Prenatal Detection of Bladder Wall Involvement in Invasive Placentation with Sequential Two-dimensional and Adjunctive Three-dimensional Ultrasonography

Min-Min Chou[1,2,3,4]*, Wei-Chi Chen[1,2], Jeng-J Tseng[1,2,3,4], Ya-Fang Chen[1], Tzu-Ting Yeh[1], Esther Shih-Chu Ho[1,2,4]

[1]Department of Obstetrics and Gynecology, Taichung Veterans General Hospital, [2]Chung Shan Medical University, [3]Hung Kuang University, and [4]National Yang-Ming University, School of Medicine, Taichung, Taiwan.

SUMMARY

Objective: The purpose of this study was to determine the diagnostic capability of sequential two-dimensional (2D) and adjunctive three-dimensional (3D) ultrasonography (US) in identifying the location and extent of placental invasion of the bladder.

Materials and Methods: Forty-five patients at risk of placenta previa were examined sequentially with 2D US and then with a targeted scan of the region of interest with adjunctive 3D US to determine whether those patients suspected of having advanced invasive placentation by conventional ultrasonographic evidence had placental invasion of the bladder. The images were coded as positive, negative or indeterminate (equivocal) for bladder invasion. Follow-up postoperative outcomes were obtained.

Results: Seven of the 45 patients exhibited characteristic ultrasonographic findings for placenta increta/percreta. Among these seven patients with advanced invasive placentation, a targeted scan with adjunctive 3D US correctly provided additional corroborative information to the 2D US indeterminate diagnosis in patients who were found with variable degrees of bladder wall involvement at surgery.

Conclusion: 3D US may be a useful adjunctive tool in refining 2D ultrasonographic techniques to identify the extent and degree of placental invasion of the bladder. The advantages of 3D US are: (1) a multiplanar image display allows viewing of sections from sagittal, coronal and axial planes at the same time, thereby more accurately determining the location and extent of placental invasion; (2) the viewing planes of the spatial angioarchitecture network can be arbitrarily manipulated to better delineate the aberrant vessels protruding into the bladder; (3) 3D reconstruction images can be clearly displayed by live 3D in a rotation mode for a better illustrative effect. [*Taiwan J Obstet Gynecol* 2009;48(1):38–45]

Key Words: bladder, placenta previa, placentation, three-dimensional imaging, ultrasonography

Introduction

The challenging problem of abnormal placentation has become increasingly clinically significant in obstetric practice, in part because of the dramatic rise in cesarean deliveries over the past four decades. The incidence of placenta accreta and its variants has increased at an alarming rate, from less than 1 in 30,000 deliveries in the 1930s through the 1950s to 1 in 2,500 in 1980. At our institution, a tertiary level teaching hospital, the incidence (1:625) is comparable with a recent literature report of a 1:533 incidence for the period 1982–2002 [1,2].

Severe invasive placentation unexpectedly encountered at the time of delivery can lead to catastrophic consequences, such as potential risks of uterine rupture,

*Correspondence to: Dr Min-Min Chou, Department of Obstetrics and Gynecology, Taichung Veterans General Hospital, 160, Taichungkang Road, Section 3, Taichung 407, Taiwan.
E-mail: mmchou@vghtc.gov.tw
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life-threatening hemorrhagic shock, and even death [3–5]. Therefore, it is of utmost importance that the degree of invasive placentation be precisely known before delivery so that an experienced multidisciplinary team can be assembled in advance to manage the potential complications, with the intention of minimizing maternal morbidity and mortality.

Because reliable diagnosis is of such importance regarding this clinical entity, virtually all types of imaging techniques have been tried in an attempt to improve prenatal diagnostic accuracy. Until recently, two-dimensional (2D) ultrasonography (US) remained the standard screening tool for the diagnosis of invasive placentation. Currently, there is a lack of scientific evidence supporting the general diagnostic superiority of three-dimensional (3D) over 2D scanning. Nonetheless, one area in which 3D US seems to afford advantages over 2D is the imaging of abnormal placentation. With its multiplanar capability providing images which may be unobtainable with 2D, combined with the dynamic assessment of uteroplacental vascularity using power Doppler, 3D US may lead to a clearer, more accurate delineation of invasive placentation [6,7].

The purpose of this study, therefore, was to describe our experience using sequential 2D and adjunctive 3D US, and to assess their diagnostic capabilities in identifying the location and extent of placental invasion of the bladder.

Materials and Methods

Forty-five patients with placenta previa, referred to our institution between January 2003 and December 2005 for detailed imaging evaluation of suspicious abnormal placentation, were examined sequentially with 2D US followed by 3D US. The study was approved by the institutional review board of Taichung Veterans General Hospital. All patients first underwent conventional 2D imaging in both grayscale, color and/or power Doppler modes with the use of a Voluson 730 Expert (General Electrical Imaging Systems, Kretztechnik, Zipf, Austria) or Acuson 128 XP/10 ultrasound machine (Acuson Corp., Mountain View, CA, USA). The transvaginal scanning technique with the bladder semidistended to provide better delineation of the uterine serosa–bladder wall boundary zone was utilized for the first- or early second-trimester scan. For patients with an anterior or central placenta previa and a suspicious area outside the range of the transvaginal probe, we used the transabdominal approach to diagnose invasive placentation in the late second and third trimesters.

The 2D US and color Doppler imaging criteria suggestive of placenta previa accreta, increta or percreta have been described previously [8–10]. The findings of each 2D examination were interpreted by three expert obstetricians trained in prenatal ultrasound according to conventional criteria and who coded the images as positive, negative or indeterminate for bladder involvement. The broader definition of bladder involvement included densely tight adherence of the placenta to the bladder surface as well as obvious bladder wall invasion. A conventional 2D image was classified as demonstrating suspicious bladder involvement if it showed an abnormal uterine margin–bladder wall interface with loss, disruption, and/or projection of a focal exophytic placental mass into the bladder wall, and/or color Doppler imaging demonstrating aberrant vessels present within the most peripheral aspect of the placenta at the uterine wall–bladder interface. No bladder involvement was reported if the entire region of interest (ROI) under scrutiny was visualized and appeared to have a normal anatomic structure. Bladder involvement was reported as indeterminate if it could neither be ruled in nor out.

Adjunctive 3D color power Doppler scanning was then performed with a commercially available 3D US machine (Voluson 730 Expert, General Electrical Imaging Systems, Kretztechnik, Zipf, Austria). For acquisition of the 3D US volume set, the tissue block of the targeted ROI of the myometrial–placental–bladder area was mechanically swept through in a so-called "fan scan" using a dedicated transabdominal 4–8 MHz motor-driven curvilinear probe. Immediately after image acquisition was completed, the volume images were displayed on the monitor in a multiplanar form, including sagittal, coronal and axial planes. In addition, the volumes of a defined cube could be manipulated to bring out a particular scan plane or reconstructed to a volume-rendered image, and the general morphologic condition of the vascular network within a ROI could be obtained in angio or power mode. Based on our observations, we have tentatively proposed 3D US diagnostic criteria for advanced invasive placentation with suspected bladder involvement as follows: (1) a loss of the echolucent space between the bladder and the placenta in coronal and axial scans; (2) invasion of the bladder by the infiltrating placenta with irregularity and disruption of the normal bladder wall architecture and/or a focal exophytic placental mass projecting into the bladder in coronal and axial scans; and (3) aberrant blood vessels in the spatial vascular network in the ROI extending into the bladder in rotational angiography.

The clinical characteristics, interventional procedures, and outcomes were recorded. Follow-up clinical data

were obtained from the obstetricians at the time of delivery and from histopathologic reports.

Families were shown instructive volume-rendered images of their virtualized pathologic condition of invasive placentation during counseling sessions. Appropriate managing strategies were offered according to the adjunctive 3D US findings.

Results

A summary of maternal characteristics, US features, and surgical outcomes is shown in the Table. The mean age of the patients was 34.43 ± 0.87 years (range, 30–37 years). The mean interpregnancy interval was 3.86 ± 1.28 years (range, 1–11 years). Seven of the 45 patients exhibited characteristic US findings specific for advanced invasive placentation. All abnormally adherent placentas were predominantly anterior or central-type previa. All diagnoses except for one were made in the second and third trimesters at a mean gestational age of 23.71 ± 3.13 weeks (range, 9–35 weeks). All seven patients had a history of previous cesarean deliveries and/or uterine curettages for abortions. The mean estimated blood loss was 8,457.14 ± 2,916.38 mL (range, 4,000–20,000 mL).

In the seven patients with advanced invasive placentation, adjunctive 3D multiplanar imaging revealed densely adherent placenta invading the superficial bladder base in three patients (Figure 1), evidence of obvious bladder invasion in two patients (Figures 2 and 3), and no evidence of tight bladder adherence or invasion in the remaining two patients (Figure 4). A variable state of a non-hierarchic vascular network without orderly arrangement or irregular branching and densely clustered blood vessels was clearly depicted in the 3D spatial angioarchitecture in the ROI, particularly in two patients with obvious bladder wall invasion. Aberrant blood vessels extending into the bladder were clearly illustrated by 3D rotational angiography (Figures 2B and 3). In contrast, 2D US findings were reported to give an indeterminate diagnosis for these patients.

There were no maternal deaths or long-term maternal morbidities in the series. Inadvertent ureteral injury resulting from failure of preoperative placement of a ureteral stent was encountered in one patient (Case 3). The patient underwent primary repair and re-anastomosis of the right ureter with an uneventful recovery. Primary postpartum hemorrhage occurred in another patient (Case 5). Re-exploration was performed, and bleeding was found from the left engorged ovarian vascular plexus and bladder base which was controlled with left salpingo-oophorectomy and ligation of the bleeding vessels in the bladder base.

Histopathologic examination of all placentas revealed that chorionic villi had invaded the full thickness of the myometrium and destroyed the uterine wall to reach and/or penetrate the serosa.

Discussion

The hemorrhagic and surgical complications associated with invasive placentation vary significantly depending on the extent of placental invasion, severity of associated uteroplacental hypervascularization, and involvement of adjacent structures such as the bladder or intestine [11]. From a clinical standpoint, placenta increta without bladder involvement is usually treated in the same way as placenta accreta, since the surgery and blood loss are usually the same and most obstetricians are able to manage these two clinical entities [3]. In contrast, for patients with placenta percreta with tight bladder adherence or obvious bladder invasion, correct antenatal diagnosis and the appropriate management strategy can mean the difference between life and death. This is because infiltrating placental tissue invades the extensively vascularized lower uterine segment and the bladder, posing a serious risk of life-threatening hemorrhage. Moreover, the surgical dissection of placenta closely adherent to the bladder wall, and/or partial cystectomy is a very difficult and bloody procedure. Therefore, we consider the correct diagnosis of milder forms of bladder involvement with tight adherence of the placenta to the bladder wall to be very important. Although this clinical entity is not technically invasion of the bladder wall, it is of the same clinical significance, because surgery is still problematic and can lead to a torn bladder wall, resulting in massive blood loss [3].

A case has been reported of a patient with placenta percreta and bladder involvement who survived after two major surgical procedures and massive blood transfusions at 39 weeks' gestation, despite a total estimated blood loss of 47,000 mL [2]. In the past decade, we also encountered a similar case with an estimated blood loss of 25,000 mL at 28 weeks' gestation. Recently, we also encountered one case of severe invasive placentation unexpectedly found at the time of cesarean delivery which led to both life-threatening hemorrhage and vesicovaginal fistula. These case reports affirmed our concern that there is a crucial need for assessment of the presence and extent of bladder invasion by the infiltrating placenta, because many practitioners lack the expertise to achieve the desired level of diagnosis and management.

Previous reports have emphasized that grayscale US findings are usually adequate for the evaluation of

Table. A summary of maternal characteristics, ultrasonographic features, and outcomes of seven cases of invasive placentation

Case	Age (yr)	Prior surgery	Interpregnancy interval (yr)	GA at Dx (wk)	2D US features	3D US Features	GA at delivery (wk)	Operative procedure(s)	EBL (mL)	Pathology
1	36	1 LSCS	2	9	Lacunae	Normal echolucent space between placenta and bladder wall, smooth echogenic U-B line, and diffuse hypervascularization	13	Conservative treatment failure with uterine artery embolization, TAH	4,000	Increta
2	37	1 LSCS	1	24	Lacunae and focal projections across U-B line	Focal exophytic placental mass projecting into the bladder on coronal and axial scans and rotational angiography demonstrates aberrant blood vessels of non-hierarchic vascular network in the region of interest extending into the bladder	27	C/H, focal bladder wall resection and repair, and internal iliac artery ligation	17,300	Percreta
3	30	1 LSCS	3	26	Lacunae and focal projections across U-B line	Tight adherence of placenta to the bladder wall, U-B interface hypervascularization and large rosette of varicosities in the area of the bladder base	30	C/H, inadvertent ureteral injury due to failed preoperative placement of ureteral stent, primary repair and re-anastomosis of right ureter, and suture ligation of bleeding vessels in the bladder base	9,900	Increta/ percreta
4	35	1 LSCS	11	29	Lacunae and focal projections across U-B line	Tight adherence of placenta to the bladder and U-B interface hypervascularization	32	C/H	6,600	Increta/ percreta
5	35	3 LSCS	5	25	Lacunae and bulging	Superficial bladder wall invasion by the placenta;	27	C/H, re-exploration with LSO due to	20,000	Percreta

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Table. *(continued)*

Case	Age (yr)	Prior surgery	Interpregnancy interval (yr)	GA at Dx (wk)	2D US features	3D US Features	GA at delivery (wk)	Operative procedure(s)	EBL (mL)	Pathology
					U-B line	U-B interface hypervascularization and large rosette of varicosities in the area of the bladder base		rebleeding from left ovarian vascular plexus and bladder base		
6	33	1 LSCS 1 D&C	3	35	Focal projections across U-B line	Partial adherence of the placenta to the bladder and U-B interface hypervascularization	36	C/H	5,500	Increta
7	35	1 LSCS	2	18	Focal interruption of U-B line	Tight bladder adherence, irregularity of U-B interface, and U-B interface hypervascularization	19	Temporary common iliac artery balloon inflation and TAH	850	Twin A, percreta; Twin B, normal placentation

GA = gestational age (weeks); Dx = diagnosis; 2D = two-dimensional; US = ultrasonography; 3D = three-dimensional; EBL = estimated blood loss; LSCS = lower segment cesarean section; U-B = uterine serosa–bladder; TAH = total abdominal hysterectomy; C/H = cesarean hysterectomy; LSO = left salpingo-oophorectomy; D&C = dilatation and curettage.

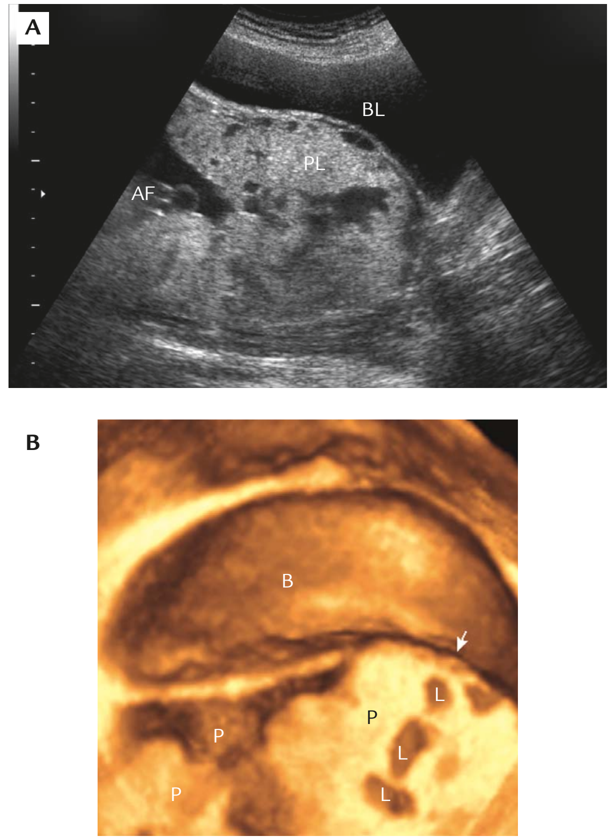
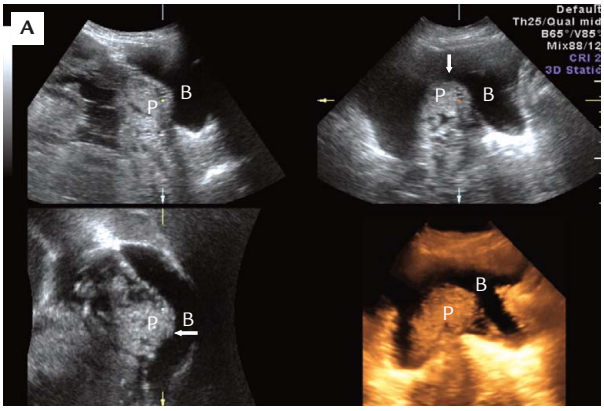
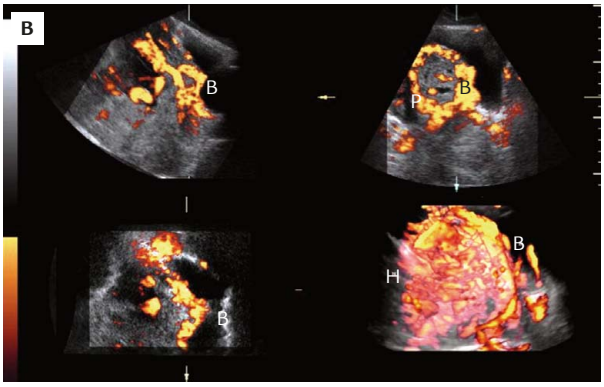


Figure 1. (A) Conventional two-dimensional ultrasound shows bulging uterine margin–bladder wall interface with multiple placental lakes. AF = amniotic fluid; BL = bladder; PL = placenta. (B) Multiplanar images show the densely adherent placenta invading the superficial bladder wall (arrow), but no actual extension into the bladder mucosa. B = bladder; L = lacunae; P = placenta.

abnormally adherent placentas [8]. Others have emphasized that color Doppler imaging is a very useful adjunct to diagnosis [9,10]. Although it would be ideal to identify bladder involvement by placenta percreta with certainty, currently there is no diagnostic "gold standard" imaging modality which can reliably predict the degree of bladder invasion found at surgery [6].

The border between the bladder and myometrium is normally echogenic, linear, and smooth in appearance. Although specific 2D US criteria for detection of bladder involvement have not been developed, the conventional criteria of focal disruption, nodular projections or bulging of the uterine margin–bladder wall are still probable signs of suspicious bladder wall involvement. Two-dimensional imaging can detect these specific signs; however, it is very difficult to differentiate between bulging arising from increased vascularity, adherence, and/or actual growth into the bladder from the sagittal view. Comstock [3] has suggested that the transducer should be perpendicular to the bladder wall during evaluation of bladder integrity to avoid potential diagnostic errors.





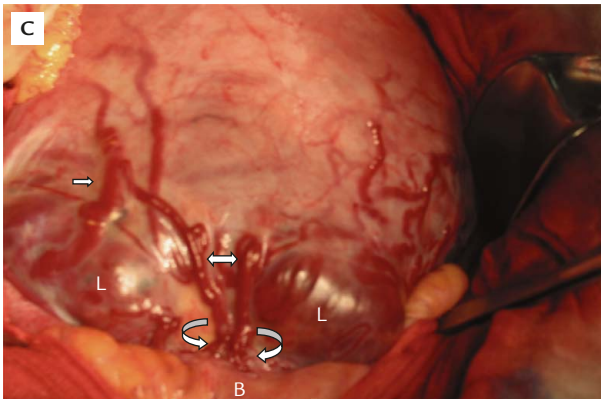


Figure 2. (A) Multiplanar images of the placenta percreta with bladder invasion (Case 2). The upper left image in the sagittal plane shows focal nodular projections of the linear bladder–uterine interface. The lower left and upper right images in the coronal and axial views clearly show the absence of the uterine margin–bladder line. The placenta has invaded into the superficial bladder wall (arrow). The lower right image of the three-dimensional (3D) reconstruction precisely illustrates the enhanced spatial resolution pattern of placental invasion into the bladder wall. B = bladder; P = placenta. (B) Densely nonhierarchical vascular network with no orderly arrangement or irregular and clustering blood vessels is clearly shown in the 3D spatial angioarchitecture pattern in the region of interest. Note the demonstration of aberrant vessels protruding into the bladder, particularly in the axial view. B = bladder; P = placenta. (C) Intraoperative photograph showing prominently engorged aberrant vessels (arrows) supplying the impending rupture of vascular lakes (L) as well as the bladder (curved arrows). B = bladder.

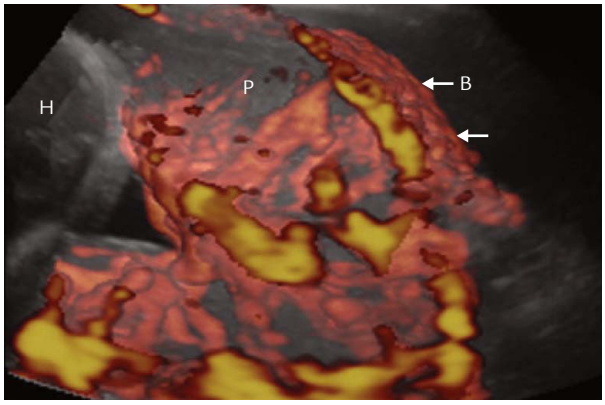


Figure 3. Three-dimensional power Doppler imaging of the placenta percreta. The spatial uteroplacental angioarchitecture network pattern clearly illustrates the densely clustered blood vessels on the bladder side of the uterine wall–bladder interface (arrows). B = bladder; H = head; P = placenta.

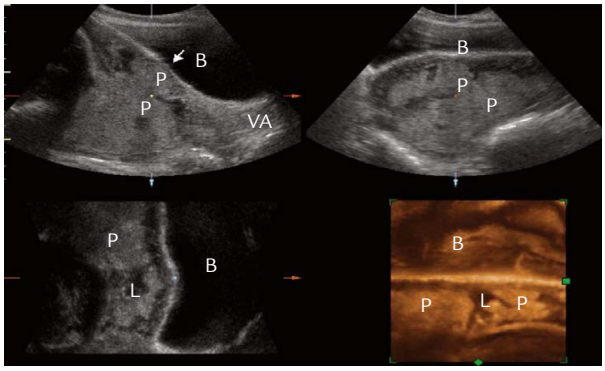


Figure 4. Multiplanar images of placenta increta without bladder involvement. The upper left image in a conventional sagittal plane shows thinning of the bladder–uterine line (arrow), and focal obliteration of the echolucent space between the placenta and the bladder. The lower left and upper right images clearly show the normal echolucent space present between the placenta and the bladder wall with a normal thick uterine–bladder line in the coronal and axial views, respectively. The lower right image of a three-dimensional reconstruction clearly shows the smooth integrity of the regular bladder–uterine interface line. B = bladder; L = lacunae; P = placenta, VA = vagina.

The multiplanar capability of 3D US, which allows structures to be visualized from multiple viewpoints, is the key advantage of its use. A multiplanar image display allows sequential screening through the targeted uteroplacental region and adjacent bladder in a series of slices to view the sections from sagittal, coronal and axial planes at the same time, thereby giving a much more coherent view of the extent of placental invasion. In particular, with the partial full-bladder screening technique, the disruption of the regular anatomic structure of the uterine margin–bladder wall can be imaged easily in coronal and axial views. Additionally, by using the reference points in each image (i.e. frontal, coronal and axial views) and by scrolling through one image while

maintaining the other two constant, the exact location of the area in question can be elucidated. Furthermore, these viewing planes can also be arbitrarily manipulated individually or in tandem to bring out a particular scan plane to better delineate the spatial structure of the placental–myometrial–bladder interface. 3D reconstruction images can also be vividly displayed by live 3D in a rotation mode for a better illustrative spatial effect. This allows the obstetrician to be more confident in diagnosing both the presence and absence of placental invasion of the bladder.

Moreover, this new combined power Doppler US and 3D imaging technique provides a means to assess general morphologic conditions of spatial angioarchitecture parameters such as the cluster and branching patterns of a vascular network in the region of the uterine wall–bladder interface using a rotational angiography system. These viewing planes can be arbitrarily manipulated to better delineate the demonstration of aberrant vessels protruding into the bladder, and this specific vascular feature is believed to be another indicator of placental invasion of the bladder. The knowledge of spatial vessel distribution in this critical area is of extreme clinical significance in surgical planning.

Timely pregnancy termination is an appropriate management option to decrease morbidity and mortality. Correct antenatal diagnosis of the extent of placental invasion before delivery allowed us to be best prepared. We recommend making rapid transfusion equipment readily available because of the speed with which massive hemorrhage can occur at the time of wide dissection of the vascular lower uterine segment and parametrial areas from the tightly adherent bladder flap. Although the meticulous techniques of cesarean hysterectomy as described by Price et al [12], Catanzarite et al [13] and Pelosi and Pelosi [14] were followed by highly experienced surgeons in this study, the mean operative blood loss was still massive. Levine et al [15] and Zacharias et al [16] reported their experience with the use of prophylactic internal iliac artery balloon occlusion catheters in patients requiring a cesarean hysterectomy for placenta accreta. Their preliminary findings suggested that transarterial balloon occlusion procedures did not improve the surgical outcomes. They speculated that this lack of success may reflect their inability to preoperatively select the optimal placement site of the occlusion balloons. Additionally, the rich collateral network of vessels in the pelvis may interfere with the efficacy of selective arterial occlusion [11,15]. Recently, a newer intervention technique of temporary balloon occlusion of the common iliac artery was described by Shih et al [17] and can be utilized more effectively to minimize blood loss when a cesarean hysterectomy is performed for placenta percreta. Further studies are needed to validate its efficacy and safety.

In conclusion, 3D US can further refine conventional ultrasonographic techniques to reliably assess the presence or absence of placental invasion of the bladder. The advantage is due to the multiplanar imaging capability of 3D US combined with a dynamic assessment of the uterine wall–bladder interface spatial vascular network. Recognizable 3D photographic images are provided, giving a clear view of the severity of advanced invasive placentation to the patients. Hence, 3D US offers affected patients an improved visual perspective of their pathologic condition compared with 2D US. The obstetrician is thus better equipped to counsel patients and their families about the risks of potential life-threatening hemorrhage and massive blood transfusions and to psychologically prepare them for the appropriate surgical interventions.

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