RESEARCH PAPER

Artificial Intelligence–Driven Multimodal Imaging for Cancer During Pregnancy: Advances in Maternal–Fetal Diagnostics and Precision Oncology

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ABSTRACT
Cancer diagnoses during pregnancy are rising as a result of women delaying childbearing and increasing use of non-invasive prenatal diagnostics for foetal aneuploidy screening and accidental maternal cancer detection. Pregnant women have a harder time with imaging and cancer staging. Picture interpretation is hampered by physiological changes in pregnant tissues. In addition, underutilization of imaging tests and inappropriate staging may result from a lack of defined imaging procedures, fear of (unnecessary) foetal radiation, and confusion regarding the safety of imaging modalities. Ultrasound and magnetic resonance imaging (MRI) are ideal for the evaluation of locoregional illnesses because they do not use radiation. MRI can also stage distant disease by whole-body evaluation, combine anatomical and functional information by diffusion weighted imaging without gadolinium, and provide a more reproducible comprehensive assessment of an organ or region. CT and nuclear imaging should be used judiciously to balance maternal benefit and foetal danger. The foetal radiation threshold should not be exceeded by total radiation exposure. Only perform imaging if it is necessary for diagnosis or may alter treatment. The interdisciplinary team relies on radiologists to select imaging modalities that strike a balance between the benefits to the mother and the risks to the fetus and to direct treatment decisions. We review clinical applications and imaging breakthroughs for cancer patients during pregnancy to discuss potential issues.

Keywords: Artificial Intelligence, Cancer During Pregnancy, Radiological Risk Stratification, Deep Learning, Radiomics, Maternal-Fetal Imaging, Oncology Imaging, Machine Learning
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I. INTRODUCTION

The estimated 1000–2000. cancer-related pregnancies are uncommon. Delaying childbearing until later in life may increase its prevalence. Prenatal non-invasive testing for foetal aneuploidy may also increase the number of unintentional maternal cancers. During pregnancy, breast, haematologic, gynecologic, gastrointestinal, thyroid, and melanoma cancers are the most common. It is difficult to evaluate cancer in pregnancy clinically. Fatigue, changes in the breast, and constipation—common gestational symptoms—coincide with cancer symptoms, which may delay diagnosis until the cancer has progressed. Prenatal non-invasive testing may identify tumors in the mother before they cause symptoms, which calls for diagnostic imaging [1]. To improve the mother's oncology without affecting the child's growth, doctors adhere to non-pregnant patients' treatment plans. Oncologic treatment during pregnancy is preferred over voluntary preterm birth or abortion in this instance. At three and six years, the long-term outcomes of children who received chemotherapy during the second or third trimester appear to be promising. Pregnant cancer patients require precise diagnosis and treatment response in order to receive complicated but successful treatment. Imaging for diagnosis needs to be precise. The benefits to the mother and the risks to the unborn must be balanced when imaging cancer patients who are pregnant. This prevents the standardization of diagnostic methods and increases the risk of underutilization of diagnostic imaging, resulting in poorer diagnostic (and therapeutic) treatment than for patients who are not pregnant. As a result, radiologists and nuclear imaging specialists ought to participate in decisions regarding the most effective diagnostic strategies made by multidisciplinary teams[2]. Due to their high accuracy and low radiation, ultrasound and MRI are ideal imaging modalities for use as a first line of defense. When the benefit to the mother outweighs the risk to the fetus, CT, PET/CT, and bone scintigraphy may be used to solve unsolved imaging or diagnostic issues. We will discuss recent advancements and clinical applications of cancer imaging during pregnancy [3].

Table 1 Cancer distribution during pregnancy

S. No.	Type of Tumour/Cancer	Number of Cases	Percentage
1	Breast Cancer	462	41%
2	Head and Neck Cancer	147	13%
3	Anaemia	113	10%
4	Ovarian Cancer	88	8%
5	Blood Cancer	68	6%
6	Gastrointestinal Cancer	45	4%
7	Melanoma	46	4%
8	Thyroid Cancer	37	3%
9	Brain Cancer	21	2%
10	Remaining Cases	139	21%

II. SAFETY CONSIDERATIONS

The fetus appears to be safe from proper ultrasound. However, extended ultrasound exposure may have teratogenic effects, hence the FDA has restricted the spatial-peak temporal average intensity to 720 mW/cm2. Nonobstetric ultrasound systems, such as those used for cancer diagnostics, generate greater temperatures than obstetric ultrasound systems. In comparison to color and spectral Doppler, B mode is less sensitive to temperature changes. As a result, when ultrasonography is able to reliably evaluate illness and provide therapeutic benefit, it should only be used sparingly. Using oppler at low output, early prenatal examinations should last no longer than 30 minutes [4]. When imaging with ionizing radiation in pregnant patients, the lowest possible dose should always be used. Foetal exposure to ionizing radiation poses the greatest threat to pregnant patients and varies with gestational age, radiation dosage, and exposure duration. To prevent foetal mortality, growth restriction, microcephaly, and intellectual damage, it is imperative that cumulative foetal radiation exposure not exceed 100 mGy be avoided at all costs. Importantly, all of the current ionizing radiation imaging techniques expose foetuses to less than 50 mGy, which has not been linked to abnormalities, growth restriction, or pregnancy loss9. The foetal risk from one test is low (Table 2). To avoid exceeding the threshold, cumulative foetal radiation exposure must be monitored in the event that multiple imaging investigations are required [5].

Table 2 Foetal radiation dosage for various ionising radiation methods

S. No.	Imaging Method	Radiation Dose to Foetus (mGy)
1	Chest X-ray	< 0.01
2	Head Computed Tomography (CT) Scan	< 0.005 – 0.5
3	Mammography (Two-Plane Bilateral)	< 0.01
4	Coronary Angiography	0.001 – 0.66
5	99mTc Bone Scintigraphy	3.3
6	18F-FDG PET/CT	10 – 50
7	CT Scan of Pelvis and Abdomen	8 – 25

Underappreciated risks of in-utero radiation exposure include foetal carcinogenesis and genetic abnormalities. These stochastic effects are directly linked to radiation dosage without a threshold dose, therefore they may occur at low doses. During the first trimester, the risk of cancer is highest, and fetal exposure to 10-20 mGy may increase the risk of leukemia by 1.5 to 2.9. Ionizing radiation imaging should be used when clinically indicated due to the low likelihood of developing childhood cancer following a normal pregnancy. Even if incidence rates rise, this will still result in a very low cumulative risk for childhood cancer. Avoiding radiation exposure to the foetus is crucial [6]. The easiest approach is to use imaging techniques with comparable diagnostic performance and no ionizing radiation. When ionizing radiation imaging is required, cross-sectional imaging is preferred to projection radiographs and intravenous and peroral iodination. Apart from mammography and extremities sarcoma radiographies, projection radiography, especially chest radiography, has a limited role in pregnancy cancer staging. Because of its low likelihood of treatment change and low sensitivity to metastasis detection, radiation exposure is unnecessary. Direct exposure in the examination field is the sole danger to the foetus. Internal scatter radiation only causes a small amount of indirect foetal radiation exposure. According to the American College of Radiology, abdominal shielding during radiography or CT treatments cannot significantly minimise foetal radiation and should never be done. During an abdominal-pelvic CT, the foetus should not be exposed to radiation by wearing a lead apron around the pelvis. Due to a highly attenuating material, the radiation and imaging optimization system of the CT scanner must increase tube radiation output to penetrate the shield and maintain diagnostic image quality in the imaging region. This raises the dose to the fetus[7]. CT is a typical cancer imaging technology that benefits pregnant cancer patients. Due to the low radiation exposure, CT of the head, cervical spine, extremities (excluding the pelvis and hips), and thorax outside the radiation field is safe for the fetus. Because of its direct and extensive availability, CT is ideal for emergency situations. Compared to ventilation-perfusion scanning, dedicated chest contrast-CT is accurate and safe for suspected pulmonary embolism with a reduced foetal radiation dose.16 Before imaging the belly with direct foetal exposure, assess the risks and advantages. Technology like reducing voltage and current, raising pitch, expanding beam collimation, and restricting scanned area coverage may lessen radiation dosage. Ultra-low-dose CT with iterative reconstruction has high diagnostic accuracy.

To avoid emitting 100 mGy of radiation, restrict the scan to one contrast-phase scan. It is recommended because intravenous iodinated contrast provides more therapeutic information than non-enhanced CT does. Low-osmolarity, water-soluble iodinated contrast agents that have not caused neonatal hypothyroidism are the current radiological standard. In nations that routinely screen newborns for neonatal hypothyroidism, there is no need for postpartum treatment. Without regular screening, a single laboratory test should be performed in the first week of life. However, in the absence of contraindications, MRI is the preferred method for imaging the abdomen and pelvis because it doesn't use radiation and provides more accurate local staging and characterisation of pelvic tumors than CT does[8]. In bone scintigraphy, PET imaging is frequently used for staging and response evaluation. At the moment, hybrid nuclear imaging-CT systems that are routinely used in clinical settings are utilized. Fluorodeoxyglucose (FDG) and technetium 99m, two of the most common tracers, are safe for pregnant women. Iodine-131 is unsafe during pregnancy owing to the foetal thyroid risk. Instead, use technetium 99m for maternal thyroid imaging. Radioisotope radiation enters the foetal blood through the placenta and accumulates in the bladder and other tissues and organs of the mother. Radiation exposure for the fetus is determined by its weight, radiotracer, and dosage. During nuclear imaging, several safeguards reduce the amount of radiation given to fetuses. To prevent tracer accumulation in the maternal bladder, a bladder catheter is placed with intravenous hydration for renally excreted tracers. Dose calculation must account for physiological changes in

pregnancy that may affect radiotracer efficacy. Foetuses are exposed to low doses of radiation by nuclear imaging tracers; however, hybrid imaging with CT, which is the standard, increases the cumulative dose due to exposure to CT and radioisotopes. Thus, PET/CT is not a first-line prenatal imaging modality.

Cross-sectional MRI is the recommended diagnostic technique and can be used at any gestational age. The potential teratogenic effects of the static magnetic field in MRI, the heating effects of radiofrequency that slow the growth of the fetus, and the acoustic noise from rapid gradient switching that makes it hard to hear have mostly been proven to be false. No research has shown that magnetic fields teratogenically affect foetuses up to 9 years following exposure. Tissue heating at current field strengths and clinical scan periods has not resulted in injury, and there has been no post-natal hearing impairment or low birth weight observed. Tissue heating is limited, however, by some fundamental measures. Radiofrequency pulses heat tissue at a certain absorption rate. Common hardware and software components such multichannel phased-array coils and parallel transmission reduce the specific absorption rate of most clinical MRI systems to the FDA-mandated 4W/kg safety margin [9].

MRIs with a 2W/kg specific absorption rate scan pregnant individuals. The MRI technique is changed to interleave low and high specific absorption rate sequences and restrict examination duration to 30 minutes. If the procedure follows these guidelines, each trimester may get MRI up to 3 Tesla.23 The American College of Radiology advises against using gadolinium since its teratogenicity and danger of nephrogenic systemic fibrosis are unclear.23 Gadolinium chelates pass the placenta and circulate between the foetus and amniotic fluid, increasing the risk of dechelation with long-term exposure to free hazardous ions. Thus, non-contrast dependent sequences should be used wherever feasible. Using high contrast anatomical sequences with the clinically accessible non-contrast dependent diffusion-weighted imaging (DWI) sequence to characterise tissue function nearly invariably achieves this.

III. GENERAL CONSIDERATIONS IN DIAGNOSTIC IMAGING IN PREGNANCY

Specific questions about organ diagnosis can be answered by ultrasound. Early locoregional examination of breast cancer, thyroid cancer, ovarian tumours, and superficial lymph nodes is regularly performed using it. Ultrasound is less reproducible for deeper abdominal structures and larger organs because of the superimposing of intestinal gases, air-filled lungs, obesity, and the uterus during pregnancy. As a result, clinical staging should not be done in depth using ultrasonography. The reproducibility of organ system and whole-body evaluations has recently been improved by MRI. MRI can combine extremely precise anatomical information with DWI to determine the extent of a locoregional tumor because it provides excellent soft tissue contrast. This permits cancer identification, characterisation, and response evaluation by exploring differential water molecule displacements based on cellular microstructure alterations defined by apparent diffusion coefficient. On DWI, tumours show as bright lesions at 1000 s/mm2 with decreased background signal from organs, blood vessels, bodily fluids, and treatment-induced necrosis and fibrosis (Figure 1). DWI does not need gadolinium to provide image contrast, making it safer for pregnant women and identifying primary tumours, nodal, and distant metastases with comparable accuracy[10].

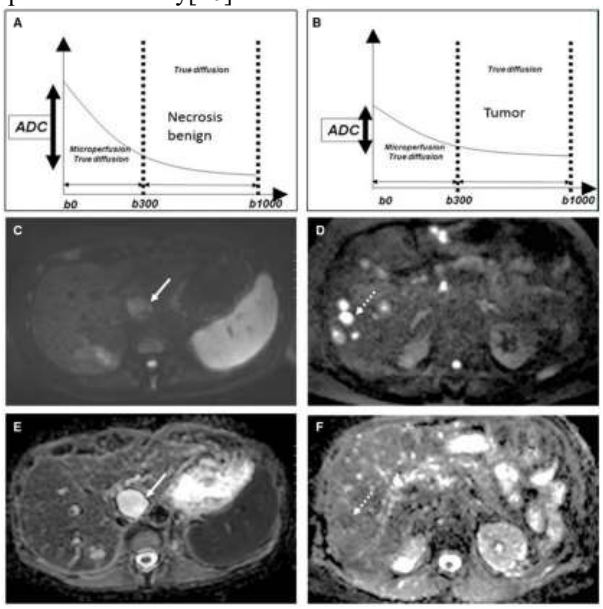

Figure 1 Using diffusion-weighted imaging, benign biliary cysts (arrow) and malignant liver metastases (dashed arrow) were characterized. (A) The biliary cyst signal decay curve exhibits a high apparent diffusion coefficient due to a significant decrease in signal intensity across successive b-value sequences. A brilliant, hypointense biliary cyst is depicted on the apparent diffusion coefficient map. (B) The apparent diffusion coefficient of the liver metastasis signal decay curve is low due to a restricted drop in signal intensity across successive b-value sequences. On the b1000 imaging, the liver metastasis is hyperintense, whereas on the apparent diffusion coefficient map, it is hypointense.

Due to its high sensitivity and low fetal radiation exposure, CT, the clinical standard for lung metastases, may safely replace chest radiography. Chest CT ought to be the initial imaging technique because melanoma, head and neck cancers, and sarcomas are all susceptible to lung metastases. Using CT to identify lung metastases, MRI is showing promise. With whole-body diffusion-weighted/MRI staging, this may reduce the need for chest CT. Due to the variety and rarity of pregnant cancers, standardizing imaging procedures are challenging to develop. This approach necessitates multimodal planning, which is a drawback. Advanced cancer can be staged using hybrid PET/MRI and whole-body diffusion-weighted MRI without or with low radiation dose. Whole-body diffusion-weighted MR imaging has been shown to be more effective than FDG-PET/CT and CT at detecting distant metastases, lymph node metastases, and lymphoma. When pregnant cancer patients underwent whole-body diffusion-weighted/MRI testing, the results showed excellent interreader agreement, with 90% accuracy for primary tumors, 98.5–99.5% accuracy for nodal metastases, and 90%–100% accuracy for distant metastases. Compared to contrast-enhanced MRI, CT, FDG-PET/CT, and bone scintigraphy, whole-body diffusion-weighted/MRI

detected hepatic, peritoneal, and skeletal metastases more accurately. Hybrid PET/MRI detects brain, bone, and liver metastases better than PET/CT while reducing foetal dosage exposure. DWI increases PET specificity and sensitivity. There has not yet been a comprehensive PET/MRI study of pregnant cancer patients[11]. Clinical whole-body diffusion-weighted MRI and PET/MRI are performed by a lot of large-volume expert centers. Whole-body diffusionweighted/MRI for staging advanced cancers during pregnancy may become more common due to the widespread availability of MR systems and sequences, the clinically efficient scan time of 38 minutes, increased standardization in imaging technique and interpretation, increased radiologist training, and the absence of radiation. By utilizing only the imaging modalities necessary to determine locoregional disease extent and distant staging, an acceptable diagnostic work-up should achieve the same accuracy as in patients who are not pregnant without putting the unborn in danger. In order to tailor the patient's diagnostic approach, a pre-arranged multidisciplinary board discusses local imaging expertise, the type of cancer, and imaging equipment.

IV. DIAGNOSIS AND STAGING BY TUMOR TYPE

A. Breast cancer

Breast cancer in pregnancy is generally detected by a palpable lump, requiring quick evaluation. Breast ultrasonography is the first imaging technique (Figure 2). It may quickly detect benign cysts and galactocoeles without additional evaluation. has an 80.1% pooled sensitivity and 88.4% specificity for cancer identification. A biopsy is needed for any solid breast lesion. If ultrasound results are inconclusive, mammography is used to look for tissue deformation or microcalcifications in one mediolateral oblique view.

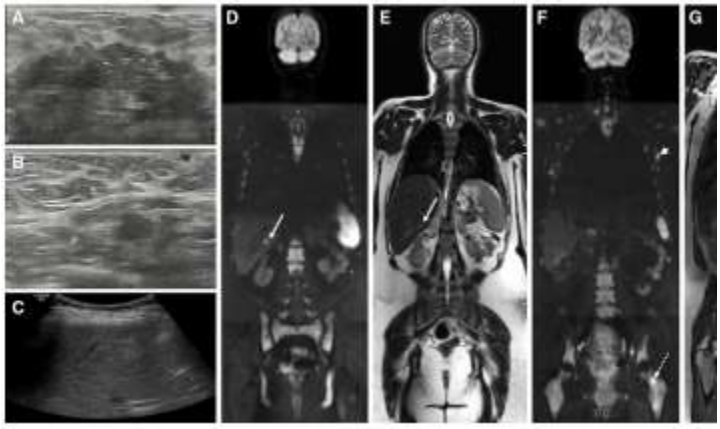

Figure 2 Large left breast tumor (A) and left axilla lymphadenopathy (B) are detected on breast ultrasonography in a pregnant woman with locally advanced breast cancer. at whole-body diffusion-weighted MRI, (D) b1000 diffusion-weighted sequence indicating a bright liver lesion matching the solid lesion at (E) T2-weighted sequence consistent with liver metastasis (arrows). Ultrasound indeterminate screening. In addition, (F) the b1000 diffusion-weighted sequence depicts lymph node metastasis as a bright nodular lesion (arrowheads), and (G) the T1-weighted sequence depicts a bright lesion at the left femur with T1 hypointensity supporting bone metastasis.

If there is cancer, treatment planning requires locoregional and distant staging. Primary tumor characteristics like size, local extent, multifocality in the ipsilateral or contralateral breast, as well as regional and supraclavicular lymph nodes, are all examples of this. When microcalcifications are present, mammography with craniocaudal and mediolateral oblique views of both breasts and ultrasonography can define tumour extent and multifocality. This combination method improves surgical therapy by detecting 15.5% of cancer in the ipsilateral breast and 3.9% in the contralateral breast. Pregnant women may avoid MRI to avoid exposure to gadolinium because the incremental cancer detection rate of ultrasound paired with mammography is comparable to that of breast MRI[12]. Ultrasound is the most effective tool for assessing supraclavicular nodal metastasis and regional staging prior to treatment. The clinician can use it to make decisions about sentinel node biopsy, axillary lymph node dissection, or neoadjuvant therapy in addition to prognostic information. Fine needle aspiration cytology or core needle biopsy should rule out suspicious lymph nodes. Ultrasound sensitivities range from 26.4 percent to 92 percent, with specificities ranging from 55.6 percent to 98.1 percent.33 Tumour stage determines distant staging imaging. The liver, bones, and lung are most affected. Although their diagnostic value is debated, chest x-rays and liver ultrasounds are routinely performed on asymptomatic women with early-stage breast cancer. Advanced imaging should only be done on people who have metastasis symptoms, node-positive locally advanced breast cancer, and more tumor markers. The high sensitivity of 87.1 percent for liver metastases in chest CT and MRI with DWI sequence may be utilized for staging. MRI with a T1-weighted sequence and DWI of the entire spine and pelvis is the most effective method for detecting bone metastases. Bone scintigraphy should only be used if an MRI is either inconclusive or unavailable. It is not clear whether pregnant bone scintigraphy is useful. Whole-body diffusion-weighted MRI may be performed in one step if it is available (Figure 2). It can identify liver and peritoneal metastases and detect skeletal metastases better than CT and bone scintigraphy, with equivalent diagnostic performance as PET/CT. Correlation with breath-hold Dixon-based anatomical sequences in the MR procedure must be sensitive for DWI to identify lung metastases. For regional breast staging, DWI may supplement ultrasonography and whole-body diffusion-weighted/MRI. For breast cancer regional nodal staging, DWI has sensitivities of 72.4 percent to 97.7 percent, specificities of 54.4% to 91.7%, and 75.7% to 78.9% for multifocality or contralateral breast involvement[13].

B. Lymphoma

The most common haematologic tumor during pregnancy is Hodgkin lymphoma, which affects more women of reproductive age. Because of its slow growth, Hodgkin lymphoma therapy may be delayed until delivery, resulting in disagreement regarding therapeutic management and advanced staging. However, because conventional chemotherapy can have an impact on the development of the fetus and necessitate obstetric follow-up, proper staging helps with maternal clinical

care, long-term survival, and fetus management in symptomatic and advanced Hodgkin lymphoma. Although whole-body diffusion-weighted MRI has demonstrated high concordance, up to 99.4% with FDG-PET/CT, for the diagnosis of nodal and extranodal lymphoma, as well as 93% accuracy for bone marrow involvement, PET/CT remains the clinical standard for lymphoma. Whole-body diffusion-weighted/MRI may be a non-irradiating alternative to FDG-PET/CT for diagnosing and staging pregnant lymphoma patients (Figure 3). PET/CT and whole-body diffusion-weighted/MRI staging had similar progression-free survival curves, indicating similar patient management effects. PET/CT predicts interim and post-treatment response with greater than 99 percent accuracy using whole-body diffusion-weighted MRI. In Hodgkin lymphoma, interim response evaluation may predict prognosis and modify therapy to prevent maternal and foetal toxicity (Figure 3)[14].

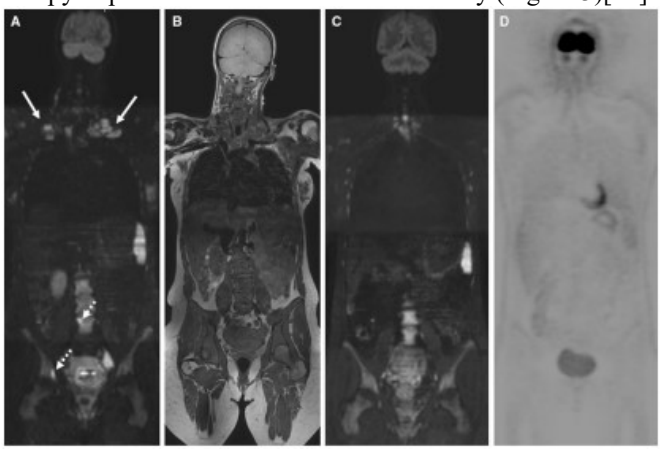

Figure 3 During non-invasive prenatal testing, the unintentional discovery of Hodgkin lymphoma in a pregnant woman. Two bright bone marrow lesions at the right acetabulum and the fourth lumbar vertebral body correspond to diffuse hypo-intensity at (B) the T1-weighted sequence, which shows bright and enlarged lymphadenopathies in the bilateral base of the neck (arrows). After two rounds of treatment, an interim whole-body diffusion-weighted MRI reveals complete response. The end-of-treatment hybrid positron emission tomography/CT showed full response after delivery.

C. Cervical cancer

Treatment for cervical cancer varies depending on the stage of pregnancy. In non-pregnant individuals, MRI complements clinical evaluation for locoregional staging. To evaluate locoregional disease, MRI can accurately and consistently assess prognostic characteristics of tumors, such as tumor size, parametrial and pelvic wall invasion, invasion of adjacent organs, lymph nodes, and metastases. MRI with DWI and a T2-weighted sequence is the most accurate method for locoregional staging. According to one study, parametrial invasion detection specificity was increased by 85.2%–88.7% when DWI was added to T2. PPV and reader trust are improved (from 96.5% to 99%) without compromising sensitivity (from 67 to 75 percent). T2-DWI boosted parametrial invasion prediction sensitivity from 86% to 90% compared to T2-weighted MRI alone in another investigation.15 DWI enhances subcentimeter lymph node staging accuracy. FDG-PET/CT (0.92) and DWI (0.91) had significantly higher nodal staging area under the curves than CT (0.83) in a meta-analysis of 67 trials. DWI detects lymph node metastases with the greatest sensitivity (88%), but low specificity (83%). Therefore, DWI cannot replace cervical cancer surgery staging in pregnant women[15]. Evaluation of neo-adjuvant chemotherapy response using MRI is also reproducible. After neoadjuvant treatment for stage IB1 to IIB cervical malignancies, MRI had the best sensitivity (96%), whereas transrectal ultrasonography has similar accuracy (77%).

T2/DWI MRI and the entire abdomen should be used for locoregional staging of cervical cancer during pregnancy and response evaluation to examine local tumor extension, pelvicaortic lymph nodes, liver, bone, and peritoneum for maximum accuracy. Another contrast-enhanced chest CT is required to evaluate pulmonary metastases (Figure 4). For ambiguous distant results that are required for curative therapy, FDG-PET with low-dose CT may be utilized.

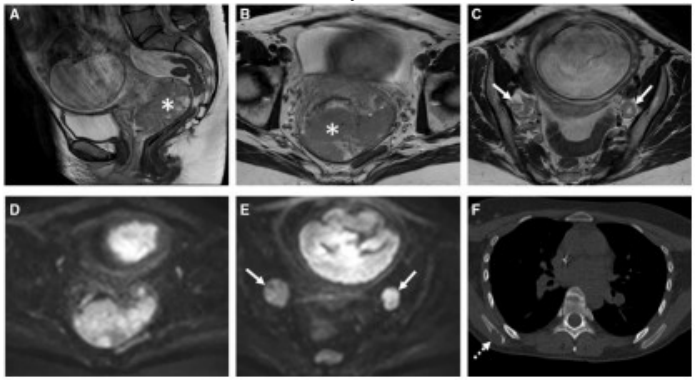

Figure 4 A woman who was pregnant was found to have uterine cervical carcinoma. A large cervix tumor (asterisk) and prolabating proximal vagina without parametrial invasion and bilateral para-iliac lymphadenopathies (arrows) are seen on diffusion-weighted pelvic imaging and T2-weighted MRI. (F) Skeletal metastases are suggested by the right scapula osteolytic lesion on the chest CT.

D. Ovarian cancer

Transvaginal ultrasonography is the first pregnant ovarian cyst imaging method. The International Ovarian Tumour Analysis studies have codified ovarian pathology for examiners with different levels of ultrasonography proficiency. Ovarian cyst classification using subjective criteria, rules, risk models, and combination interpretation methodologies has sensitivity up to 90%–96%. In addition to assisting in the evaluation of masses that are sonographically ambiguous, MRI may be able to accurately characterize ovarian masses. Dynamic contrast-enhanced MRI, which is required during pregnancy, will not be included in the procedure, reducing the specificity of the malignancy prediction process. To predict malignancy, dynamic contrast-enhanced MRI is required in addition to DWI and regular T1- and T2-weighted sequences. Non-contrast sequences are used to predict the majority of benign characteristics. Therefore, the best method for excluding ovarian cancer is a pelvic MRI during pregnancy. Neoadjuvant chemotherapy is the best treatment for advanced ovarian cancer

until foetal development and complete cytoreduction after birth4. Whole-body diffusion-weighted/MRI outperformed CT and PET/CT in predicting the original tumor (primary ovarian cancer vs. other origin), peritoneal disease burden, and distant metastases. Whole-body diffusion-weighted MRI better predicts operability and detects unresectable cancer locations than CT, and DWI of peritoneal metastases correlates well with surgical peritoneal burden (Fig. 5). In our experience, whole-body diffusion-weighted/MRI, which relies on DWI for illness detection, does not significantly suffer from gadolinium deficiency during pregnancy. Patients with and without ovarian cancer may benefit from staging and measuring operability with whole-body diffusion-weighted/MRI[16]..

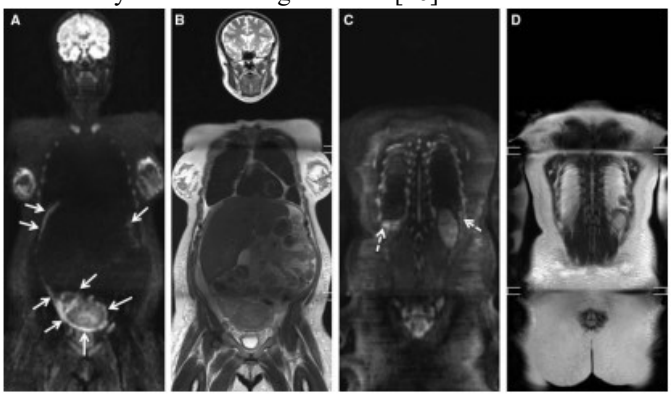

Figure 5 Gynaecologic ultrasonography shows malignant ovarian tumour in pregnant woman. The diffuse and multifocal bright confluent peritoneal and pleural lesions seen on the B1000 whole-body diffusion-weighted MRI are consistent with diffuse metastases (A,C). (B,D) T2-weighted scans reveal ascites, bilateral pleural fluid thickening, and the peritoneal plane.

E. Gastrointestinal cancer

The most frequent gastrointestinal malignancies during pregnancy are colorectal. Chemotherapy and surgery depend on illness stage. The lymph nodes, liver, lung, and peritoneum all host the majority of metastases. The majority of the time, CT is used to stage cancer patients' thorax and abdomen. Ultrasound and/or (mainly) MRI are acceptable for pregnant individuals. Ultrasound may screen liver metastases, however colon cancer therapy is now started after cross-sectional imaging, independent of tumour stage.

Because it accurately assesses the main tumor, lymph nodes, mesorectal fascia, and extramural venous invasion, MRI is best for locoregional rectal cancer staging. An MRI should be performed first on patients who have not been treated for colorectal liver metastases, particularly those who may be candidates for hepatic resection. For patients with colorectal cancer, an MRI is a one-time imaging procedure because it provides body-wide staging information. For colorectal cancer staging, whole-body diffusion-weighted/MRI has the same diagnostic value as CT and requires fewer tests than CT.47 Whole-body diffusion-weighted MRI also detects peritoneal metastases better than CT (97.8% vs. 43.2%). Wholebody diffusionweighted/MRI predicts operability more accurately than CT with a sensitivity of 90.6%. Compared to CT alone, colorectal cancer preoperative staging does not appear to be improved by PET scans with or without integrated CT. Based on these findings, whole-body diffusion-weighted MRI or MR abdomen with chest CT are safer and more reliable methods than CT and PET/CT for staging pregnant colon cancer.

F. Thyroid cancer

The treatment of thyroid carcinoma depends on the stage it is in when it first appears. Ultrasound and fine needle aspiration cytology are the principal thyroid cancer and regional lymph node diagnostic methods. Thyroid cancer nodal metastases, like those of other head and neck cancers, are hypervascular and can be seen with color-doppler imaging. For regional nodal staging, ultrasound outperforms CT and MRI with an accuracy of 89 percent at 6 mm nodes. Ultrasonography alone is sufficient for imaging T1–T2 minor thyroid tumors. Before surgery, larger tumors (T3–T4) require additional local disease evaluation. For diagnostic whole body scintigraphy and postnatal therapy, non-contrast enhanced MRI with DWI is preferred to CT because it eliminates iodinated contrast, which can interfere with Iodine-131. The lungs, bone, and occasionally the liver are the most common sites of metastases. Pre-operative distant staging is only required for anaplastic thyroid cancer or signs of metastasis. Lung metastasis screening is best with chest CT. Like breast cancer, most liver and bone imaging is done with MRI and DWI. Because distant metastases, particularly to the lung, have a favorable prognosis and do not influence thyroidectomy and neck dissection, well-differentiated (papillary and follicular) thyroid tumors are not staged prior to surgery for distant disease. After ablative iodine therapy, iodine-131 whole-body scans are used for definitive staging in pregnant and post-operative patients. A second chest CT scan may reveal secondary metastases.

G. Melanoma

The most important prognostic markers, invasion depth and regional lymph node status, are the foundation for melanoma imaging staging. With sensitivities ranging from 39.4 to 89.4 percent at diagnosis, ultrasound is the primary imaging method for regional lymph node involvement. Core needle biopsy or fine needle aspiration cytology can improve precision. No imaging method can exclude nodal micrometastases, hence sentinel node biopsy is the norm in clinically node-negative melanoma patients and safe in pregnant individuals.

For patients with low-risk distant metastases, chest CT should be used instead of chest radiography. Ultrasound evaluates liver and regional lymph nodes. In high-risk patients, non-contrast brain, chest, and CT MRI with DWI of the liver and axial skeleton may reveal distant metastases. For ambiguous remote results that are required for curative therapy, FDG-PET may be used in conjunction with low-dose CT. WBDW/MRI is a suitable option for staging high-risk pregnant women since it has greater sensitivity for liver, bone, and brain metastases than PET/CT but worse accuracy for nodal metastases.

V. CONCLUSION

It's hard to imagine a pregnant woman with cancer. Using only imaging modalities that permit therapy adjustment, the diagnostic work-up ought to be adequate and provide accuracy comparable to that of patients who are not pregnant and do not

pose a risk to the foetus. Standardizing the diagnostic approach is difficult because of the balance between maternal benefit and fetus risk. There is also a risk of underusing diagnostic imaging and providing suboptimal diagnostic (and therapeutic) management when compared to patients who are not pregnant. The best diagnostic methods should be selected by a multidisciplinary team that includes nuclear imaging specialists and radiologists. Due to their low radiation and clinical accuracy, ultrasound and MRI are preferred primary imaging modalities. CT, PET/CT, and bone scintigraphy can be used in unresolved cases when the benefit to the mother outweighs the risk to the unborn and the fetal exposure is limited to 100 mGy. For accurate single-step staging without fetal radiation, whole-body diffusion-weighted/MRI and PET/MRI may be sufficient.

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