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Evaluation of perioperative complications using a newly described staging system for placenta accreta spectrum

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Francesco D'Antonio; Amarnath Bhide; Christoph Lees

Abstract: Introduction

The antenatal diagnosis of placenta accreta spectrum (PAS) is in large
part subjective and based on expert interpretation. The aim of this study
was to externally evaluate a recently developed staging system based on
specific and defined prenatal ultrasound (US) features in a cohort of
women at risk of PAS undergoing specialist prenatal US, in particular
relating to surgical morbidity at delivery.

Materials and Methods

Database study of cases with confirmed placenta previa. In all, the
placenta was evaluated in a systematic fashion. PAS was subclassified in
PAS0-PAS3 according to the loss of clear zone, placental lacunae, bladder
wall interruption, uterovesical hypervascularity and increased
vasculature in the parametrial region.

Results

43 cases were included, of whom 33 had major placenta previa. 31 cases
were categorized as PAS0; 3, 4 and 5 cases as PAS1, PAS2 and PAS3,
respectively. All women underwent caesarean section and hysterectomy was
required in 10. The comparison of the perinatal outcomes among the PAS
categories yielded greater operative time (50 (35-129) minutes for PAS0
vs 70 (48-120) for PAS1 vs 95 (60-150) for PAS2 vs 100 (87-180) for PAS3,
 $p < 0.001$) and estimated blood loss (800 (500-2500) mls for PAS0 vs 3500
(800-7500) for PAS1 vs 2850 (500-7500) for PAS2 vs 6000 (2500-11000) for
PAS3, $p < 0.001$) for the highest PAS categories, which were also associated
with a higher rate of hysterectomy ($p < 0.001$), blood transfusion ($p = 0.002$)
and admission to ITU or HDU ($p < 0.001$) and longer postoperative admission
of 3 (1-9) days for PAS0 vs 3 (2-12) for PAS1 vs 4.5 (3-6) for PAS2 vs 5
(3-22) for PAS3, $p = 0.02$.

Conclusion

Perioperative complications are closely associated with PAS stage. This information is useful for counselling women and may be important in allocating staff and infrastructure resources at the time of delivery.

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To the Editor in Chief

European Journal of Obstetrics & Gynecology and Reproductive Biology

Professor Janesh Gupta

London, 02.03.2020

Dear Professor Gupta,

We are submitting the manuscript entitled **“Evaluation of perioperative complications using a newly described staging system for placenta accreta spectrum.”** for consideration of publication in the European Journal of Obstetrics & Gynecology and Reproductive Biology.

Prenatal ultrasound is currently considered the primary tool for the antenatal diagnosis and characterization of the placenta accreta spectrum (PAS) disorders. Its predictive value to diagnose and classify PAS is mostly considered dependent upon the extent of the placental invasion, however a wide variation in the clinical course of women presenting with the same degree of placental invasion has been reported. The ultrasound-based PAS staging system was first described in 2019 and suggested for the antenatal risk stratification of surgical outcome. In this study we aimed to externally evaluate the PAS staging system by evaluating the perioperative outcomes of a selected cohort of women at risk of PAS submitted to expert prenatal ultrasound and delivered at a large UK maternity unit.

To our knowledge this is the first study conducted to externally evaluate a recently proposed staging system correlating prenatal US and perioperative outcomes in women with placenta previa, and our work has confirmed that the PAS scoring system performs well when applied to a cohort of women at risk of PAS undergoing prenatal US at single referral Unit. We believe our data will inform management and meaningfully assists clinicians in allocating staff and infrastructure resources at the time of delivery.

This work has entailed the retrospective analysis of fully anonymized data for women undergoing routine clinical care and does not require ethics evaluation. This manuscript describes original work and is not under consideration by any other journal. All authors approved the manuscript and this submission.

Data from this research was presented as Oral Presentation at the 29th World Congress on Ultrasound in Obstetrics and Gynecology.

We hope the manuscript is of sufficient interest for it to be considered for peer review, thank you in advance for your consideration.

Yours sincerely,

Andrea Dall'Asta

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TITLE PAGE

Evaluation of perioperative complications using a newly described staging system for placenta accreta spectrum.

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Abstract

Introduction

The antenatal diagnosis of placenta accreta spectrum (PAS) is in large part subjective and based on expert interpretation. The aim of this study was to externally evaluate a recently developed staging system based on specific and defined prenatal ultrasound (US) features in a cohort of women at risk of PAS undergoing specialist prenatal US, in particular relating to surgical morbidity at delivery.

Materials and Methods

Database study of cases with confirmed placenta previa. In all, the placenta was evaluated in a systematic fashion. PAS was subclassified in PAS0-PAS3 according to the loss of clear zone, placental lacunae, bladder wall interruption, uterovesical hypervascularity and increased vascularity in the parametrial region.

Results

43 cases were included, of whom 33 had major placenta previa. 31 cases were categorized as PAS0; 3, 4 and 5 cases as PAS1, PAS2 and PAS3, respectively. All women underwent caesarean section and hysterectomy was required in 10. The comparison of the perinatal outcomes among the PAS categories yielded greater operative time (50 (35–129) minutes for PAS0 vs 70 (48–120) for PAS1 vs 95 (60–150) for PAS2 vs 100 (87–180) for PAS3, $p < 0.001$) and estimated blood loss (800 (500–2500) mls for PAS0 vs 3500 (800–7500) for PAS1 vs 2850 (500–7500) for PAS2 vs 6000 (2500–11000) for PAS3, $p < 0.001$) for the highest PAS categories, which were also associated with a higher rate of hysterectomy ($p < 0.001$), blood transfusion ($p = 0.002$) and admission to ITU or HDU

1 (p<0.001) and longer postoperative admission of 3 (1–9) days for PAS0 vs 3 (2–12) for PAS1 vs 4.5
2 (3–6) for PAS2 vs 5 (3–22) for PAS3, p=0.02.
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6 **Conclusion**

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10 Perioperative complications are closely associated with PAS stage. This information is useful for
11 counselling women and may be important in allocating staff and infrastructure resources at the
12 time of delivery.
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19 **Keywords:** abnormally invasive placenta, morbidly adherent placenta, caesarean hysterectomy,
20 low-lying placenta, bladder invasion.
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29 **Abbreviations:**

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- 33 - PAS: placenta accreta spectrum;
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- 35 - US: ultrasound;
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- 38 - CS: caesarean section;
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- 41 - MRI: magnetic resonance imaging;
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- 43 - EBL: estimated blood loss;
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- 45 - FFP: fresh frozen plasma;
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- 47 - ICU: intensive care unit;
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- 49 - HDU: high-dependence unit.
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Introduction

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4 Placenta accreta spectrum (PAS) encompasses different conditions characterised by an abnormal
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6 adherence or abnormal invasion of trophoblastic tissue into the myometrium[1]. Within the
7
8 limitation of the extremely heterogeneous definitions, placenta accreta is a general term used to
9
10 describe the situation when part of the placenta, or the entire placenta, invades the uterine wall
11
12 and is inseparable from it[1-2], while placenta increta and percreta represent more specific
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14 definitions of abnormal trophoblastic invasion involving only the myometrium or both the
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16 myometrium and the serosa, occasionally deeper into adjacent organs, respectively[3]. The
17
18 incidence of PAS has progressively risen over recent decades, mainly due to the increasing
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20 caesarean section (CS) rates and the higher incidence of placenta praevia[3,4].
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28 PAS disorders may be associated with life-threatening postpartum haemorrhage with the need for
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30 peripartum hysterectomy[5]. The diagnosis may become clinically evident only after the delivery
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32 of the fetus, when attempts to remove the placenta may result in severe uterine bleeding,
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34 however the antenatal diagnosis of PAS has proved to be effective in reducing the risks associated
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36 with the condition[6-8]. Furthermore, accurate evaluation of the depth of invasion of the
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38 myometrium has been suggested to be of clinical importance as this is used to anticipate the need
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40 to ensure the availability of different interventions such as vascular surgical expertise,
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42 interventional radiology, intensive care and massive transfusion facilities[9].
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50 Ultrasound (US) with the adjunct of Colour and/or Power Doppler technique is currently
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52 considered the primary tool for the antenatal diagnosis of PAS[10-12], most commonly in the
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54 second and third trimester, with magnetic resonance imaging (MRI) being a complementary
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56 method for the assessment of those cases where US is not conclusive[3,13].
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1 The predictive value of prenatal US ultrasound to diagnose and classify PAS is dependent upon
2 several factors, which include operator experience, gestational age at assessment and degree of
3 placental invasion[4,14,15]. However, although the depth of invasion represents one of the major
4 determinants of the surgical outcome in PAS, a wide variation in the clinical course of women
5 presenting with the same degree of placental invasion has been reported[8,16]. In 2019 a staging
6 system based on prenatal US findings was suggested for the antenatal risk stratification of surgical
7 outcome[16]. The aim of this study was to externally evaluate the PAS US staging system by
8 evaluating the perioperative outcomes of a selected cohort of women at risk of PAS submitted to
9 expert prenatal ultrasound and delivered at a large UK maternity unit.
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Methods

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4 This was a database study conducted at a referral Fetal Medicine unit between 2014 and 2018. For
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6 the purposes of the study all cases referred for expert prenatal sonographic evaluation due to the
7
8 finding of low-lying placenta at screening ultrasound were retrieved, however only those with
9
10 confirmed placenta previa were considered eligible. Once cases were identified from the medical
11
12 database used for routine clinical care (Astraia Software GmbH, Munich, Germany), review of
13
14 electronic ultrasound records or stored ultrasound data and, where appropriate, case notes was
15
16 undertaken. Placenta previa was defined based on the ultrasound demonstration of the lower
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18 placental edge either covering the internal cervical os or in close proximity (less than 2 cm) [3]
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20 within 7 days from the actual date of delivery or beyond 34 weeks of gestation.
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28 At our unit all the scans were performed as per local protocol, in cases at risk for PAS the placental
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30 tissue was evaluated in a systematic fashion using two-dimensional (2D) transabdominal gray scale
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32 US combined with Color and/or Power Doppler with the maternal bladder part full as
33
34 recommended[17] in order to clearly visualize the serosa-bladder interface with careful attention
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36 paid to homogeneity and echogenicity patterns of the placenta and interruption of the
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38 hyperechoic surface between the uterine serosa and bladder wall, then colour and/or power
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40 Doppler was applied to map the intraplacental and subplacental vascularization, the uterine
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42 serosa-bladder interface and the inferior part of the lower uterine segment together with the
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44 parametrial region[18,19]. Transabdominal three-dimensional (3D) ultrasound together with
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46 color/power Doppler was performed at discretion of the Fetal Medicine consultant based upon
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48 clinical and sonographic findings. Similarly, prenatal magnetic resonance imaging (MRI) was
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50 performed at discretion of the examiner of after multidisciplinary team discussion in order to
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52 complement the antenatal imaging findings[20].
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5 As per the purpose of the study, the US pictures together with the report of last US examination
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9 prior to delivery were retrieved for all the included cases and assessed in order to evaluate the
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As per the purpose of the study, the US pictures together with the report of last US examination prior to delivery were retrieved for all the included cases and assessed in order to evaluate the previously reported ultrasound signs[3]:

1. Loss of clear zone, defined as a loss, or irregularity, of hypoechoic plane in myometrium underneath placental bed ('clear zone').
2. Placental lacunae, defined as the presence of numerous lacunae, often containing turbulent flow visible on gray scale or Color Doppler ultrasound.
3. Bladder wall interruption, defined as loss or interruption of bright bladder wall (hyperechoic band or 'line' between uterine serosa and bladder lumen).
4. Uterovesical hypervascularity, defined as striking amount of Color Doppler signal seen between myometrium and posterior wall of bladder, including vessels appearing to extend from placenta, across myometrium and beyond serosa into bladder or other organs; often running perpendicular to myometrium.
5. Increased vascularity in the parametrial region, defined as the presence of hypervascularity extending beyond the lateral uterine walls and involving the region of the parametria.

Within our cohort of women with placenta previa, these parameters were used to classify PAS as previously described[16]:

PAS0: Placenta previa with no US signs of invasion or placenta previa with placental lacunae but no evidence of abnormal uterine-bladder interface (loss of the clear zone and/or bladder wall interruption).

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PAS1: Presence of at least two ultrasound signs among:

- Placental lacunae
- Loss of the clear zone
- Bladder wall interruption

PAS2: PAS1 + uterovesical hypervascularity

PAS3: PAS1/PAS2 + evidence of increased vascularity in the inferior part of the lower uterine segment extending in the parametrial region.

The doctors undertaking the ultrasound review and PAS scoring (AD, GP) had no knowledge of the outcome of the delivery, details of which were stored separately to the fetal medicine reports and were not accessed.

As per routine clinical practice in cases of placenta previa, all women underwent planned caesarean section. The decision as to whether to plan caesarean hysterectomy was at discretion of the lead clinician based upon antenatal clinical and imaging findings, while emergency hysterectomy was undertaken in the case of uncontrolled bleeding during caesarean section. Postnatal ascertainment of placenta accreta, increta or percreta was confirmed either intraoperatively or at pathology reports from placental or hysterectomy specimens. Operative and postoperative outcomes and additional postoperative information including the surgical outcome, the intraoperative estimated blood loss (EBL), the operative times, the need of transfusion of blood products, fresh frozen plasma (FFP), platelets and/or cryoprecipitate, the postoperative transfer to intensive care unit (ICU) or high-dependence unit (HDU) and the length of hospital admission following surgery were retrieved from the hospital clinical database (CERNER, US Cerner Health Facts®, Cerner Corp., Kansas City, MO).

1 For this study, research ethics approval was not required as all cases were routinely and
2 retrospectively collected and datasets were fully anonymized prior to analysis, and the data
3 collection was registered with the audit department.
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8 Statistical data analysis was performed with IBM SPSS Statistics v. 20.0 (IBM, Armonk, NY, USA).
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10 Outcome frequencies were calculated and compared across the groups with the Chi-square and
11 the Kruskal–Wallis test. We considered $p < 0.05$ as statistically significant. This study was reported
12 according to the STROBE guidelines[21].
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Results

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4 Overall, 43 cases were included for data analysis, among whom 33 with major placenta previa. The
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6 demographic features of the included cases are summarized in Table 1. The study population
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8 consisted in 27 non-nulliparous women who all but four had a history of previous hysterotomy,
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10 most commonly for caesarean section. The placental location was anterior in 23 cases. After the
11
12 evaluation of the sonographic data, 31 cases were categorized as PAS0, while PAS1, PAS2 and
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14 PAS3 accounted for 3, 4 and 5 cases, respectively. Antenatal MRI was performed in 7 cases
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16 without adding any additional information.
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23 Delivery outcomes are summarized in Table 2. All women underwent caesarean section, which
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25 was performed in an emergency setting in 23 cases (53.5%). All the included women had an EBL
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27 equal to or above 500 mls and 22/43 (51.2%) above 1000 mls. Hysterectomy was performed in 10
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29 women (total hysterectomy in 7 patients; subtotal hysterectomy in 3). In 3/10 cases the
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31 histopathological diagnosis was partially or not consistent with the antenatal US findings. In one
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33 case the placenta was left in situ following the delivery of the fetus with successful haemostasis
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36 (Table 3).
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42 The comparison of the perinatal outcomes among the PAS categories showed greater operative
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44 time (50 (35 – 129) for PAS0 vs 70 (48 – 120) for PAS1 vs 95 (60 – 150) for PAS2 vs 100 (87 – 180) for PAS3,
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46 $p < 0.001$) and estimated blood loss (800 (500 – 2500) for PAS0 vs 3500 (800 – 7500) for PAS1 vs 2850 (500
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48 – 7500) for PAS2 vs 6000 (2500 – 11000) for PAS3, $p < 0.001$) for the highest PAS categories, which were
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50 also associated with a higher rate of hysterectomy (3.2% for PAS0 vs 33.3% for PAS1 vs 75.0% for PAS2
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52 vs 100% for PAS3, $p < 0.001$), intraoperative or postoperative transfusion (22.6% for PAS0 vs 66.7% for
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54 PAS1 vs 75.0% for PAS2 vs 100% for PAS3, $p = 0.002$), post-surgical admission to ITU or HDU (29% for
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56 PAS0 vs 66.7% for PAS1 vs 100% for PAS2 and PAS3, $p < 0.001$) and longer postoperative admission
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(3 (1 – 9) for PAS0 vs 3 (2 – 12) for PAS1 vs 4.5 (3 – 6) for PAS2 vs 5 (3 – 22) for PAS3, $p=0.02$) (Table 4, Figures 1 and 2). No difference was found in the gestational age at delivery and in the incidence of emergency caesarean section within the PAS categories.

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Discussion

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4 The findings from this single centre study suggest that the recently proposed PAS classification
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6 system allows for risk-stratification of adverse perinatal outcomes within a population of women
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8 at risk of PAS. More specifically, the degree of severity of the placental invasion according to
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10 prenatal US findings and the scoring system was closely associated with perioperative outcomes,
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12 the incidence of adverse outcomes was higher the more advanced was the PAS category.
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16 Over the last two decades, advances in antenatal US imaging have allowed improved detection
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18 and characterization of the abnormalities of the placental invasion, whose features are
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20 summarized in the recently published recommendations of the International Federation of
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22 Gynecology and Obstetrics[1]. While these qualitative descriptions are both valid and useful, they
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24 do not allow to a clinician to draw any inferences of US findings in relation to the clinical outcomes
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26 that are of importance to patients. This information is essential for clinical management and
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28 counselling, and it is this we have successfully achieved using the PAS system and relating it to
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30 postnatal outcomes.
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34 Previous attempts to classify PAS disorders based on prenatal US findings proved to be effective in
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36 predicting the severity of PAS when related to intraoperative or pathology findings[22-24]. It is
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38 important to note, however, that the depth of the placental invasion does not represent the only
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40 determinant of the perioperative outcome in women at risk of PAS as this may vary even in cases
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42 with similar/comparable depth of the placental invasion.
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46 To our knowledge there is very limited data on the correlation between antenatal US findings and
47
48 perioperative outcomes. Only the study by Cali et al., which contained the first description of the
49
50 PAS scoring methodology, demonstrated increased EBL, operative times and hospital stay as well
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52 as an increased need for transfusion, surgical complications and transfer to ICU in women with
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54 higher PAS category[16]. The reported blood loss and number of red blood cell units transfused
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1 vary greatly between different studies probably because of the non-standardisation of the case
2 descriptions, different local transfusion policies and method of estimating of the intraoperative
3 the blood loss. We report greater EBL and total number of units of blood transfused than the
4 study by Calì et al.[16] in which the PAS scoring system was described, however these data fall
5 within the ranges outlined in cohorts reported by Marcellin et al.[25] and by Pinto et al.[26],
6 especially in relation to EBL at caesarean hysterectomy. It is important to note, however, that such
7 quantitative outcomes have been reported to be less when electively planned[27] but vary widely
8 across different centres and series[25,26].
9

10 We confirm that the PAS scoring system performs well when applied to a cohort of women at risk
11 of PAS undergoing prenatal US at single referral Unit. More specifically, within our population the
12 severity of the PAS US stage was positively associated with the EBL, the operative time and the
13 postoperative admission and the frequency of transfusion of blood products, need for
14 hysterectomy and transfer to HDU or ITU following delivery were higher in the more severe PAS
15 categories. Of the 43 women who underwent US staging 10 had hysterectomies, in 7 cases PAS
16 was suspected and histopathological analysis subsequently confirmed the diagnosis on
17 hysterectomy specimens. In 3 cases the antenatal US diagnosis and histopathological analysis did
18 not fully concur. In one of these, PAS was not suspected but was found at histopathology, and in
19 another PAS was suspected but not confirmed on histology. Of note, both these cases were
20 characterized by oligohydramnios making US imaging difficult. We hypothesize that for optimal
21 imaging normal amniotic fluid is required and preferably a partially full maternal bladder to
22 visualize the myometrium and the bladder mucosa. The third case in which the antenatal US was
23 not usefully predictive was a placenta previa major with suspected PAS through the posterior
24 lower uterine segment, and hysterectomy was performed due to uterine atony not responsive to
25 conservative manoeuvres.
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1 On the other hand, if we assume that PAS>0 is suggestive of PAS, it should be noted that one
2 quarter of these women did not require hysterectomy. It is therefore important not to assume
3 that a diagnosis of PAS inevitably needs hysterectomy. With the development of techniques such
4 as interventional radiology[28,29] and the as yet experimental technique of placental bed
5 excision[30], it may be that planned hysterectomy is reserved only for cases of placenta percreta.
6
7 Our strong impression is that in most cases of PAS, the area of abnormal placental invasion is
8 localized, hence the diagnosis of the condition as either present or not may mask the subtlety of
9 diagnosis, where a placenta with only a small patch of adherence may appear normal on prenatal
10 US and lead to minimal surgical complications, but the same degree of placental invasion covering
11 a larger area would be diagnosed fulfilling the criteria for the condition. The issue of quantification
12 as opposed to qualitative appearance of placenta on US has not been considered before and is a
13 topic worthy of further study.
14

15 To our knowledge this is the first study conducted to externally evaluate a recently proposed
16 staging system correlating prenatal US and perioperative outcomes in women with placenta
17 previa. We show a correlation between US findings and clinical outcomes with perioperative
18 complications being closely associated with the PAS stage. This represents a major strength of the
19 study as all cases were managed by the same practitioners according to the standardized internal
20 protocol. However, the retrospective design is a limitation of the study, requiring in this case the
21 retrospective categorization of PAS group. It is yet to be evaluated whether the clinical
22 implementation of the PAS scoring system is effective in optimizing the management of women at
23 risk for PAS.
24

25 In conclusion, in this first study to externally evaluate the recently proposed PAS scoring system
26 starting from the retrospective analysis of US images we find that perioperative complications are
27 closely associated with the PAS stage. Further prospective studies will determine whether the
28

clinical implementation of the PAS scoring system is of value in surgical planning and improving
the outcomes of women affected by PAS disorder.

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Table 1 – Demographic features and sonographic findings in the included cases at last scan.

Maternal age (years) Median (range)	34 (20 – 44)
Parity n (%)	Nulliparae 16 (37.2%) Primiparae 10 (23.3%) Higher order multiparae 17 (39.5%)
Previous uterine surgery n (%)	No 20 (46.5%) CS x1 9 (20.9%) CS x2 6 (14.0%) CS x3 6 (14.0%) CS x4 1 (2.3%) Hysterotomy for RPOC 1 (2.3)
Gestational age at last scan (weeks^{+days}) Median (range)	33 ⁺² (24 ⁺⁶ – 36 ⁺⁴)
Placental location n (%)	Anterior 23 (53.5%) Bilobed 1 (2.3%) Posterior 19 (44.2%)
UtA PI percentile Median (range) n=10	5 (1 – 60)
Placental lacunae n (%)	Yes 14 (32.6%)
Loss of clear zone n (%)	Yes 12 (27.9%)
Bladder wall interruption n (%)	Yes 9 (20.9%)
Uterovesical hypervascularity n (%)	Yes 9 (20.9%)
Increased vascularity in the parametrial region n (%)	Yes 6 (14.0%)
Additional US findings n (%)	IUGR 4 (9.3%) Multiple fibroids 1 (2.3%)
Antenatal MRI n (%)	Yes 7 (16.3%)

Data presented as number (%) or as median (range)

n=43 unless otherwise stated

CS: caesarean section

RPOC: retained products of conception

PAS: placenta accreta spectrum

UtA PI: uterine artery pulsatility index

IUGR: intrauterine growth restriction

MRI: magnetic resonance imaging

Table 2 – Perioperative outcomes of the included cases.

Gestational age at delivery (weeks^{+days}) Median (range)	36 ⁺¹ (25 ⁺⁶ – 39 ⁺⁰)
Mode of delivery n (%)	EICS 20 (46.5%) EmCS CAT1 2 (4.7%) EmCS CAT2 9 (20.9%) EmCS CAT3 12 (27.9%)
Estimated blood loss (mL) Median (range)	1000 (500 – 11000)
Hysterectomy n (%)	Yes, total 7 (16.3%) Yes, subtotal 3 (7.0%)
Surgical complications n (%)	Uterine atony conservative management 2 (4.7%) Urinary tract injury 3 (7.0%) Need for relaparotomy 2 (4.7%) Placenta left in situ 1 (2.3%)
Operative time Median (range)	56 (35 – 180)
Blood transfusion n (%)	Yes 17 (39.5%)
Preoperative Hb Median (range)	114 (102 – 139)
Postoperative Hb Median (range)	102 (76 – 134)
Delta Hb Median (range)	11 (0 – 38)
Postoperative admission n (%)	ICU 4 (9.3%) HDU 16 (37.2%) Recovery 23 (53.5%)
Length of postoperative admission Median (range)	3 (1 -22)

Data presented as number (%) or as median (range)

n=43 unless otherwise stated

EICS: elective caesarean section

EmCS: emergency caesarean section

CAT1: category 1; CAT2: category 2; CAT3: category 3

Hb: haemoglobin

ICU: intensive care unit

HDU: high dependence unit

Table 3 – Histopathological findings in women undergoing hysterectomy in relation to placenta accreta spectrum (PAS) group.

Case N	PAS category	Intraoperative findings	Histopathology
1	PAS 2	Placenta percreta through bladder serosa at superior aspect of bladder. Abnormal vasculature seen through parametrium and into right broad ligament.	Intraoperative findings confirmed
2	PAS 1	Placenta adherent to lower segment, percreta on the left side of the lower segment and over uterovesicle peritoneum. Partial removal of the placenta.	Intraoperative findings confirmed
3	PAS 3 – PPROM + oligohydramnios	Abruption/partially accreta.	PAS excluded
4	PAS 0 - oligohydramnios	Placenta percreta.	Intraoperative findings confirmed
5	PAS 3	Placenta accreta.	Placenta increta
6	PAS 2	Placenta morbidly adherent posteriorly and to right lateral wall.	Intraoperative findings confirmed
7	PAS 3	Placenta increta left in situ.	Intraoperative findings confirmed
8	PAS 3	Placenta infiltrating the posterior bladder serosa and the uterine posterior and left lateral lower segment.	Intraoperative findings confirmed
9	PAS 2	Placenta accreta (“did not separate”).	PAS confirmed
10	PAS 3	Placenta partially adherent posteriorly to very thin lower segment. Placenta largely detached after Syntometrine and removed. Then atony.	PAS excluded

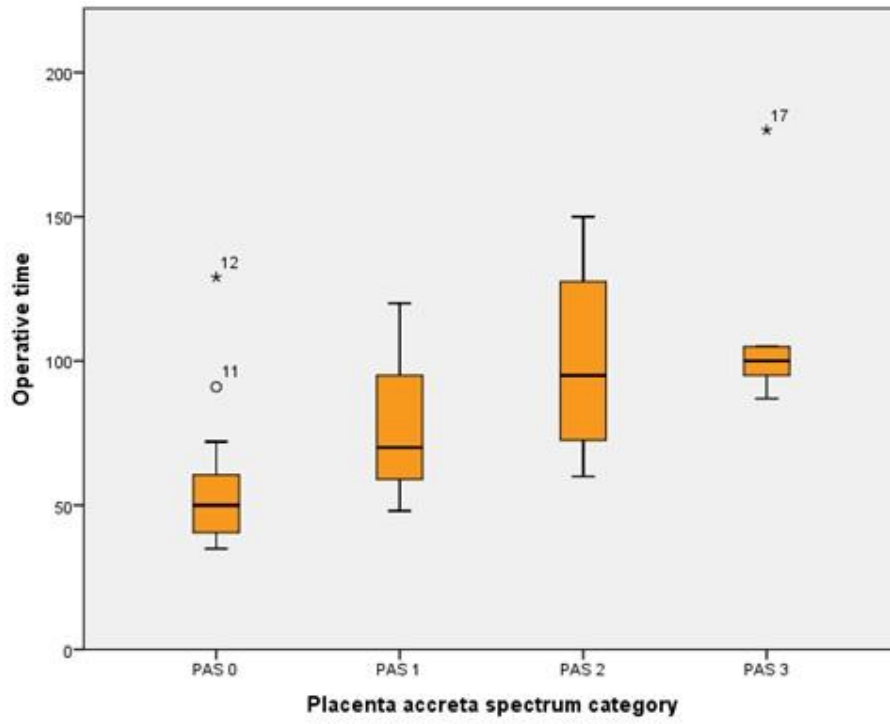
Table 4 – Perioperative outcomes of the included cases according to the placenta accreta spectrum (PAS) category.

	PAS 0 n=31	PAS 1 n=3	PAS 2 n=4	PAS 3 n=5	p
Gestational age at delivery (weeks⁺days⁻) Median (range)	37 ⁺⁰ (26 ⁺³ – 39 ⁺⁰)	33 ⁺⁵ (31 ⁺⁵ – 37 ⁺⁰)	33 ⁺⁴ (25 ⁺⁶ – 36 ⁺⁴)	34 ⁺¹ (33 ⁺⁰ – 36 ⁺⁵)	0.11
Mode of delivery n (%)	EICS 15 (48.4%) EmCS CAT1 0 (0.0%) EmCS CAT2 8 (25.8%) EmCS CAT3 8 (25.8%)	EICS 1 (33.3%) EmCS CAT1 1 (33.3%) EmCS CAT2 0 (0.0%) EmCS CAT3 1 (33.3%)	EICS 2 (50.0%) EmCS CAT1 0 (0.0%) EmCS CAT2 1 (25.0%) EmCS CAT3 1 (25.0%)	EICS 2 (40.0%) EmCS CAT1 1 (20.0%) EmCS CAT2 0 (0.0%) EmCS CAT3 2 (40.0%)	0.21
Estimated blood loss (mL) Median (range)	800 (500 – 2500)	3500 (800 – 7500)	2850 (500 – 7500)	6000 (2500 – 11000)	0.001
Hysterectomy n (%)	1 (3.2%)	1 (33.3%)	3 (75.0%)	5 (100%)	<0.001
Operative time (mins) Median (range)	50 (35 – 129)	70 (48 – 120)	95 (60 – 150)	100 (87 – 180)	0.001
Blood transfusion n (%)	7 (22.6%)	2 (66.7%)	3 (75.0%)	5 (100%)	0.002
Packed cells, units Median (range)	2 (2 – 6)	5.5 (4 – 7)	7 (5 – 10)	10 (4 – 13)	0.02
Platelets, units Median (range)	-	0.5 (0 – 1)	1 (0 – 2)	2 (0 – 2)	0.04
FFP, units Median (range)	0 (0 – 2)	2 (0 – 4)	4 (2 – 5)	4 (0 – 8)	0.04
Cryoprecipitate, units Median (range)	-	1 (0 – 2)	0 (0 – 6)	2 (0 – 4)	0.19
Total units of blood transfused, units Median (range)	2 (2 – 8)	9 (4 – 14)	10 (10 – 22)	20 (4 – 22)	0.02
Preoperative Hb (grams/L) Median (range)	113.5 (102 – 139)	113 (112 – 114)	111 (108 – 114)	115 (103 – 127)	0.85
Postoperative Hb (grams/L) Median (range)	101 (76 – 134)	104.5 (98 – 111)	107.5 (90 – 112)	102 (94 – 123)	0.78
Delta Hb (grams/L) Median (range)	11.5 (0 – 38)	8.5 (3 – 14)	4 (0 – 24)	11 (0 – 23)	0.67
Postoperative admission n (%)	HDU 9 (29.0%) ITU 0 (0.0%) Recovery 22 (71.0%)	HDU 1 (33.3%) ITU 1 (33.3%) Recovery 1 (33.3%)	HDU 4 (100%) ITU 0 (0.0%) Recovery 0 (0.0%)	HDU 2 (40%) ITU 3 (60%) Recovery 0 (0.0%)	<0.001
Length of	3 (1 – 9)	3 (2 – 12)	4.5 (3 – 6)	5 (3 – 22)	0.02

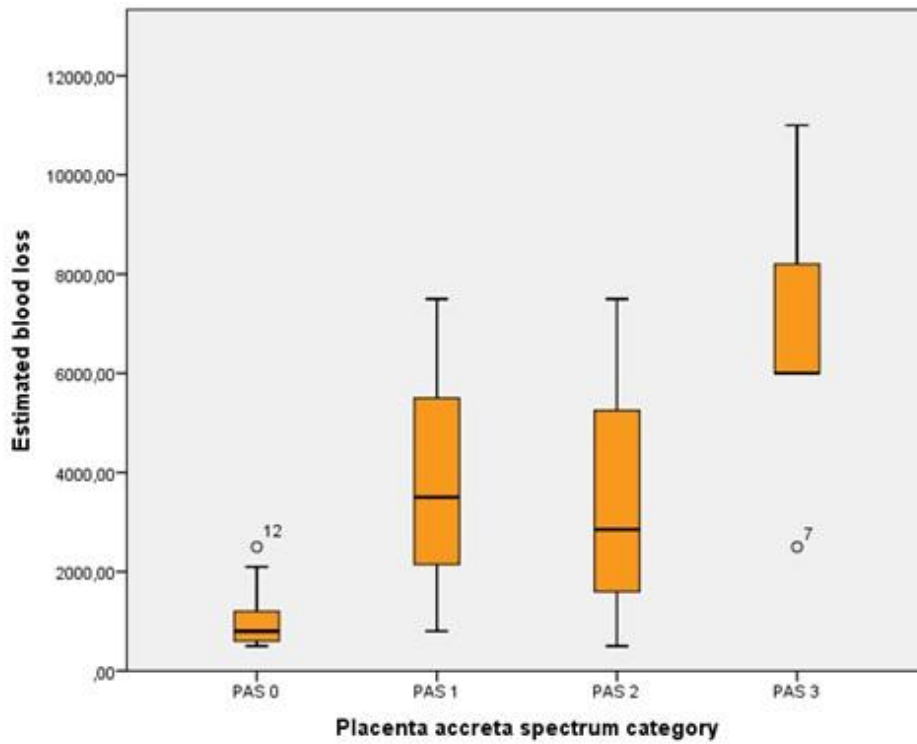
postoperative admission (days) Median (range)					
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Figure 1 – Perioperative outcomes according to placenta accreta spectrum (PAS) group categories 0-3: (a) operative time; (b) estimated blood loss; (c) number of units of blood products transfused; (d) length of postoperative admission.

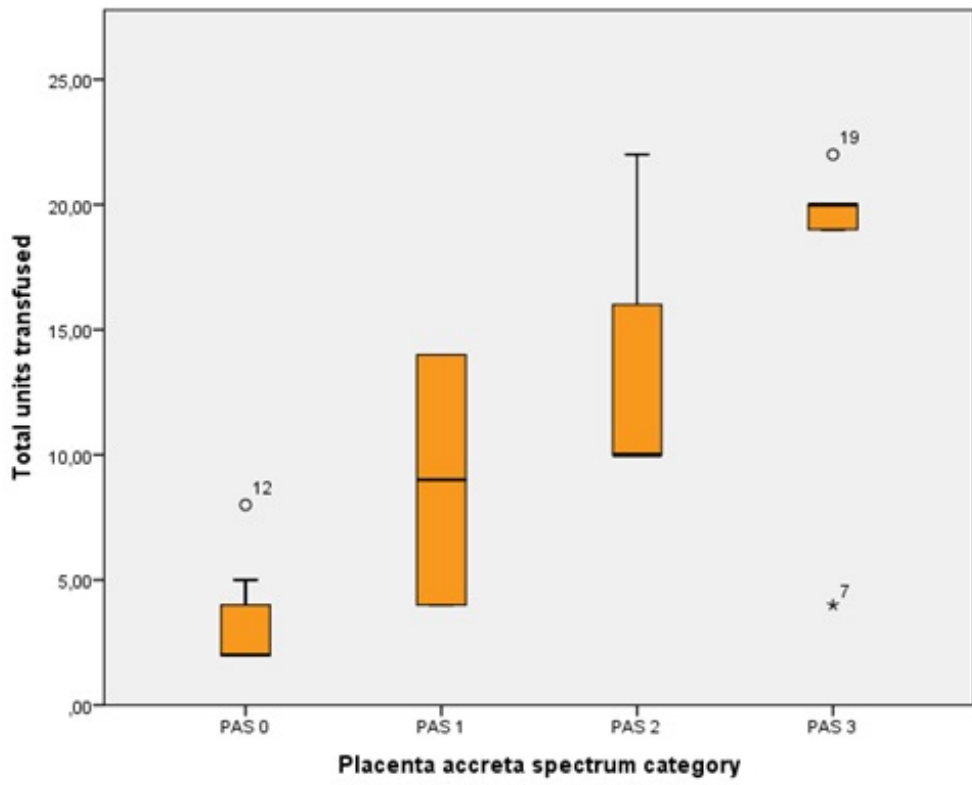
a)



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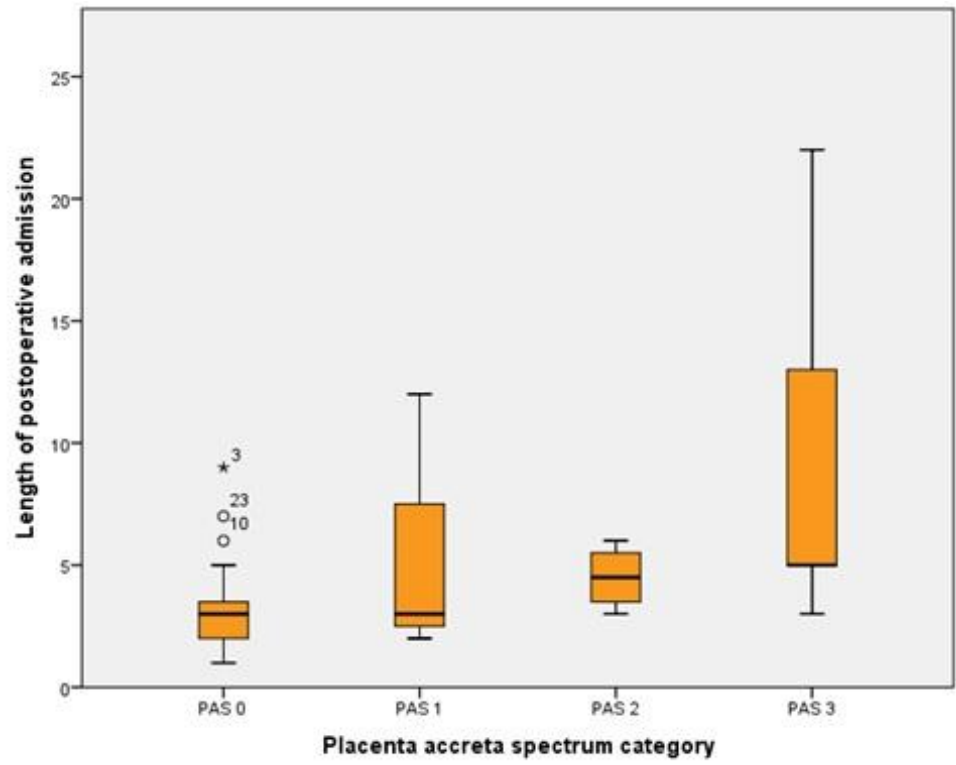
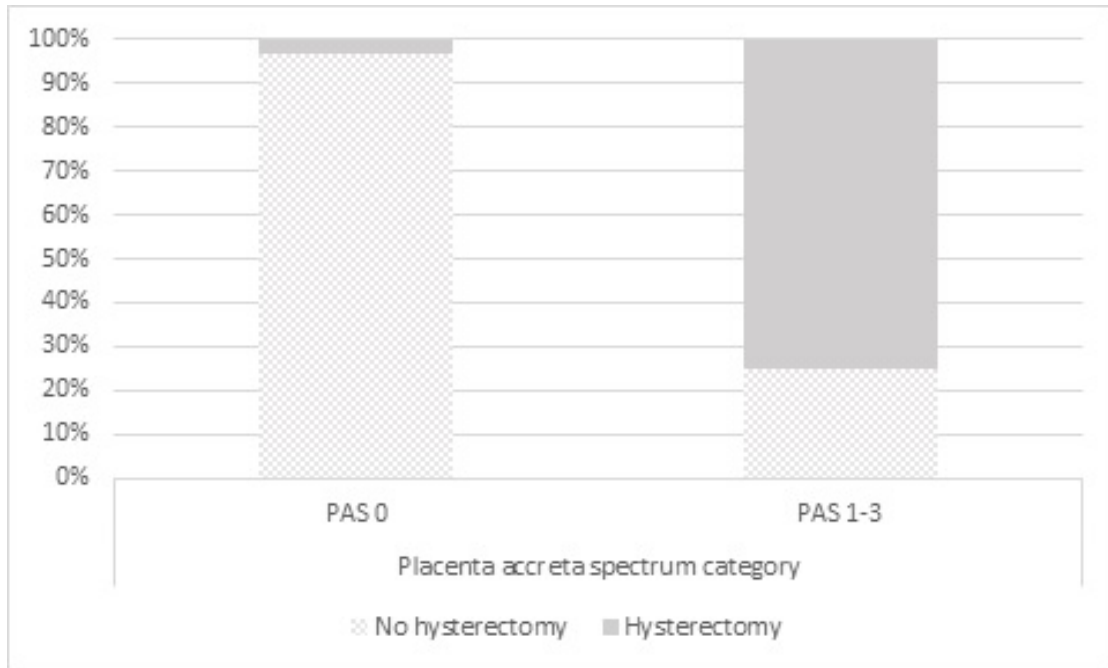
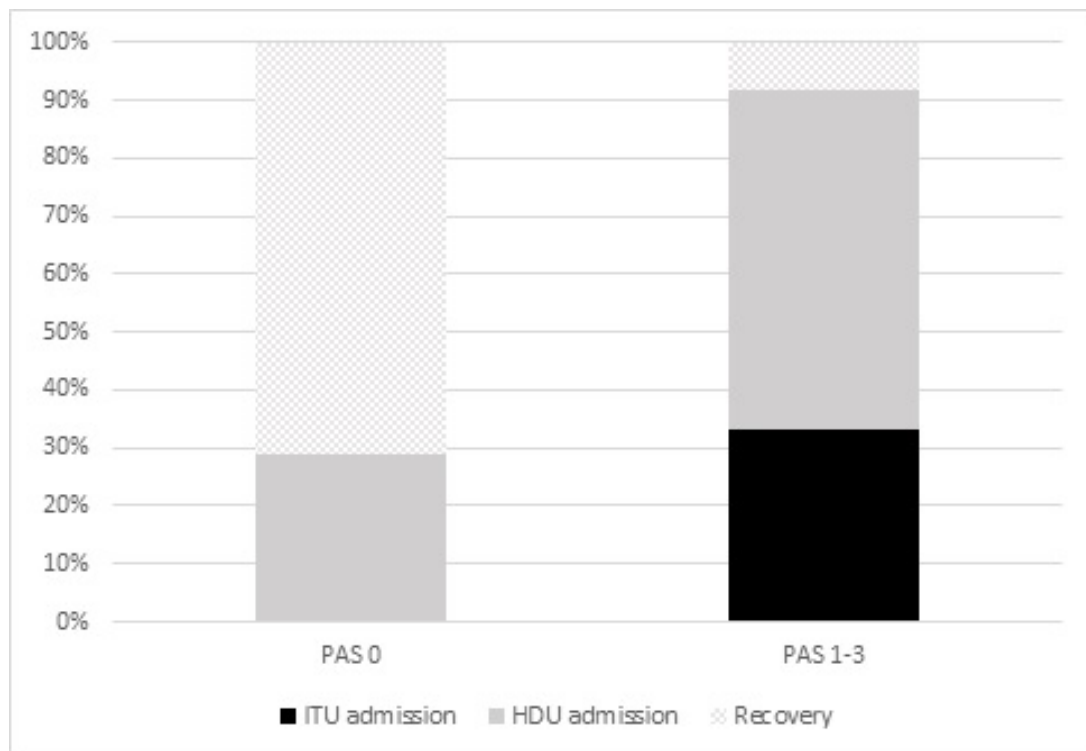


Figure 2 – Perioperative outcomes in women with no evidence of morbidly adherent placenta (PAS 0) versus those with ultrasound suspicion of deeply invading placenta (PAS 1-3). (a) need to perform hysterectomy; (b) postnatal admission to high-dependence unit (HDU) or intensive care unit (ITU).

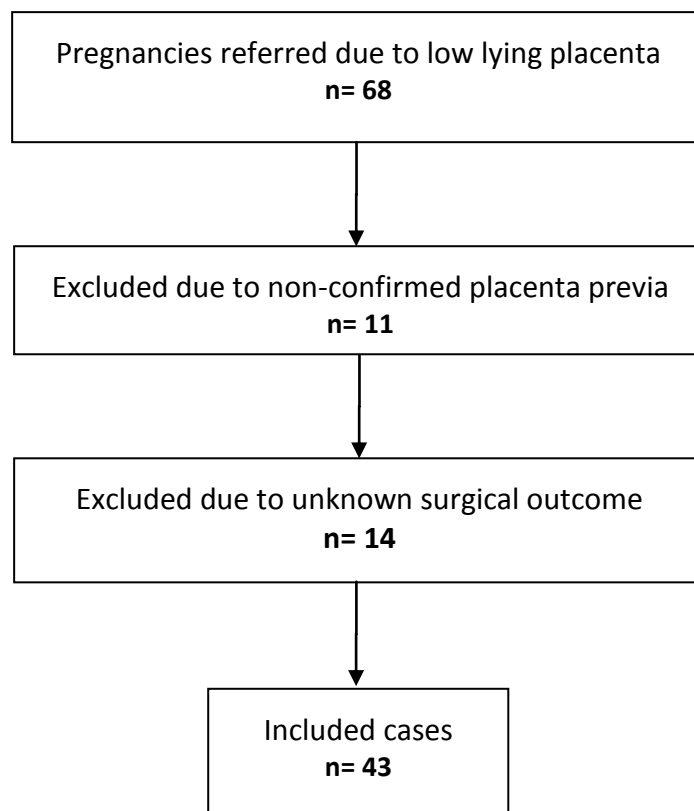
a)



b)



Flow chart (according to STROBE guidelines) for inclusion of cases.



Manuscript title:

Evaluation of perioperative complications using a newly described staging system for placenta accreta spectrum.

Authors: Andrea Dall'Asta, Giuseppe Cali, Francesco Forlani, Gowrishankar Paramasivam, Serena Girardelli, Joseph Jazbek, Francesco D'Antonio, Amarnath Bhide, Christoph C Lees

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: