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Trauma in pregnant women: Assessing detection of post-traumatic placental abruption on contrast-enhanced CT versus Ultrasound

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Abstract

Objectives—To evaluate detection of post-traumatic placental abruption with contrast-enhanced CT (CECT) and comparison with Ultrasound (US).

Methods—Picture Archive and Date System (PACS) database at a level-1 trauma center was retrospectively reviewed using keywords pregnancy, trauma, and/or placental abruption over 10 years. CT was compared to US, if performed within 24 hours. 2 subspecialty-trained radiologists blindly reviewed the studies. Placental features on delivery and pregnancy outcomes were used as reference standard. Lack of adverse pregnancy/fetal outcome was treated as the absence of abruption.

Results—CECT was performed in 36 patients, with 27 US within 24 hours. There were 3 complete and 8 partial abruptions. Reader sensitivity for CT was 100% for both reviewers; however, specificity was 54.5% and 56.7%. No sonographic abnormality was noted in both partial and complete abruption. Using kappa statistics, inter-observer agreement was low for both CT (0.169) and US (0.078). False-positive reads were from misinterpretation of normal placental structures like cotyledons, age-related infarcts, and marginal sinus of the placenta.

Conclusions—CECT identifies post-traumatic placental abruption with high sensitivity but low specificity for clinically significant abruptions, and performs better than US. Pitfalls from normal placental structures mimicking abruption should be avoided. US markedly underdiagnoses abruption.

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All the authors declare no conflict of interest.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was waived by IRB due to retrospective nature of the study.

Keywords

Placental abruption; trauma; CT; Ultrasound; US; Computed tomography

Introduction

Trauma complicates approximately 5% of all pregnancies (1). Placental abruption is one of the most devastating consequences of abdominal trauma in a pregnant patient. As high as 89% of pregnant women may develop severe maternal–fetal outcomes after trauma. Of these, up to 59% can suffer from placental abruption and 11% may face fetal demise from placental and non-placental causes (2, 3). Despite known limitations of ultrasound, it is still a widely used modality for the evaluation of trauma in pregnant patients given the absence of radiation with this modality (3, 4). In addition to the well-known limitations of ultrasound in detecting maternal trauma, fetal and placental evaluations with ultrasound are also fraught with poor sensitivity (4). Multiple review articles have alluded to this limitation, but an objective evaluation has not been yet performed (3–6). Ultrasound has progressively increasing limitations with advancing gestation and provides best results in the first and early second trimester (6). Fetuses older than 24–26 weeks are considered viable and all efforts should be made to expedite diagnosis and minimize fetal mortality (7).

Major feature of abruption on CECT is placental non-enhancement (8, 9). Larger degrees of placental non-enhancement are associated with greater risk of fetal demise (9). Saphier et al proposed a grading for placental evaluation on CECT to risk stratify pregnant patients undergoing evaluation post trauma (9). They also highlighted the normal variants in an effort to educate radiologists and improve accuracy of placental evaluation on CT (8, 9). Both these studies state the suboptimal ultrasound evaluation of the placenta in pregnant patients in the setting of trauma. Placental evaluation with CT has multiple limitations particularly due to lack of adequate literature elaborating the spectrum of normal imaging findings and expected findings with trauma (8, 9). Utilization of CT in pregnant patients is also a rare occurrence due to concerns for irradiating the developing fetus with detrimental outcomes including birth defects and childhood malignancy (10, 11). Risk–benefit assessment should be performed before irradiating a pregnant patient. Indeed, in life-threatening situations CT should be performed, as it would be done in a non-pregnant patient. Additionally, with recent developments in CT dose reduction, such as iterative reconstruction of images, radiation dose reduction can be achieved without compromising image quality and diagnosis (10, 11).

In this study, we assess the sensitivity and specificity of diagnosing placental abruption on CECT in pregnant women with high-impact abdominal trauma, such as high-speed motor vehicle collision and clinical suspicion of placental abruption. The performance of CT was compared with US in detecting abruption, when performed in the same patient. Causes of false-positive interpretation were explored and compared with surgical pathology, where available.

Materials and Methods

Study design and patient population

In this IRB-approved, HIPAA compliant study, PACS database at a level 1-trauma center was retrospectively reviewed using keywords pregnancy, trauma, and/or placental abruption over a duration of 10 years. Informed consent was waived due to retrospective nature of the study. Exclusion criteria included non-contrast imaging only. CECT findings were compared to Ultrasound, if performed within a 24-hour interval. A total of 36 patients, 1 with twin gestation, underwent CECT. One patient had non-contrast CT and was excluded from the evaluation. Of these, 27 had US performed within 24 hours and were included in the analysis. Placental ultrasound images were judged for complete and adequate assessment to ensure optimal evaluation. The reviewers ascertained that the entire placenta had been imaged in the cine and static images.

CT technique

All CT examinations were performed on either 16- or 64-detector scanners (GE LightSpeed 16 or GE LightSpeed 64, General Electric Medical Systems, Waukesha, Wisconsin). Scan parameters for the 16-detector scanner were as follows: Detector configuration 16 × 1.25, beam collimation 20 mm, 120 kVp, variable mA (automated dose modulation), noise index 14, pitch 1.375, and gantry rotation speed 0.6 seconds. Scan parameters for the 64-detector scanner were as follows: Detector configuration 64 × 0.6, beam collimation 40 mm, 120 kVp, variable mA (automated dose modulation), noise index 30 (at slice thickness 1.25 mm), pitch 0.98, and gantry rotation speed 0.5 seconds. Post-contrast imaging was performed after injection of 120–150 ml of intravenous iodinated contrast at the rate of 2–4 ml/seconds, in standard portal venous phase per trauma protocol, with a 70-second delay. Images were reconstructed at 1.25 mm and 5 mm intervals. Coronal and sagittal reformats were also available for review. Studies were reviewed on a PACS workstation (iSite version 3.6, Philips Healthcare).

US technique

Gray scale and Color Doppler imaging was used to evaluate placental morphology and vascularity. In keeping with national standards, the ultrasound was performed by sonographers under the supervision of a radiologist. The initial exam was performed by sonographers followed by additional imaging acquired by radiologist, on an as-needed basis. Before including a patient for statistical analysis, adequate placental image acquisition was adjudged by the reviewers.

Image analysis

2 subspecialty-trained abdominal imagers blindly reviewed CECT and US images, with 15 years and 17 years of experience with obstetric imaging. The CTs and US were evaluated independently at separate times, without the knowledge of findings of the other modality. CT criteria for abruption included focal thickening, heterogeneous enhancement, and partial or complete non-enhancement. The reviewers categorized the imaging findings based on the

grading scale suggested by Saphier et al. as placental enhancement of 100%, >50% (homogeneous enhancement), >50% (heterogeneous enhancement), 25–50%, or <25%.

For ultrasound, the readers assessed for focal placental thickening, thickened heterogeneous placenta, hyperechoic placental hematoma, and preplacental and/or retroplacental subchorionic and subamniotic hematomas. Fetal cardiac activity was documented and its absence suggestive of secondary evidence for placental abruption.

Reference standard

Placental gross pathology features on delivery were used as reference standard. In patients, who did not deliver in the immediate post-traumatic period and continued with a healthy pregnancy, lack of adverse pregnancy/fetal outcome was treated as the absence of clinically significant abruption. The goal of the study was to evaluate for clinically significant abruptions and the authors acknowledge that our study design may not optimally assess small abruptions not resulting in fetal morbidity, particularly in the pregnancies, which continued beyond the trauma episode and delivered at a later time and/or outside institutions.

Statistical Analysis

Sensitivity and specificity calculations were performed for both CT and US, using the reference standard as described above. Inter-observer concordance for CT and US was calculated using Kappa statistics. Intra-observer concordance for CT and US was also calculated using Kappa statistics. All analyses were performed with SAS Version 9.2 (SAS Institute Inc., Cary, NC, USA).

Results

27 pregnant women were included in the study with mean age of 28 years and 5 months (range 16 years 2 months to 35 years and 10 months). Both second and third trimester gestations were included in the cohort with the gestational age ranging from 24 weeks 5 days to 36 weeks 4 days. The women who were imaged with CT all had high-impact trauma such as high-speed motor vehicle collision. 21 patients had ultrasound before CT and the remaining 6 patients had CT before ultrasound. Among the 36 patients, there were 3 clinically confirmed, surgical pathology proven cases of complete abruption and 8 cases of partial abruption (Figures 1 and 2). Both subspecialty-trained reviewers with extensive obstetric experience identified all the cases of partial and complete abruptions on CT. Sensitivity was 100% for both reviewers. Negative predictive value was also 100%, which means that a completely normal placenta on CT, excludes any clinical suspicion of placental abruption. However, low specificity was noted for clinically significant abruptions (involving more than 25% of the placenta per the Saphier scale) for both the reviewers at 54.5% and 56.7%. Low specificity could partially be explained by small number of patients and contrast timing. All the patients who had placental abruption also had other intra-abdominal visceral injury, which included liver laceration, splenic laceration, bowel hematoma, and renal contusions. 21 of the remaining patients in our cohort had visceral injury without the evidence for placental injury. Based on these values, one in four patients with other sites of visceral injury is likely to have post-traumatic placental abruption.

On the contrary, ultrasound identified only the cases of complete abruption, which was secondarily inferred due to fetal demise (Figure 2). Even in the cases of complete abruption, no focal placental abnormalities were identifiable. Additionally, US did not identify any of the cases of partial abruption. Neither CT nor US demonstrated any retroplacental hematomas, which are a common finding assessed when evaluating for placental abruption.

Inter-observer concordance between the two trained readers was calculated using Kappa statistics. Kappa value for CT was 0.403, implying medium agreement between the readers. Upon further review of the data, the reviewers agreed on all abruptions which involved 50% or more of the placenta. However, there was discrepancy in readings in which the non-enhancement involved less than 25% of the placenta. Kappa value for US was 0.030, implying a low agreement between the readers. Kappa statistics also demonstrated low concordance for CT and US evaluations for the same reviewer. Kappa value for reader 1 was 0.331 and that for reader 2 was 0.168.

Discussion

Our results demonstrated that CECT is a highly sensitive modality to evaluate for placental abruption in the setting of high-impact maternal trauma, although it suffers from low specificity. However, the biggest strength of CT is its 100% negative predictive value. A homogeneously enhancing placenta on CT reliably excludes any clinically significant placental abruption. Ultrasound is a widely used modality, which markedly underdiagnoses placental abruption. However, the need for rigorous training of radiologists to identify placental abruption on CT is needed as evidenced by low specificity of the CT evaluation as well as low inter-observer concordance, even with experienced radiologists.

Our results are concordant with that of previous authors, who have demonstrated a high sensitivity of CT in detecting post-traumatic placental abruption (8, 9). A significant rate of false-positive interpretations points to lack of familiarity with the expected appearance of the placenta on contrast-enhanced CT, given its rarely performed in a gravid patient. Most of false-positive reads were from normal placental structures such as cotyledons (Figure 3), venous lakes, age-related infarcts, and marginal sinus of the placenta, misinterpreted as abruption. None of these had adverse fetal outcome. Based on the readers' experience, the placenta was most optimally evaluated on delayed phase imaging, wherein a more homogeneous placental enhancement was noted. Using this information, a protocol modification may be suggested, wherein a split-bolus contrast injection may be performed to allow adequate assessment of both maternal viscera and the fetus and placenta. However, further investigation will be required to validate this technique. If there is diagnostic dilemma on routine imaging and/or fetal monitoring abnormalities, low dose delayed imaging may also be performed, with iterative reconstruction techniques, while theoretically keeping the total radiation dose similar. Using a uniform reporting system such as that advised by Saphier et al will help improve accuracy and help remove the inter-observer subjectivity from imaging interpretation (9).

Ultrasound was noted to be markedly insufficient in diagnosing placental abruption. US only identified cases of complete abruption, which were secondarily inferred due to fetal demise and subsequently, confirmed on delivery. No focal placental abnormalities, parenchymal hematomas, and/or retroplacental hematomas were identified with both cases of complete and partial abruption. This may be related to subtle changes in echotexture, which may not be reliably identified early on, which is the most crucial period to identify abnormalities, necessitating emergent delivery of a viable fetus. As with ultrasound in general, a large degree of variability in technique exists in between performers (both physicians and sonographers). Hence, the use of this modality in critical cases is fraught with limitations. CT should be considered in such high-risk patients, where the risk of radiation to fetus is outweighed by benefits related to maternal and fetal morbidity and mortality.

Interestingly, the authors noted the lack of retroplacental hematoma in cases of both complete and partial abruption, both with CT and US. This may point toward a different pathogenesis of traumatic placental abruption, which may involve shear injury with devascularization of the placenta rather than a retroplacental hematoma, which cleaves off the placenta from the uterus, which is a common occurrence with hypertensive gestations. Moreover, on US, retroplacental hemorrhage in an acute setting may appear isoechoic to hyperechoic to the placenta leading to limitations in identifying this entity (5, 12). In certain cases, this may be perceived as placental thickening, which may not be appropriately interpreted by an untrained provider (5, 12).

We acknowledge our limitations with a very small number of patients in our cohort, which is related to the infrequent use of CT in the pregnant population. Additionally, contrast timing may not be uniform in these patients and may show different contrast phases depending on the patient physiology. We also acknowledge the variability of technique and performance with US examinations; however, this is reflective of current practice trends, where most of the US are performed by technologists under a supervising radiologist.

In conclusion, contrast-enhanced CT should be considered in the evaluation of high-risk maternal trauma to adequately evaluate for maternal and fetal injuries, including placental abruption. While CT should not be performed to diagnose abruption, which remains a clinical diagnosis, this entity should be actively sought and recognized on CT performed for the work up of severe trauma. Among the multitude of injuries, diagnosing abruption may help prioritize fetal management alongside the management of maternal injuries. Use of ultrasound in this setting may lead to underdiagnosis of placental abruption and may delay delivery of an at-risk fetus, leading to increased rates of fetal loss. CT protocol modification with the use of split-bolus techniques or use of delayed low-dose imaging may be necessary and needs to be investigated further.

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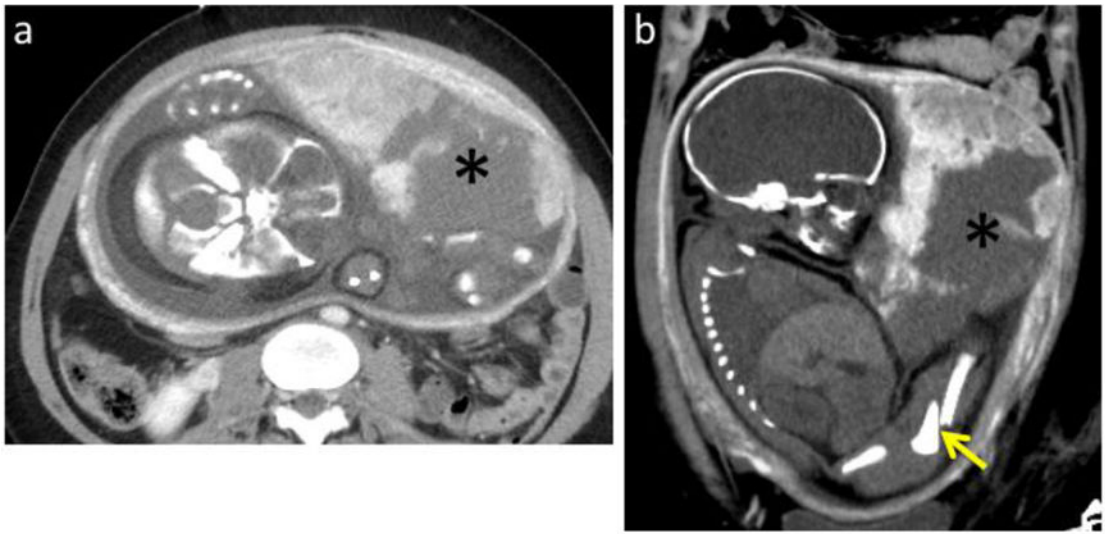

Figure 1.
A 36-year-old 32 weeks pregnant woman status post motor vehicle accident. a) Contrast-enhanced CT demonstrated full thickness non-enhancement of the anteriorly located placenta (asterisk), involving more than 50% of the placenta, consistent with partial abruption. b) Coronal reformats from the contrast-enhanced CT redemonstrate the placental findings (asterisk). Fetus had a femur fracture in utero as well (arrow).

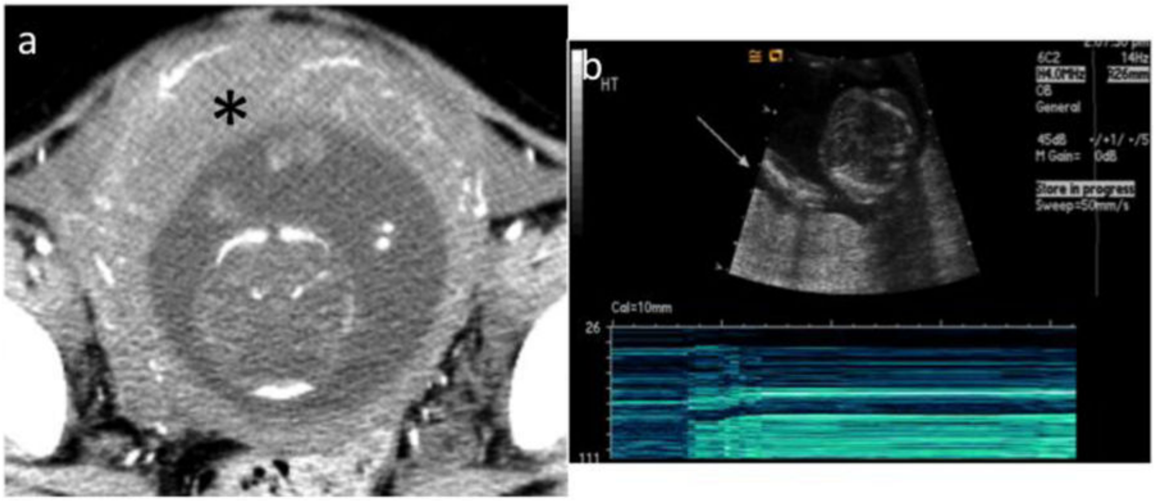

Figure 2.

A 25-year-old female at 29 weeks gestation ejected from the vehicle after an accident. a) Contrast-enhanced CT demonstrated complete non-enhancement of the anteriorly located placenta (asterisk), consistent with complete abruption. Surrounding myometrium demonstrates enhancing vessels. b) No fetal heart rate noted on US consistent with fetal demise. No focal placental abnormality was present.

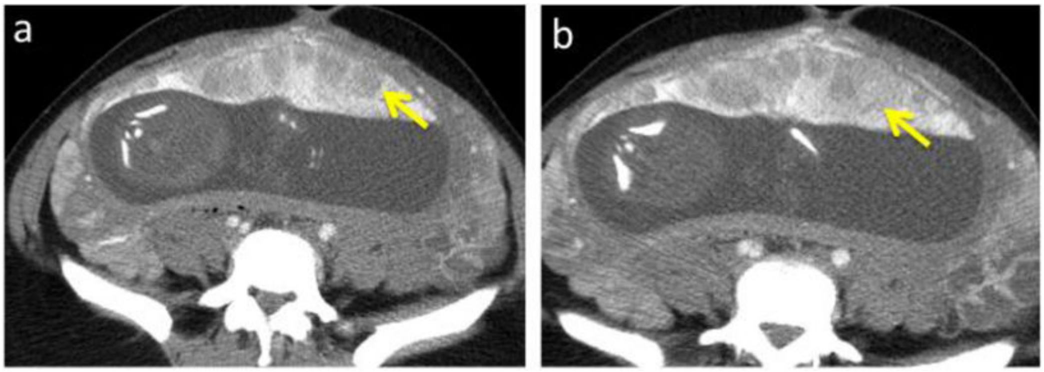

Figure 3.

A 28-year-old female at 36 weeks of gestation status post motor vehicle accident. a and b) Contrast-enhanced CT demonstrate rounded hypodense structures present throughout the placenta, representing placental cotyledons (arrows). This was misinterpreted as partial abruption.