4) of surgical procedure. Ureteral damage and ureteral or vesicovaginal fistulas were

reported in 1.80% (95% CI, 1.2-2.5) and 1.81% (95% CI, 1.0-2.9) of cases, respectively (Table 3).

In the subgroup of patients who had conservative management (partial myometrial resection of the PAS area or the placenta left in situ), urologic complications were reported in 12.22% (95% CI, 7.5-17.8) of cases and cystotomy in 9.58% (95% CI, 5.7-14.4). Intentional cystotomy was performed in 2.86% (95% CI, 0.7-6.5), while whereas unintentional opening of the bladder occurred in 7.28% (95% CI, 2.2-14.9) of cases. Ureteral damage and ureteral or vesicovaginal fistulas were reported in 2.05% (95% CI, 0.6-4.3) and in 0.42% (95% CI, 0.01-1.1) of the included cases.

Stratification analyses: PAS grade, emergency intervention, ureteral stents and number of cases per year

PAS grade

Urologic complications occurred in 9.42% (95% CI, 5.4-14.4) of patients with placenta accreta-increta compared to 38.52% (95% CI, 21.6-57.0) for those described as placenta percreta, mainly cystotomy (5.53% (95% CI, 0.6-15.1) in placenta accreta/increta and 21.97% (95% CI, 15.4-45.5) in placenta percreta) (Table 4). Intentional cystotomy was performed in 6.50% (95% CI, 0.2-20.9) of patients with placenta accreta/increta and 11.47% (95% CI, 2.0-27.2) for those with placenta percreta. Unintentional cystotomy was found in 5.08% (95% CI, 0.03-11.8) and 4.47% (95% CI, 1.7-8.4) of the cases of placenta accreta/increta and placenta percreta, respectively. Ureteral injury was reported in 1.33% (95% CI, 0.07-4.11) in placenta accreta/increta and 3.56% (95% CI, 0.9-7.8) in placenta percreta. The occurrence of urologic complications was higher in patients undergoing hysterectomy compared to uterine preserving approaches (Table 4).

Type of intervention

Urologic complications were reported in 15.44% (95% CI, 8.1-24.6) of patients undergoing planned compared to 24.61% (95% CI, 13.0-38.5) of those with an emergency intervention (Table 5).

Annual number of surgical procedure

The incidence of urologic complications was similar to that reported in the primary analysis when considering only studies with >12 cases per year (Table S3).

DISCUSSION

Main findings

Our systematic review provides a comprehensive evaluation of the incidence of urologic complications associated with surgery for PAS. Patients with placenta percreta and those requiring an emergent delivery had the highest incidence of urologic complications, mainly cystotomy.

Strengths and limitations

The main strengths of the present study include a thorough literature search, large sample size, multitude of outcomes explored and stratification of the analysis according to the type of intervention and severity of PAS disorders at birth, while its main limitations rely in the retrospective non-randomized design of the included studies, dissimilarity in the included populations and heterogeneity in outcome assessment. In particular, we could not stratify all the secondary analyses according to the type of surgical procedure, gestational age at surgery or use of interventional radiology techniques. Assessment of the potential publication bias may also be a limitation due to the nature of the outcome evaluated (outcome rates, with the left-side limited to a value of zero).

Clinical and research implications

The rate of CD has been increasing annually; however, the overall rate of lower urinary tract injury has not changed and has remained at 0.3 % of all CDs⁸⁰. In hysterectomy for benign indications, urologic complications have been reported in about 1% of cases including ureteral injuries in 1%, bladder injuries in 0.7% and genitourinary fistulas in 0.3% of cases⁸¹. Urologic complications in the context of radical hysterectomy for oncological conditions are higher with 1.48 % of patients reported with these complications⁸². By contrast, surgical procedures in

cases of PAS are usually complex, associated with a high risk of massive obstetric bleeding and of urological complications, such as injuries of the ureter and bladder²⁹. The risk of major surgical complications is also increased in cases where there is high vascularity across myometrial placental bladder interface, extensive bladder adhesions, large area of dehiscent myometrium including most of the utero-bladder interface and placental bulging⁸³. In particular, when the latter is protruding laterally into the parametria there is often increased broad ligament vascularity which when combined with thick adhesions between the herniated sac containing part of the placenta can make the surgical dissection difficult and increasing the risk of major intra-operative bleeding. Placental bulging can also cover the junction between the lower uterine segment and the cervix increasing the risk of ureteral injury and/or of the bladder trigone if a hysterectomy is required.

Placenta percreta represent the most severe clinical phenotype of PAS and occurs in case of an extended remodelling of the lower uterine segment with part of the basal plate of an anterior low-lying/placenta previa visible through the scar area ⁸⁴⁻⁸⁷. A recent systematic review⁸⁸ of case reports described as placenta percreta in the international literature, which included histopathologic findings and gross images found no histologic evidence supporting the existence of a condition where the villous tissue penetrates the entire uterine wall including the serosa and beyond. Thus, it is likely that many of the cases described as percreta in the present study may not have been associated with accreta placentation but the consequence of LUS remodelling after multiple CDs. However, these cases are surgically complex that part of the placenta is accreta or not⁸⁸.

Accurate risk stratification is also crucial for an objective presurgical planning⁸⁹. Imaging features such as myometrial thinning and placental bulging are well established signs of extensive uterine remodeling on both ultrasound⁹⁰ and magnetic resonance imaging (MRI)⁹¹

and should alert the surgical team about anatomical changes that can impact the risk of intraoperative complications⁹². More specific ultrasound signs associated with a high probability of PAS at birth⁹² such as increased sub-placental vascularity and placental lacunae are well established but there are limited data on the use of these imaging techniques in identifying patients at high risk of surgical morbidity. Several ultrasound and MRI staging systems of PAS have been reported in the published literature, but they still require validation in larger cohort⁹³⁻¹⁰⁰. More importantly, these studies have used composite scores of adverse surgical outcomes mainly based upon parameters which cannot directly reflect the surgical complexity, such as the need of blood transfusion of blood product, and are largely influenced by other cofactors, such as surgeon's experience or type of intervention.

Optimal surgical management of PAS disorders is difficult to defined yet as there are no randomized trials comparing the different surgical strategies for patients at high risk of PAS^{102,103}. Primary hysterectomy is currently the most common surgical procedure for PAS management worldwide. More recently conservative techniques have been proposed, such as the one step surgery or the Triple P procedures⁹³, but these also require a surgical expertise beyond that require for a standard CD. There is also high heterogeneity between studies regarding the different surgical steps (i.e. bladder dissection), surgical expertise and confirmation of the diagnosis of PAS and extension of the accreta lesion limiting the interpretation of the results⁹⁴. Alternatively, management of PAS can imply leaving the placenta in the uterus and waiting for progressive delivery of the placenta which can occur months after the CD²⁴. The findings highlight the need for a standardized reporting protocol for the different type of urologic complications according to the PAS grade, type of surgery and surgical technique used.

However, irrespective of the type of management adopted, surgery for PAS implies the need of an extensive knowledge of the pelvic anatomy and vascularity. Abnormal pelvic angioarchitecture which co-exist with PAS can lead to a distortion of the normal relationship between the uterus and the ureters, thus making their damage more likely. Furthermore, massive blood loss which can occur in the context of PAS may require an expedite execution of the caesarean hysterectomy to avoid patient's death. In this scenario, it is collective authors' opinion that women with PAS should be managed in centers with high expertise in surgical management of these complications, with the potential capacity to involve surgeons with high expertise in pelvic dissection, including gynecologic oncologists and urologists.

Conclusions

Patients undergoing surgery for PAS disorders have a high risk of urological complications, irrespective of the type of intervention, which occurred more commonly in those undergoing emergency surgery and in cases presenting with major uterine remodeling. The data of this systematic review support the need for a tailored management and the need for multidisciplinary management including a urologist. The high heterogeneity between the studies analyzed in the systematic review highlight the need for a standardized protocols that include detailed description of the finding at birth to allow for better prenatal identification of cases at high risk of urologic morbidity. Multicentric prospective studies are needed to confirm to develop management strategies to reduce the burden of urologic complications in patients with PAS

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FIGURE LEGEND

Figure 1. Systematic review flowchart.

Table 1. General characteristics of the studies included in the systematic review.

Author	Year	Country	Study design	Period considered	Diagnosis of PAS	Stratification according to the type of intervention, interventional radiology techniques or use of ureteral stenting	Surgical technique	Cases (n)
Dawood ¹⁸	2022	Egypt	RCT	2017-2020	Prenatal and at the time of CD	Not performed	Conservative surgery	200
Kuznetsova ¹⁹	2022	Russia	Retrospective	2015-2018	Prenatal	Not performed	Conservative surgery	41
Munoz ²⁰	2022	United States	Retrospective	2011-2021	Prenatal	Not performed	Hysterectomy	122
Overton ²¹	2022	United States	Retrospective	2018-2020	Prenatal and at the time of CD	Not performed	Hysterectomy	30
Pavon-Gomez ²²	2022	Colombia	Retrospective	2017-2021	Prenatal and at the time of CD	Not performed	Hysterectomy	114
Scaglione ²³	2022	United States	Retrospective	2001-2021	Prenatal and at the time of CD	Performed	Hysterectomy	236
Senthiles ²⁴	2022	France	Prospective	2013-2015	Prenatal	Not performed	Hysterectomy and conservative surgery	148
Smith ²⁵	2022	United States	Retrospective	2008-2020	Prenatal	Not performed	Hysterectomy	18
Taskeen ²⁶	2022	Kuwait	Retrospective	2018-2020	Prenatal and at the time of CD	Not performed	Hysterectomy	36
Xin ²⁷	2022	China	Retrospective	2016-2020	Prenatal and at the time of CD	Not performed	Hysterectomy and conservative surgery	166
Bakacak ²⁸	2021	Turkey	Retrospective	2005-2019	Prenatal and at the time of CD	Not performed	Hysterectomy	93
Erfani ²⁹	2021	United States	Retrospective	2011-2020	Prenatal and at the time of CD	Performed	Hysterectomy	292
Matsuzaki ³⁰	2021	United States	Retrospective	2015-2017	Prenatal and at the time of CD	Not performed	Hysterectomy and conservative surgery	8030
Morlando ³¹	2021	Multinational	Retrospective	2014-2019	Prenatal and at the time of CD	Not performed	Hysterectomy and conservative surgery	356
Perveen ³²	2021	Pakistan	Retrospective	2018-2020	Prenatal	Not performed	Hysterectomy and conservative surgery	40
Soleymanimajd ³³	2021	United Kingdom	Retrospective	2011-2020	Prenatal and at the time of CD	Not performed	Hysterectomy	24

Udden ³⁴	2021	Sweden	Retrospective	2003-2020	Prenatal and at the time of CD	Not performed	Hysterectomy	33
van Beekhuizen ³⁵	2021	Multinational	Retrospective	2008-2019	Prenatal and at the time of CD	Not performed	Hysterectomy and conservative surgery	442
Chahal ³⁶	2020	India	Retrospective	2014-2017	Prenatal and at the time of CD	Performed	Hysterectomy and conservative surgery	64
Dall' Asta ³⁷	2020	Italy	Retrospective	2014-2018	Prenatally	Not performed	Hysterectomy	43
Nisar ³⁸	2020	Pakistan	Retrospective	2016	Prenatal and at the time of CD	Not performed	Not reported	68
Saha ³⁹	2020	India	Prospective	2015-2017	Prenatal	Not performed	Hysterectomy	12
Celik ⁴⁰	2019	Turkey	Retrospective	2009-2019	NS	Not performed	Hysterectomy	88
Crocetto ⁴¹	2019	Italy	Retrospective	2010-2018	Prenatal	Not performed	Hysterectomy	44
Dawood ⁴²	2019	Egypt	Retrospective	2015-2017	Prenatal and at the time of CD	Not performed	Conservative surgery	91
Nieto-Calvache ⁴³	2019	Colombia	Retrospective	2011-2019	Prenatal and at the time of CD	Performed	Hysterectomy and conservative surgery	65
Sak ⁴⁴	2019	Turkey	Retrospective	2015-2016	Prenatal and at the time of CD	Not performed	Hysterectomy	37
Zuckerwise ⁴⁵	2019	United States	Retrospective	2012-2018	Prenatal	Not performed	Hysterectomy	49
Marcellin ⁴⁶	2018	France	Retrospective	2003-2017	Prenatal and at the time of CD	Not performed	Hysterectomy and conservative surgery	156
Meller ⁴⁷	2018	Argentina	Retrospective	2013-2017	Prenatal	Not performed	Hysterectomy	110
Ozcan ⁴⁸	2018	Turkey	Retrospective	2015-2017	Prenatal	Not performed	Hysterectomy	66
Shmakov ⁴⁹	2018	Russia	Retrospective	2015-2017	Prenatal	Not performed	Hysterectomy and conservative surgery	54
Thabet ⁵⁰	2018	Egypt	Retrospective	2013-2016	Prenatal	Not performed	Conservative surgery	78
Zhao ⁵¹	2018	China	Retrospective	2013-2016	Prenatal	Not performed	Conservative management	62
Alanwar ⁵²	2017	Egypt	Retrospective	2014-2016	Prenatal	Not performed	Hysterectomy and conservative surgery	342
Lee ⁵³	2017	United States	Retrospective	2005-2015	Prenatal and at the time of CD	Not performed	Hysterectomy and conservative surgery	21
Pala ⁵⁴	2017	Turkey	Retrospective	2012-2016	NR	Not performed	Hysterectomy	36

Chaudhari ⁵⁵	2017	India	Retrospective	2012-2014	Prenatal	Not performed	Hysterectomy and conservative surgery	30
Karaman ⁵⁶	2016	Turkey	Retrospective	2013-2016	Prenatal	Not performed	Conservative surgery	12
Camuzcuoglu ⁵⁷	2015	Turkey	Retrospective	2009-2014	Prenatal	Not performed	Hysterectomy	58
Fitzpatrick ⁵⁸	2015	United Kingdom	Retrospective	2010-2011	Prenatal and at the time of CD	Not performed	Hysterectomy and conservative surgery	134
Norris ⁵⁹	2015	Australia	Retrospective	2009-2013	Prenatal and at the time of CD	Performed	Hysterectomy and conservative surgery	49
Shabana ⁶⁰	2015	Egypt	Retrospective	2011-2014	Prenatal and at the time of CD	Not performed	Conservative surgery	71
Thurn ⁶¹	2015	Denmark, Finland, Iceland, Norway, and Sweden	Retrospective	2009-2012	Prenatal and at the time of CD	Not performed	Hysterectomy and conservative surgery	205
Shamshirsaz ⁶²	2014	United States	Retrospective					
Alchalabi ⁶³	2014	Jordan	Retrospective	2003-2012	Prenatal and at the time of CD	Not performed	Hysterectomy	23
Asicioglu ⁶⁴	2014	Turkey	Retrospective	2005-2010	Prenatal and at the time of CD	Not performed	Hysterectomy and conservative surgery	46
Brookfield ⁶⁵	2014	United States	Retrospective	1999-2002	NR	Not performed	Hysterectomy	77
Cali ⁶⁶	2014	Italy	Retrospective	2009-2013	Prenatal	Performed	Hysterectomy	43
Woldu ⁶⁷	2014	United States	Retrospective	2000-2011	Prenatal and at the time of CD	Performed	Hysterectomy	83
Chantraine ⁶⁸	2013	Belgium	Retrospective	1998-2011	Prenatal and at the time of CD	Not performed	Hysterectomy and conservative surgery	66
Chung ⁶⁹	2013	China	Retrospective	2005-2011	Prenatal and at the time of CD	Not performed	Hysterectomy and conservative surgery	15
Guleria ⁷⁰	2013	India	Retrospective	2001-2010	Prenatal and at the time of CD	Not performed	Hysterectomy and conservative surgery	56
Eller ⁷¹	2011	United States	Retrospective	1996-2008	NR	Not performed	Hysterectomy	141
Meyer ⁷²	2011	United Kingdom	Retrospective	2008-2010	Prenatal	Not performed	Conservative management	12
Tikkanen ⁷³	2011	Finland	Retrospective	1998-2010	Prenatal and at the time of CD	Not performed	Hysterectomy and conservative surgery	44
Sultana ⁷⁴	2011	India	Retrospective	2008-2010	Prenatal	Not performed	Hysterectomy	32

Angstmann ⁷⁵	2010	Australia	Prospective	2001-2009	Prenatal and at the time of CD	Performed	Hysterectomy	26
Hoffman ⁷⁶	2010	United States	Retrospective	2003-2009	Prenatal and at the time of CD	Performed	Hysterectomy	29
Senthiles ⁷⁷	2010	France	Retrospective	1993-2007	Prenatal and at the time of CD	Not performed	Conservative surgery	167
Warshak ⁷⁸	2010	United States	Retrospective	1990-2008	Prenatal and at the time of CD	Not performed	Hysterectomy	99
Wright ⁷⁹	2010	United States	Retrospective	1998-2007	NR	Not performed	Hysterectomy	1798

Table 2. Quality assessment of the included studies according to Newcastle-Ottawa scale (NOS)

Authors	Year	Selection	Comparability	Outcome
Dawood ¹⁸	2022	★★★	★★	★★
Kuznetsova ¹⁹	2022	★★	★★	★★
Munoz ²⁰	2022	★★	★★	★★
Overton ²¹	2022	★★	★★	★★
Pavon-Gomez ²²	2022	★★★	★★	★★
Scaglione ²³	2022	★★★	★★	★★
Senthiles ²⁴	2022	★★	★	★
Smith ²⁵	2022	★★	★★	★
Taskeen ²⁶	2022	★★	★	★
Xin ²⁷	2022	★	★	★
Bakacak ²⁸	2021	★★★	★★	★★
Erfani ²⁹	2021	★★	★★	★★
Matsuzaki ³⁰	2021	★★	★★	★★
Morlando ³¹	2021	★★	★★	★★
Perveen ³²	2021	★★★	★★	★★
Soleymanimajd ³³	2021	★★★	★★	★★
Udden ³⁴	2021	★★	★	★
van Beekhuizen ³⁵	2021	★★	★★	★
Chahal ³⁶	2020	★★	★	★
Dall' Asta ³⁷	2020	★★	★★	★★
Nisar ³⁸	2020	★★	★★	★★
Saha ³⁹	2020	★★★	★★	★★
Celik ⁴⁰	2019	★★★	★★	★★
Crocetto ⁴¹	2019	★★	★	★
Dawood ⁴²	2019	★★	★★	★
Nieto- Calvache ⁴³	2019	★★	★	★
Sak ⁴⁴	2019	★	★	★

Zuckerwise ⁴⁵	2019	★★★	★★	★★
Marcellin ⁴⁶	2018	★★	★★	★★
Meller ⁴⁷	2018	★★	★★	★★
Ozcan ⁴⁸	2018	★★	★★	★★
Shmakov ⁴⁹	2018	★★★	★★	★★
Thabet ⁵⁰	2018	★★★	★★	★★
Zhao ⁵¹	2018	★★	★	★
Alanwar ⁵²	2017	★★	★★	★
Lee ⁵³	2017	★★	★	★
Pala ⁵⁴	2017	★★	★★	★★
Chaudhari ⁵⁵	2017	★★	★★	★★
Karaman ⁵⁶	2016	★★★	★★	★★
Camuzcuoglu ⁵⁷	2015	★★★	★★	★★
Fitzpatrick ⁵⁸	2015	★★	★	★
Norris ⁵⁹	2015	★★	★★	★
Shabana ⁶⁰	2015	★★	★	★
Thurn ⁶¹	2015	★	★	★
Shamshirsaz ⁶²	2014			
Alchalabi ⁶³	2014	★★★	★★	★★
Asicioglu ⁶⁴	2014	★★	★★	★★
Brookfield ⁶⁵	2014	★★	★★	★★
Cali ⁶⁶	2014	★★	★★	★★
Woldu ⁶⁷	2014	★★★	★★	★★
Chantraine ⁶⁸	2013	★★★	★★	★★
Chung ⁶⁹	2013	★★	★	★
Guleria ⁷⁰	2013	★★	★★	★
Eller ⁷¹	2011	★★	★	★
Meyer ⁷²	2011	★★	★	★
Tikkanen ⁷³	2011	★★	★★	★

Sultana ⁷⁴	2011	★★	★	★
Angstmann ⁷⁵	2010	★★★	★★	★★
Hoffman ⁷⁶	2010	★★	★★	★★
Senthiles ⁷⁷	2010	★★	★★	★★
Warshak ⁷⁸	2010	★★	★★	★★
Wright ⁷⁹	2010	★★★	★★	★★

A study can be awarded a maximum of one star for each numbered item within the Selection and Outcome categories. A maximum of two stars can be given for Comparability.

Table 3. Pooled proportions of adverse urological outcomes in women undergoing surgery for placenta accreta spectrum (PAS) disorders

Outcome	Studies	Women	Pooled proportions (95% CI)	I² (%)
<i>All cases</i>				
All urologic complications	49	1102/11618	15.29 (13.00-17.72)	87.1
Cystotomy (overall)	42	512/11286	13.02 (9.24-17.34)	96.5
Intentional cystotomy	21	21/1239	5.58 (2.74-9.34)	82.6
Unintentional cystotomy	21	38/1239	7.40 (4.34-11.18)	78.5
Ureteral damage	21	31/1391	2.45 (1.35-3.86)	47.9
Ureteral or bladder fistula	26	14/1814	1.44 (0.86-2.17)	21.8
<i>Women undergoing hysterectomy</i>				
All urologic complications	27	602/3411	19.36 (16.25-22.67)	69
Cystotomy (overall)	25	546/3379	17.05 (14.05-20.27)	70.2
Intentional cystotomy	15	129/1015	8.69 (4.79-13.61)	79.7
Unintentional cystotomy	15	102/1015	9.27 (5.21-14.36)	80.1
Ureteral damage	21	44/3098	1.80 (1.21-2.51)	12.6
Ureteral or bladder fistula	19	7/977	1.81 (1.00-2.88)	14.5
<i>Women undergoing conservative surgery or management</i>				
All urologic complications	14	99/930	12.22 (7.54-17.83)	79.9
Cystotomy (overall)	14	83/930	9.58 (5.68-14.37)	77
Intentional cystotomy	9	10/413	2.86 (0.67-6.51)	58.7
Unintentional cystotomy	9	21/413	7.28 (2.23-14.92)	79.6
Ureteral damage	13	14/839	2.05 (0.61-4.29)	65.8
Ureteral or bladder fistula	10	1/625	0.42 (0.006-1.08)	0

Table 4. Pooled proportions of adverse urological outcomes according to the severity of PAS at histopathology (placenta accreta-increta and percreta respectively)

Outcome	Studies	Women	Pooled proportions (95% CI)	I ² (%)
<i>Placenta accreta-increta (all interventions)</i>				
All urologic complications	7	436/7058	9.42 (5.42-14.40)	66.7
Cystotomy (overall)	5	27/6964	5.53 (0.56-15.13)	0
Intentional cystotomy	3	6/69	6.50 (0.17-20.89)	60.2
Unintentional cystotomy	3	3/69	5.08 (0.026-11.80)	68.1
Ureteral injury	4	2/192	1.33 (0.07-4.11)	23.1
Ureteral or bladder fistula	4	0/175	0 (0-1.97)	0
<i>Placenta accreta-increta (Hysterectomy)</i>				
All urologic complications	3	28/248	13.72 (5.26-25.32)	75.2
Cystotomy (overall)	2	14/83	17.61 (10.26-26.4)	0
Intentional cystotomy	2	6/65	6.56 (0.06-26.59)	79.8
Unintentional cystotomy	2	3/65	5.17 (0.77-27.0)	84
Ureteral injury	2	2/83	3.05 (0.47-7.76)	0
Ureteral or bladder fistula	1	-	-	-
<i>Placenta percreta (all interventions)</i>				
All urologic complications	9	360/1292	38.52 (21.63-56.99)	93.7
Cystotomy (overall)	7	132/1257	21.97 (5.43-45.52)	96.2
Intentional cystotomy	5	20/146	11.47 (2.03-27.15)	80.4
Unintentional cystotomy	5	6/146	4.47 (1.71-8.42)	1.4
Ureteral injury	6	6/197	3.56 (0.92-7.81)	36.6
Ureteral or bladder fistula	5	5/163	3.81 (1.44-7.24)	0
<i>Placenta percreta (Hysterectomy)</i>				
All urologic complications	3	68/182	37.51 (30.62-44.66)	0.5
Cystotomy (overall)	2	17/55	30.06 (14.04-49.10)	53.4
Intentional cystotomy	2	16/55	27.15 (8.35-51.76)	72.2

Unintentional cystotomy	2	1/55	2.55 (0.10-10.54)	38.8
Ureteral injury	2	4/55	8.61 (2.76-17.28)	0
Ureteral or bladder fistula	1	-	-	-
<i>Placenta percreta (conservative management)</i>				
All urologic complications	3	11/91	12.72 (6.75-20.23)	0
Cystotomy (overall)	3	10/91	11.70 (5.99-19.00)	0
Intentional cystotomy	3	4/91	5.18 (1.62-10.59)	0
Unintentional cystotomy	3	6/91	7.53 (3.07-13.76)	0
Ureteral injury	3	0/91	0 (0-3.28)	0
Ureteral or bladder fistula	3	1/91	2.09 (0.19-5.97)	0

Table 5. Pooled proportions of adverse urological outcomes in women undergoing emergency and planned surgery for placenta accreta spectrum (PAS) disorders

Outcome	Studies	Women	Pooled proportions (95% CI)	I ² (%)
<i>Planned intervention</i>				
All urologic complications	6	56/477	15.44 (8.11-24.61)	77.8
Cystotomy (overall)	2	16/268	10.73 (0.45-31.89)	87.2
Intentional cystotomy	-	-	-	-
Unintentional cystotomy	-	-	-	-
Ureteral injury	4	4/289	2.23 (0.13-6.80)	47.4
Ureteral or bladder fistula	4	1/289	0.66 (0.06-1.92)	0
<i>Emergency intervention</i>				
All urologic complications	5	82/289	24.61 (12.98-38.53)	87.9
Cystotomy (overall)	-	-	-	-
Intentional cystotomy	-	-	-	-
Unintentional cystotomy	-	-	-	-
Ureteral injury	2	1/160	1.03 (0.006-3.17)	0
Ureteral or bladder fistula	2	0/160	0 (0-1.71)	0



PRISMA 2009 Flow Diagram

