

Manuscript Number:

Title: Accreta Placentation: A systematic review of Prenatal Ultrasound
Imaging and Grading of Villous Invasiveness

Article Type: Systematic Review

Section/Category: Imaging

Corresponding Author: Professor. Eric Jauniaux, MD, PhD

Corresponding Author's Institution: University College London

First Author: Eric Jauniaux, MD, PhD

Order of Authors: Eric Jauniaux, MD, PhD; Sally L Collins, MBBS, PhD;
Davor Jurkovic, MD; Graham J Burton, MD

Manuscript Region of Origin: UNITED KINGDOM

Abstract: Determining the depth of villous invasiveness before delivery is pivotal in planning individual management of women diagnosed with placenta accreta (PA). We undertook a PubMed search using key words "placenta accreta", "placenta increta", "placenta percreta", "abnormally invasive placenta", "morbidly adherent placenta" and "placenta adhesive disorder" as related to "sonography", "ultrasound diagnosis", "prenatal diagnosis", "grey-scale imaging", three-dimensional (3D) ultrasound and "colour Doppler imaging". Eighty-three studies, including 30 cases reports describing 38 cases of PA and 53 series describing 1078 cases were analysed. Out of 53 study series, 23 did not provide data on the depth of villous myometrial invasion on ultrasound imaging or at delivery. Detailed correlations between ultrasound findings and PA grading were found in 72 cases. A loss of clear zone (62.1%) and the presence of bridging vessels (71.4%) were the most common ultrasound signs found in cases of placenta creta (PC). In placenta increta (PI), a loss of clear zone (84.6%) and subplacental hypervascularity (60%) were the most common ultrasound signs whereas, placental lacunae (82.4%) and subplacental hypervascularity (54.5%) were the most common ultrasound signs in placenta percreta (PP). No ultrasound sign or a combination of ultrasound signs were specific of the depth of accreta placentation. This may be due to the wide heterogeneity in terminology used to describe the grades of accreta placentation and differences in study design. This review emphasizes the need for further prospective studies using a standardised evidence-based approach including a systematic correlation between ultrasound signs of PA and detailed clinical and pathologic examinations at delivery.

INSTITUTE FOR WOMEN'S HEALTH



UCL Elizabeth Garrett Anderson

Institute for Women's Health

London 16th June 2016

The Editor-in-Chief
AJOG

Dear Roberto,

We are submitting our manuscript entitled "Accreta Placentation: A systematic review of Prenatal Ultrasound Imaging and Grading of Villous Invasiveness." for your consideration to publish in AJOG journal.

We were inspired by the fantastic AJOG special issue on the "Placenta" in which Graham and I were involved. The AJOG is the first choice for our review as many of the key-publications on the placenta in general and placenta accreta in particular were published in the Journal.

Our review is original and timely following the publication in January 2016 of the standardized ultrasound imaging descriptions by the European Working Group on Abnormally Invasive Placenta (EW-AIP) and the AIP international expert group. We believe that our findings will be of interest to the general readership of AJOG. As we are all involved in writing the new RCOG guidelines on placenta praevia, placenta accreta and vasa praevia and I am the coordinator of the first FIGO guidelines on placenta accreta, our paper when published should have a high citation potential.

All authors were involved in the study design and execution. EJ performed the data collection and analysis and drafted the manuscript. All authors were involved in the critical discussion. EJ is the guarantor of the study. All authors have agreed with the content of the final draft of the manuscript and that we have no conflict of interest to declare.

I hope you will find it acceptable for publication in AJOG journal.

Very best regards



Eric Jauniaux



UCL Elizabeth Garrett Anderson

Institute for Women's Health

London 16th June 2016

The Editor-in-Chief
AJOG

Statement of authorship for "Accreta Placentation: A systematic review of Prenatal Ultrasound Imaging and Grading of Villous Invasiveness." By E.Jauniaux, SL Collins, D Jurkovic, GJ Burton

This study is original and has not been submitted for publication elsewhere.

All authors were involved in the study design and execution. EJ performed the data collection and analysis and drafted the manuscript. All authors were involved in the critical discussion. EJ is the guarantor of the study.

All authors have agreed with the content of the final draft of the manuscript and that we have no conflict of interest to declare.



Eric Jauniaux

Accreta Placentation: A systematic review of Prenatal Ultrasound Imaging and Grading of Villous Invasiveness

Eric JAUNIAUX¹,MD,PhD
Sally L COLLINS²,MBBS,PhD
Davor JURKOVIC¹,MD
Graham J BURTON³,MD

1. Department of Obstetrics and Gynaecology, University College London Hospitals and UCL Institute for Women’s Health, University College London (UCL), London, UK.
2. Nuffield Department of Obstetrics & Gynaecology, University of Oxford, and the Fetal Medicine Unit, John Radcliffe Hospital, Oxford, UK
3. The Centre for Trophoblast Research, Department of Physiology, Development and Neuroscience, University of Cambridge, Cambridge, UK.

The authors reports no conflict of interest

No funding was obtained for this study.

Corresponding author: *Professor Eric Jauniaux,*
Academic Department of Obstetrics and Gynaecology,
Institute for Women’s Health, University College London,
86-96 Chenies Mews,
London WC1E 6HX, UK.
Telephone numbers: +44/207/3908113 Fax: +44/207/3908115
E-mail: e.jauniaux@ucl.ac.uk

Word count: 4430

Condensation: Heterogeneity in terminology and study designs on ultrasound diagnosis of placenta accreta limit the evaluation of the depth of myometrial villous invasion and management strategies

Short title: Grading of accreta placenta on ultrasound imaging

Abstract

Determining the depth of villous invasiveness before delivery is pivotal in planning individual management of women diagnosed with placenta accreta (PA). We undertook a PubMed search using key words “placenta accreta”, “placenta increta”, “placenta percreta”, “abnormally invasive placenta”, “morbidity adherent placenta” and “placenta adhesive disorder” as related to “sonography”, “ultrasound diagnosis”, “prenatal diagnosis”, “grey-scale imaging”, three-dimensional (3D) ultrasound and “colour Doppler imaging”. Eighty-three studies, including 30 cases reports describing 38 cases of PA and 53 series describing 1078 cases were analysed. Out of 53 study series, 23 did not provide data on the depth of villous myometrial invasion on ultrasound imaging or at delivery. Detailed correlations between ultrasound findings and PA grading were found in 72 cases. A loss of clear zone (62.1%) and the presence of bridging vessels (71.4%) were the most common ultrasound signs found in cases of placenta creta (PC). In placenta increta (PI), a loss of clear zone (84.6%) and subplacental hypervascularity (60%) were the most common ultrasound signs whereas, placental lacunae (82.4%) and subplacental hypervascularity (54.5%) were the most common ultrasound signs in placenta percreta (PP). No ultrasound sign or a combination of ultrasound signs were specific of the depth of accreta placentation. This may be due to the wide heterogeneity in terminology used to describe the grades of accreta placentation and differences in study design. This review emphasizes the need for further prospective studies using a standardised evidence-based approach including a systematic correlation between ultrasound signs of PA and detailed clinical and pathologic examinations at delivery.

Key words: Placenta, accreta, increta, percreta, ultrasound imaging, villous myometrial invasion, accreta placentation.

1
2
3
4
5 **P**lacenta accreta (PA) is an iatrogenic 20th century disorder of human placentation,
6
7
8 which is characterized by the abnormal attachment or invasion of placental tissue to the
9
10 underlying uterine musculature.¹ PA may have been observed before the 20th century⁶
11
12 but all epidemiologic studies have shown a direct association between the increase in
13
14 caesarean delivery (CD) and the increased incidence of PA in subsequent pregnancies.
15
16
17 ^{1,3-7} PA is not exclusively a consequence of CD and much smaller surgical damage to
18
19 the integrity of the uterine lining, such as following uterine curettage, manual delivery of
20
21 the placenta, post-partum endometritis and previous hysteroscopic surgery, endometrial
22
23 resection and uterine artery embolization, has been associated with PA in subsequent
24
25 pregnancies.^{1,3-8} The development of PA has also been reported in women with no
26
27 surgical history but presenting with uterine pathology such as bicornuate uterus,
28
29 adenomyosis, submucous fibroids and myotonic dystrophy.^{1,3,4} These individual case
30
31 reports, suggest that intra-myometrial implantation of villous tissue is not always
32
33 secondary to uterine surgery and may explain the few cases rare cases of PA observed
34
35 before the 20th century.
36
37
38
39
40
41

42 PA was first defined in 1937 by Irving and Hertig, as the “abnormal adherence of
43
44 the afterbirth in whole or in parts to the underlying uterine wall”.² The failure of the
45
46 placenta to separate normally from the uterus after delivery is typically accompanied by
47
48 severe postpartum haemorrhage (PPH), and attempts to remove a PA typically
49
50 provokes further major haemorrhage which is associated with increased maternal
51
52 morbidity and mortality. Modern pathologists have graded PA into placenta creta (PC)
53
54 or vera, placenta increta (PI) and placenta percreta (PP) according to the depth of
55
56 villous invasiveness.^{3,4} In PC, the villi adhere to the myometrium with no intermediate
57
58
59
60
61
62
63
64
65

1
2
3
4 decidual layers between the tip of the anchoring villi and the muscular cells. In PI, the
5
6 villi penetrate deeply into the myometrium up to the external layer whereas in PP, the
7
8 invasive villous tissue reaches and/or penetrates through the uterine serosa. Cases of
9
10 PA are also often subdivided into total, partial or focal according the amount of placental
11
12 issue involved. More recently, it has been suggested that cesarean scar pregnancy
13
14 (CSP) represents a precursor of one of the different grades of PA¹⁰⁻¹²
15
16

17
18
19 Several concepts have been proposed to explain the pathophysiology of PA. The
20
21 oldest is based on a theoretical primary defect of the biological functions of the
22
23 trophoblast, leading to excessive adherence or invasion of the myometrium. The other
24
25 prevailing hypothesis is that of a secondary defect of the endometrium-myometrial
26
27 interface leading to a failure of normal decidualization in the area of the uterine scar
28
29 allowing trophoblastic infiltration beyond the superficial myometrium and villous
30
31 development inside the myometrium.^{1,3,4} Although, the pathogenic mechanisms of the
32
33 different types of accreta placentation, including CSP, are similar, the anatomical and
34
35 clinical consequences vary widely. In placenta vera, the villi simply adhere to the
36
37 superficial layer of the myometrium whereas in placenta increta and percreta the villous
38
39 tissue invades into and may penetrate through the entire uterine wall thickness and
40
41 reach the surrounding pelvic tissues and organs.
42
43
44
45
46
47

48
49 The worst clinical outcome arises when PA and in particular, when PI or PP is
50
51 unsuspected at the time of delivery and the surgeon attempts to remove the invasive
52
53 part of the placenta leading immediately to major haemorrhage and an increasing need
54
55 for emergency hysterectomy.¹³⁻¹⁵ Prenatal diagnosis of PA has therefore become
56
57 essential for the safe management of this increasingly common obstetric
58
59
60
61
62
63
64
65

1
2
3
4 complication.¹⁶⁻¹⁸ However, recent studies from UK and USA show that PA was
5
6 undiagnosed before delivery in between half¹⁹ and a third²⁰ of the cases. Determining
7
8 the depth of placental invasion is essential for planning of individual management of
9
10 women diagnosed with PA. The aim of this review is to evaluate the value of the various
11
12 ultrasound signs described in the international literature for the diagnosis of PA in
13
14 general and for the assessment of the depth of villous invasiveness in the uterine wall in
15
16 particular.
17
18
19
20
21
22
23

24 **Material and methods**

25
26
27 We conducted a systematic review of the literature and selected relevant studies that
28
29 have been published between the first prenatal ultrasound description of PA by Tabsh
30
31 et al²² in 1982 and 30 March 2016. We undertook a PubMed and MEDLINE search
32
33 using combinations of key words of “placenta accreta”, “placenta increta”, placenta
34
35 percreta”, “abnormally invasive placenta”, “morbidly adherent placenta” and “placenta
36
37 adhesive disorder” as related to “sonography”, “ultrasound diagnosis”, “prenatal
38
39 diagnosis”, “grey-scale imaging”, three-dimensional (3D) ultrasound and “colour Doppler
40
41 imaging.” We limited the search to studies published in English.
42
43
44
45
46

47 The primary criteria were articles which correlated prenatal ultrasound imaging
48
49 with pregnancy outcome. We used ultrasound signs from the standardized descriptions
50
51 proposed recently by the European Working Group on Abnormally Invasive Placenta
52
53 (EW-AIP) and the AIP international expert group.^{23,24} On gray-scale imaging the signs of
54
55 PA are: loss of the clear zone in the myometrium under the placental bed (“clear zone”);
56
57 myometrial thinning to <1mm or undetectable; intra-placental lacunae often large and
58
59
60
61
62
63
64
65

1
2
3
4 irregular (“moth eaten” areas); bladder wall interruption or loss (hyperechoic line
5
6 between serosa and bladder lumen); placental bulge distorting the extrauterine organs;
7
8 and focal exophytic mass of placental tissue extending beyond the serosa. On colour
9
10 Doppler imaging (CDI) the signs used are: uterovesical hypervascularity between the
11
12 myometrium and the posterior wall of the bladder; subplacental hypervascularity
13
14 (placental bed); bridging vessels across the myometrium and beyond the serosa; and
15
16 lacunae feeder vessels with high velocity (turbulent) flow from the arterial vasculature of
17
18 myometrium.
19
20
21
22

23
24 The initial search provided 129 reports. Cross-referencing provided an additional
25
26 12 reports, making a total of 141 records. After the second selection, letters with no
27
28 description of the case, case reports with inconclusive diagnosis, commentaries and
29
30 reviews were excluded. A further 9 reports with no description of ultrasound features
31
32 were further excluded leaving 83 reports for analysis (Figure 1). These articles were
33
34 separated into case reports (n= 30)²⁵⁻⁵⁵ and series (n= 53)^{20,56-107}, and were reviewed
35
36 independently.
37
38
39
40

41 Data containing study setting, study type, characteristics of study population,
42
43 definition of PA, terminology, grading, ultrasound description of placental structure,
44
45 management procedures including caesarean section hysterectomy (CSHT), focal
46
47 myometrial resection (FMR), uterine artery embolization (UAE), uterine artery balloon
48
49 occlusion (UABO), uterine artery ligation (UAL) intrauterine balloon tamponade,
50
51 methotrexate (MTX), B-Lynch suture and lesions described during pathological
52
53 examination were extracted.
54
55
56
57

58 The case reports data were analysed using the StatGraphic data analysis and
59
60
61
62
63
64
65

1
2
3
4 statistical software package (Station, TX).
5
6
7

8 9 **Results**

10 11 **Case reports**

12
13
14 The case reports included 38 individual cases with prenatal ultrasound findings. There
15
16 were four case reports presenting findings on 2 individual cases^{25,34,36,45} and one
17
18 including 3 individual cases.⁴⁶ The PA grading was confirmed clinically or
19
20 histopathologically as PC in 13 cases, PI in 16 cases and PP in 9 cases. The
21
22 terminology “placenta accreta” was used by 27 authors of case reports^{25-44,46-48,50-52,54,55},
23
24 “morbidity adherent placenta” by two^{45,49} and “abnormal placentation” in one report.⁵³
25
26 Two authors reporting on three cases did not describe the past surgical history.^{25,40} In
27
28 five (14.3%) cases there was a previous history of uterine curettage only^{28,30,31,50,51} and
29
30 in seven (20.0%) the women presented with a combined history of CD, myomectomy
31
32 and/or curettage.^{30,32,36,39,45,46,55} A past obstetric history of CD was reported in 23 out of
33
34 35 remaining cases (65.7%).
35
36
37
38
39
40

41 Gray-scale imaging was used by all authors. In eight cases, including two PC,
42
43 five PI and one PP only gray-scale imaging signs were described^{25,27,33,47,48,52,55}
44
45 whereas in the remaining 30 cases, including 11 PC, 11 PI and eight PP, both gray-
46
47 scale and color Doppler imaging were reported. Table 1 displays the ultrasound signs
48
49 identified in the diagnosis of the 38 cases reports included in the review according to the
50
51 depth of villous myometrial invasion. The mean gestational age at diagnosis was 24.3
52
53 weeks (SD: 6.8; range 13-36 weeks). A loss of clear zone (92.3%) and bridging vessels
54
55 (90.9%) were the most common ultrasound signs for PC. In cases of PI, the loss of
56
57
58
59
60
61
62
63
64
65

clear zone (87.5%) and subplacental hypervascularity (81.8%) were the most common signs whereas for PP, placental lacunae were found in all cases (100%) and subplacental hypervascularity was found in six cases (75%).

A planned CD hysterectomy with or without UAE or UAL was performed in two PC, nine PI and seven PP.^{20,22,32,35-39,41,46,48,52,53} In the other 20 cases a conservative management was attempted including FMR with or without suture or MTX^{29,31,34,43,46,50} uterine curettage⁵⁵ and the placental left in situ with MTX or UAE.^{25,27,28,30,41,42,45-47,49,51} The conservative management was unsuccessful in 12 cases, including five PC, 6 PI and one PP, and required a secondary hysterectomy.^{25,27,28,30,34,41,42,44,45,49,55} A dissection or partial resection of the bladder was required in four cases of PP.^{33,35,42,54} The mean gestational age at delivery was 30.6 weeks (SD: 7.5; range 15-39 weeks). A detailed description of the pathologic findings was available in 28 cases. In the remaining 10 cases it was not available following successful conservative management but the PA grading was described at delivery.

Series reports

The 53 series included 24 prospective^{58-62,65,66,70-72,76,80,83,85,89-91,93,98,101,102,105-107} and 29 retrospective studies with a total of 1078 cases of PA. All series except eight, which did not report data on previous surgical history^{63,66,72,81,97,98,101,106}, included women presenting with placenta praevia and a history of CD and/or other uterine surgeries. In 21 series, including 568 cases of PA, the depth of villous invasiveness was not described.^{20,59,66-69,71,72,75,76,78,81,82,85,90,91,94,96,100,104,106} In the other 32 series, the distribution of the different categories of PA were reported, including 240 PC, 112 PI

1
2
3
4 and 158 PP. The terminology used to describe PA was diverse. Seven studies used the
5
6 term “morbidly adherent placenta”^{66,86,89,97,100,103,106}, two used “placental adhesive
7
8 disorders”^{70,101}, two used “abnormally invasive placentation”^{92,104}, two used “abnormally
9
10 adherent placenta” or “abnormal placental adherence”^{79,83}, one use “advanced invasive
11
12 placentation”⁹⁶ and one used the term “abnormal myometrial invasion”.⁶¹
13
14

15
16 Gray-scale ultrasound was used, and the corresponding data presented by all
17
18 authors except one.¹⁰⁴ In ten series, gray-scale imaging only was used<sup>56-
19
20 58,64,65,75,84,89,90,103</sup>, in one series sequential two- dimensional (2D) and three-dimensional
21
22 (3D) ultrasound were used.⁷⁷ In the remaining 41 series, data from both 2D grey-scale
23
24 ultrasound and CDI were available. The gestational mean range at diagnosis in 31
25
26 series for which the information was available was 20-34 weeks. Table 2 displays the
27
28 ultrasound signs used by authors to diagnosed PA in the 53 series. The most commonly
29
30 used signs were loss of clear zone (98%) and placental lacunae (96.1) for grey-scale
31
32 imaging and subplacental hypervascularity (85.7%) and bridging vessels (61.9%) for
33
34 CDI. The authors of eight series provided detailed data on 2D ultrasound examination
35
36 and placental grading.^{65,79,84,89,95,98,102,107} The corresponding data are presented in Table
37
38
39
40
41
42
43 3. The presence of placental lacunae (78.9%) and subplacental hypervascularity
44
45 (36.7%) were the most common ultrasound signs found. In three of these series^{65,84,102}
46
47 the authors provided details of the placental grading for each individual standard
48
49 ultrasound sign. These data were combined with those from the cases reports (Table 4)
50
51 raising the number of cases available for analysis to 72. This analysis confirmed that a
52
53 loss of clear zone (62.1%) and the presence of bridging vessels (71.4%) were the most
54
55 common ultrasound signs found in cases of PC, that a loss of clear zone (84.6%) and
56
57
58
59
60
61
62
63
64
65

1
2
3
4 subplacental hypervascularity (60%) were the most common sings in PI whereas
5
6 placental lacunae (82.4%) and subplacental hypervascularity (54.5%) were the most
7
8 common signs for PP. There were no ultrasound sign or combination of ultrasound
9
10 signs were specific of the depth of accreta placentation. No series reported on the
11
12 lateral extension of the accreta placentation and in particular on the involvement of the
13
14 cervix.
15
16
17

18
19 A planned CD hysterectomy, with or without UAE or UAL, was the primary
20
21 management option in 44 series. In 13 series, conservative management was
22
23 attempted depending on the degree of myometrial invasion with secondary
24
25 hysterectomy in cases of failure^{20,56,62,63,71,73,75,80,84,87,92,95,97} and in one series
26
27 conservative management was successful in all cases.⁹⁹ In seven series, no information
28
29 was available on the outcome and management.^{20,65,85,91,98,100,107} Overall, a CD
30
31 hysterectomy was performed in 597 out of 806 (74.1%) for which the data were
32
33 available. The mean gestational age range at delivery was 34-37 weeks. A detailed
34
35 description of the pathologic findings was available in 29 series. In 11 series, the
36
37 pathologic examination was reported as performed but no data were
38
39 provided^{58,59,65,67,69,81,82,87,100,104,106} and in 12 series there was no histopathologic
40
41 information.^{20,56,68,75,85,90,91,95,96,98,99,103}
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Comments

The results of this review highlight the wide heterogeneity in terminology and study designs in the published reports on the prenatal ultrasound diagnosis of PA. This hinders development of more effective strategies for antenatal screening of accreta placentation and the depth of villous myometrial invasion prior to delivery.

The origin and first use of the terminology “placenta accreta” is unknown, but according to the 1937 classic review of Irving and Hertig⁹, the first case may have been that of a Mrs Galla who died at delivery in 1588 and was found at autopsy to have a placenta previa “firmly adherent” to the internal os. Langhans¹⁰⁸ and Hart¹⁰⁹, who first described the histology of placenta accreta, also used the term “adherent placenta”. On the basis that the depth of the villous penetration of the myometrium is rarely uniform, Luke et al, suggested the name “adherent or invasive placenta” instead of PA.²¹ According to the list of 86 references included in the literature review of Irving and Hertig, the first author to use the term “placenta accreta” was Baisch in 1907.¹¹⁰ Up to the 1920s, most authors used the term “adherent placenta”, whereas after that and until the present review most authors used placenta “accreta” or “incretta”. Although also described by Irving and Hertig, the term “percreta” was only used more regularly to describe case reports from the 1950s onwards.¹¹¹ Interestingly, all the cases personally treated by Irving and Hertig cases were described as “vera” or “adherenta” where the villi were attached to the surface of the myometrium without invading it.⁹ By contrast, the term “morbidly adherent placenta” dates back to the 19th century to describe placental retention¹¹², and has been very rarely used to describe PA until recently. Our review finds that this terminology has been increasingly used over the last decade, by authors

1
2
3
4 of case reports and series of prenatal ultrasound diagnosis of PA to describe both
5
6 abnormally adherent and invasive placentas.^{45,49,66,86,89,97,100,103,106} This terminology is
7
8 inaccurate and misleading and for our analysis of the literature we have used the
9
10 standard anatomical definition i.e. PC, PI & PP which describes accurately the depth of
11
12 villous myometrial invasion.
13
14

15
16
17 Only one of the 20 cases personally treated by Irving and Hertig occurred after a
18
19 previous CD.⁹ Similarly, in their review of 86 cases reports up to 1935, only one was
20
21 found after a CD. Predisposing factors at the time were a previous manual delivery
22
23 and/or “vigorous” uterine curettage. Three decades later, CD was found in the history of
24
25 around half of the women presenting with PC or PI in subsequent pregnancy.²¹ In the
26
27 present review and in population studies, a history of one or more CD is reported as the
28
29 main predisposing factor in more than 90% of the cases of PA.^{5-7,13,14} The risks of both
30
31 placenta praevia and PA in subsequent pregnancies increase with the number of
32
33 previous CD^{7,13,114} and is higher in women with a previous classical CD.¹¹⁵ Among
34
35 women with placenta praevia, 40% of those with two previous CD and 61% of those
36
37 with three previous CD develop a PA.⁷ This risk is independent of other maternal
38
39 characteristics, such as parity, body mass index, tobacco use, and coexisting
40
41 hypertension or diabetes. Although PA only complicates about 5% of pregnancies with
42
43 placenta praevia¹³, and around 0.5% of women undergoing their second or third CD¹¹⁴,
44
45 the identification during the second trimester of a placenta praevia on ultrasound
46
47 examination in a woman with a history of CD should prompt a more detailed search for
48
49 signs of PA and evaluation of the depth of villous myometrial invasion.
50
51
52
53
54
55
56
57
58
59

60 The first antenatal grey-scale imaging descriptions of PA were reported 25 years
61
62
63
64
65

ago by Tabsh *et al*²² and ultrasonography is now the most commonly used modality for diagnosing PA. The first ultrasound sign described was the “loss of the hypoechoic retroplacental (clear) zone” found to represent an abnormal extension of the placental villi through the decidua basalis into the myometrium.^{25,56} This probably corresponds the placental basal plate or utero-placental plate described by placental anatomists.^{3,4} In 1992, Finberg and Williams⁵⁸ using higher resolution grey-scale imaging identified further signs including marked thinning or absence of the myometrial zone; thinning, irregularity, or focal disruption of the utero-placental bladder zone; intraplacental vascular lacunae and presence of focal mass-like elevations or extension of placental echogenicity (exophytic) beyond the uterine serosa. The advent of CDI enabled access to visualization of the utero-placental circulation, and indicated that most cases of PA are associated with hypervascularisation patterns within the placenta and below the placental bed or subplacental zone.²⁵ Our review indicates that these signs have been commonly used since their first description and that the loss of clear zone, the presence of placental lacunae and hypervascularity of the subplacental zone were the most frequently found ultrasound signs in PA (Table 3). When analyzed for the depth of villous myometrial invasion, a loss of clear zone was the most common grey-scale imaging sign found for PC and PI and the presence of placental lacunae for PP. On CDI, bridging vessels are more commonly reported in PC, whereas subplacental hypervascularity was the most common sign found in PI and PP (Table 4). Although placental lacunae were reported in all case reports of PP (Table 1), we found that no ultrasound sign or combination of ultrasound signs were specific of the depth of accreta placentation. This can be explained by the absence of standardised description of

1
2
3
4 ultrasound signs in previous studies, the high proportion of retrospective studies and the
5
6 lack of PA grading confirmed by histopathology in many series.
7
8
9

10 There is increasing evidence that multidisciplinary management of patients with
11 suspected PA is superior to standard obstetric care.^{16-18,116-119} For such care to be
12 organized, the diagnosis must be made prenatally. We found that most authors of series
13 published in the last decade have used both the gray-scale and CDI ultrasound signs to
14 evaluate retrospectively or prospectively the sensitivity of ultrasound in the prenatal
15 diagnosis of PA. A recent systematic review and meta-analysis by D'Antonio et al¹²⁰ of
16 23 of these studies involving 3707 pregnancies at risk of PA found that the overall
17 performance of ultrasound is excellent (sensitivity 90.7%; specificity 96.9%), and that
18 CDI has the best predictive accuracy. However, these studies may overestimate
19 accuracy because they were conducted in centers specialized in prenatal diagnostics,
20 and the number of cases of PA diagnosed prenatally were small. Out of the 22 series
21 from D'Antonio et al review that were also included in the present review, eight did not
22 present with information on the depth of villous invasion^{58,59,62,67,71,72,81,82} and one did
23 not present any histopathologic data at all.⁸⁵ This suggests that many imaging specialty
24 centers may not have access to specialist perinatal pathology. Overall, only three of the
25 series included in our review provided with a full correlation between standard 2D
26 ultrasound signs and PA grading, and were included in Table 4.^{65,84,102} More prospective
27 studies with detailed evaluation of the depth of accreta placentation at delivery are
28 needed to better evaluate the accuracy of these ultrasound signs not only in screening
29 for PA, but also in differentiating between the different levels of depth of myometrial
30 invasion.
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

1
2
3
4 Around 75% of women with PA included in the present review were managed
5
6 with planned CD hysterectomy. However, in more than half of these cases, the depth of
7
8 villous invasiveness was not described. In those series in which all⁹⁹, or a high
9
10 proportion^{75,80,87,95} of cases were successfully treated conservatively without the need
11
12 for a secondary hysterectomy, one can assume that in the corresponding cases the villi
13
14 were only superficially adherent to the myometrium. Ideally, the standard of reference
15
16 for the different grading of PA is confirmation of the final histology after hysterectomy
17
18 has been performed. The quality of the pathological examination is essential to provide
19
20 feedback on the accuracy of the prenatal diagnosis of PA. A standardized method for
21
22 gross and microscopic pathological examination of hysterectomy specimens with PA
23
24 has recently been proposed¹²¹, and likewise the standardized ultrasound descriptions of
25
26 abnormally invasive placenta^{22,24} should be used in the study design of further studies.
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Hysterectomy is not always clinically required as the bleeding can be avoided or controlled using conservative methods. In cases where a final histopathology examination is not available, the diagnosis can be based on detailed clinical information provided at the time of delivery. In women with severe PP, where there is deep invasion of the adjacent organs or structures, the clinical diagnosis is usually straightforward. By contrast, the differential diagnosis between PC and PI can be more difficult, in particular in the absence of pathological examination. The differential diagnosis between a difficult placental manual removal and an abnormally adherent placenta is also difficult in the absence of histopathological confirmation. In their classical study, Irving and Hertig highlighted this issue, and stated that “placenta accreta is not to be confused with simple retention of the after-birth either through failure of the normal mechanism of

1
2
3
4 separation in a healthy uterus or through its imprisonment behind an hour glass
5
6 contraction”.⁹ The used of a standardized clinical terminology and in particular the use
7
8 of “creta” to define abnormally adherent PA and increta and percreta to describe
9
10 abnormally invasive forms PA is essential to the precise evaluation of perinatal data.
11
12
13
14

15 Histopathologically, PA is now universally defined by a partial or complete
16
17 absence of decidua basalis, resulting in placental villi being attached to or invading the
18
19 scarred myometrium underneath.^{1,3,4} Luke et al²¹ argued against the classification of PA
20
21 proposed by some pathologists, and the further subdivision of PA into total and partial
22
23 or focal, on the basis that the histological examination in cases of abnormally adherent
24
25 placenta is “often distorted by attempt at manual placental delivery and/or post-partum
26
27 uterine curettage”. In these cases, the utero-placental interface is inevitably damaged,
28
29 impairing the histological examination and making it impossible to make the diagnosis of
30
31 abnormal adherent placenta or PC and evaluate its lateral extension. Deeper invasion
32
33 of the trophoblast into the myometrium and infiltration of chorionic villi into myometrial
34
35 vascular spaces have recently been documented in PI and PP.¹²² These changes
36
37 provoke a shift in placental blood supply from a spiral artery as found in normal
38
39 placentation to a supply from larger, deeper arteries, i.e. radial or arcuate, in abnormally
40
41 invasive placentas. These major transformations of the uteroplacental circulation can explain the
42
43 high frequency of profound vascular alterations, such as placental blood lacunae caused by blood
44
45 entering the placenta at high velocity and hypervascularisation patterns under the placental
46
47 bed found on ultrasound in PI and PP (Table 4). These findings suggest that the more
48
49 invasive the placentation the more pronounced the utero-placental vascular changes
50
51 are, and confirms the value of CDI in the screening of PA and in the evaluation of the
52
53
54
55
56
57
58
59
60
61
62
63
64
65

1
2
3
4 depth of villous myometrial invasion.
5
6

7
8 MRI is increasingly used for the diagnosis of PA and has been reported to be
9
10 useful in assessing the depth of myometrial invasion, especially with posterior
11
12 placentation. Recent systematic reviews have found that prenatal MRI is highly accurate
13
14 in diagnosing disorders of invasive placentation and that ultrasound and MRI have
15
16 comparable predictive accuracy.^{123,124} However, cost and limited access to MRI makes
17
18 it impractical as a screening tool for PA and ultrasound imaging remains the primary
19
20 screening tool for population-based studies.
21
22
23
24
25
26

27 28 **Summary and conclusions** 29 30

31
32 With the increasing numbers of CD worldwide and the long-term consequences of
33
34 uterine scars, accurate prenatal diagnosis is a pivotal factor in optimizing the
35
36 counseling, treatment, and outcome of women presenting with PA. Determining the
37
38 depth and extension of accreta placentation is essential in planning individual
39
40 management. Many series published in the literature over the last three decades do not
41
42 provide detailed data linking prenatal ultrasound signs and clinical and histopathological
43
44 findings at delivery. In addition, the inclusion of the three grades of accreta placentation
45
46 into one category has led to heterogeneous data which are difficult to interpret. This can
47
48 explain the major variability in terms of prenatal diagnosis accuracy, outcome and
49
50 management in specialist centres, and can also explain why antenatal detection rates
51
52 remain low in recent general population studies.
53
54
55
56
57

58
59 Pathological studies and the data of the present review suggest that PA should
60
61
62
63
64
65

1
2
3
4 be separated into abnormally adherent and abnormally invasive placental tissues as
5
6 these are anatomically different entities with different clinical outcomes. The term
7
8 “morbidly adherent placenta” is inaccurate and misleading and should refer only to the
9
10 first degree of accreta placentation where the villi simply adhere to the myometrium. PI
11
12 and PP represent the most severe degree of PA and should be referred to as
13
14 abnormally invasive placentation. We therefore recommend that sonographers use the
15
16 term placenta “creta” if they think placentation is superficial and invasive if they think it is
17
18 deep to discriminate when they are reporting their ultrasound findings. Further
19
20 prospective studies that present for each individual case standardised ultrasound signs
21
22 and complete clinical and pathological data are now essential to take the prenatal
23
24 screening of PA from specialist centres to the general population, and to improve the
25
26 outcome of this increasingly common major obstetric complication.
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

REFERENCES

1. Jauniaux E, Jurkovic D. Placenta accreta: pathogenesis of a 20th century iatrogenic uterine disease. *Placenta*. 2012;33:244-51.
2. Harer WB. Placenta accreta. Report of eight cases. *Am J Obstet Gynecol* 1956;72:1309–14.
3. Fox H, Sebire NJ. *Pathology of the placenta* 3rd edition, Saunders-Elsevier, Philadelphia, 2007.
4. Benirschke K, Burton GJ, Baergen RN. *Pathology of the human placenta*, 6th edition, Springer-Verlag, Berlin, 2012.
5. Miller DA, Chollet JA, Goodwin TM. Clinical risk factors for placenta previa-placenta accreta. *Am J Obstet Gynecol* 1997;177:210–4.
6. Wu S, Kocherginsky M, Hibbard JU. Abnormal placentation: twenty-year analysis. *Am J Obstet Gynecol* 2005;192:1458–61.
7. Bowman ZS, Eller AG, Bardsley TR, Greene T, Varner MW, Silver RM. Risk Factors for Placenta Accreta: A Large Prospective Cohort. *Am J Perinatol*. 2014;31:799-804.
8. Kanter G, Packard L, Sit AS. Placenta accreta in a patient with a history of uterine artery embolization for postpartum hemorrhage. *J Perinatol*. 2013;33:482-3.
9. Irving C, Hertig AT. A study of placenta accreta. *Surgery, Gynecol Obstet* 1937;64:178-200.
10. Timor-Tritsch IE, Monteagudo A, Cali G, Palacios-Jaraquemada JM, Maymon R, Arslan AA, Patil N, Popiolek D, Mittal KR. Cesarean scar pregnancy and early placenta accreta share common histology. *Ultrasound Obstet Gynecol*. 2014;43:383-95.
11. Timor-Tritsch IE, Monteagudo A, Cali G, Vintzileos A, Viscarello R, Al-Khan A, Zamudio S, Mayberry P, Cordoba MM, Dar P. Cesarean scar pregnancy is a precursor of morbidly adherent placenta. *Ultrasound Obstet Gynecol*. 2014;44:346-53.
12. Zosmer N, Fuller J, Shaikh H, Johns J, Ross JA. Natural history of early first-trimester pregnancies implanted in Cesarean scars. *Ultrasound Obstet Gynecol*.

- 2015;46:367-75.
13. Solheim KN, Esakoff TF, Little SE, Cheng YW, Sparks TN, Caughey AB. The effect of cesarean delivery rates on the future incidence of placenta previa, placenta accreta, and maternal mortality. *J Matern Fetal Neonatal Med.* 2011;24:1341-6.
14. Bowman ZS, Manuck TA, Eller AG, Simons M, Silver RM. Risk factors for unscheduled delivery in patients with placenta accreta. *Am J Obstet Gynecol.* 2014;210:e1-6.
15. Creanga AA, Bateman BT, Butwick AJ, Raleigh L, Maeda A, Kuklina E, Callaghan WM. Morbidity associated with cesarean delivery in the United States: is placenta accreta an increasingly important contributor? *Am J Obstet Gynecol.* 2015;213:384.e1-11.
16. Warshak CR, Ramos GA, Eskander R, Benirschke K, Saenz CC, Kelly TF, Moore TR, Resnik R. Effect of predelivery diagnosis in 99 consecutive cases of placenta accreta. *Obstet Gynecol.* 2010;115:65-9.
17. Weiniger CF, Einav S, Deutsch L, Ginosar Y, Ezra Y, Eid L. Outcomes of prospectively-collected consecutive cases of antenatal-suspected placenta accreta. *Int J Obstet Anesth.* 2013;22:273-9.
18. Hall T, Wax JR, Lucas FL, Cartin A, Jones M, Pinette MG. Prenatal sonographic diagnosis of placenta accreta: Impact on maternal and neonatal outcomes. *J Clin Ultrasound.* 2014;42:449-55.
19. Fitzpatrick K, Sellers S, Spark P, Kurinczuk J, Brocklehurst P, Knight M. The management and outcomes of placenta accreta, increta, and percreta in the UK: a population-based descriptive study. *BJOG.* 2014;121:62-71.
20. Bowman ZS, Eller AG, Kennedy AM, Richards DS, Winter TC, Woodward PJ, Silver RM. Accuracy of ultrasound for the prediction of placenta accreta. *Am J Obstet Gynecol.* 2014;211:177.e1-7.
21. Luke RK, Sharpe JW, Greene RR. Placenta accreta: the adherent or invasive placenta. *Am J Obstet Gynecol.* 1966;95:660-8.
22. Tabsh KM, Brinkman CR 3rd, King W. Ultrasound diagnosis of placenta increta. *J Clin Ultrasound.* 1982;10:288-90.

23. Collins SL, Ashcroft A, Braun T, Calda P, Langhoff-Ross J, Morel O et al.,
Proposed for standardized ultrasound descriptions of abnormally invasive
placenta (AIP). *Ultrasound Obstet Gynecol.* 2016;47:271-275.
24. Alfirevic Z, Tang A-W, Collins SL, Robson SC, Palacios-Jaraquemadas, on
behalf of the Ad-hoc International AIP Expert group. Pro forma for ultrasound
reporting in suspected abnormally invasive placenta (AIP); an international
consensus. *Ultrasound Obstet Gynecol.* 2016;47:276-278.
25. Pasto ME, Kurtz AB, Rifkin MD, Cole-Beuglet C, Wapner RJ, Goldberg BB.
Ultrasonographic findings in placenta increta. *J Ultrasound Med.* 1983;2:155-9.
26. Chou MM, Ho ES, Lu F, Lee YH. Prenatal diagnosis of placenta previa/accreta
with color Doppler ultrasound. *Ultrasound Obstet Gynecol.* 1992;2:293-6.
27. McCool RA, Bombard AT, Bartholomew DA, Calhoun BC. Unexplained
positive/elevated maternal serum alpha-fetoprotein associated with placenta
increta. A case report. *J Reprod Med.* 1992;37:826-8.
28. Rosemond RL, Kepple DM. Transvaginal color Doppler sonography in the
prenatal diagnosis of placenta accreta. *Obstet Gynecol.* 1992;80:508-10.
29. Bromley B, Pitcher BL, Klapholz H, Lichter E, Benacerraf BR. Sonographic
appearance of uterine scar dehiscence. *Int J Gynaecol Obstet.* 1995;51:53-6.
30. Wheeler TC, Anderson TL, Kelly J, Boehm FH. Placenta previa increta
diagnosed at 18 weeks' gestation. Report of a case with sonographic and
pathologic correlation. *J Reprod Med.* 1996;41:198-200.
31. Jauniaux E, Toplis PJ, Nicolaides KH. Sonographic diagnosis of a non-previa
placenta accreta. *Ultrasound Obstet Gynecol.* 1996;7:58-60.
32. Chou MM, Ho ES. Prenatal diagnosis of placenta previa accreta with power
amplitude ultrasonic angiography. *Am J Obstet Gynecol.* 1997;177:1523-5.
33. Leaphart WL, Schapiro H, Broome J, Welander CE, Bernstein IM. Placenta
previa percreta with bladder invasion. *Obstet Gynecol.* 1997;89:834-5.
34. Kirkinen P, Helin-Martikainen HL, Vanninen R, Partanen K. Placenta accreta:
imaging by gray-scale and contrast-enhanced color Doppler sonography and
magnetic resonance imaging. *J Clin Ultrasound.* 1998;26:90-4.
35. Kim H, Hill MC, Winick AB, Shen T. Prenatal diagnosis of placenta accreta with

- pathologic correlation. Radiographics. 1998;18:237-42.
36. Maldjian C, Adam R, Pelosi M, Pelosi M 3rd, Rudelli RD, Maldjian J. MRI appearance of placenta percreta and placenta accreta. Magn Reson Imaging. 1999;17:965-71.
37. Ito T, Katagiri C, Ikeno S, Takahashi H, Nagata N, Terakawa N. Placenta previa increta penetrating the entire thickness of the uterine myometrium: ultrasonographic and magnetic resonance imaging findings. J Obstet Gynaecol Res. 1999;25:303-7.
38. Megier P, Harmas A, Mesnard L, Esperandieu OL, Desroches A. Picture of the month. Antenatal diagnosis of placenta percreta using gray-scale ultrasonography, color and pulsed Doppler imaging. Ultrasound Obstet Gynecol. 2000;15:268.
39. Chou MM, Tseng JJ, Hwang JI, Ho ES, Lee YH. Sonographic appearance of tornado blood flow in placenta previa accreta/increta. Ultrasound Obstet Gynecol. 2001;17:362-3.
40. Shih JC, Cheng WF, Shyu MK, Lee CN, Hsieh FJ. Power Doppler evidence of placenta accreta appearing in the first trimester. Ultrasound Obstet Gynecol. 2002;19:623-5.
41. Taipale P, Orden MR, Berg M, Manninen H, Alafuzoff I. Prenatal diagnosis of placenta accreta and percreta with ultrasonography, color Doppler, and magnetic resonance imaging. Obstet Gynecol. 2004;104:537-40.
42. Luo G, Perni SC, Jean-Pierre C, Baergen RN, Predanic M. Failure of conservative management of placenta previa-percreta. J Perinat Med. 2005;33:564-8.
43. Wong HS, Zuccollo J, Parker S, Burns K, Tait J, Pringle KC. Antenatal diagnosis of non-previa placenta increta with histological confirmation. Ultrasound Obstet Gynecol. 2006;27:467-9.
44. Ben Nagi J, Ofili-Yebovi D, Marsh M, Jurkovic D. First-trimester cesarean scar pregnancy evolving into placenta previa/accreta at term. J Ultrasound Med. 2005;24:1569-73.
45. Thia EW, Lee SL, Tan HK, Tan LK. Ultrasonographical features of morbidly-

- adherent placentas. Singapore Med J. 2007;48:799-802.
46. Wong HS, Zuccollo J, Tait J, Pringle K. Antenatal topographical assessment of placenta accreta with ultrasound. Aust N Z J Obstet Gynaecol. 2008;48:421-3.
47. Yee YH, Kung FT, Yu PC, Hsu TY, Cheng YF. Successful conservative management of placenta previa totalis and extensive percreta. Taiwan J Obstet Gynecol. 2008;47:431-4.
48. Wong HS, Zuccollo J, Tait J, Pringle KC. Placenta accreta in the first trimester of pregnancy: sonographic findings. J Clin Ultrasound. 2009;37:100-3.
49. Morel O, Desfeux P, Fargeaudou Y, Malartic C, Rossignol M, Perrotez C, Barranger E. Uterine conservation despite severe sepsis in a case of placenta accreta first treated conservatively: 3-month delayed successful removal of the placenta. Fertil Steril. 2009;91:1957.e5-9.
50. Yang JI, Lee KM, Kim HY, Kim HS. "The eye of a typhoon" ultrasonographic finding in a case of placenta previa accreta. Arch Gynecol Obstet. 2012;286:263-4
51. Yarandi F, Eftekhari Z, Shojaei H, Rahimi-Sharbat F, Baradaran F. Conservative management of placenta increta: case report and literature review. Acta Med Iran. 2011;49:396-8.
52. Pereira N, Yao R, Guilfoyle DS, Richard SD, Plante LA. Placenta membranacea with placenta accreta: radiologic diagnosis and clinical implications. Prenat Diagn. 2013;33:1293-6.
53. Moretti F, Merzotis M, Ferraro ZM, Oppenheimer L, Fung Kee Fung K. The importance of a late first trimester placental sonogram in patients at risk of abnormal placentation. Case Rep Obstet Gynecol. 2014:345-348.
54. Ozyurek ES, Kahraman AA, Yildirim D, Karacaoglu UM. Clinical presentation of placenta percreta with uterine incarceration in the second trimester. J Obstet Gynaecol. 2015;35:641-3.
55. Matsuzaki S, Matsuzaki S, Ueda Y, Tanaka Y, Kakuda M, Kanagawa T, et al. A Case Report and Literature Review of Midtrimester Termination of Pregnancy Complicated by Placenta Previa and Placenta Accreta. AJP Rep. 2015;5:e6-e1.
56. Kerr de Mendonça L. Sonographic diagnosis of placenta accreta. Presentation of

- 1
2
3
4 six cases. J Ultrasound Med. 1988;7:211-5.
5
6 57. Hoffman-Tretin JC, Koenigsberg M, Rabin A, Anyaegbunam A. Placenta accreta.
7 Additional sonographic observations. J Ultrasound Med. 1992;11:29-34.
8
9 58. Finberg HJ, Williams JW. Placenta accreta: prospective sonographic diagnosis in
10 patients with placenta previa and prior cesarean section. J Ultrasound Med.
11 1992;11:333-43.
12
13 59. Lerner JP, Deane S, Timor-Tritsch IE. Characterization of placenta accreta using
14 transvaginal sonography and color Doppler imaging. Ultrasound Obstet Gynecol.
15 1995;5:198-201.
16
17 60. Levine D, Hulka CA, Ludmir J, Li W, Edelman RR. Placenta accreta: evaluation
18 with color Doppler US, power Doppler US, and MR imaging. Radiology.
19 1997;205:773-6.
20
21 61. Twickler DM, Lucas MJ, Balis AB, Santos-Ramos R, Martin L, Malone S, et al.
22 Color flow mapping for myometrial invasion in women with a prior cesarean
23 delivery. J Matern Fetal Med. 2000;9:330-5.
24
25 62. Chou MM, Ho ES, Lee YH. Prenatal diagnosis of placenta previa accreta by
26 transabdominal color Doppler ultrasound. Ultrasound Obstet Gynecol.
27 2000;15:28-35.
28
29 63. Chou MM, Tseng JJ, Ho ES. The application of three-dimensional color power
30 Doppler ultrasound in the depiction of abnormal uteroplacental angioarchitecture
31 in placenta previa percreta. Ultrasound Obstet Gynecol. 2002;19:625-7.
32
33 64. Lam G, Kuller J, McMahon M. Use of magnetic resonance imaging and
34 ultrasound in the antenatal diagnosis of placenta accreta. J Soc Gynecol
35 Investig. 2002;9:37-40.
36
37 65. Comstock CH, Love JJ Jr, Bronsteen RA, Lee W, Vettraino IM, Huang RR, et al.
38 Sonographic detection of placenta accreta in the second and third trimesters of
39 pregnancy. Am J Obstet Gynecol. 2004;190:1135-40.
40
41 66. Moodley J, Ngambu NF, Corr P. Imaging techniques to identify morbidly
42 adherent placenta praevia: a prospective study. J Obstet Gynaecol. 2004;24:742-
43 4.
44
45 67. Warshak CR, Eskander R, Hull AD, Scioscia AL, Mattrey RF, Benirschke K, et al.
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

- Accuracy of ultrasonography and magnetic resonance imaging in the diagnosis of placenta accreta. *Obstet Gynecol.* 2006;108:573-81.
68. Sumigama S, Itakura A, Ota T, Okada M, Kotani T, Hayakawa H, et al. Placenta previa increta/percreta in Japan: a retrospective study of ultrasound findings, management and clinical course. *J Obstet Gynaecol Res.* 2007;33:606-11.
69. Wong HS, Cheung YK, Strand L, Carryer P, Parker S, Tait J, Pringle KC. Specific sonographic features of placenta accreta: tissue interface disruption on gray-scale imaging and evidence of vessels crossing interface- disruption sites on Doppler imaging. *Ultrasound Obstet Gynecol.* 2007;29:239-41.
70. Masselli G, Brunelli R, Casciani E, Poletti E, Piccioni MG, Anceschi M, et al. Magnetic resonance imaging in the evaluation of placental adhesive disorders: correlation with color Doppler ultrasound. *Eur Radiol.* 2008;18:1292-9.
71. Japaraj RP, Mimin TS, Mukudan K. Antenatal diagnosis of placenta previa accreta in patients with previous cesarean scar. *J Obstet Gynaecol Res.* 2007;33:431-7.
72. Wong HS, Cheung YK, Zuccollo J, Tait J, Pringle KC. Evaluation of sonographic diagnostic criteria for placenta accreta. *J Clin Ultrasound.* 2008;36:551-9.
73. Dwyer BK, Belogolovkin V, Tran L, Rao A, Carroll I, Barth R, Chitkara U. Prenatal diagnosis of placenta accreta: sonography or magnetic resonance imaging? *J Ultrasound Med.* 2008;27:1275-81
74. Miura K, Miura S, Yamasaki K, Yoshida A, Yoshiura K, Nakayama D, et al. Increased level of cell-free placental mRNA in a subgroup of placenta previa that needs hysterectomy. *Prenat Diagn.* 2008;28:805-9.
75. Mazouni C, Palacios-Jaraquemada JM, Deter R, Juhan V, Gamberre M, Bretelle F. Differences in the management of suspected cases of placenta accreta in France and Argentina. *Int J Gynaecol Obstet.* 2009;107:1-3.
76. Shih JC, Palacios Jaraquemada JM, Su YN, Shyu MK, Lin CH, Lin SY, et al. Role of three-dimensional power Doppler in the antenatal diagnosis of placenta accreta: comparison with gray-scale and color Doppler techniques. *Ultrasound Obstet Gynecol.* 2009;33:193-203.
77. Chou MM, Chen WC, Tseng JJ, Chen YF, Yeh TT, Ho ES. Prenatal detection of

- bladder wall involvement in invasive placentation with sequential two-dimensional and adjunctive three-dimensional ultrasonography. *Taiwan J Obstet Gynecol.* 2009;48:38-45.
78. Warshak CR, Ramos GA, Eskander R, Benirschke K, Saenz CC, Kelly TF, et al. Effect of predelivery diagnosis in 99 consecutive cases of placenta accreta. *Obstet Gynecol.* 2010;115:65-9.
79. Woodring TC, Klauser CK, Bofill JA, Martin RW, Morrison JC. Prediction of placenta accreta by ultrasonography and color Doppler imaging. *J Matern Fetal Neonatal Med.* 2011;24:118-2.
80. El Behery MM, Rasha L E, El Alfy Y. Cell-free placental mRNA in maternal plasma to predict placental invasion in patients with placenta accreta. *Int J Gynaecol Obstet.* 2010;109:30-3.
81. Esakoff TF, Sparks TN, Kaimal AJ, Kim LH, Feldstein VA, Goldstein RB, et al. Diagnosis and morbidity of placenta accreta. *Ultrasound Obstet Gynecol.* 2011;37:324-7.
82. Fishman SG, Chasen ST. Risk factors for emergent preterm delivery in women with placenta previa and ultrasound findings suspicious for placenta accreta. *J Perinat Med.* 2011;39:693-6.
83. Hamada S, Hasegawa J, Nakamura M, Matsuoka R, Ichizuka K, Sekizawa A, et al. Ultrasonographic findings of placenta lacunae and a lack of a clear zone in cases with placenta previa and normal placenta. *Prenat Diagn.* 2011;31:1062-5.
84. Lim PS, Greenberg M, Edelson MI, Bell KA, Edmonds PR, Mackey AM. Utility of ultrasound and MRI in prenatal diagnosis of placenta accreta: a pilot study. *Am J Roentgenol.* 2011;197:1506-13.
85. Mansour SM, Elkhyat WM. Placenta previa-accreta: Do we need MR imaging. *Egypt J Radiol Nuc Med.* 2011;42:433-442.
86. Wong HS, Cheung YK, Williams E. Antenatal ultrasound assessment of placental/myometrial involvement in morbidly adherent placenta. *Aust N Z J Obstet Gynaecol.* 2012;52:67-72
87. Chantraine F, Blacher S, Berndt S, Palacios-Jaraquemada J, Sarioglu N, Nisolle M, et al. Abnormal vascular architecture at the placental-maternal interface in

- placenta increta. *Am J Obstet Gynecol.* 2012;207:188.e1-9.
88. Ballas J, Pretorius D, Hull AD, Resnik R, Ramos GA. Identifying sonographic markers for placenta accreta in the first trimester. *J Ultrasound Med.* 2012;31:1835-41.
89. Calì G, Giambanco L, Puccio G, Forlani F. Morbidly adherent placenta: evaluation of ultrasound diagnostic criteria and differentiation of placenta accreta from percreta. *Ultrasound Obstet Gynecol.* 2013;41:406-12.
90. Weiniger CF, Einav S, Deutsch L, Ginosar Y, Ezra Y, Eid L. Outcomes of prospectively-collected consecutive cases of antenatal-suspected placenta accreta. *Int J Obstet Anesth.* 2013;22:273-9.
91. Elhawary TM, Dabees NL, Youssef MA. Diagnostic value of ultrasonography and magnetic resonance imaging in pregnant women at risk for placenta accreta. *J Matern Fetal Neonatal Med.* 2013;26:1443-9.
92. Chalubinski KM, Pils S, Klein K, Seemann R, Speiser P, Langer M, et al. Prenatal sonography can predict degree of placental invasion. *Ultrasound Obstet Gynecol.* 2013;42:518-24.
93. Maher MA, Abdelaziz A, Bazeed MF. Diagnostic accuracy of ultrasound and MRI in the prenatal diagnosis of placenta accreta. *Acta Obstet Gynecol Scand.* 2013;92:1017-22.
94. Asıcıoglu O, Şahbaz A, Güngördük K, Yildirim G, Asıcıoglu BB, Ülker V. Maternal and perinatal outcomes in women with placenta praevia and accreta in teaching hospitals in Western Turkey. *J Obstet Gynaecol.* 2014;34:462-6.
95. Riteau AS, Tassin M, Chambon G, Le Vaillant C, de Laveaucoupet J, Quéré MP, et al. Accuracy of ultrasonography and magnetic resonance imaging in the diagnosis of placenta accreta. *PLoS One.* 2014;9:e94866.
96. Zhou J, Li J, Yan P, Ye YH, Peng W, Wang S, Wang XT. Maternal plasma levels of cell-free β -HCG mRNA as a prenatal diagnostic indicator of placenta accrete. *Placenta.* 2014;35:691-5.
97. Laban M, Ibrahim EA, Elsafty MS, Hassanin AS. Placenta accreta is associated with decreased decidual natural killer (dNK) cells population: a comparative pilot study. *Eur J Obstet Gynecol Reprod Biol.* 2014;181:284-8.

- 1
2
3
4 98. Algebally AM, Yousef RR, Badr SS, Al Obeidly A, Szmigielski W, Al Ibrahim AA.
5
6 The value of ultrasound and magnetic resonance imaging in diagnostics and
7
8 prediction of morbidity in cases of placenta previa with abnormal placentation.
9
10 Pol J Radiol. 2014;79:409-16.
- 11 99. Hall T, Wax JR, Lucas FL, Cartin A, Jones M, Pinette MG. Prenatal sonographic
12
13 diagnosis of placenta accreta: Impact on maternal and neonatal outcomes. J Clin
14
15 Ultrasound. 2014;42:449-55
- 16
17 100. Rac MW, Dashe JS, Wells CE, Moschos E, McIntire DD, Twickler DM.
18
19 Ultrasound predictors of placental invasion: the Placenta Accreta Index. Am J
20
21 Obstet Gynecol. 2015;212:343.e1-7.
- 22 101. Pilloni E, Alemanno MG, Gaglioti P, Sciarrone A, Garofalo A, Biolcati M, et
23
24 al. Accuracy of ultrasound in antenatal diagnosis of placental attachment
25
26 disorders. Ultrasound Obstet Gynecol. 2016;47:302-7.
- 27
28 102. Satija B, Kumar S, Wadhwa L, Gupta T, Kohli S, Chandoke R, et al. Utility
29
30 of ultrasound and magnetic resonance imaging in prenatal diagnosis of placenta
31
32 accreta: A prospective study. Indian J Radiol Imaging. 2015;25:464-70.
- 33 103. Gilboa Y, Spira M, Mazaki-Tovi S, Schiff E, Sivan E, Achiron R. A novel
34
35 sonographic scoring system for antenatal risk assessment of obstetric
36
37 complications in suspected morbidly adherent placenta. J Ultrasound Med.
38
39 2015;34:561-7.
- 40
41 104. Collins SL, Stevenson GN, Al-Khan A, Illsley NP, Impey L, Pappas L, et al.
42
43 Three-Dimensional Power Doppler Ultrasonography for Diagnosing Abnormally
44
45 Invasive Placenta and Quantifying the Risk. Obstet Gynecol. 2015;126:645-53.
- 46 105. Rezk MA, Shawky M. Grey-scale and colour Doppler ultrasound versus
47
48 magnetic resonance imaging for the prenatal diagnosis of placenta accreta. J
49
50 Matern Fetal Neonatal Med. 2016;29:218-23.
- 51
52 106. Tovbin J, Melcer Y, Shor S, Pekar-Zlotin M, Mendlovic S, Svirsky R, et al.
53
54 Predicting of morbidly adherent placenta using a scoring system: A prospective
55
56 study. Ultrasound Obstet Gynecol. 2016 in press.
- 57 107. Kumar I, Verma A, Ojha R, Shukla RC, Jain M, Srivastava A. Invasive
58
59 placental disorders: a prospective US and MRI comparative analysis. Acta
60
61
62
63
64
65

- Radiol. 2016 in press.
108. Langhans T. Die losung der muetterlichen eihaeute. Arch F Gynaek. 1875;8:287-97.
109. Hart DB. A contribution to the pathology symptoms and treatment of adherent placenta. Edinburgh Med J. 1889;34:816-9.
110. Baisch K. Zur pathologischen anatomie der placenta accreta. Arb Geb Pathol Anat Bact. 1907-1908;6:265-70.
111. McCarthy EJ, Nichols EO. Ruptured uterus due to placenta percreta. Am J Surg. 1950;80:485-6.
112. McDonald KN. How to prevent septicaemia in cases of morbidly adherent placenta. BMJ. 1885;1:779-80.
113. Klar M, Michels KB. Cesarean section and placental disorders in subsequent pregnancies - a meta-analysis. J Perinat Med. 2014;42:571-83.
114. Silver RM, Landon MB, Rouse DJ, Leveno KJ, Spong CY, Thom EA et al. Maternal morbidity associated with multiple repeat cesarean deliveries. Obstet Gynecol. 2006;107:1226-32.
115. Gyamfi-Bannerman C, Gilbert S, Landon MB, Spong CY, Rouse DJ, Varner MW et al. Risk of uterine rupture and placenta accreta with prior uterine surgery outside of the lower segment. Obstet Gynecol. 2012;120:1332-7.
116. Tikkanen M, Paavonen J, Loukovaara M, Stefanovic V. Antenatal diagnosis of placenta accreta leads to reduced blood loss. Acta Obstet Gynecol Scand. 2011;90:1140-6.
117. Seet EL, Kay HH, Wu S, Terplan M. Placenta accreta: depth of invasion and neonatal outcomes. J Matern Fetal Neonatal Med. 2012;25:2042-5. Kayem G, Deneux-Tharaux C, Sentilhes L; PACCRETA group. Clinical situations at high risk of placenta ACCRETA/percreta: impact of diagnostic methods and management on maternal morbidity. Acta Obstet Gynecol Scand. 2013;92:476-82.
118. Chantraine F, Braun T, Gonser M, Henrich W, Tutschek B. Prenatal diagnosis of abnormally invasive placenta reduces maternal peripartum hemorrhage and morbidity. Acta Obstet Gynecol Scand. 2013;92:439-44.

- 1
2
3
4 119. Silver RM, Fox KA, Barton JR, Abuhamad AZ, Simhan H, Huls CK, Belfort
5 MA, Wright JD. Center of excellence for placenta accreta. *Am J Obstet Gynecol.*
6 2015;212:561-8.
7
8
9
10 120. D'Antonio F, Iacovella C, Bhide A. Prenatal identification of invasive
11 placentation using ultrasound: systematic review and meta-analysis. *Ultrasound*
12 *Obstet Gynecol.* 2013;42:509-17.
13
14
15 121. Dannheim K, Shaiker SA, Hecht JL. Hysterectomy for placenta accreta:
16 Methods for gross and microscopic pathology examination. *Arch Gynecol Obstet.*
17 2016;293:951-8.
18
19
20 122. Parra-Herran C, Djordjevic B. Histopathology of placenta creta: chorionic
21 villi intrusion into myometrial vascular spaces and extravillous trophoblast
22 proliferation are frequent and specific findings with implications on diagnosis and
23 pathogenesis. *Int J Gynecol Pathol.* 2016. [Epub ahead of print].
24
25
26 123. Meng X, Xie L, Song W. Comparing the diagnostic value of ultrasound and
27 magnetic resonance imaging for placenta accreta: a systematic review and meta-
28 analysis. *Ultrasound Med Biol.* 2013;39:1958-65.
29
30
31 124. D'Antonio F, Iacovella C, Palacios-Jaraquemada J, Bruno CH, Manzoli L,
32 Bhide A. Prenatal identification of invasive placentation using magnetic
33 resonance imaging: systematic review and meta-analysis. *Ultrasound Obstet*
34 *Gynecol.* 2014;44:8-16.
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Table 1: Ultrasound signs identified in the diagnosis of 38 cases reports ranked according to the depth of villous myometrial invasion.

Ultrasound signs	PC n(%)	PI n(%)	PP n(%)
<u>Grey-scale Parameters</u>	(n=13)	(n=16)	(n=9)
Loss of clear zone	12(92.3)	14(87.5)	5(55.6)
Myometrial thinning	6(46.2)	11(68.8)	3(33.3)
Placental lacunae	5(38.5)	9(56.3)	9(100)
Bladder wall interruption	1(7.7)	2(12.5)	2(22.2)
Placental bulge	-	1(12.5)	1(11.1)
Focal exophytic mass	-	-	1(11.1)
<u>CDI Parameters</u>	(n=11)	(n=11)	(n=8)
Uterovesical hypervascularity	1(9.1)	2(18.2)	2(25.0)
Subplacental hypervascularity	5(45.5)	9(81.8)	6(75.0)
Bridging vessels	10(90.9)	7(63.6)	2(25.0)
Lacunae feeder vessels	2(18.2)	6(55.5)	4(50.0)
CDI= Color Doppler Imaging; PC= placenta creta or vera; PI= placenta increta; PP= placenta percreta.			

Table 2: Distribution of the ultrasound sign used in the diagnosis of PA in 53 series.

Ultrasound signs	n (%)
<u>Grey-scale Parameters</u> (n=52)	
Loss of clear zone	50(98.0)
Myometrial thinning	34(66.7)
Placental lacunae	49(96.1)
Bladder wall interruption	30(58.8)
Placental bulge	11(22.0)
Focal exophytic mass	13(25.5)
<u>CDI Parameters</u> (n=42)	
Uterovesical hypervascularity	20(47.6)
Subplacental hypervascularity	36(85.7)
Bridging vessels	26(61.9)
Lacunae feeder vessels	22(52.4)
CDI= Color Doppler Imaging	

Table 3: Distribution of standard ultrasound signs found in eight studies presenting detailed data on depth of villous myometrial invasion.

Variables	References								
	65	79	84	89	95	98	102	107	T
	n	n	n	n	n	n	n	n	n
No of cases	15	10	9	41	26	32	10	9	152
<u>Placental grading</u>									n
PC	8	8	5	15	16	16	3	1	72
PI	3	1	3	9	--	12	4	2	34
PP	4	1	1	17	10	4	3	6	46
<u>Grey-scale Parameters</u>									%
Loss of clear zone	7	10	4	37	23	20	5		69.7
Myometrial thinning					19	32	3		51.0
Placental lacunae	10	10	5	30	23	28	5	9	78.9
Bladder wall interruption	3				15	16	1		23.0
Placental bulge			1		9				6.6
Focal exophytic mass			1		11				7.9
<u>CDI Parameters (n= 128)</u>									%
Uterovesical hypervascularity					11	30	2	6	11.3
Subplacental hypervascularity		10				30		7	36.7
Bridging vessels					12				9.3
Lacunae feeder vessels							5	6	8.6

CDI= Color Doppler Imaging; ; PC= placenta creta or vera; PI= placenta increta; PP= placenta percreta.

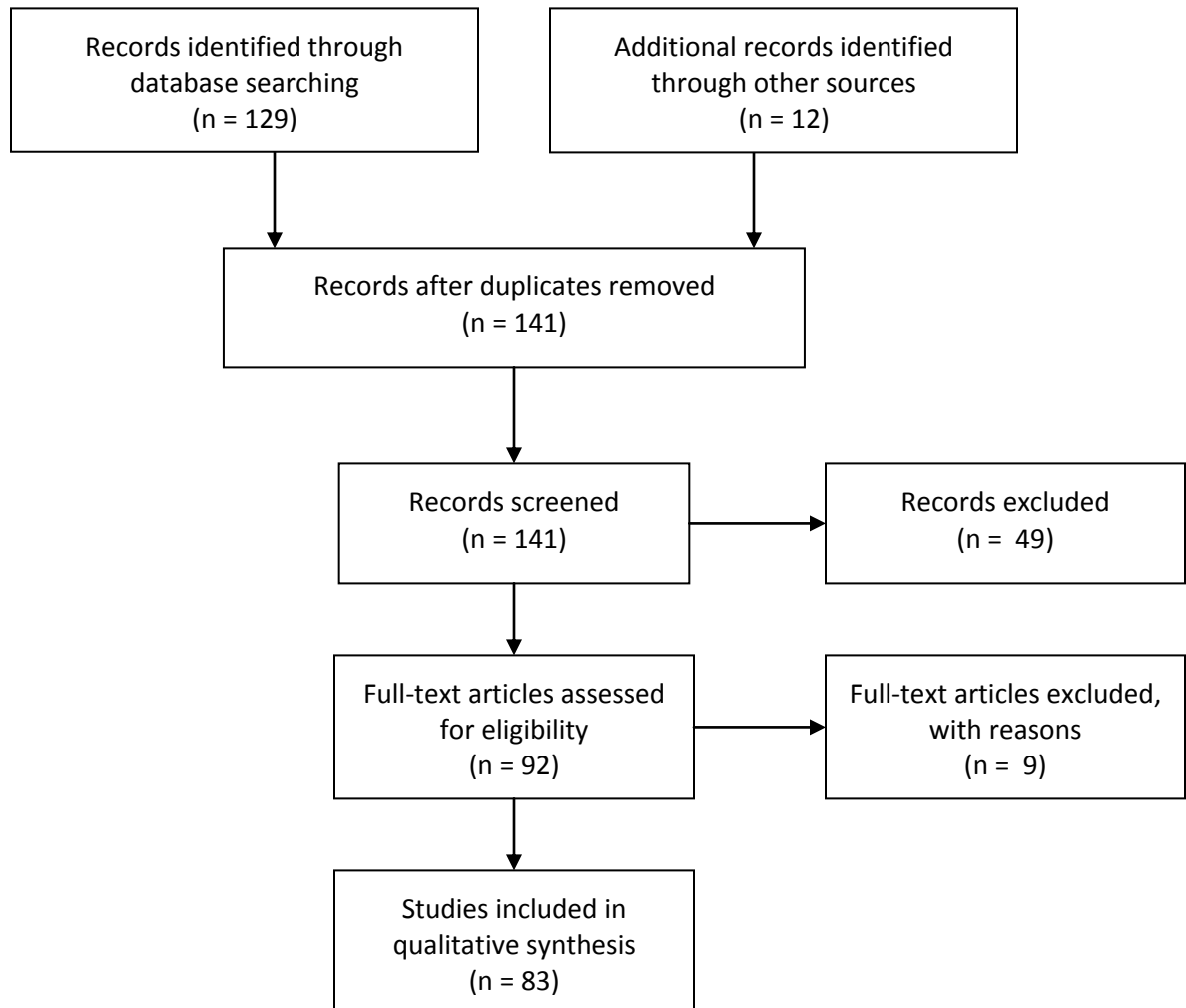
References 65 and 83 included only grey-scale imaging data.

Table 4: Ultrasound signs identified in the diagnosis of 38 cases reports and in 3 series^{65,84,102} including 34 cases ranked according to the depth of villous myometrial invasion.

Ultrasound signs	PC	PI	PP
	n(%)	n(%)	n(%)
<u>Grey-scale Parameters</u>	(n=29)	(n=26)	(n=17)
Loss of clear zone	18(62.1)	22(84.6)	8(47.1)
Myometrial thinning	6(20.7)	12(46.2)	4(23.5)
Placental lacunae	16(55.2)	16(61.5)	14(82.4)
Bladder wall interruption	2(6.9)	2(7.7)	5(29.4)
Placental bulge	-	1(3.9)	2(11.8)
Focal exophytic mass	-	-	2(11.8)
<u>CDI Parameters</u>	(n=14)	(n=15)	(n=11)
Uterovesical hypervascularity	3(21.4)	2(13.3)	2(18.2)
Subplacental hypervascularity	5(35.7)	9(60.0)	6(54.5)
Bridging vessels	10(71.4)	7(46.7)	2(18.2)
Lacunae feeder vessels	4(28.6)	8(53.3)	5(45.5)
CDI= Color Doppler Imaging; PC= placenta creta or vera; PI= placenta increta; PP= placenta percreta.			

Figure legend

Fig 1: Flow diagram for the selection of cases reports and series on ultrasound imaging of PA.

Figure 1

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit www.prisma-statement.org.