

Prenatal Imaging of Fetal Sacrococcygeal Teratoma: Complementary Roles of Ultrasound and Magnetic Resonance Imaging

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ABSTRACT

Purpose: Congenital Sacrococcygeal Teratoma (SCT) is the most common solid tumor of the fetus, with a birth prevalence of approximately 1 in 20,000 to 1 in 40,000 live births. The increase in the number of cases of prenatally diagnosed SCT due to the widespread use of anomaly ultrasound scanning makes it vital to conduct proper prenatal evaluation of fetuses. This paper aims to review the role of ultrasound and fetal MRI as diagnostic methods for evaluating prenatally SCTs.

Methods: A narrative literature review was performed by searching PubMed/MEDLINE and EMBASE for peer-reviewed, English-language studies published between 1990 and 2025.

Conclusion: Prenatal ultrasonography examination is widely applied as the main imaging method for the prenatal diagnosis of SCTs. Features with a bad prognosis on ultrasound scans are predominance of solid SCT morphology, highly vascular tumor, fast growth of the tumor, placentomegaly, and fetal hydrops. MRI provides more detailed evaluation of intrapelvic tumor infiltration, soft tissue composition, and involvement of the spinal canal in SCTs in particular in Altman types II-IV. Prognostic markers of the imaging include tumor volume-to-fetal weight ratio, tumor growth rate, and solid tumor proportion. Ultrasound remains the first-line modality for detection, hemodynamic assessment, and surveillance, whereas MRI is a complementary second-line modality for defining intrapelvic and spinal extent, particularly in Altman types II-IV or when ultrasound is inconclusive.

Keywords: Sacrococcygeal teratoma; prenatal diagnosis; fetal MRI; ultrasonography prenatal; hydrops fetalis.

INTRODUCTION

Sacrococcygeal teratoma (SCT) represents the most frequent solid neoplasm in fetuses and neonates, comprising more than 50% of all fetal tumors detected prenatally.[1] (Figure 1) The birth prevalence of this tumor varies from about 1 in 20,000 to 1 in 40,000 live-born infants with a highly significant sex preference — three to four times more females than males are affected.[2,3] A cohort study in the West Midlands over 18 years, likewise, found this sex preference among the perinatal outcomes linked to SCT detected before birth.[4] With the increased popularity of obstetric ultrasound examination during pregnancy, SCTs have been increasingly diagnosed prenatally, contributing up to 50% to 82% of all SCTs.[5,6]



Figure 1: Prenatal schematic illustration of fetal sacrococcygeal teratoma. Created in <https://BioRender.com> The SCT develops in the sacrococcygeal area and has an anatomic classification system known as the Altman classification which consists of four types, depending on the relation between the external and intrapelvic extension of the tumor, where the method of treatment is chosen according to.[2] Most of the SCTs diagnosed

in utero have benign nature; however, their malignant potential is significantly enhanced with either delay in diagnosis or delayed surgical resection.[3] Other than the malignant tendency of SCT, the perinatal risks involved in the SCT detected in utero are much higher due to different pathophysiologic mechanisms — such as the shunting through arteriovenous fistula within the tumor to develop cardiac failure, hydrops, placental enlargement, and mirror syndrome — not seen in the postnatally diagnosed cases.[7,8]

Obstetric ultrasound continues to be the gold standard for prenatal detection and surveillance and aids in real-time assessment of tumor size, shape, vascularization, and fetal/maternal complications.[9] Ultrasound is known to suffer from several limitations, which include limited field of vision, acoustic shadowing by bony structures, reliance on fetal position and amniotic fluid content, and inability to determine the exact extent of intrapelvic/intervertebral tumor involvement in every case.[10] Fetal MRI has proven itself as a useful adjunct modality, which provides better visualization due to enhanced contrast, larger field of vision, and ability to map the exact anatomy of the tumor independent of fetal position, maternal physique, or oligohydramnios. [11,12] Although several reviews have addressed fetal teratomas and the prenatal assessment and management of SCT in general,[6,8] a focused synthesis of the complementary role of ultrasound and fetal MRI is lacking, covering early detection, Altman typing, hemodynamic surveillance, differential diagnosis, prognosis, and surgical planning of SCT.

METHODS

A narrative literature search was performed in the PubMed/MEDLINE and EMBASE databases for English-language articles published between 1990 and 2025 pertaining to prenatal ultrasound and MRI assessment of SCT. This review will attempt to fill the gap by critically evaluating the advantages and disadvantages of each modality, their agreement and discrepancy during clinical cases, and formulating an optimal approach to imaging for the prenatal diagnosis of fetal SCT.

EMBRYOLOGY AND PATHOLOGY

It is also vital to learn about the embryology of SCT to be aware of its anatomic localization, histologic heterogeneity, and the potential for tumor formation. Although the tumorigenesis process is not entirely known yet, there are two hypotheses concerning its etiology. The first theory, which is more widely supported, assumes that the source of SCT is the totipotent cells of Hensen's node, or the anterior organizing center of the primitive streak. The totipotent cells experience a complete degeneration process by the end of the fourth gestational week.[13] The remnants of totipotent cells in the sacrococcygeal region after their natural regression become involved in an unusual differentiation, resulting in the formation of teratoma.[14] The sacrococcygeal region can be considered the region with the highest number of primitive cells for the longest period of time during the process of embryogenesis, which explains the fact that it is the most common region of extragonadal germ cell tumors in neonates.[13] There is also another hypothesis that links the development of SCT to primordial germ cells (PGCs), whose deviation from the normal migration route leads to the ectopic localization of PGCs in the sacrococcygeal region while moving from the yolk sac to the gonadal ridges through the hindgut.[14] According to the definition, teratomas have tissue components of all three germinative layers of the embryo – ectoderm, mesoderm, and endoderm.[13] Consequently, the tissue makeup of SCT also varies widely and includes structures such as squamous epithelium, neural elements, bone, cartilage, glandular tissue, fat, and sometimes even well-formed organoid structures. Gonzalez-Crussi Classification System for Histological Grading of SCTs is performed according to four grades: Grade 0 (mature, benign, well-differentiated), Grade 1 (immature, probably benign, contains areas of undifferentiated tissue less than 10% of the entire sample), Grade 2 (immature, potentially malignant, consists of immature tissue from 10 to 50% of the total sample) and Grade 3 (definitely malignant, more than 50% of the sample comprises undifferentiated tissue).[15] The results of the nationwide Japanese study showed that immaturity or malignancy was an independent predictor of poor prognosis compared to mature teratoma.[16]

In general, prenatal ultrasound does not reliably predict the maturity of the lesion, however, some ultrasound characteristics, such as the majority of solid masses and high vascularization tend to be more typical for immature and/or malignant tissues.[17]

Anatomically speaking, the classification suggested by Altman in his American Academy of Pediatrics Surgical Section (AAPSS) study of 1973 is regarded as a gold standard.[2](Figure 2)

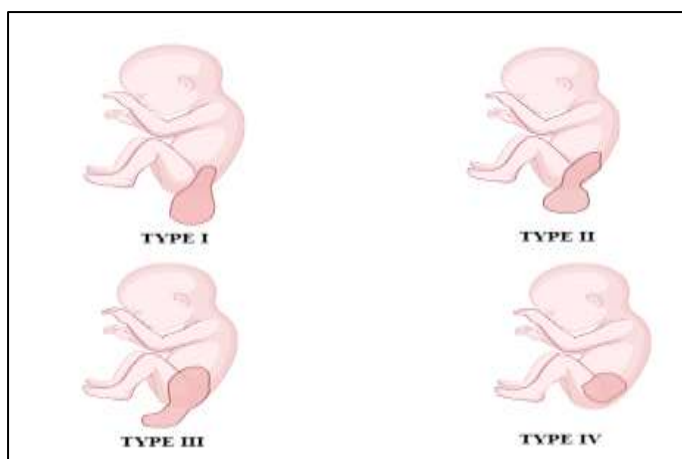


Figure 2: Schematic illustration of the Altman classification of fetal sacrococcygeal teratoma. Created in <https://BioRender.com>

According to this classification, SCT is subdivided into four types based on the ratio of external and internal tissues:

- Type I: External mass with a small or negligible presacral mass component (accounts for 47-62% of all SCTs). (Figure 3)
- Type II: External mass with considerable pelvic extension.(Figure 4)
- Type III: The external mass is present, but the predominant component is an intrapelvic and intra-abdominal mass. (Figure 5)
- Type IV: Intrapelvic or presacral mass without an external mass (least common form of SCT, accounts for 5-9% of all SCTs, highest malignancy potential). [13](Figure 6)

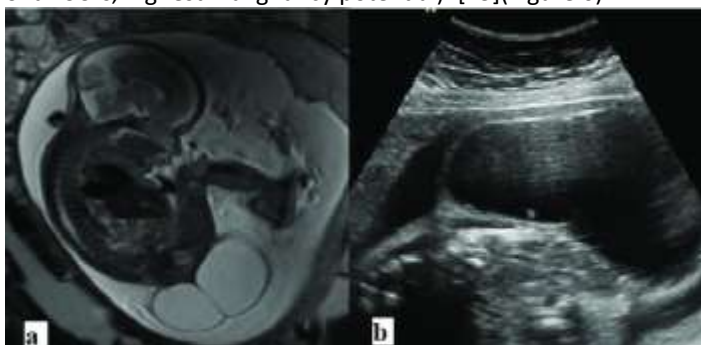


Figure 3: Type I sacrococcygeal teratoma. (a) Sagittal T2-weighted MR image and (b) corresponding grayscale ultrasound image, obtained during the second trimester, show a mixed cystic and solid mass arising from the coccyx; no intrapelvic extension is identified. Reproduced from [46]: Tosun M, Çam İ, Uslu H, Doğan Y, Anık Y. A single-center experience of magnetic resonance imaging findings of fetal sacrococcygeal teratomas. (Reproduced from Turk J Med Sci 2022;52(4):1190–1196, under the Creative Commons Attribution 4.0 International License (CC BY 4.0).)

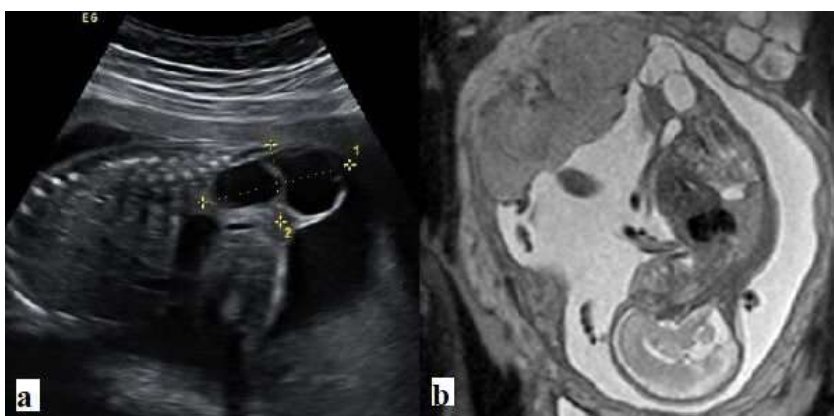


Figure 4: Type II sacrococcygeal teratoma. (a) Grayscale ultrasound image and (b) coronal T2-weighted MR image show a large septate cystic mass arising from the coccyx with a small intrapelvic component. The yellow calipers

in (a) denote the tumor measurement. (Reproduced from [46]: Tosun M, Çam İ, Uslu H, Doğan Y, Anık Y. Turk J Med Sci 2022;52(4):1190–1196, under CC BY 4.0.)

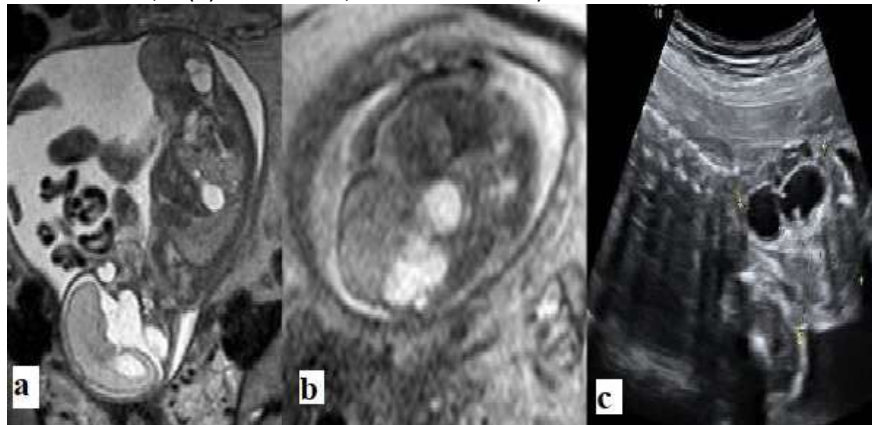


Figure 5: Type III sacrococcygeal teratoma in a fetus at 32 weeks' gestation. (a) Sagittal and (b) axial T2-weighted MR images, no contrast material administered, and (c) grayscale ultrasound image show a large tumor of mixed signal intensity extending into the abdomen. (Reproduced from [46]: Tosun M, Çam İ, Uslu H, Doğan Y, Anık Y. Turk J Med Sci 2022;52(4):1190–1196, under CC BY 4.0.)

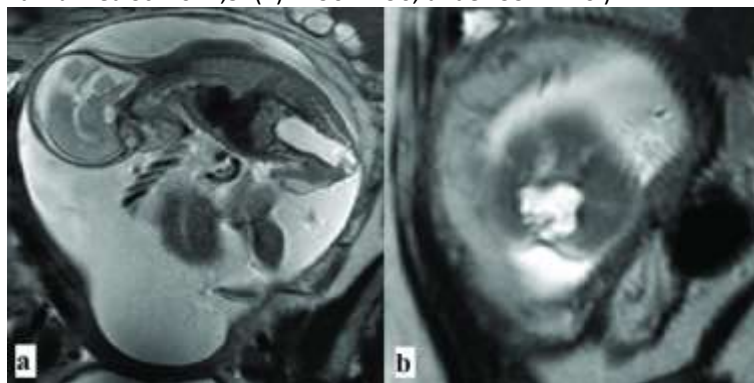


Figure 6: Type IV sacrococcygeal teratoma. (a) Sagittal and (b) axial T2-weighted MR images show a tumor developing entirely within the fetal pelvis; the urinary bladder is displaced, with increased vertical dimension and lobulated, thickened contours, and associated polyhydramnios. (Reproduced from [46]: Tosun M, Çam İ, Uslu H, Doğan Y, Anık Y. Turk J Med Sci 2022;52(4):1190–1196, under CC BY 4.0.)

Altman staging system has certain implications in terms of imaging – Type I tumors are the easiest to identify and image through ultrasonography, while Type II, III and IV become progressively more difficult to image without MRI.[6] Changes of Altman types may occur at any time during pregnancy because of SCT enlargement, so serial imaging is required.[13]

ULTRASOUND IN PRENATAL EVALUATION OF SCT

ROLE AS PRIMARY MODALITY

Another important technique that is widely used in the prenatal diagnosis of SCT and long-term monitoring of pregnant patients is obstetric ultrasonography.[8] This imaging modality is distinguished by such features as its high accessibility, absence of ionizing radiation, real-time imaging, cost-effectiveness, and concurrent evaluation of fetal dimensions, amniotic fluid volume, and fetal heart rate.[8] Ultrasound is highly effective for detecting the external component of SCT in specialized fetal medicine practice, but its sensitivity for intrapelvic components is substantially lower. [CITATION NEEDED: the previous reference (an MRI study) does not support this statement] The second-trimester anomaly scan practice guidelines of the Society of Fetal Medicine involve systematic evaluation of fetal sacral region, which is the most common technique for prenatal identification of SCT.[19]

TIMING OF DETECTION

The majority of SCTs are diagnosed through second-trimester anomaly scan typically performed between 18 to 22 weeks.[9] An increasing number of reports on SCTs diagnosed in the first trimester have been observed. The

first trimester detection of SCTs was firstly described by Roman et al. when SCT was identified via nuchal translucency scan performed at 12+3 weeks of gestation with the use of 3-D ultrasound.[20] Detection was even earlier at 13 weeks of pregnancy reported by Spingler et al., where an SCT that was 1.5 cm in size protruding from the coccygeal region and increased vascular perfusion on Doppler was noted.[21] Early detection will allow more counseling and follow-up but the prognosis of SCT in small infants is not clear yet.

SONOGRAPHIC CHARACTERISTICS

The features of SCT on sonography are a complex mass arising from the sacrococcygeal region, which could be cystic, solid, or mixed in echogenicity.[9] In the popular study series done by Shue et al., majority of SCT has been found to be mixed cystic-solid, as in the previous series done by Holterman et al.[9,22] In a study series conducted by Tongsong et al., a mixed or solid type of echotexture has been found to be a common presentation of SCT on prenatal sonogram.[23] The purely cystic type is characteristic of benign mature teratoma while solid or mainly solid type suggests immaturity/malignancy. The calcifications are noted as echogenic foci with posterior acoustic shadowing. It should be noted whether the mass is related to the spine or sacrococcyx as a sign of dysraphism.[6]

SIZE ASSESSMENT AND THREE-DIMENSIONAL ULTRASOUND

Measurement of the dimensions of the external lesion can be achieved through routine two-dimensional ultrasonography. However, volumetric estimation of the tumor requires 3D imaging and is critical in defining the tumor volume/ fetal weight ratio (TFR), which has been found to be a useful predictor of prognosis in SCT.[24] In addition, 3D and 4D ultrasonography gives images of the surface anatomy of the external lesion and the relationship to the perineum and lower limbs of the fetus, hence the benefit of counselling parents.[20] However, 3D ultrasonography does not solve the problem of the inherent shortcoming of ultrasonography in evaluating the extent of the pelvic region involved in SCT.

COLOR DOPPLER AND SPECTRAL DOPPLER

Color Doppler and Spectral Doppler are both valuable diagnostic imaging techniques in determining vascularity in SCTs prenatally. The solid portions in SCTs derive their blood supply from branches of the middle sacral artery and therefore present increased internal vascularity in color Doppler.[25] Fetal hydrops associated with SCT involves the vascular steal phenomenon where the high vascular tumor steals most of the cardiac output in the fetus.[7] The blood flow evaluation of the tumors using color Doppler gives information on hemodynamic abnormalities, while spectral Doppler of tumor vessels gives low resistance waveform with resistance indices of 0.60 to 0.70.[25]

Assessment of MCA-PSV is done in order to detect fetal anemia caused by intratumoral hemorrhage. Fetal echocardiography must be done for detection of cardiomegaly, elevated ventricular output and early hydrops indicating deterioration of the hemodynamic status and requiring urgent interdisciplinary consultation.[7,8]

PROGNOSTIC SONOGRAPHIC MARKERS AND SERIAL MONITORING

Serial ultrasound is the key to prenatal monitoring of SCT. These are the ultrasonographic markers of unfavorable pregnancy outcomes .(Table 1) Solid tumor: In the systematic review of 11 studies including 447 patients, Van Heurn et al. reported that solid tumor features, hypervascular tumor, cardiomegaly, fetal hydrops and placentomegaly were statistically significantly associated with poor prognosis.[5] Further independent analysis of the same authors confirmed these findings in an independent fetal series.[26] Tumor-to-fetus weight ratio (TFR): Rodriguez et al. reported an association between unfavorable pregnancy outcomes and a TFR above 0.12 before 24 weeks,[24] and this cutoff was subsequently validated as a predictor of poor prognosis in a retrospective single-institution series of 37 patients by Shue et al.[22] Growth rate: In a multicenter study, Vinit et al. demonstrated that growth rate was independently associated with complications and death.[27]

Table 1. Sonographic prognostic markers in prenatally diagnosed sacrococcygeal teratoma.

Marker	Finding	Ref.
Solid tumor morphology	Predominantly solid tumors are associated with poor outcome; purely cystic tumors had a good prognosis in one series	5,22
Hypervascularity	Associated with poor outcome	5
Cardiomegaly	Associated with poor outcome; OR 10.3 (95% CI 1.9-55.8) in the Dutch national cohort	5,26

Marker	Finding	Ref.
Fetal hydrops	Associated with poor outcome; OR 21.0 (95% CI 2.6-275.1) in the Dutch national cohort; reported mortality 30%-50%	5,26,29
Placentomegaly	Associated with poor outcome; indicates high-output fetal heart failure	5,8
Tumor volume to fetal weight ratio (TFR)	TFR above 0.12 before 24 weeks of gestation predicts poor outcome	22,24
Tumor growth rate	Independently associated with complications and death	27
Polyhydramnios	Results from impaired swallowing and increased fetal urine output; risk of preterm labor and premature rupture of membranes	8

Those sonographic and volumetric parameters were then introduced into a formal prognostic classification system in order to counsel patients.[28] Placentomegaly and polyhydramnios: Placentomegaly (placental thickening due to edema) indicates high-output fetal heart failure. Polyhydramnios results from impaired fetal swallowing due to mass effect and from increased fetal urine output, and may lead to preterm labor and premature rupture of membranes.[8]

Fetal hydrops: Hydrops is one of the strongest adverse prognostic markers in prenatally diagnosed SCT, and mortality in affected fetuses has been reported to be as high as 30% to 50%.[29] In the Dutch national cohort, hydrops carried an odds ratio of 21.0 (95% CI 2.6-275.1) for poor outcome, although the wide interval reflects the small sample size.[26] Hydrops developing early in gestation carries a particularly poor prognosis, and fetal intervention may be considered in selected cases.[29]

MATERNAL MIRROR SYNDROME

Mirror syndrome is another important maternal complication of fetal SCT, and it should be considered while performing imaging. This syndrome arises due to physiological changes in a woman which are quite alike to those appearing in the hydropic fetus. Symptoms of maternal mirror syndrome include hypertension, edema of the extremities, proteinuria, and pulmonary edema.[30] Mirror syndrome occurring in a woman having fetal SCT, as shown by the early echocardiographic signs of right ventricular failure and placentomegaly without fetal hydrops, was described by Finamore et al.[31] Detection of placental enlargement, polyhydramnios, and progressive deterioration of the fetal heart function should alert one to mirror syndrome as it may indicate that the disease has progressed to severe fetal cardiac dysfunction. Mirror syndrome has traditionally been regarded as an ominous sign,[32] although some cases have been reported to resolve after fetal treatment.[29]

LIMITATIONS OF ULTRASONOGRAPHY

Despite the advantages of ultrasonography in pregnant patients, it still has some major drawbacks in diagnosing SCT. First of all, the intrapelvic and presacral portions of the tumor necessary for accurate Altman staging and planning of surgery cannot be visualized because of acoustic shadows caused by fetal bones (pelvis/sacrum).[25] Besides, maternal obesity, oligohydramnios, and fetal positioning worsen the image quality significantly. Ultrasound cannot detect spinal canal invasion and differentiate between SCT and neural tube defects in complex anatomic locations.[10]

INDICATIONS FOR FETAL MRI

The following cases require performing fetal MRI as an additional investigation method: inability to visualize the intrapelvic portion of the tumor using ultrasound; doubt about Altman classification; suspicion of spinal cord or intraspinal involvement; large tumor with a considerable volume of the solid portions; need for anatomical mapping prior to the surgery; and low diagnostic quality of ultrasound imaging.[10,12] The best gestational age for performing fetal MRI is considered to be after 18 weeks' gestation since the fetus becomes large enough to have detailed anatomical pictures.

TECHNIQUE

The MRI examination is carried out at 1.5T or 3T using scanner without sedation of mother or fetus since fast imaging methods allow for small influence of fetal movements. Standard sequences are single-shot fast spin-echo sequences (SSFSE/HASTE) in axial, coronal, and sagittal planes that provide T2 weighted images with high quality soft-tissue contrast. T1 sequences are additional tests that help to evaluate the fatty component (high T1 signal) and hemorrhage inside the mass.[30] Contrast agents based on Gadolinium are not used because of possible adverse fetal effect and passing through placental barrier, but can be used in certain clinical cases.

MRI APPEARANCES

On fetal MRI, SCTs appear as heterogeneous, presacral or sacrococcygeal mass that has various signal properties because of different tissue composition inside the mass. Cystic tissue on MRI is represented by bright T2 signal regions, and solid tissue – by moderate T2 signal regions. Lipomatous tissue and hemorrhage both appear as bright T1 signal regions; fat-suppressed T1 images help to distinguish them. The architecture of the SCT, based on the composition of cystic, solid and fatty components, is well visible on MRI as compared to ultrasound, especially in intrapelvic parts.[11,12]

For the study by Avni et al., in their 12 patients, MRI revealed SCT to be purely cystic with little septa (three cases), highly septated/microcystic (eight cases), and purely solid mass (one case).[11] In the study by Danzer et al. of 22 patients, MRI revealed purely cystic tumors (five), a microcystic tumor (one), mixed cystic-solid tumors (twelve), and solid tumors (four).[12]

ALTMAN STAGING CLASSIFICATION ON MRI

It should be noted that correct typing based on Altman staging can only be performed by proper assessment of extraperitoneal and intrapelvic tumor extent. According to Danzer et al., MRI provided better characterization of the intrapelvic and intraperitoneal tumor extent and gave more details about the compression of the bladder, rectum, and distal ureters.[12] Correct typing based on Altman was provided for all patients by MRI. In a cohort of 60 fetuses with abdominal or sacrococcygeal masses (52 of them SCT), Li et al. reported that prenatal ultrasound gave incorrect or ambiguous diagnoses in 11 cases and concluded that MRI had high diagnostic accuracy; type IV SCTs were prone to misdiagnosis and carried a poorer prognosis.[18] This was shown by the work of Cain-Trivette et al., which stated that MRI

allowed risk stratification and surgical planning in four out of five SCT cases; in one SCT patient, however, reclassification was necessary during surgery despite preoperative imaging being high-resolution.[33]

SPECIFIC ADVANTAGES OF MRI OVER ULTRASOUND

Definition of intrapelvic extension: Clinical value of MRI mostly relies on detection of intrapelvic and abdominal portions of the tumor concealed under acoustic shadowing on US which helps to determine the Altman classification type and thus select a strategy for operation, including sacral approach in case of Types I and II and a combination of abdominoperineal approaches in case of Types III and IV.[10]

Spinal canal evaluation: MRI still provides the most reliable diagnostic tool for investigation of spinal canal infiltration and intraspinal growth of tumor. It also enables to distinguish SCT from congenital diseases such as myelomeningocele and terminal myelocystocele.[34,35] Involvement of adjacent organs: MRI provides for better assessment of anatomic relationship between the lesion and the urinary bladder, rectum, and pelvic muscles. Urethral obstruction or bladder displacement is more easily diagnosed by MRI rather than by ultrasonography.[12] Tissue characterization: MRI provides for better tissue characterization due to different MRI signal from fat, hemorrhage, or fluid content within the mass. Fat content in the tumor is considered characteristic for SCT, especially for teratomatous form.[30]

Clinical Implications: Various research papers have reported significant changes in pre-natal care in a substantial number of cases because of the results of fetal MRI that have affected counseling, Altman classification reassessment, and improved surgical planning.[11,12,18,33] For instance, Mahmood et al. reported a single case in which prenatal and neonatal MRI were correlated with operative findings, and MRI depicted the intrapelvic contents and the absence of neural tube involvement better than ultrasound.[36] In the same way, Quinn et al. demonstrated that prenatal MRI increased diagnostic confidence and changed the management of a proportion of patients referred for MRI.[37]

LIMITATIONS OF MRI

The motion artifact resulting from fetal movements is the major problem for MRI technology, which affects image quality by distorting the fine structure of anatomic structures. Lack of any contrast enhancing technique makes it difficult to assess the vascular nature of the tumor, which can be accomplished with Doppler ultrasonography. It is very difficult to visualize calcifications with MRI; hence postnatal CT is better for that purpose. Also, the depiction of bony structures, which is needed for the operation of coccygectomy, is much better on postnatal CT. Lastly, MRI is not readily available in most secondary and tertiary hospitals in India, and requires specialized interpretation skills.

COMPLEMENTARY ROLES: US AND MRI TOGETHER

In connection with the interrelationship between the two techniques in the diagnosis and surveillance of SCT in pregnancy, ultrasound and MRI could be considered complementary, rather than competing modalities. Though,

the total agreement about tumor size in the two imaging techniques has been reported by Avni et al. and Danzer et al., MRI gives much more information about the size, histological appearance, and location of the lesion.[11,12]

The main differences between the two imaging techniques are summarized in Table 2. According to the currently available data, the following guidelines are offered for the application of MRI additional to ultrasound:

Type I according to Altman: ultrasound is sufficient both for diagnosis and longitudinal monitoring. MRI should be used in case of suspicion of presacral involvement or tumor size large enough to affect delivery planning.

Types II and III according to Altman: high recommendation for MRI. The underestimation of the tumor volume in pelvis with the help of ultrasound technique is frequent among these two groups, which leads to misclassification as type I.[6]

Type IV according to Altman: ultrasound imaging relies on indirect signs (bladder in the forward position, presacral density), but not on the direct visualization of the tumor. MRI is the imaging modality of choice in the lesion detection and characterization. Adekola et al. give a review of the clinical value of MRI in the diagnosis of type IV cystic SCT compared with cloacal malformations and other presacral lesions.[35]

Table 2. Comparison of prenatal ultrasound and fetal MRI in sacrococcygeal teratoma.

Feature	Ultrasound	Fetal MRI
Role	First-line modality for detection, surveillance, and hemodynamic assessment	Complementary second-line modality, used when ultrasound is insufficient
Intrapelvic and presacral extent	Limited by acoustic shadowing from fetal bones	Superior; multiplanar and independent of fetal position, maternal habitus, and amniotic fluid volume
Altman typing	Reliable for type I; intrapelvic extent in types II-IV is often underestimated	More accurate, particularly for types II-IV
Spinal canal involvement	Cannot reliably detect; poor differentiation from neural tube defects	Most reliable
Tissue characterization	Cystic, solid, and calcified (echogenic with shadowing) components	Cystic, solid, fat, and hemorrhagic components
Vascularity and hemodynamics	Color and spectral Doppler, MCA-PSV, fetal echocardiography, amniotic fluid assessment	Limited; no routine contrast enhancement
Calcification	Visible as echogenic foci	Poorly visualized
Main limitations	Maternal obesity, oligohydramnios, fetal position	Fetal motion artifact; requires specialized interpretation
Availability	Widely available, no ionizing radiation, cost-effective, real-time	Not readily available in many secondary and tertiary hospitals in India

DIFFERENTIAL DIAGNOSIS ON PRENATAL IMAGING

Differential diagnosis of the posterior or presacral fetal mass is described in detail below. It is important to distinguish these lesions since they have different treatment approaches.

Myelomeningocele/Spina Bifida and Terminal Myelocystocele: The first disease in the differential diagnosis of a posterior or presacral fetal mass is neural tube defect that can be easily mistaken for SCT. Neural tube defects are situated dorsal to the sacrum and are associated with spinal dysraphism, whereas SCT arises from the coccyx, with an external component and, in Altman types II-IV, an intrapelvic (presacral) component. It is also important to look for other signs of neural tube defects as ventriculomegaly, Chiari II malformation, as well as lemon and banana signs on fetal ultrasound. Yu et al. compared ultrasound features of these lesions emphasizing that ultrasound is not reliable method for their differentiation and MRI is preferable.[34]

Sacral Meningocele (Currarino Syndrome): The Currarino syndrome consists of a triad of sacral dysgenesis (scimitar sacrum), anorectal malformation, and presacral mass because of the autosomal dominant mutation in the MNX1 gene.[38] Definitive diagnosis can be made using MRI.

Prenatal Imaging Dilemma: Distinguishing Type IV SCT and Cloacal Malformation – The differentiation of Type IV SCT and cloacal malformation in terms of prenatal imaging was described by Sahinoglu et al. pointing out the similarities of their locations and urinary tract abnormalities.[39] MRI is crucial for the differentiation of these diseases considering their relationships to the rectum, bladder, and genitalia.

Rhabdomyosarcoma and neuroblastoma – rare during the prenatal period, but should be included in the differential diagnosis of presacral tumors – the presence of homogeneous solid mass in MRI images without fat and cystic components, which serves as a marker for these tumors, but the final diagnosis can only be made by histopathology.

IMAGING FOR THE FETAL INTERVENTION AND

EX UTERO INTRAPARTUM TREATMENT (EXIT)

Fetal intervention in SCT is done for a subset of SCT patients who have suffered from hydrops, high-output heart failure, or tumor growth during prenatal development, when non-interventional therapy and delivery are not possible.[8]

Color Doppler study of vascularization of the tumor and Doppler echocardiography of the fetal blood flow are mainly used to diagnose the need for intervention and to monitor the course of treatment.[8] Mirror syndrome has traditionally been regarded as a poor prognostic sign and a relative contraindication to fetal intervention;[32] however, a recent review reported that maternal mirror syndrome resolved after fetal treatment in some cases and can itself be an indication for prenatal treatment.[29] RFA, laser ablation and open fetal surgery are performed under continuous ultrasonographic control and focus on occlusion of the tumor's main supply vessels in order to minimize arteriovenous shunting.[29] Radiofrequency ablation directed to tumor vascular pedicle has been reported as a technique aimed to reduce high-output cardiac failure in selected fetuses.[40] In the systematic review by Konno et al. (2024) of 157 fetuses (16 open fetal surgery, 48 percutaneous intervention, and 93 without intervention), survival was 56.2% after open fetal surgery, 45.8% after percutaneous intervention, and 71.0% without intervention.[41] These groups are not directly comparable, because intervention is reserved for fetuses with severe complications such as hydrops and high-output cardiac failure; the higher survival without intervention therefore most likely reflects case selection rather than a harmful effect of treatment.[29]

The ex utero intrapartum treatment (EXIT), which involves partial delivery and treatment of the fetus before the umbilical cord is ligated while the placental circulation is still present, is used only in large mass SCT cases, where the fetus needs to be delivered or when airway access is required.[42] The use of MRI before EXIT procedure is the decisive factor in proper anatomic planning, particularly for tumors involving intrapelvic regions with poor visualization on US.

POSTNATAL IMAGING CORRELATION AND FOLLOW-UP

Postnatal MRI is the main modality for preoperative planning, and CT is used selectively, given the radiation exposure in neonates. Postnatal CT is more effective than fetal MRI in visualizing the presence of calcification and osteofixation of the sacrum and coccyx region. Firszt et al. described the fetal MRI and postnatal CT findings of SCT in a case report.[10] Li et al. likewise reported high accuracy of prenatal MRI when compared with follow-up findings.[18] Outcomes of prenatally diagnosed SCT have also been reported in a nationwide Japanese survey.[43]

AFP can also serve as a tumor marker after birth. Although it is necessary to take into account high levels of AFP after birth in connection with the high level of production of this protein by fetal liver, failure of postnatal decrease or a new elevation should be considered for further investigation with postnatal MRI to find out residual or recurrent tumor.[32] Long-term follow-up with regular MRI examinations and measurement of AFP in all SCT survivors is necessary because there is a risk of recurrence of malignant tumor during their lives, particularly in those with immature histology and incomplete tumor removal.[17] Early series have shown that perinatal mortality associated with SCT occurs mainly due to surgical problems and prematurity, but not because of cancer itself. That is why a multidisciplinary approach to the management of childbirth is very important.[44]

SPECIAL CONSIDERATIONS FOR THE INDIAN SITUATION

There are less cases of prenatal diagnosis of SCT in India compared to the developed countries because there are many deliveries that occur in secondary and district hospitals where advanced ultrasonography and fetal MRI are not available. Yadav et al. prospective study carried out in tertiary hospital in India has shown that delayed diagnosis is one of the problems in Indian setting, especially in patients with Types III and IV SCT.[45]

The following special considerations should be considered by Indian radiologists when performing obstetric ultrasonography: Firstly, all screening examinations on anomalies in the second trimester should include thorough visualization of sacrococcygeal region, especially in sagittal and axial planes. One should keep in mind that sacral region is not always included in the protocols of anomaly screening studies in underprivileged

environments and Types I and Type II sacrococcygeal teratomas with predominantly external part may be missed when sacral region is not properly evaluated.

Secondly, urgent referral to a tertiary center, which is equipped with fetal MRI facilities for the patients with the diagnosis of SCT is vital, especially if there is suspicion of intrapelvic tumor parts due to ultrasound examinations. Referral delay may result in improper surgical planning and insufficient tumor excision.

Thirdly, if there are no fetal MRI facilities available, it is necessary to get as much information from Doppler ultrasound as possible in order to stratify the risks most appropriately. This information includes vascularization of the tumor, MCA-PSV, cardiac size of the fetus, and amniotic fluid index.

DISCUSSION

Prenatal imaging of SCT for three decades brought great achievements, turning simple anomaly scans into multi-modality protocol addressing all the aspects of the antenatal care. The literature reviewed here indicates that ultrasound and fetal MRI agree on basic findings such as tumor size, but each provides information that the other cannot reliably supply, which supports their complementary roles in prenatal care.

Ultrasound is vital in the diagnosis of SCT, hemodynamic assessment, and continuous surveillance. Color Doppler imaging, cardiac output estimation, early diagnosis of hydrops fetalis, measurement of amniotic fluid index, and clinical decision making according to the aforementioned criteria cannot be achieved with MRI to the same extent.

It is especially important to carry out continuous surveillance with the help of Doppler ultrasound because of the rapid changes in the hemodynamic status from compensated to decompensated. Fetal MRI allows getting the required anatomical resolution in order to properly classify the tumor according to Altman classification, especially if intrapelvic tumor part is extensive. Incorrect classification of types II and III as type I will have definite clinical consequences, including improper surgical planning and high probability of residual disease. Evidence provided by Danzer et al. and Li et al. supports a substantial influence of MRI on clinical management.[12,18]

Lastly, TFR, which has been validated as an imaging predictor of poor prognosis in retrospective series,[22,24] deserves special attention. If TFR is higher than 0.12 prenatally before 24 weeks' gestational age, this points to a particularly high-risk group that requires consultation immediately. For this group of cases, 3D volumetry should be performed, and it is reasonable to recommend 3D volumetry for the evaluation of fetuses in tertiary centers.

Taking into account the fact that in practice there is no access to fetal MRI in secondary care and district hospitals in India, learning all aspects of ultrasonographic assessment of SCT, including three-dimensional volumetric evaluation, Doppler investigation, calculation of TFR, and recognition of Type IV SCT according to secondary criteria, becomes an essential public health issue in India. If MRI is available in a tertiary referral hospital, there must be a protocol for referral of cases where ultrasound investigation is not sufficient for proper characterization.

CONCLUSION

The diagnosis of fetal sacrococcygeal teratoma is a difficult one requiring the imaging approach that should include the systematic multi-disciplinary management in order to provide adequate diagnosis and treatment of the disease. Obstetric ultrasonography along with the option of color Doppler and 3D volume evaluation serves as the main imaging modality for early detection, Altman classification of the extrinsic masses, hemodynamic evaluation, and follow-up throughout pregnancy. Fetal MRI gives additional information about intrapelvic extension of the tumor, soft-tissue anatomy of tumors, spinal cord integrity, and the nature of tumor tissues mainly in Altman types II-IV teratomas and cases when ultrasonographic examination is not enough. The application of an imaging strategy using both imaging modalities, depending on indications, where ultrasound is a first-line imaging modality and MRI is second-line imaging modality, is the approach best supported by the available evidence for accurate tumor classification and for surgical and perinatal planning in this high-risk condition; whether this strategy improves perinatal outcomes has not been directly tested.

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Conflict of Interest

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