Original Article

A Novel Scoring System for Predicting Adherent Placenta in Women with Placenta Previa

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Declarations of interest: none.

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Abstract

Introduction

Placenta previa (PP) is one of the most significant risk factors for adherent placenta (AP). The aim of this study was to evaluate the diagnostic efficacy of a novel scoring system for predicting AP in pregnant women with PP.

Methods

This prospective cohort study enrolled 175 women with PP. The placenta previa with adherent placenta score (PPAP score) is composed of 2 categories: (1) past history of cesarean section (CS), surgical abortion, and/or uterine surgery; and (2) ultrasonography and magnetic resonance imaging findings. Each category is graded as 0, 1, 2, or 4 points, yielding a total score between 0 and 24. When women with PP had PPAP score ≥8, they were considered to be at a high risk for AP and received placement of preoperative internal iliac artery occlusion balloon catheters. If they were found to have AP during CS, they underwent hysterectomy or placenta removal using advanced bipolar with balloon catheter occlusion. The predictive accuracy of PPAP score was evaluated.

Results

In total, 23 of the 175 women with PP were diagnosed as having AP, histopathologically or clinically. Twenty-one of 24 women with PPAP score ≥8 had AP, whereas two of 151 women with PPAP score <8 had AP. The scoring system yielded 91.3% sensitivity, 98.0%

specificity, 87.5% positive predictive value, and 98.7% negative predictive value for predicting AP in women with PP.

Discussion

This prospective study demonstrated that PPAP scoring system may be useful for predicting AP in women with PP.

Keywords:

Adherent placenta, Placenta previa, Prenatal diagnosis, Scoring system, Ultrasonographic examination, Magnetic resonance imaging

Introduction

Adherent placenta, including placenta accreta, increta, and percreta, is a life-threatening obstetrical condition. Clinical complications of adherent placenta involve massive hemorrhage, damage to adjacent organs, cesarean hysterectomy, and maternal death. It is well known that placenta previa is one of the most significant risk factors for adherent placenta [1, 2]. Prenatal prediction of adherent placenta in pregnancies complicated by placenta previa can help minimize complications by enabling obstetricians to plan for resources that may be required during cesarean delivery, including obstetric anesthesia, appropriate surgical expertise, available blood products, and interventional radiology for uterine artery embolization [3, 4]. Therefore, accurate prenatal prediction of adherent placenta in pregnancy with placenta previa is important.

Prenatal ultrasonography [5-7] and magnetic resonance imaging (MRI) [8, 9] are useful methods of predicting adherent placenta. Some investigators have suggested that diagnostic scoring systems consisting of several ultrasound (US) findings suggestive of adherent placenta can be more useful in predicting adherent placenta than prenatal diagnosis using a single US finding [10-12]. However, these previous studies evaluated the diagnostic efficacy of the scoring systems for predicting adherent placenta in pregnant women with at least one previous cesarean section (CS) and/or placenta previa, or

low-lying placenta, retrospectively or prospectively [10-12]. Optimal cut-off values of the scores determined in these studies yielded 72.0%–94.2% sensitivity, 52.5%–85.0% specificity, 63.4%–70.0% positive predictive value (PPV), and 86.0%–100% negative predictive value (NPV) for the prediction of adherent placenta [10, 11].

The aim of this prospective study was to evaluate the diagnostic accuracy of a novel scoring system that assigns a placenta previa with adherent placenta (PPAP) score. The PPAP score is determined using histories of CS and uterine surgery, as well as findings of US and MRI examinations.

Materials and Methods

Study design and participants

The institutional review board of Kobe University Hospital approved this prospective cohort study. Pregnant women with placenta previa who received prenatal care and delivered at the university hospital from January 2011 to July 2017 were enrolled. Informed consent was obtained from all patients. Study participants underwent clinical interviews, regarding past histories of CS, surgical abortion, and/or uterine surgery during their first visit. When they visited the university hospital prior to 32 wks gestation (GW), they received both US and MRI examinations used in determining the PPAP score. US and MRI examinations were performed between 28 and 32 GW. If participants were referred from another hospital/clinic past 32 GW, they underwent US examinations during their first visit, and MRI examinations were then performed within 1 wk after their first visit.

US examinations were performed by perinatologists (K.T. and M.M.) using the Voluson 730 or Voluson E8 Expert system (GE Healthcare, Milwaukee, WI, USA) with a 2–5-MHz transabdominal convex transducer and a 4–9-MHz transvaginal transducer, or using the ProSound α7 or Arietta A60 system (Hitachi Aloka Medical, Tokyo, Japan) with a 2-MHz transabdominal convex transducer and a 5-MHz transvaginal transducer. Perinatologists checked the presence of placental lacunae (PL), loss of the retroplacental

hypoechoic clear zone (LCZ), and turbulent blood flow (TBF) in the arteries radiating from the placenta toward the uterine serosa, as detected by color Doppler using transabdominal ultrasonography. They also checked the presence of irregularity of the border between the placenta and myometrium around internal uterine os, which we referred to as an “irregular sign”, using transvaginal ultrasonography (Fig. 1). Either of the two perinatologists (K.T. and M.M.) performed US examination, determined the score of each variable regarding US findings, and saved the appropriate US images. The other perinatologist evaluated the saved US images. If the score of each variable determined by the two perinatologists were different, the higher score of the two was selected.

MRI examinations were performed using a 1.5T MRI system (Gyroscan NT, Philips, Best, Netherlands). Following the localizer scan, the MRI protocol included examination using half-fourier acquisition with single shot turbo spin echo, balanced-fast field echo, and axial double-echo gradient-echo chemical shift imaging. Radiologists (Y.U., U.T., and K.K.) evaluated the MRI images and determined whether or not an adherent placenta was present. MRI findings suggestive of adherent placenta included indistinctness or the absence of myometrial wall at the placental site, loss of the thin T2 dark uteroplacental interface, a nodular interface between the placenta and the uterus, a mass effect of the placenta on the uterus causing uterine outer bulge, heterogeneous signal intensity within the placenta, dark intraplacental bands on T2-weighted images, and

abnormal dilated venous lakes within the placenta [9, 13, 14]. When women had at least one MRI finding mentioned above, they were highly suspected of having adherent placenta. Two of the 3 radiologists (Y.U. and K.K.) were board-certified genitourinary radiologists, each of whom had more than 10 years' experience, and the remaining one radiologist (U.T.) was a specialists in genitourinary field with more than 5 years' experience. Each of the 3 radiologists independently evaluated the MRI images, and the final diagnosis were made by majority rule.

Women who delivered by emergency CS before scoring the PPAP score were excluded from this study.

Procedures

The PPAP score is composed of 2 categories: (1) past history of CS, surgical abortion, and/or uterine surgery; and (2) US and MRI examination findings. Each category was graded as 0, 1, 2, or 4 points, and the sum of the scores for all the variables as defined as the PPAP score, yielding a number between 0 and 24. The variables and scores in the PPAP scoring system are shown in Table 1. We selected the variables that were widely accepted as significant risk factors or US findings associated with adherent placenta in previous studies [1, 7, 9, 15-19]. We also determined scores assigned to each variable, based on these results [17, 20, 21]. During the planning of this prospective study, we assigned 4 or 2 points for suspicion of adherent placenta by dynamic contrast-enhanced MRI or plain MRI,

86 respectively [22]. However, we removed the former from the variables in the PPAP scoring
87 system, because the use of gadolinium is controversial due to its unknown effects to the
88 fetus [23]. In our previous study, pregnant women with placenta previa underwent both US
89 and MRI examinations to diagnose adherent placenta prenatally [20]. We used data from
90 the 26 patients with placenta previa who delivered through December 2010, including five
91 with adherent placenta; a cut-off value of the PPAP score for the prediction of adherent
92 placenta in pregnancy with placenta previa was determined to be ≥8 using receiver
93 operating characteristic (ROC) analysis (Additional file 1: Fig. S1).

94 From January 2011, the PPAP scoring system has been used prospectively for
95 predicting adherent placenta in pregnancy with placenta previa. When patients with
96 placenta previa had a PPAP score ≥8, they were suspected of having adherent placenta, and
97 thus, received preoperative internal iliac artery occlusion balloon catheters placement. After
98 fetal delivery by a cesarean section using transverse uterine fundal incision method, the
99 internal iliac artery occlusion balloon catheters were inflated. After occlusion of the artery,
100 local injection of oxytocin into the myometrium and uterine massage were performed to
101 induce spontaneous placental separation. If placental separation didn't occur at all, cesarean
102 hysterectomy was performed. When the placenta was not partially separated, partial
103 resection of uterine wall or removal of placenta using advanced bipolar (LigaSure^{TM} Small
104 Jaw Medtronic, Covidien product, Minneapolis, MN, USA) were performed. If the women

had a strong desire for future fertility, conservative approach, i.e. leaving the placenta in situ, was considered. The diagnosis of adherent placenta was confirmed histopathologically or clinically. A clinical adherent placenta was diagnosed when an operator had to use advanced bipolar to remove the placenta during CS. The predictive accuracy of the PPAP score for adherent placenta was evaluated.

Statistical analysis

Clinical characteristics and prenatal US and MRI findings were compared between pregnant women who had placenta previa with adherent placenta and those without adherent placenta. Differences between the 2 groups were analyzed using the Mann–Whitney U test, Fisher's exact test, and chi-square test. A correlation between the PPAP score and the amount of intraoperative blood loss was determined by a regression analysis. Statistical significance was considered present at p values less than 0.05. All statistical analyses were performed using SPSS software, version 19 (SPSS Inc., Chicago, IL, USA).

Results

A flowchart of the subjects in this prospective cohort study is shown in Fig. 2.

During the study period, 185 pregnant women with placenta previa delivered. The last participant was recruited on July 21, 2017. Twenty-three of the 185 (12.4%) patients with placenta previa had adherent placenta: 4 cases were confirmed clinically, and 19 cases were confirmed histopathologically (12 cases of placenta accrete, 5 cases of placenta increta, and 2 cases of placenta percreta). In addition, fifteen of the 162 women without adherent placenta had intraoperative blood loss over 2500 ml. Their large blood loss caused by uncontrollable hemorrhage from placental implantation site or uterine atony, but not by adherent placenta.

Ten of the 185 (5.4%) pregnant women with placenta previa had delivered before recieving the PPAP score; therefore, a total of 175 women were analyzed in this prospective study. Two of the 10 women who had delivered before scoring the PPAP score received neither US nor MRI examinations, because they required emergency CS as soon as they were transferred to the university hospital because of severe bleeding. The remaining eight women received US examinations alone, because they underwent emergency CS before MRI examinations. The median score was 2 (range, 0–4) in the latter eight women, who did not have added scoring points that included MRI findings. Ten women who were excluded from analysis did not have adherent placenta.

Table 2 shows the clinical characteristics of the 23 women with and 152 without adherent placenta. Gravidity, parity, number of previous CS, proportion of patients with past history of uterine surgery, and blood loss volume in the adherent placenta group were significantly higher than in the no adherent placenta group. GW at diagnostic workup and GW at delivery in the adherent placenta group were earlier than in the no adherent placenta group.

US and MRI findings are shown in Table 3. The proportion of women with anterior placental location in the adherent group was higher than that in the no adherent placenta group. Furthermore, the proportion of women with US findings suggestive of adherent placenta defined in this study (i.e., PL, LCZ, TBF, and irregular signs) and that of women who were diagnosed with adherent placenta by MRI in the adherent placenta group was higher than that in the no adherent placenta group. The PPAP score of the adherent placenta group was significantly higher than that of the no adherent placenta group [median (range): 14 (4–22) vs 2 (0–12); $p<0.01$]. The details of the PPAP score in the adherent placental group was shown in Table 4.

Among 175 women who were enrolled in this prospective study, 24 of the 175 (13.7%) patients had a PPAP score ≥8 (Fig. 2). Twenty-one of the 24 (87.5%) patients with a PPAP score ≥8 had adherent placenta, including 18 cases, which were confirmed histopathologically, and three, which were confirmed clinically. Conversely, 151 of the

159 175 (86.3%) patients had a PPAP score <8, and 2 of those 151 patients (1.3%) had adherent
160 placenta, including one patient who underwent hysterectomy (Fig. 2). Table 5 shows the
161 clinical characteristics, US and MRI findings for two women with adherent placenta that
162 could not be predicted by the PPAP scoring system, who were the same as case 22 or case
163 23 in Table 4.

164 The PPAP scoring system yielded 91.3% sensitivity, 98.0% specificity, 87.5%
165 PPV, 98.7% NPV and 97.1% accuracy for the prediction of adherent placenta in pregnancy
166 with placenta previa. In addition, regression analysis identified a modest positive
167 correlation between the PPAP score and the amount of intraoperative blood loss ($r = 0.43$,
168 $p<0.01$) (Fig. 3).

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Discussion

This prospective study is the first to evaluate the efficacy of the scoring system for predicting adherent placenta among women with placenta previa, regardless of a history of CS. This study found that the PPAP scoring system yielded 91.3% sensitivity, 98.0% specificity, 87.5% PPV, 98.7% NPV, and 97.1% accuracy for the prediction of adherent placenta in pregnancy with placenta previa.

To the best of our best knowledge, there are four studies that evaluate the diagnostic efficacy of the scoring system for predicting adherent placenta, including three retrospective studies and one prospective study [10-12, 24]. These studies enrolled pregnant women who had at least one previous CS and/or placenta previa, or US findings suggestive of adherent placenta.

Additionally, two of the four previous studies aimed to determine more effective parameters for predicting adherent placenta and appropriate weighing of each parameter using logistic regression models, and also aimed to determine an optimal cut-off value of the scoring system via ROC analysis [10, 11]. These two studies showed 72.0%–94.2% sensitivity, 52.5%–85.0% specificity, 63.4%–70.0% PPV, 86.0%–100% NPV for the prediction of adherent placenta. In the remaining two studies, parameters, weighting of each parameter, and cut-off values were predetermined [12, 24], showing 69.6%–97.0% sensitivity, 98.7% specificity, 84.2% PPV and 97.1% NPV. In contrast, the

present study prospectively enrolled pregnant women with placenta previa alone, regardless of a history of CS and/or surgery. Repeated CS, as well as other procedures associated with uterine endometrial injuries, including surgical abortion, transcervical resection, myomectomy, and myometrium resection for adenomyosis, are known to be risk factors for adherent placenta [17, 25]. Therefore, we defined past history of surgeries other than CS as variables in the PPAP scoring system. Indeed, the one woman who didn't have previous caesarean section but have a past history of uterine artery embolization (case 9 in Table 4) could be diagnosed with adherent placenta by the PPAP scoring system. The PPAP scoring system may be practically suitable in identifying the patients who are at high risk for adherent placenta among pregnant women with placenta previa. In the present study, the PPAP scoring for the prediction of adherent placenta failed in two women: one had a history of myomectomy and another had a past history of myometrium resection for adenomyosis. A history of myomectomy and myometrium resection may increase a risk of adherent placenta in women with placenta previa. Especially, the woman with unpredictable adherent placenta and a past history of myometrium resection for adenomyosis (case 23 in Table 4, 5) had life-threatening hemorrhage exceeding 11 liters, and she had neither US nor MRI findings suggestive of adherent placenta. When patients with both placenta previa and a past history of myometrium resection for adenomyosis were received caesarean section, special attention should be paid to the risk of adherent

placenta regardless of US or MRI findings.

The present study showed, for the first time, that the presence of irregular signs resulted in 56.5% sensitivity, 99.3% specificity, 92.9% PPV, 93.8% NPV and 93.7% accuracy in predicting adherent placenta in women with placenta previa. MRI findings of placental protrusion into the internal uterine os (placental protrusion sign) are useful in the diagnosis of adherent placenta in women with placenta previa [9]. US findings of irregular signs assessed in the present study may correspond with MRI finding of placental protrusion sign.

There had been no study that included MRI findings as variables in the scoring systems for predicting adherent placenta. The present study, for the first time, included MRI findings as a parameter of the scoring system for diagnosing adherent placenta, and showed MRI findings yielding 87.0% sensitivity, 85.5% specificity, 47.6% PPV, 97.7% NPV, and 85.7% accuracy for predicting adherent placenta in women with placenta previa. In the present study, three women couldn't be diagnosed with adherent placenta by MRI (case 18 in Table 4, and case 22, 23 in Table 4, 5). In one case (case 18 in Table 4), adherent placenta could be predicted by US findings and a past history, not by MRI. On the other hand, adherent placenta couldn't be predicted by neither US nor MRI in the other one case (case 23 in Table 4, 5). If the variable of MRI findings were excluded from the PPAP scoring system, and a cut-off value of the score was changed 8 into 6, the remaining one

228 woman (case 22 in Table 4, 5) could be diagnosed with adherent placenta, whereas the
229 number of women who received unnecessary preoperative placement of internal iliac artery
230 occlusion balloon catheters increased from 3 to 10.

231 We had performed preoperative internal iliac artery occlusion balloon catheters
232 placement against patients with placenta previa who had a PPAP score ≥8. The average
233 blood loss at delivery in women with placenta accrete had been reported to be 3000–5000
234 ml [26]. During the study period, the average of intraoperative blood loss in 21 women with
235 adherent placenta who received preoperative internal iliac artery occlusion balloon
236 catheters was 4334 ml. In the twenty-one women, the average and standard deviation of
237 intraoperative blood loss in the 5 women who had bladder injury during the operation, due
238 to placental invasion or strong adhesion between bladder and uterus, or those in the 16
239 women without bladder injury were 11455±7289 ml or 2109±1060 ml, respectively. It was
240 suggested that preoperative internal iliac artery occlusion balloon catheter was helpful in
241 reducing intraoperative blood loss in women who had adherent placenta without risk of
242 damage to the bladder. However, other strategies, such as abdominal aortic artery occlusion
243 balloon catheters, may be needed to reduce intraoperative blood loss in women had the
244 risks of both adherent placenta and bladder injury.

245 This prospective study demonstrated that PPAP scoring system may be useful in
246 predicting adherent placenta in pregnant women with placenta previa. In addition,

247 regression analysis identified a modest positive correlation between the PPAP score and the
248 amount of intraoperative blood loss. This result may provide useful information to
249 clinicians.

250 There are some potential limitations associated with this study. Kobe University
251 Hospital has a maternal–fetal center where pregnant women who are at high risk for
252 adherent placenta are often referred from other hospitals and clinics. The scale of the study,
253 which included 23 cases of adherent placenta, was not large enough. Therefore, further
254 studies are required to confirm the conclusions of this study.

255

256 **Acknowledgments**

257 We acknowledge and thank Takuya Okada, Masato Yamaguchi, and Koji Sugimoto, at the
258 Department of Radiology and Center for Endovascular Therapy, Kobe University Graduate
259 School of Medicine, for supporting us with interventional radiology procedures at the time
260 of operation.

261

262 **Conflicts of Interest**

263 The authors report no conflict of interest.

264

265 **Funding sources**

266 This research did not receive any specific grant from funding agencies in the public,
267 commercial, or not-for-profit sectors.

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358

359 **Table 1.** Variables and scores in the PPAP scoring system

	Variable		Level of variable	Score
Past history	No. of previous CS		0	0
			1	2
			≥2	4
	No. of previous surgical abortions		<3	0
			≥3	2
	Other uterine surgeries		No	0
			Present	2
			Placenta located on uterine scar	4
Imaging examination	USG	Grade of placental lacunae	0	0
			1	2
			≥2	4
		Loss of clear zone	Absent	0
			Equivocal	2
			Present	4
		Turbulent blood flow	Absent	0
			Equivocal	1
			Present	2
		Irregular signs	Absent	0
			Present	2
	MRI	Adherent placenta suspected	No	0
			Yes	2

360 CS, cesarean section; MRI, magnetic resonance imaging; PPAP, placenta previa with adherent placenta;

361 USG, ultrasonography

362 **Table 2**. Clinical characteristics of participants (women with placenta previa)

	Adherent placenta (n = 23)	No adherent placenta (n = 152)	p-value
Age, yrs	35 (24–43)	35 (23–44)	0.9
Gravidity	2 (0–8)	1 (0–6)	< 0.05
Parity	1 (0–5)	0 (0–3)	< 0.01
No. of previous CS	1 (0–5)	0 (0–2)	< 0.01
No. of previous surgical abortion	0 (0–2)	0 (0–4)	0.4
Past history of uterine surgery (except for CS and surgical abortion)	26.3%	6.2%	< 0.05
Gestational weeks at diagnostic workup	30 (28–35)	31 (28–36)	< 0.05
Gestational weeks at delivery	35 (28–38)	37 (28–38)	< 0.01
Blood loss at CS, mL	2,465 (860–25,370)	1,409 (485–4,800)	< 0.01

363 CS, cesarean section. Data are expressed as the median (range); Wilcoxon rank sum test,

364 Mann–Whitney U test.

365

366 **Table 3.** Comparison of US and MRI findings

			Adherent placenta (n = 23)	No adherent placenta (n = 152)	*p*-value
US					
	Anterior placental location		73.9%	23.7%	< 0.01
	Placenta lacunae				
		≥ Grade 1	91.3%	33.6%	< 0.01
		≥ Grade 2	73.9%	7.2%	< 0.01
	Loss of clear zone		73.9%	2.0%	< 0.01
	Turbulent blood flow		39.1%	2.0%	< 0.01
	Irregular sign		56.5%	0.7%	< 0.01
MRI			87.0%	14.5%	< 0.01

367 MRI, magnetic resonance imaging; US, ultrasound. Data are expressed as the median (range) or %

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Table 4. The details of the PPAP score, intraoperative findings, and histopathological diagnosis in 23 women with adherent placenta

No.	Past history	Imaging examination		PPAP score	Operative procedures	Histo-pathological diagnosis
		US	MRI			
1	CS 2 times (4), myomectomy (4)	PLG3 (4), LCZ (4),TBF (2), Irr. sign (2)	(2)	22	CS+Hys.	Perc.
2	CS 1 time (2), hysteroscopic adhesiolysis (4)	PLG2 (4), LCZ (4),TBF (2), Irr. sign (2)	(2)	20	Pl. rem. by LigaSure	N.D.
3	CS 5 times (4)	PLG2 (4), LCZ(4),TBF (2), Irr. sign (2)	(2)	18	CS+Hys.	Acc.
4	CS 2 times (4)	PLG3 (4), LCZ(4),TBF (2), Irr. sign (2)	(2)	18	CS+Hys.	Inc.
5	CS 2 times (4), myomectomy (2)	PLG2 (4), LCZ(4),TBF (2)	(2)	18	CS+Hys.	Acc.
6	CS 1 time (2)	PLG3 (4), LCZ(4),TBF (2), Irr. sign (2)	(2)	16	CS+Hys.	Inc.
7	CS 1 time (2)	PLG3 (4), LCZ(4),TBF (2), Irr. sign (2)	(2)	16	CS+Hys.	Acc.
8	CS 1 time (2)	PLG2 (4), LCZ(4), Irr. sign (2)	(2)	14	Part. res. of ut. wall	Acc.
9	UAE (2)	PLG2 (4), LCZ(4), Irr. sign (2)	(2)	14	CS+Hys.	Inc.
10	CS 1 time (2)	PLG2 (4), LCZ(4), Irr. sign (2)	(2)	14	CS+Hys.	Acc.
11	CS 2 times (4)	PLG1 (2), LCZ(4), TBF (2)	(2)	14	CS+Hys.	Acc.
12	CS 1 time (2)	PLG2 (4), LCZ(2), TBF(2), Irr. sign (2)	(2)	14	CS+Hys.	Perc.
13	CS 2 times (4)	PLG2 (4), LCZ(4)	(2)	14	Pl. rem. by LigaSure	N.D.
14	CS 1 time (2)	PLG1 (2), LCZ(4), Irr. sign (2)	(2)	12	CS+Hys.	Acc.
15	CS 2 times (4)	PLG2 (4), Irr. sign (2)	(2)	12	CS+Hys.	Acc.
16	CS 1 time (2)	PLG2 (4), LCZ(4)	(2)	12	CS+Hys.	Acc.
17	CS 1 time (2)	PLG3 (4), LCZ(4)	(2)	12	CS+Hys.	Inc.
18	CS 2 times (4)	PLG2 (4), LCZ(4)	(0)	12	CS+Hys.	Acc.
19	CS 2 times (4)	LCZ(4)	(2)	10	CS+Hys.	Acc.
20	CS 2 times (4)	PLG2(4)	(2)	10	Pl. rem. by LigaSure	N.D.
21	CS 1 time (2)	PLG1 (2), Irr. sign (2)	(2)	8	CS+Hys.	Inc.
22	Myomectomy (4)	PLG1 (2)	(0)	6	Pl. rem. by LigaSure	N.D.
23	Myometrium resection for adenomyosis (4)	(0)	(0)	4	CS+Hys.	Acc.

The number in ( ) indicates the score for each variable.

PPAP, placenta previa with adherent placenta; US, ultrasound; MRI, magnetic resonance imaging; CS, cesarean section; UAE, uterine artery embolization; PLG, placental lacunae grade; LCZ, loss of clear zone; TBF, turbulent blood flow; Irr. sign, Irregular sign; Hys., hysterectomy; Pl. rem., Placenta removal; Part. res. of ut. wall, Partial resection of uterine wall; Acc., Accreta; Inc., Increta; Perc., Percreta; N.D., Not determined.

Table 5. Two women with adherent placenta who had a PPAP score < 8

No.	Age (years old)	Gravidity / Parity	A past history of uterine surgery	Weeks of gestation at scoring	US findings	MRI findings	PPAP score	Weeks of gestation at birth	Operative procedure	Intra-operative blood loss, ml	Histo-pahological diagnosis
22	31	0/0	Myomectomy	34	Grade 1 placental lacunae	None	6	37	CS and placenta removal using energy device	1,600	N.D.
23	42	0/0	Myometrium resection for adenomyosis	31	None	None	4	34	CS and hysterectomy	11,225	Accreta

PPAP, placenta previa with adherent placenta; US, ultrasound; MRI, magnetic resonance imaging; CS, cesarean section; N.D., Not determined.

Figure legends

Figure 1: **(A)** Transvaginal sonogram shows the presence of the irregular sign in a case with adherent placenta. **(B)** Transvaginal sonogram shows the absence of the irregular sign in a case without adherent placenta. Dashed white marks indicate the border between the placenta and myometrium around internal uterine os,

Figure 2: A flow diagram of the study participants

During the study period, 185 pregnant women with placenta previa had delivered at Kobe University Hospital. Ten women delivered before scoring the PPAP score. Therefore, the remaining 175 pregnant women with placenta previa were evaluated. Twenty-four (13.7%) of the 175 had a PPAP score ≥8. Adherent placenta was confirmed in 23 cases, including 19 cases confirmed histopathologically, and 4 cases confirmed clinically.

Abbreviations: PPAP, placenta previa with adherent placenta.

Figure 3. Correlations between the PPAP score and the amount of intraoperative blood loss in patient with placenta previa (n = 175). Closed circle indicates pregnant women with placenta percreta (n = 2); dark gray circle indicates women with placenta increta (n = 5); light gray circle indicates women with histopathologically or clinically confirmed placenta accreta (n = 16); open circle indicates women without adherent placenta (n = 152). A solid

400 line indicates an approximately straight line represents a correlation between the two

401 parameters.

402 Abbreviations: PPAP, placenta previa with adherent placenta

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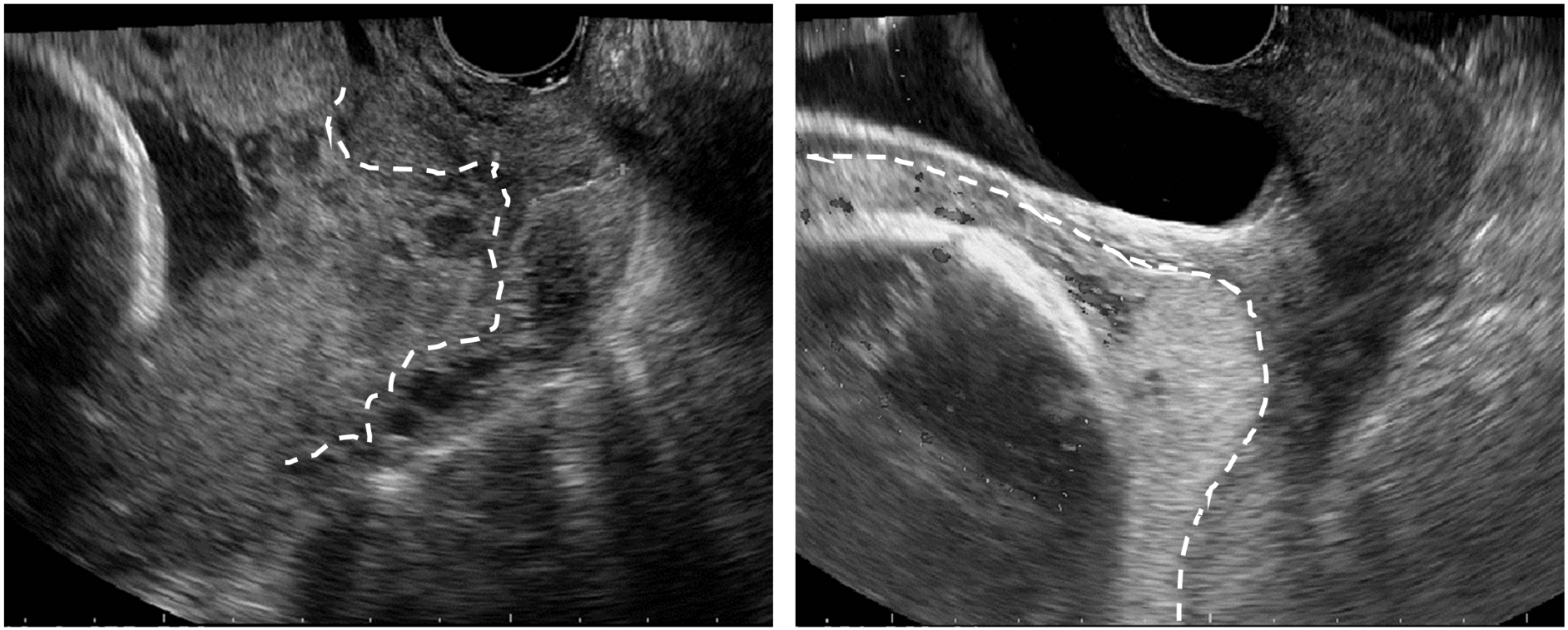


Figure 1.

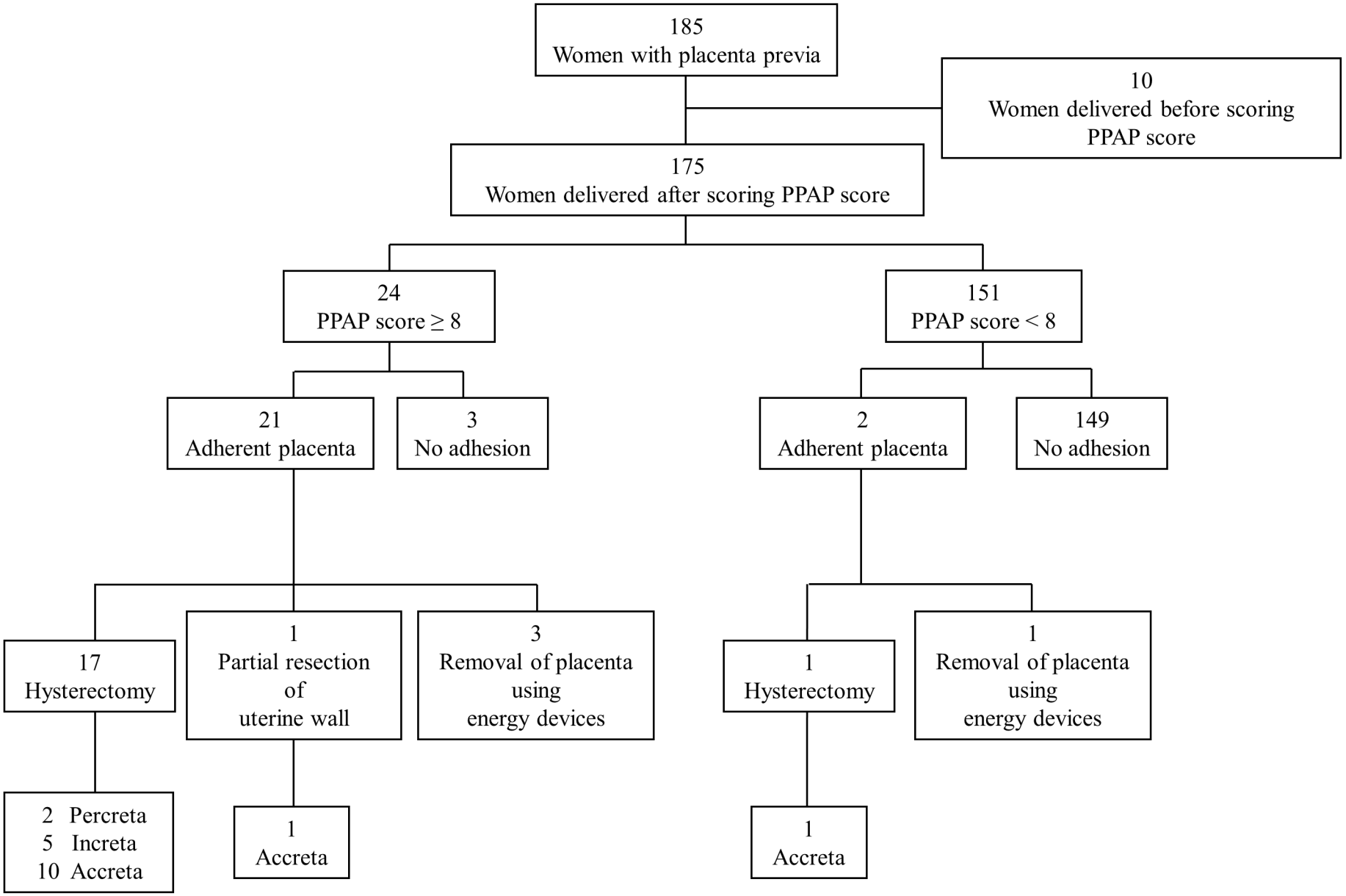


Figure 2. A flow diagram of the study participants

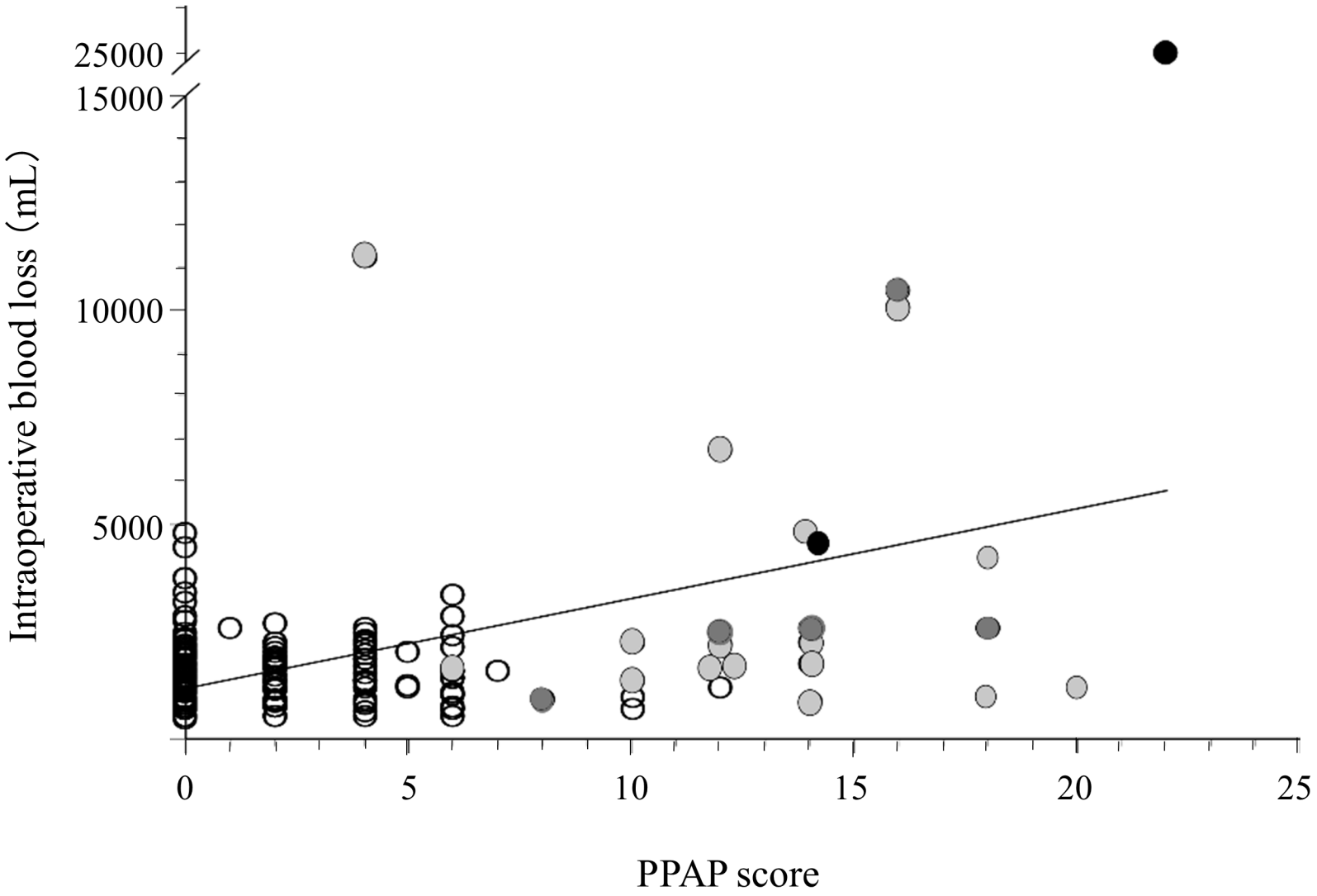
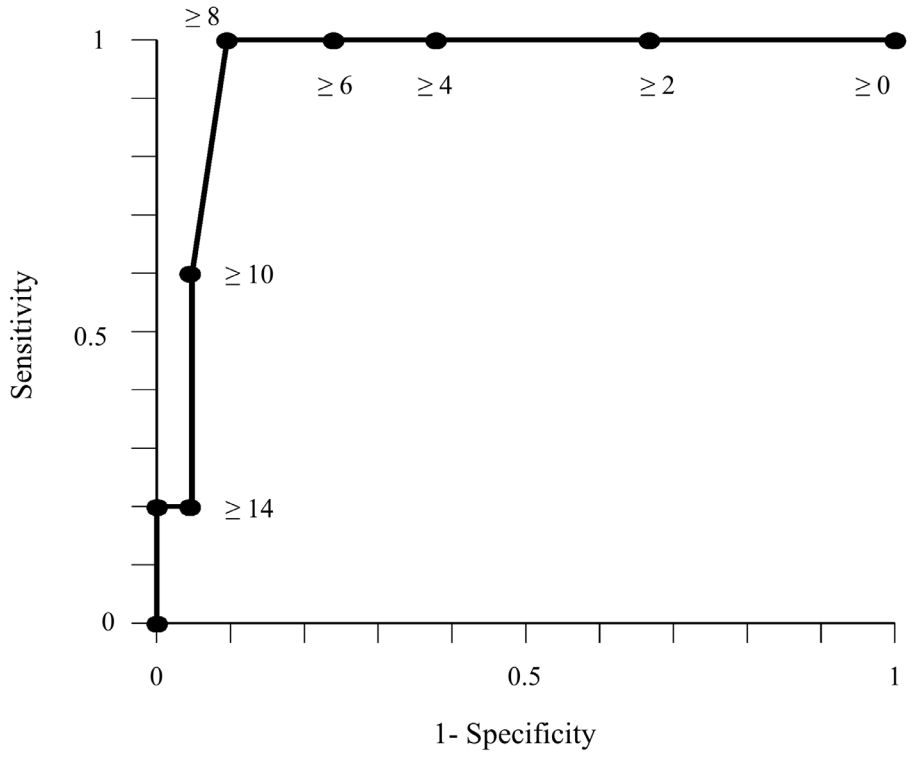


Figure 3. Correlations between PPAP score and intraoperative blood loss in patients with placenta previa (n = 175)



Supplemental figure 1. ROC curve for the prediction of PPAP during pregnancy

A cut-off value of PPAP score for predicting adherent placenta in patients with placenta previa was determined using ROC analysis. PPAP score was calculated for each patient in a group of 26 pregnant women with placenta previa who underwent US and MRI examinations and delivered at Kobe University Hospital from July 2008 to December 2010, including five women with adherent placenta.[20]

ROC, receiving operating characteristic; PPAP, placenta previa with adherent placenta. AUC=0.95; values in graph indicate the PPAP score.