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Implementation and Outcomes of a Model of Care for Placenta Accreta Spectrum in a Community-Based Private Practice

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Abstract

Objective The aim of the study is to describe a model of care and outcomes for placenta accreta spectrum (PAS) implemented in the context of a community based non-academic health system.

Study Design The program for management of PAS includes a multidisciplinary team approach with protocols for ultrasound assessment, diagnosis, and surgery. The program was implemented in the two largest private hospitals in the Twin Cities, Minnesota, United States. Maternal and fetal outcomes as well as cost were compared for histopathologic confirmed PAS cases before (2007–2014, $n = 41$) and after (2015–2017, $n = 26$) implementation of the PAS program.

Results Implementation of the PAS program was associated with ICU admission reductions from 53.7 to 19.2%, $p = 0.005$; a decrease of 1,682 mL in mean estimated blood loss (EBL) ($p = 0.061$); a decrease in transfusion from 85.4 to 53.9% ($p = 0.005$). The PAS program also resulted in a (non-significant) decrease in both surgical complications from 48.8 to 38.5% ($p = 0.408$) and postoperative complications from 61.0 to 42.3% ($p = 0.135$). The total cost of care for PAS cases in the 3 years after implementation of the program decreased by 33%.

Conclusion The implementation of a model of care for PAS led by a perinatology practice at a large regional non-academic referral center resulted in reductions of ICU admissions, operating time, transfusion, selected surgical complications, overall postoperative complications, and cost.

Keywords

- accreta
- increta
- percreta
- placenta accreta spectrum

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Key Points

- Implementation of a PAS care model resulted in reduced ICU admissions from 53.7% to 19.2%.
- Patient safety increased by reducing blood loss, transfusions and postoperative complications.
- This model decreased operating time, as well as total cost of care by 33%.

Placenta accreta spectrum (PAS) is a broad term that encompasses the range of pathologic placental adherence to the uterine myometrium including placenta accreta, increta, or percreta. PAS can have life threatening consequences for both the mother and her fetus, with increased risk for massive hemorrhage and associated complications such as multisystem organ failure, acute respiratory distress syndrome, disseminated intravascular coagulation (DIC), and death.[1] Due to indicated preterm delivery, the neonates additionally carry the risks associated with prematurity. The incidence of PAS has increased in the United States, from <1 in 2000 in the 1980s to recent estimates as high as 1:272 to 1:800 pregnancies, with variation in rates due to definition.[2–7] The rise in Cesarean sections (C-sections)[8] is likely the major contributing factor to the increase in PAS.[2]

Management of PAS varies widely in the United States.[9] In 2015, Silver et al[2] provided guidance on what a "Center for Excellence" in care for PAS should include. Centers with multidisciplinary expertise and experience in the care of this condition optimize maternal and neonatal outcomes with early recognition and planned delivery. The recent consensus statement on PAS from the American College of Obstetrics and Gynecology (ACOG) and the Society for Maternal Fetal Medicine (SMFM), includes the recommendation of care provided by multidisciplinary care teams accustomed to the management of PAS.[10] To date, a few such programs have provided evidence in support of improved outcomes associated with a multidisciplinary care model.[5,11–14]

Given few studies available evaluating these models of care at non-academic settings, and the potential severity of these rare conditions, it is important to refine our understanding of these models. This study examines outcomes of PAS before and after the implementation of a PAS program of care led by maternal fetal medicine specialists (MFMs) in a non-academic regional referral center.

Materials and Methods

Setting

The PAS program was implemented at the two largest private hospitals in the Twin Cities in Minnesota (U.S.): Abbott Northwestern Hospital and United Hospital. The hospitals are part of Allina Health, a large not-for-profit network of 12-hospitals and 90+ clinics serving Minnesota and western Wisconsin. These two hospitals delivered over 8,600 infants in 2017. Both hospitals are designated as Level IV for maternal care as defined by the American College of Obstetricians and Gynecologists.[15] Care for high-risk pregnancies at Allina Health is provided by maternal MFMs at Minnesota Perinatal Physicians (MPP). As part of a multistate perinatal health center, MPP receives referrals from throughout the region, and provides collaborative care with primary obstetrical providers and neonatal specialists as needed.

Development of a PAS Program

Prior to the creation of this program, patients with PAS were treated on a case-by-case basis by MFM in collaboration with gynecologic oncology. There was neither any surgical standardization for these cases nor there were consistent team members. Some surgeries would include a urologist or perfusionist but these roles were not consistently included in all surgeries. In addition, prior to program development, surgical devices such as LigaSure were not utilized. In 2015, the MPP team implemented a PAS program for the diagnosis and management of PAS which includes care provided by a multidisciplinary team of MFM's, obstetricians, perinatal sonographers, urologists, interventional radiologists, perfusionists (a specially trained medical staff who is responsible for running the Cell Saver in the operating room), intensivists, anesthesiologists, neonatologists, nurse care coordinators, and a team of cross trained ICU/OB nurses. The site has a blood bank with massive transfusion protocol aligned with guidelines for center for excellence for PAS recommendations.[2] The practice uses perinatal trained sonographers to perform all ultrasound examinations. Patients with suspected PAS are scanned by the perinatal sonographer with the MFM in the ultrasound suite working in tandem with the perinatal sonographer. A team of eight MFM surgeons was formed with two MFMs leading the surgical team for each surgery under the new model (as opposed to one MFM and one gynecologic oncologist). This team can be pulled together rapidly 24 hours a day to meet the urgent needs of this critical patient population. The formation of the multidisciplinary approach was to emphasize the importance of a standardized preoperative, intraoperative, and postoperative regimen. Intraoperative technique was standardized to utilize surgical devices such as LigaSure which replaced suture ligation as the primary method of securing vascular pedicles. This PAS program is designed as a multidisciplinary approach similar to that which is outlined in the center for excellence guidelines.[2] While some models[4,12–14] include a significant role for gynecologic–oncology surgeons, our model does not. Rather, the PAS program, similar to the multidisciplinary program described by Al-Khan,[5] is led and implemented entirely by MFMs who have all received training in surgical techniques for PAS management through MPP. As the level of expertise varied with each provider, each MFM member was proctored on 10- to 15-cases with experienced surgeons in addition to surgical cases logged during MFM fellowship training. Once the senior team member

determined that the necessary skills were demonstrated for surgical care, the surgeon was added to the list of surgeons on the PAS team. Prior to program implementation in 2015 all MFM involvement was isolated to a single physician with over 20 years of PAS surgical experience. In 2015, the surgical team expanded to eight MFM surgeons with varying degrees of PAS surgical experience ranging from 3 to 26 years.

In addition to the multidisciplinary team, the PAS Program uses preoperative and intraoperative techniques and a process similar to those described elsewhere[12] with a few exceptions. Details of these techniques are described in Appendix and ►Fig. A1.

Sample Selection Criteria

All cases were identified which had a peripartum hysterectomy between January 1, 2007 and December 31, 2017. Of these cases, only those with histopathologic confirmed diagnosis of PAS were included in the study. Patients were excluded who had opted out of the use of their data for research purposes through the Minnesota Research Authorization process. Cases where the diagnosis of accreta occurred after delivery were excluded. Additionally, cases where the perinatology team was not involved in either the delivery or any aspect of the prenatal care of the patient were excluded as these cases were not exposed to the same model of care.

Data Collection and Measures

Data for this retrospective study came from Allina Health's electronic health record. The use of these data was approved by the Allina Health Institutional Review Board. Select measures were collected through a data extraction process while other measures were collected via chart audit. Initial review of pathology reports was done by a study coordinator with verification as needed by MFMs. Chart audits were conducted by MFMs and the practice manager (a Registered Nurse).

Patient characteristics included age of mother at delivery and self-reported race and Hispanic ethnicity. Pregnancy characteristics included gravida, parity, singleton versus multiple gestation, history (and count) of C-sections, history (and count) of uterine surgeries other than C-section, placenta previa in the current pregnancy or a prior pregnancy, in vitro fertilization in this pregnancy, smoking during pregnancy, and hospitalizations with bleeding during the study pregnancy. Prior suspected placenta accreta was captured from clinical assessment notes for prior deliveries. Measures about diagnosis of PAS included whether the diagnosis was identified with an MRI, and degree of placental invasion (accreta, increta, percreta) from pathology reports. Cases had a histopathologic confirmed diagnosis of accreta, increate, or percreta. Specifically, accreta was diagnosed when the villi attached to the myometrium, increta was diagnosed when the villi invaded the myometrium, and if villi invaded the serosa or surrounding structures the case was diagnosed as percreta. Measures about delivery included if the cesarean procedure was scheduled or emergent, gestational age, operating time (minutes from incision to closure), estimated blood loss (EBL, mL), transfusion of blood products during delivery, use of cell salvage transfusion, ICU admission, length of stay, and interventional radiology utilization (embolization or iliac balloon). Other surgical measures included type of hysterectomy (supracervical or total). Surgical complications included uterine rupture, vascular injury, neurological injury, cystotomy (incidental or intentional), bladder resection, ureteral neocystotomy, intestinal injury, and wound complications requiring antibiotics or opening the wound. Postoperative complications included hemorrhage, ileus bowel obstruction, inability to extubate, fever, infection, thromboembolic, acute kidney injury need for re-exploration, multiorgan failure, or death. Adverse transfusion reactions were also documented and included DIC (defined by laboratory abnormalities such as thrombocytopenia [<100,000], prolonged prothrombin time and partial thromboplastin time, and low fibrinogen [<250]), transfusion-associated circulatory overload, or transfusion-related acute lung injury. Infant outcomes included live birth or fetal death, Apgar scores at 1- and 5 minutes, neonatal intensive care unit or special care nursery admission, and birthweight.

Cost of care for the delivery hospitalization was available for 4 years prior to (2011–2014) and 3 years after (2015–2017) implementation of the program. Cost was measured by summing charges from the hospital discharge record and included the following subcategories: drug supply, laboratory, radiology, room, operating room, respiratory care, therapy, other, and unclassified. Cost data for the study is only valid for determining the effect of implementing this program at this Health system, which is not directly comparable to other facilities.

Analysis

The patient and pregnancy characteristics were compared using frequencies and means. For comparisons of sample characteristics and outcomes between time periods we conducted Fisher's exact tests for categorical variables, *t*-tests for continuous variables, and Mann–Whitney U tests for assessing the equality of distributions. All analyses were conducted using Stata version 15.1 (StataCorp College Station, TX).

Results

A total of 80,154 deliveries occurred at the two study hospitals from 2007 to 2017, with 76,048 (95%) patients giving permission to use records for research. Of these, 137 cases were identified as having a hysterectomy done the same day as delivery. Nearly one-third (42) of the cases were determined to have indications for the hysterectomy other than PAS (►Fig. 1). Of these, only three cases indicated suspected PAS in the record as the reason for hysterectomy, but pathology reports for these three cases did not confirm PAS and thus were excluded from the study. There were 95 cases with histopathologic confirmed diagnosis of PAS; 28 cases were excluded because of either diagnosis at the time of delivery or the MPP providers were not involved in the prenatal care or delivery. The remaining 67 cases represent the final study sample. Severity of invasion based on pathology diagnosis was 18% accreta, 27% increta, and 55% percreta.

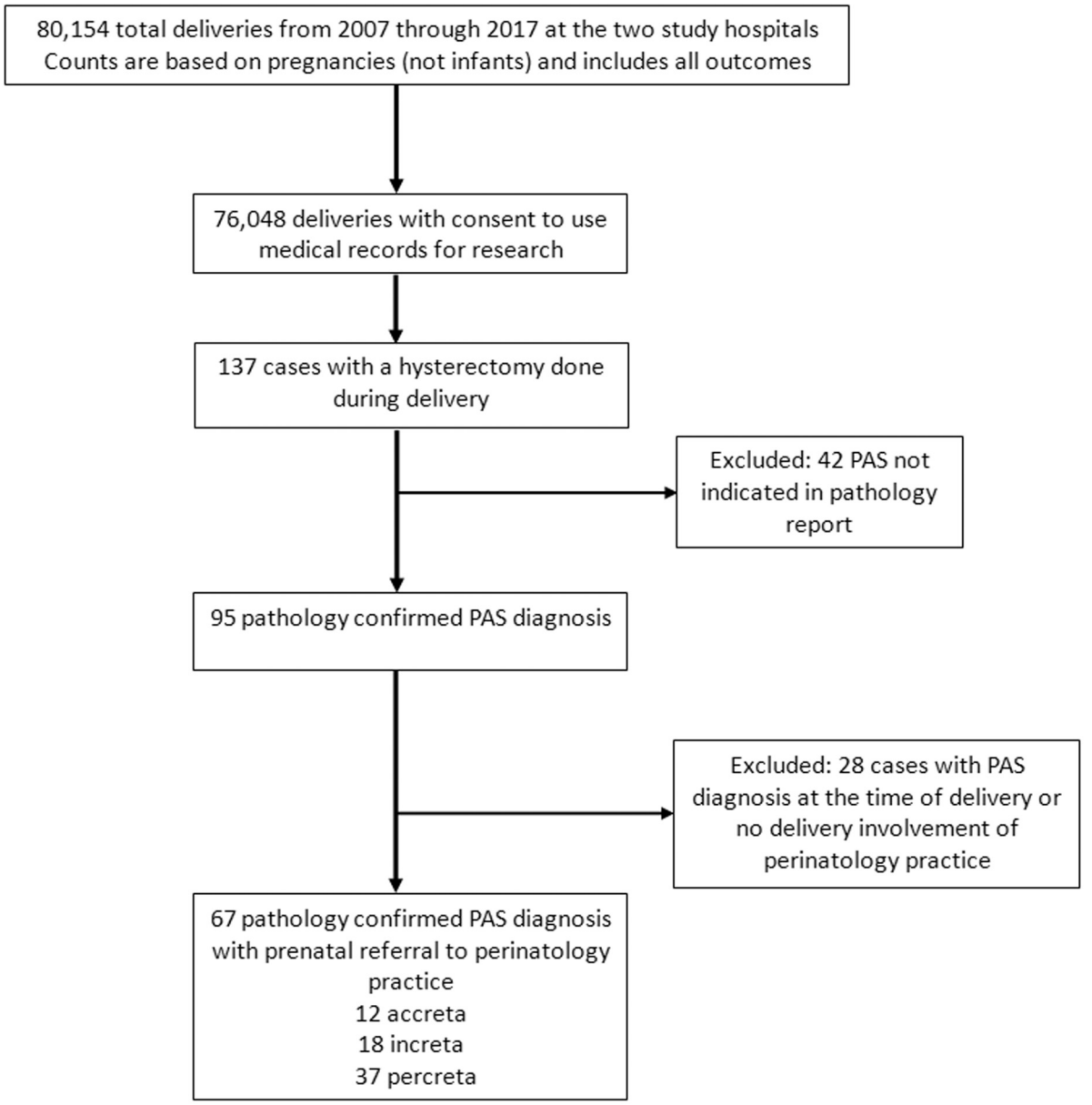

Fig. 1 Study sample identification process.

In our final study sample the median number of risk factors for PAS per patient was 2: 95.5% prior C-section(s), 46.3% other prior uterine surgery(ies), 91% current placenta previa, 9% smoked during pregnancy, 4.5% prior pregnancy with suspected accreta, and 1.5% IVF treatment for the study pregnancy, (►**Table 1**). All women had a parity of 1 or more with a median parity of 3 and median gravida of 5. There were no differences between the cases occurring in the two time periods with regard to age, race, body mass index, risk factors present, parity, gravida, or severity of invasion.

Comparisons of diagnosis and outcomes before and after the multidisciplinary program show no significant differences overall in scheduled deliveries versus unscheduled deliveries (►**Table 2**). Of the 10 unscheduled deliveries in the first time period, nine were due to PAS indications and one was due to other obstetric indications (specifically, PPROM). For the eight unscheduled in the second time period, seven were due to PAS and one was due to other indications (preeclampsia). All cases defined as PAS indications were for preterm labor and/or bleeding. Common risk factors among this group of unscheduled deliveries included previa/low lying placenta in current pregnancy and history of multiple prior cesarean deliveries. Other factors seen were history of PPROM, history of preterm labor with preterm delivery, history of medically indicated preterm delivery (i.e., hypertensive disorders of pregnancy), AMA, and twin pregnancy.

There were no significant differences between the two time periods with regard to gestational age at delivery. Differences between the two time periods indicate reduced operating time of approximately 53 minutes during the second time period ($p = 0.069$) and a substantial decrease in blood loss and blood product transfusion, and an

Table 1 Characteristics of women with diagnosis of morbidly adherent placenta delivered before (2007–2014) and after implementation of a multidisciplinary program (2015–2017).

Maternal characteristics	Total ($n = 67$) Mean (SD) or %(n)	2007–2014($n = 41$) Mean (SD) or %(n)	2015–2017($n = 26$) Mean (SD) or %(n)	p-Value
Maternal age, mean (SD)	34.8 (4.94)	35.3 (5.19)	34.0 (4.49)	0.277
20–24 y	1.5% (1)	2.4% (1)	0.0% (0)	0.033
25–29 y	17.9% (12)	9.8% (4)	30.8% (8)	
30–34 y	26.9% (18)	36.6% (15)	11.5% (3)	
35–39 y	35.8% (24)	29.3% (12)	46.2% (12)	
40 + y	17.9% (12)	22.0% (9)	11.5% (3)	
Race				
African American	25.4% (16)	21.6% (8)	30.8% (9)	0.411
American Indian	1.6% (1)	0.0% (0)	3.9% (1)	
Asian/PI	3.2% (2)	5.4% (2)	0.0% (0)	
White	69.8% (44)	73.0% (27)	65.4% (17)	
Hispanic	1.6% (1)	0.0% (0)	3.9% (1)	0.413
BMI at first prenatal visit, mean (SD)	29.0 (7.77)	29.1 (8.07)	29.0 (7.46)	0.965
Gravida, median [IQR]	5 [2, 15]	3 [2, 15]	5 [2, 12]	0.430
Parity, median [IQR]	3 [1, 11]	3 [1, 11]	3 [1, 7]	0.660
Parity, categories				
0	0.0% (0)	0.0% (0)	0.0% (0)	0.225
1	19.4% (13)	24.4% (10)	11.5% (3)	
2 +	80.6% (54)	75.6% (31)	88.5% (23)	
Gestation				
Singleton	97.0% (65)	95.1% (39)	100.0% (26)	0.518
Multiple	3.0% (2)	4.9% (2)	0.0% (0)	
Risk factors present				
Prior C-section	95.5% (64)	95.1% (39)	96.2% (25)	1.000
Number of prior C-sections, mean (SD)	2.48 (1.32)	2.46 (1.45)	2.50 (1.10)	0.913
Prior uterine surgeries	46.3% (31)	48.8% (20)	42.3% (11)	0.605
Number of prior uterine surgeries, mean (SD)	0.96 (1.33)	1.12 (1.50)	0.69 (0.97)	0.200
Placenta previa in this pregnancy	91.0% (61)	92.7% (38)	88.5% (23)	0.670
Prior pregnancy with clinical suspicion of accreta	4.5% (3)	7.3% (3)	0.0% (0)	0.277
IVF this pregnancy	1.5% (1)	2.4% (1)	0.0% (0)	1.000
Smoking during pregnancy	9.0% (6)	9.8% (4)	7.7% (2)	1.000
Number of risk factors present, median [IQR]	2 [1, 4]	3 [1, 4]	2 [1, 3]	0.243
1	4.5% (3)	4.9% (2)	3.9% (1)	0.388
2	49.3% (33)	43.9% (18)	57.7% (15)	
3	40.3% (27)	41.5% (17)	38.5% (10)	
4	6.0% (4)	9.8% (4)	0.0% (0)	
Diagnosis and level of invasion				
Hospitalizations with bleeding in pregnancy				
0	52.2% (35)	43.9% (18)	65.4% (17)	0.410
1	26.9% (18)	31.7% (13)	19.2% (5)	
2	16.4% (11)	19.5% (8)	11.5% (3)	
3 +	4.5% (3)	4.9% (2)	3.9% (1)	

(*Continued*)

Table 1 (*Continued*)

Maternal characteristics	Total ($n = 67$) Mean (SD) or %(n)	2007–2014($n = 41$) Mean (SD) or %(n)	2015–2017($n = 26$) Mean (SD) or %(n)	p-Value
Diagnosis with MRI	43.3% (29)	56.1% (23)	23.1% (6)	0.008
Placental invasion level				
Accreta	17.9% (12)	14.6% (6)	23.1% (6)	0.646
Increta	26.9% (81)	29.3% (12)	23.1% (6)	
Percreta	55.2% (37)	56.1% (23)	53.9% (14)	

Abbreviations: BMI, body mass index; C-section, cesarean section; IVF, in vitro fertilization; MRI, magnetic resonance imaging; PI, pacific islander.

associated increase in cell salvage use. ICU admissions decreased from 53.7 to 19.2% ($p = 0.005$). The use of interventional radiology decreased as well, primarily due to a reduction in iliac balloons. Surgical complications decreased from 48.8 to 38.5% (not significant), with the largest reductions seen in intentional cystotomy and bladder resection. Postoperative complications also showed a non-significant reduction from 61.0 to 42.3%. Specific postsurgical complications with the largest decreases were ileus bowel obstruction, inability to extubate, fever, and need for re-exploration. There were no cases of maternal mortality in either period. We saw no changes in fetal or infant measures.

The mean cost for the treatment of PAS patients in the 4 years prior to the program was $39,671. Cost of care for PAS cases in the 3 years after implementation of the program decreased by 33% from $39,671 to $26,703 ($p = 0.103$). Among more severe cases (increta and percreta), the mean cost of care was reduced by 35% from $40,906 to $26,379 ($p = 0.107$).

Discussion

The implementation of a PAS program similar to the center for excellence model[2] and recommended by ACOG and SMFM[1,10] at a non-academic community-based health system led to decreased ICU admissions, operating time, blood loss, and reduced need for blood product transfusion. We also saw a trend toward decreased surgical and postoperative complications including a marked decrease in intentional cystotomy. We found no differences in neonatal outcomes.

While our study saw a substantial reduction in total costs, these differences were not statistically significant, which is likely the result of a limited sample size for such a specialized procedure. The observed difference is likely driven by decreased ICU stays, decreased use of interventional radiology, reduction in transfusion, and decreased operating time.

While other studies examining the impact of a multidisciplinary approach for PAS[5,11,12,14] uniformly identified improved maternal outcomes, there were several notable similarities and differences between our findings as well as notable differences in program models. Our PAS program demonstrated a significant decrease in ICU admissions over time. These findings were shared by only one other study.[5] Another study taking place at a single hospital found a decrease in ICU admissions in their hybrid OR model of care, when compared with their conventional model of treatment, although it was not statistically significant.[16] Shamshirsaz et al[12] did not examine ICU admissions as an outcome but rather indicated ICU recovery was a standard part of their model, and Smulien did not find a significant reduction[14] which could be due to their small sample size. The marked decrease in ICU admission in our study may be due to many factors, including the decrease in transfusion therapy, a lower incidence of coagulopathic processes (DIC), all of which would reduce the need for postoperative critical care management. This was reflected in the overall cost of care in our system which decreased by approximately one-third.

As with other models[5,12,14] our study identified a significant decrease in EBL. As described by Shamshirsaz et al,[12] our model includes the use of the LigaSure device exclusively in the second time period which may be the primary contributing factor to the demonstrated reduction in blood loss due to better secured hemostasis of the primary and collateral vascular pedicles. Our patients in the second time period did not have uterine artery catheterization as a routine part of the procedure, yet experienced less blood loss. This supports the claim that uterine artery catheterization and embolization is not needed in these cases.[17]

Reduction of transfusion of blood products in our study (from 85.4 to 53.9%) is correlated with broader utilization of thromboelastography (TEG/ROTEM) (from 35.0 to 65.4%). The use of this technology lessens the need for component replacement therapy and thereby reduces the risk of maternal morbidity of transfusion. Shamshirsaz et al[12] also switched to the use of this method in their program. The consistent use of the cell salvage likely contributed to the reduced need for transfusion as well.

Other studies have documented the association between reduced operating time and fewer postsurgical complications and this is demonstrated by our reduced blood loss and reduced need for transfusion as well as postsurgical complications. It is of particular note that a decrease in intentional cystotomy was seen with our model of care. We believe this result is most likely due to standardization within the urology group post intervention. Prior to intervention, there was a preference for intentional cystotomy especially in cases of percreta. After standardization of surgical technique, the preference was for intentional cystotomy only in cases when surgical dissection was not able to be performed due to concerns for increased maternal hemorrhage. Clinical ramifications include decreased need for indwelling catheters

Table 2 Maternal and infant outcomes for women with morbidly adherent placenta diagnosis ($n = 67$) before (2007–2014) and after implementation of a multidisciplinary program (2015–2017)

	2007–2014 ($n = 41$)	2015–2017 ($n = 26$)	*p*-Value
Diagnosis and delivery	%(*n*) or mean (SD)	%(*n*) or mean (SD)	
Delivery type, C-section			
Scheduled	75.6% (31)	69.2% (18)	0.566
Unscheduled	24.4% (10)	30.8% (8)	
Gestational weeks at delivery, mean(SD)	33.57 (2.99)	33.71 (2.91)	0.851
$24^{0/7}$–$29^{6/7}$ wk	12.2% (5)	11.5% (5)	0.676
$30^{0/7}$–$33^{6/7}$ wk	17.1% (7)	26.9% (7)	
$34^{0/7}$–$34^{6/7}$ wk	39.0% (16)	23.1% (6)	
$35^{0/7}$–$35^{6/7}$ wk	19.5% (8)	26.9% (7)	
$36^{0/7}$ wk £	12.2% (5)	11.5% (3)	
Maternal outcomes			
Operating time in minutes, mean (SD)	310.03 (132.53)	257.54 (72.42)	0.069
Bleeding (EBL) mL, mean (SD)	4,561.80 (4158.89)	2,879.04 (2129.13)	0.061
Bleeding (EBL) mL, [range]	[750, 22,000]	[675, 10,000]	
Transfusion of blood products during delivery	85.4% (35)	53.9% (14)	0.005
Cell saver transfusion during delivery	35.0% (14)	65.4% (17)	0.016
ICU admission	53.7% (22)	19.2% (5)	0.005
ICU length of stay in days, mean (SD)	1.78 (0.88)	2.20 (1.64)	0.427
Length of stay total in days, mean (SD)	5.41 (1.66)	5.31 (2.00)	0.813
Interventional radiology (any)	65.9% (27)	7.7% (2)	<0.001
Interventional radiology, iliac balloon	65.0% (26)	3.9% (1)	<0.001
Interventional radiology, embolization post	7.3% (3)	3.9% (1)	0.559
Type of hysterectomy			
Supracervical	7.3% (3)	11.5% (3)	0.555
Total	92.7% (41)	88.5% (23)	
Antenatal corticosteroid given	70.0% (28)	76.9% (20)	0.537
Surgical complications	**48.8% (20)**	**38.5% (10)**	**0.408**
Uterine rupture	0.0% (0)	0.0% (0)	
Cystotomy – intentional	34.2% (14)	7.7% (2)	
Cystotomy – unintentional	7.3% (3)	7.7% (2)	
Vascular injury	0.0% (0)	0.0% (0)	
Neurological injury	2.44% (1)	0.0% (0)	
Bladder resection	12.5% (5)	4.0% (1)	
Ureteral neocystotomy	2.4% (1)	3.9% (1)	
Intestinal injury	0.0% (0)	0.0% (0)	
Wound complications	7.3% (3)	16.0% (4)	0.412
Postoperative complications	**61.0% (25)**	**42.3% (11)**	**0.135**
Post-surgical hemorrhage	4.9% (2)	3.9% (1)	
Ileus bowel obstruction	29.3% (12)	11.5% (3)	
Inability to extubate post-surgery	37.5% (15)	19.2% (5)	
Fever	19.5% (8)	7.7% (2)	
Infection	17.1% (7)	15.4% (4)	
Thromboembolic	7.3% (3)	3.9% (1)	

(*Continued*)

Table 2 (*Continued*)

	2007–2014 (*n* = 41)	2015–2017 (*n* = 26)	*p*-Value
Acute kidney Injury	0.0% (0)	0.0% (0)	
Re-exploration	9.8% (4)	3.9% (1)	
Multiorgan failure	2.4% (1)	3.9% (1)	
Mortality	0.0% (0)	0.0% (0)	
Noninfectious adverse transfusion reactions	**24.4% (10)**	**7.7% (2)**	**0.108**
Disseminated intravascular coagulation	24.4% (10)	7.7% (2)	
Transfusion-associated circulatory overload	0.0% (0)	3.9% (1)	
Transfusion-related acute lung injury	0.0% (0)	3.9% (1)	
	2007–2014	**2015–2017**	
Infant outcomes[a]	**(*n* = 43)**	**(*n* = 26)**	***p*-Value**
Birth outcome			
Live birth	95.3% (41)	100.0% (26)	0.523
Fetal death	4.7% (2)	0.0% (0)	
Outcomes among live births	**(*n* = 41)**	**(*n* = 26)**	
Apgar 1-minute score, mean (SD)	6.55 (2.10)	6.80 (1.91)	0.631
< 7	37.5% (15)	32.0% (8)	0.652
7–10	62.5% (25)	68.0% (17)	
Apgar 5-minute score, mean (SD)	8.13 (1.34)	7.69 (1.69)	0.253
< 7	7.5% (3)	15.4% (4)	0.420
7–10	92.5% (37)	84.6% (22)	
Birthweight in grams, mean (SD)	2285.06 (668.71)	2303.74 (656.92)	0.912
< 2,500 g	59.0% (23)	57.7% (15)	0.918
2,500 + g	41.0% (16)	42.3% (11)	
NICU or SCN admission	87.8% (36)	92.3% (24)	0.697

Abbreviations: C-section, cesarean section; EBL, estimated blood loss; ICU, intensive care unit; NICU, neonatal intensive care unit; SCN, special care nursey.
[a]infant outcomes are calculated among all fetuses in the study pregnancies (*n* = 2 twin, *n* = 65 singleton pregnancies).

and bladder complications. Interestingly, cystotomy varied between other models evaluated. Al-Khan et al report no use of cystotomy but dissection of the bladder from the uterine serosa in most percreta and increta cases.[5] The Baylor team reported an increase in cystotomy, and in fact describe their new protocol as including intentional cystotomy for more severe cases.[12]

Our finding of no differences in neonatal outcomes was also similar to other studies.[5,12,14,16] Little improvement in neonatal outcomes may be the expected outcome with these models given the necessity of early delivery.

Of prior studies of similar programs at single centers, three were at academic centers,[5,12,18] one was a hospital with an OBGYN residency program within a private health system,[14] and two were in a single site private community-based hospital.[13,16] The context of the PAS program described here is most similar to that of this last program,[13] as our site has no academic affiliation. Our findings of improved outcomes demonstrate the ability of a community-based health system to implement a PAS program as effective as those demonstrated in the context of academic centers. All of the patients reported in this study did not wish to retain future fertility and therefore were treated definitively with hysterectomy at the time of delivery which is consistent with the recommended standard of care.[19] Less invasive treatment options are available for patients who wish to retain future fertility. Various techniques of uterine sparing surgery including uterine resection with reconstruction and expectant management with the placenta left in situ have been successful in some cases.[20,21] Despite reported success of these conservative techniques, they are not without risk of morbidity to the mother.[22] Our study focused on outcomes for patients with histologically confirmed PAS. Patients who elected for conservative management were excluded as there was no histologic diagnosis of PAS in those cases which made it difficult to draw any conclusions from the outcomes of those specific cases in this study.

Strengths and Limitations

Our study has several strengths and limitations that should be considered in the interpretation of findings. The requirement for pathologic confirmation is a strength of the study

ensuring we focused on confirmed PAS cases, and those at highest risk for severe outcomes. Additionally, our study includes data from a private multi-hospital system which serves a broad socio-economic spectrum. It may be important to note that variability in findings could be associated with variation in inclusion criteria across studies of PAS[6,7,23] such as inclusion of focal cases of accreta not requiring hysterectomy.[5] The pre-post observational model includes risk of confounders. However, implementation of a randomized control trial to test a multidisciplinary model is unrealistic given the rarity of the condition and often the requirement for emergent surgeries of the patients involved. The smaller sample size may have limited the ability to detect significant differences for some outcomes (i.e., cost and cystotomy).

Despite the limitations of this study, our findings indicate that a PAS program directed by MFM specialists in the context of a non-academic setting has the potential to decrease morbidity and decrease costs of treatment.

Disclosure of Interest

None declared.

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Appendix. Description of diagnostic, delivery planning, preoperative, and intraoperative technique standards for the PAS program

Diagnosis

Patients with risk factors or concern for PAS on prior ultrasound are evaluated in the maternal–fetal medicine clinic at 20 weeks for level two ultrasound and transvaginal imaging. If ultrasound findings are consistent with PAS, follow-up transabdominal and transvaginal ultrasounds are performed at 28 weeks and 32 weeks to assess placentation for surgical planning.

Delivery planning

Patients with placenta previa and placenta accreta spectrum without antepartum complications: plan for delivery at 34 weeks gestation. Patients with placenta previa and suspected placenta percreta with a cervical measurement less than 2.5 cm, plan for delivery at 32 weeks. Patients with bladder invasion and hematuria, plan delivery at 28 weeks. Patients with accreta without evidence of placenta previa, plan for delivery at 36 weeks gestation with individualization based on history.

Surgical Approach

Ureteric stents were placed prior to surgery in the majority of cases. The use of uterine artery (iliac) balloons was not advised as part of the treatment of PAS under the protocol after 2015 given risks identified in the literature[16] and the high degree of collateral uterine blood flow noted in pregnancy. The Ligasure bipolar cautery device is used for hemostasis, and thromboelastography (TEG) is used to guide transfusion. Vascular pedicles were tied, while Ligasure was used for dissection and ligation. Intentional cystotomies, uterine artery catheters, and postoperative ICU care are individualized based on intraoperative findings but are not standard. When used, uterine artery catheters were placed through the femoral artery. They were placed only when imaging suggested severe PAS with increta or percreta. In addition cell salvage was available for all surgeries and broadly used as part of our program. The placenta was allowed to deliver spontaneously through the incision, if it did not, then for those cases with minimal invasion based on imaging, a gentle attempt to remove the placenta was made.

Surgical approach was by modified radical hysterectomy (MRH) which included mobilization of the ureters and exposure of the iliac vessels bilaterally. Pedicle division and hemostasis are achieved with large bipolar cautery device (Ligasure; Covidien, Mansfield, MA). In addition, ovaries are preserved and bilateral salpingectomy is performed. In most cases, total hysterectomy is performed, however, there are few cases in which supracervical hysterectomy is required due to bleeding concerns or adhesive disease between the bladder and cervix.

Initial fluid therapy with colloid (5% albumin/single dose 500 mL) was given prior to the cesarean hysterectomy to facilitate acute volume expansion given that this reduces intraoperative crystalloid requirements and facilitates hemodilution prior to hemorrhage.[17] MTP was utilized in 1:1:1 (PRBC: FFP: PLT) ratio as well as Cell Salvage (Cell Saver) to reduce PRBC transfusion requirements. Serum electrolytes were assessed frequently (K^{+}/Ca^{2+}). Laboratory profiles are obtained that include ABG, Hgb/Hct, serum lytes, INR, partial thromboplastin time [PTT], fibrinogen, platelets, Mg^{2+} by the attending anesthesia team every 30 minutes or more often as patient hemodynamics indicate. Thromboelastography (TEG)/ROTEM was utilized to more precisely guide transfusion therapy to target specific factor deficiencies. Goals for resuscitation were: mean arterial pressure (MAP)[3] 65 mm Hg, systolic arterial pressure 80 to 100 mm Hg, Hgb 7 to 9 g/dL, INR $<$1.5; activated partial thromboplastin time $<$42 seconds, fibrinogen $>$150 to 200 mg%, platelets $>$50k, pH 7.35 to 7.45, core temp $>$35°C, base deficit $<$3.0/lactate $<$2 mEq/L.[18]

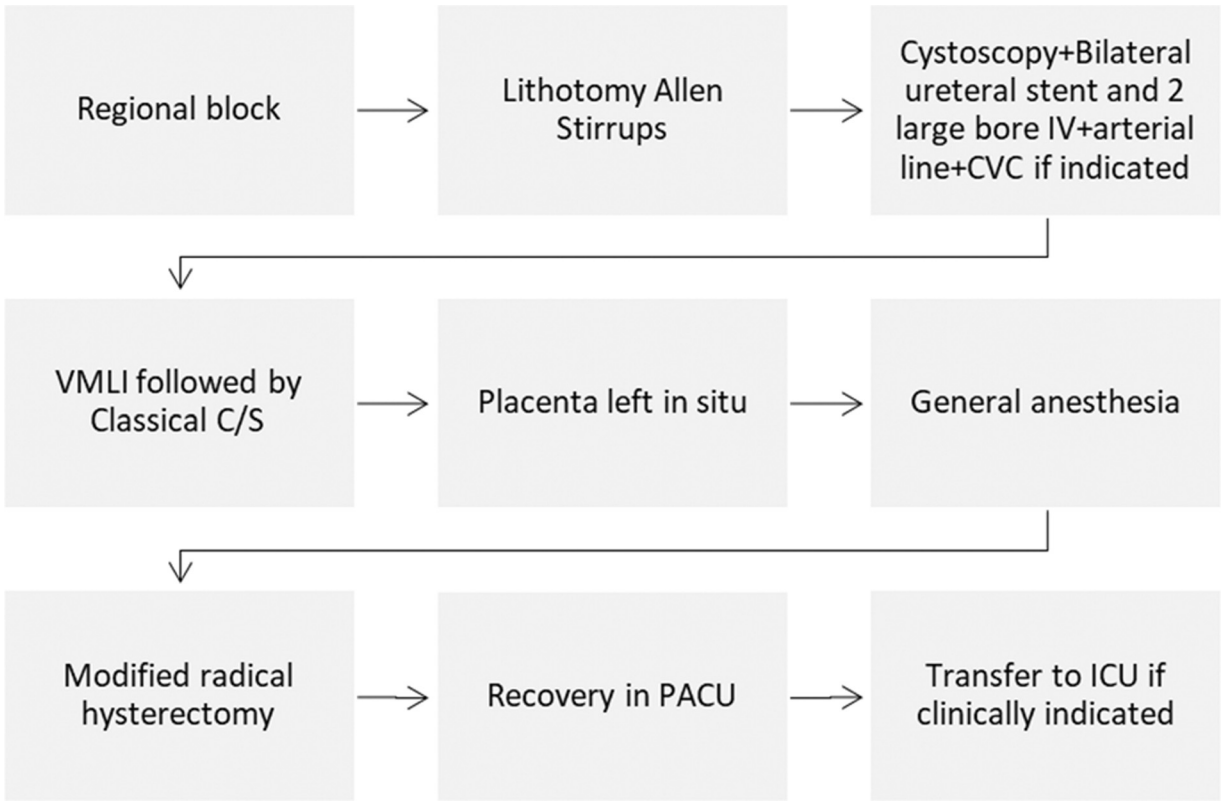

Fig. A1 Standardized operating room management.

