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Radiological staging in pregnant patients with cancer

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INTRODUCTION

Malignant diseases during pregnancy are relatively rare, with an estimated incidence of 1 in 1000 pregnancies.[1] Owing to an increasing delay of pregnancy to the third and fourth decades of life, cancer will occur increasingly more frequently during pregnancy. Diagnosis is reportedly often delayed during pregnancy, due to overlapping symptoms of pregnancy and malignant disease, leading to higher stages of disease at diagnosis.[1]

After a malignant tumour is diagnosed during pregnancy, the pregnant patients with cancer must be provided with diagnostic imaging for the evaluation of disease extent, and to allow the same high-quality therapy planning as that received by a non-pregnant patient. At the same time, it is of the utmost importance to limit harm to the fetus from diagnostics and therapeutics as much as possible. Diagnostic imaging for staging purposes relies, to a large extent, on ionising radiation used in CT and in nuclear imaging modalities, as well as on the intravenous application of contrast agents. These methods cannot be recommended outright during pregnancy, due to possible detrimental effects on the fetus. In the pregnant patient, the attending physician is challenged with the choice of diagnostic imaging modalities, while limiting danger to the fetus as much as possible, and still enabling disease management similar to that in a non-pregnant patient. Therefore, malignant disease in pregnant patients should be managed by a multidisciplinary tumour board that has the competence to evaluate different strategies for staging, including invasive and non-invasive methods. In this article, the challenging task of finding appropriate imaging modalities for the staging of different malignant tumours that occur during pregnancy will be discussed.

IONISING RADIATION

Proliferating cells are more sensitive to radiation effects than cells that have completed cell division.[2] The human embryo or fetus is a rapidly proliferating organism and, therefore, especially sensitive to radiation effects. Potential adverse effects from prenatal radiation due to imaging may comprise spontaneous abortion, congenital malformations (teratogenesis) and carcinogenesis (table 1).[2–4]

To evaluate the risk the fetus undergoes due to imaging of the pregnant patient, the range of radiation dose that is applied during the most common imaging studies must be considered (table 2).

Spontaneous abortion

Radiation exposure over 50–100 mGy during the first 2 weeks after conception and before implantation results in either spontaneous abortion or a completely unaffected embryo ('all-or-none effect').[4–6] The likelihood of inducing abortion at doses below 50 mGy is low and supposedly not distinguishable from zero.[6 7] It is noteworthy that the average risk of spontaneous abortion is approximately 15% without any additional ionising radiation due to imaging.[7]

Teratogenesis

Teratogenesis is a non-stochastic or deterministic effect of radiation, for which a threshold exists, estimated to be around 50–100 mGy. Above this threshold, cellular repair mechanisms fail, leading to loss of tissue function. The severity of this effect increases with dose.[2 4 6 8] During organogenesis (between 3 and 8 weeks of gestation) and during the early fetal period (until the 15th week of gestation), when rapid neuronal development and migration take place, the fetus is most susceptible to the teratogenic effects of radiation.[4 6 7] Radiation exposure above 100 mGy during that time may lead to mental retardation, microcephaly and intrauterine growth restriction.[2 4 6] After 16 weeks of gestation, the threshold for teratogenic effects is around 500–700 mGy.[7] Outside this time window, and especially after 26 weeks of gestation, teratogenic effects are extremely unlikely at dose levels reached in diagnostic radiology.[9 10]

Table 1 Overview of potential adverse effects resulting from prenatal exposure to ionising radiation

Effect	Most sensitive period after conception (d)	Threshold dose at which an effect was observed (mGy)	Absolute incidence (%/mGy)	Comment
Prenatal death	0–8	100	0.1	If the conceptus survives, it is thought to develop fully, without radiation damage
Growth retardation	8–56	200	NA	
Organ malformation	14–56	100	0.05	
Small head size	14–105	NA	0.05–0.10	Mental retardation in 25% of children with small head size
Severe mental retardation	56–105	100	0.01–0.04	
Reduction of IQ	56–105	100	0.01–0.03	
Childhood cancer	0–77	–	0.017	Most commonly leukaemia
Inheritable damage			0.0003 in males 0.0001 in females	

Modified after references[6 10] and[81].
NA, not applicable.

The risk for radiation-induced mental retardation is highest from the 8th to the 15th week.[2] During this time, the average IQ reduction is approximately 2.5–3.1 IQ-points per 100 mGy above a threshold of 100 mGy.[2 11]

Intrauterine growth retardation after fetal irradiation above the same threshold does occur, but is usually transient, meaning that the fetus is able to recover with time.[7]

Furthermore, the probability of a fetus not developing any malformation is 96%. This probability is still 95.9% after a fetal dose of 50 mGy, and 95.8% after 100 mGy.[6 12] The fetal dose usually does not exceed 50 mGy in a single radiological imaging study. The American College of Obstetricians and Gynecologists has even stated that exposure to <50 mGy has not been associated with an increase in fetal anomalies or pregnancy loss at all.[13] Therefore, carcinogenesis is often the radiation effect that should concern radiologists and treating physicians more than teratogenesis.

Table 2 Ranges of radiation dose applied during the most common imaging studies

Imaging	Typical fetal radiation dose (mGy)
Chest radiograph	<0.01
Mammography (2 planes, bilateral)	<0.01
CT of the head	<0.005–0.5
CT of the chest	0.01–0.66
CT of the abdomen/pelvis	8–25
^{99m}Tc bone scintigram	3.3
^{18}F-FDG PET	1.1–9.04

Modified after references[1 7 52] and[82].
^{18}F-FDG PET, ^{18}F fluorodeoxyglucose positron emission tomography.

Carcinogenesis

Carcinogenesis is a stochastic effect of radiation that does not result in a loss of tissue function, but does result in DNA mutations. Carcinogenic effects can occur at any dose and do not require any dose threshold. The probability of the effect to occur increases linearly with dose.[2] After an abdominal CT with a maximum uterine dose of 50 mGy, the relative risk of childhood malignancies may approximately double.[14–16] More specifically, carcinogenic risk varies according to the trimester in which radiation exposure happens. It is assumed to be highest after radiation exposure during the first trimester of pregnancy, with the relative risk for childhood cancer from the same dose of ionising radiation estimated to be 3.19 in the first trimester, and around 1.3 in the second and third trimesters, when organogenesis has been completed.[2 4 17] But, it is important to remember that the baseline cumulative risk of childhood cancer without any kind of diagnostic imaging during pregnancy is very low, at 1–2.5 per 1000 until the age of 15 years.[4 18] Therefore, after intrauterine radiation exposure of 50 mGy, even 1.3–3.19 times this incidence rate could still be considered a low risk for childhood cancer.

Termination of pregnancy

Because of the quite minor risk of teratogenesis or carcinogenesis after radiation doses of up to 100 mGy,

termination of pregnancy would not be justified. Above 200–500 mGy, the decision to abort a fetus has to be made based on individual circumstances, such as the requirement for serial-cross sectional imaging studies, interventions or radiation therapy.[4] Above 500 mGy, clinically significant fetal damage may result from diagnostic imaging, such as significant mental radiation after radiation exposure during the 7th–25th weeks of gestation. Therefore, termination of pregnancy may be recommended in this setting.[4 6 19]

IMAGING MODALITIES

When choosing an appropriate imaging modality to evaluate the local extent or distant spread of a malignant lesion during pregnancy, the following issues should be considered: (1) safety of the fetus; (2) probability of metastatic disease and (3) the ability to achieve a staging accuracy similar to that in a non-pregnant patient.[4] Non-ionising imaging modalities, such as ultrasound (US) and MRI, are preferable when equivalent in accuracy to imaging that involves ionising radiation. When ionising radiation is used for imaging, the cumulative uterine dose should be kept as low as reasonably achievable (ALARA).[4]

Projection radiography

If the fetus is not directly within the region to be examined, fetal radiation exposure is generally negligible and pregnancy should not alter the decision to perform an indicated examination.[4] Generally, projection radiography has only limited sensitivity in the detection of metastatic disease. The radiologist should be aware that, after a chest radiograph with either positive or negative findings concerning metastatic disease, further imaging of the chest may be warranted. If the probability is low that projection radiography would definitely answer a clinical question, MRI (preferably without contrast) or CT (if it does not directly involve the fetus) should be considered.

CT

The fetal dose in CT scans of the maternal head, neck and extremities results from scatter radiation, and is negligible. The dose increases tremendously when the fetus is in the field of view.[8] Technicians and radiologists exposing the pregnant patient and the fetus to ionising radiation are especially obliged to adhere to the principles of keeping the radiation dose as low as reasonably achievable (ALARA). To achieve the lowest reasonably possible dose that still would allow accurate image quality, technicians and radiologists should adjust the following parameters: tube potential (kV) may be lowered based on the patient's body weight; the tube current-time product (mAs) may be decreased; the pitch may be increased above 1; the number of acquisitions may be limited to one; automated exposure control, automatic tube current modulation and iterative reconstruction, may be used.[4 6 20 21] Caution is warranted when decreasing radiation dose during CT. Situations should be avoided in which diagnostic accuracy is diminished due to low image quality and examinations involving ionising radiation might then have to be repeated.

Abdominal shielding during any CT does not result in substantial dose reduction, because most of the fetal dose results from internal scatter radiation rather than from direct radiation. Alternatively, internal shielding using oral barium in suspensions beyond 30% does reduce the fetal radiation dose.[22]

Iodinated contrast agents

A single layer of chorionic epithelium serves as an interface between the maternal and fetal circulation in the placenta. Iodine-based contrast agents are limited in their ability to cross the placenta, due to their relatively high molecular weights.[23] Nevertheless, measurable amounts of iodinated contrast agents were detected in the fetus after intravenous administration of typical clinical doses to the mother.[24] After the iodinated contrast agent transverses the placenta and enters the fetal blood stream, it is excreted by the fetal kidneys and reaches the amniotic fluid via fetal urine. The fetus swallows amniotic fluid continuously, which lets the contrast enter the fetal gut. Alternative routes from maternal blood into the amniotic fluid have also been suggested.[23 25]

It is recommended that an iodinated contrast agent be used if the expected information could affect treatment during pregnancy and if it is unjustifiable to delay the examination until after pregnancy.[4 24 26] In vivo tests in animals did not reveal any mutagenic or teratogenic effects. But, to date, well-controlled studies of the teratogenic effects in pregnant women have not been performed.[24] Fetal thyroid gland function is essential for the development of the central nervous system. Postnatal hypothyroidism has rarely been reported after the injection of high doses of fat-soluble iodinated contrast agents. Conversely, an intravenously administered low-osmolarity, water-soluble iodinated contrast agent does not have short-term effects on thyroid function in the newborn, probably because the overall amount of excess iodide in the fetal circulation is small and transient.[24] However, long-term effects are still unknown. To date, no single case of neonatal hypothyroidism from maternal intravascular injection of water-soluble iodinated contrast agents has been documented.[26 27] Newborns are now routinely evaluated for hypothyroidism during the first week of life. If this screening is performed, no extra attention is felt to be necessary for cases of intravenous administration of iodinated, water-soluble contrast agents at routine clinical doses during pregnancy.[24 28 29] In countries without routine screening for hypothyroidism, an extra test should be performed during the first week of life if an iodinated contrast agent was administered to the mother during pregnancy.

A general rule for the imaging strategy in a pregnant patient is to intravenously administer the iodinated contrast agent for an examination that would also be performed with contrast agent if the patient was not pregnant. Otherwise, it might be necessary to repeat the examination because of imaging limitations due to the lack of contrast.[4 8]

Mammography

When abdominal shielding is used, mammography does not present a risk to the fetus.[30 31] If, after initial breast ultrasound (US), mammography is needed, it should start with one mediolateral-oblique view. In case of a suspicious mass, craniolateral and mediolateral-oblique views of both breasts are usually acquired to evaluate the patient for widespread suspicious microcalcifications, multicentric and bilateral disease.[30]

Ultrasound

US is frequently the first-line imaging tool for the evaluation of the fetus and mother. US is generally considered a safe imaging modality, but should nevertheless be performed only when indicated.[32] Energy deposition by US exposure and subsequent tissue heating with haemorrhage or cavitation should be limited. The examiner should adhere to the ALARA principle, although no teratogenic effects from US have been found in humans thus far.[33] The US examination should be limited to 30 min; Doppler US should not be routinely used in early pregnancy, due to higher energy deposition in the body tissues.[4 33]

MRI

To date, MRI during pregnancy has not been shown to have any adverse effects on the fetus. Nevertheless, the safety of MRI during pregnancy needs to be further investigated.[34] Unlike with CT, the potential fetal risks due to MRI are predominantly teratogenic, not carcinogenic.[34] The potential teratogenic effects of MRI result from the static magnetic field, which can potentially alter cell migration, proliferation and differentiation.[34 35] The majority of studies supporting the potential teratogenic effects of MRI have been performed in animals and have reported controversial results.[36] Studies performed in humans have not found adverse effects from MRI for as much as 9 years after the exposure of the fetus.[37–39] Generally, MRI is to be preferred over ionising radiation, whenever possible.[4] In 2013, the American College of Radiology stated that MRI can be used in pregnant patients regardless of gestational age when the results are likely to influence treatment and cannot be obtained by other non-ionising means, and when MRI cannot be postponed until after gestation.[35] There are still no data about the risks of exposure during the first trimester; therefore, it may still be sensible to avoid unnecessary scanning during this period. The fetus is more susceptible to teratogenic effects during this developmental phase and heat loss may be more compromised during the first trimester, because placental blood flow is not yet properly established.[40] The static magnetic field, the time-varying magnetic field gradients and radiofrequency pulses, may potentially harm the fetus.[34 35]

Radiofrequency pulses deposit energy within body tissues, potentially increasing body temperature. This energy deposition is measured as the specific absorption rate (SAR) in watts per kilogram (W/kg). An increase in temperature has been shown to cause malformations in animals[34 41 42] and teratogenic effects have also been postulated for humans in cases where the maternal temperature increase is >2–2.5°C for 30–60 min.[4 36] Controversial estimations have been published concerning a potential increase in fetal body temperature during MRI. In case of a maternal whole-body exposure of 2 W/kg for a duration of 7.5 min, the fetal body temperature may increase by >1°C. Therefore, it would not be recommended to scan pregnant patients above the normal whole-body SAR level of 2 W/kg.[40] Thus, it is recommended that MRI protocols be designed in such a way that higher SAR sequences (ie, HASTE/SSFSE) and lower SAR sequences are interleaved.[40] Furthermore, it is recommended that pregnant patients be imaged at field strengths of no more than 3 T, to keep the SAR low.[34 43 44]

In animals, it has been postulated that electromagnetic fields may alter cell migration, proliferation and differentiation.[45] In humans, thus far, no detrimental effects have been shown. Nevertheless, it is recommended that the only MR examinations that should be performed are those that are considered necessary during pregnancy, and to postpone any elective MRI until after gestation.[4]

Rapid gradient switching causes considerable noise during MRI. Up to 80–120 dB may be produced during an MRI protocol at 3 T, noise that has been reported to cause temporary hearing loss in those patients examined.[4 46] Therefore, the use of headphones or earplugs or both has become common practice to protect patients from hearing loss. Above 90 dB, the fetal ear may also be permanently damaged, especially after 34 weeks of gestation, when the fetal ear is developed.[4 34] The maternal body attenuates at least 30 dB. If MRI produces 120 dB, 90 dB could still reach the fetal ear and put it at risk for substantial damage.[4 34] Therefore, sequences that cause loud noise, such as fast gradient echo sequences, should be kept as short as possible.[4] To date, no association of prenatal MRI and postnatal hearing impairment has been observed.[39]

Gadolinium-based contrast agent

In animals, gadolinium has been shown to have teratogenic effects when administered in high doses.[47] To date, no adverse event effects on the human fetus when gadolinium-based contrast agents were administered at clinically recommended doses during pregnancy have been documented.[4 23 48] In a single-cohort study of 26

women, exposure to gadolinium chelates during the first trimester showed neither teratogenic nor mutagenic effects on the fetus.[24 49] But, to date, no controlled studies of teratogenic effects have been undertaken, and it is not clear how gadolinium affects the fetus. Therefore, during pregnancy and especially organogenesis, gadolinium should be administered only if there is an absolutely essential clinical indication, if the potential benefits justify the unknown potential fetal risk and if there is no alternative, such as contrast-enhanced CT, to address the clinical question.[4 16 24] Gadolinium crosses the placenta and, after renal excretion, may accumulate in the amniotic fluid. Subsequent dissociation of the toxic, free gadolinium ion is possible, which could carry a risk for the development of nephrogenic systemic fibrosis (NSF) in the mother and the child.[24] Therefore, a gadolinium-based contrast agent that is associated with a low risk for developing NSF (gadobutrol (Gadovist), gadoteridol (Prohance), gadoterate meglumine (Dotarem))—at the lowest possible dose—should be used.[24 50]

Positron emission tomography and scintigraphy

In PET and scintigraphy, the fetus is exposed to ionising radiation by the radioactive tracer that accumulates in maternal body tissues and organs, then crossing the placenta to enter the fetal circulation.[51] Typically, the tracer dose is reduced, to minimise fetal exposure, with a compensatory increase in image acquisition time.[51] During ^{18}F fluorodeoxyglucose positron emission tomography (^{18}F-FDG PET), the fetus is exposed to doses of approximately 0.00616–0.0305 mGy/MBq, with the overall fetal dose usually below 10 mGy (table 2).[52]

In scintigraphic imaging during pregnancy, the most common isotope in use is ^{99m}Tc, as is used for bone scintigraphy. During this examination, the fetus is exposed to a radiation dose of <5 mGy.[4 51] For thyroid gland scintigraphy during pregnancy, ^{123}I or ^{99m}Tc are recommended tracers, because of their short half-life.[4 13]

For tracers that are excreted renally, adequate hydration, intravenous application of 20 mg of furosemide 15 min after tracer application and bladder catheterisation are recommended, to minimise fetal radiation.[51]

While PET and scintigraphy alone cause only minor radiation exposure of the fetus, PET/CT exposes the fetus to a relatively high radiation dose due to the combination of two imaging methods involving ionising radiation. Therefore, PET/CT should be postponed until after completion of pregnancy.[1 53] PET/MRI is a reasonable alternative to eliminate the ionising radiation from CT, which could be considered for the staging of lymphoma, for example.[54]

IMAGING OF METASTATIC SPREAD TO SPECIFIC REGIONS OF THE BODY

Metastatic pulmonary nodules

Pulmonary metastases can be evaluated with chest radiographs, CT or with dedicated MRI. CT offers the highest sensitivity, with only minor radiation exposure of the fetus (table 2).[55 56] Chest radiographs in the posteroanterior and lateral views may generally be accepted as screening tools in non-pregnant patients with known malignant disease, but with a low clinical suspicion of metastatic disease.[57] Chest CT is much more sensitive for the detection of pulmonary metastases, due to the higher spatial resolution and lack of superimposition of anatomical structures. In case of clinical suspicion of pulmonary metastases or a high propensity of the underlying malignancy for metastatic spread to the lungs, as is the case in sarcomas, head and neck cancer, and advanced stage melanoma, CT of the chest is indicated in the non-pregnant patient.[57] The same indications for radiological screening for pulmonary metastases should be applied to pregnant patients. Chest radiography and chest CT without contrast only result in minimal radiation exposure of the fetus (table 2), while the finding of pulmonary metastases as a sign of disease spread may tremendously affect treatment. Increasing numbers of studies exist that report MRI of the chest to perform similarly to CT in the detection of pulmonary metastases, thus supporting an increasing role of MRI; this needs to be further evaluated.[58–62] MRI should only be used for the detection of pulmonary metastases if the radiologist and technician are experienced in the application of MRI for this indication, otherwise, CT of the chest may be considered.

Metastatic mediastinal lymphadenopathy

To evaluate mediastinal lymph nodes for metastatic disease, MRI has been shown to be comparable to CT.[63] If a patient needs imaging of the chest to evaluate for pulmonary metastases and there is a reasonable chance of having mediastinal metastatic lymph adenopathy, chest CT acquired after the intravenous application of iodinated contrast agent appears to be a reasonable imaging strategy to allow assessment of the lung parenchyma and an optimised evaluation of mediastinal structures at the same time. After administration of an iodinated contrast agent during pregnancy, screening of the newborn for hypothyroidism is warranted, as mentioned above.

Bone metastases

To scan for distant metastases in the bones, MRI that includes T1-weighted sequences, short τ inversion recovery sequences and diffusion-weighted imaging is the primary imaging method of choice during pregnancy.[64–67] Bone scintigraphy during pregnancy is recommended only if MRI cannot be performed or cannot sufficiently answer the question of whether skeletal metastases are present.

Brain metastases

To scan for brain metastases in patients with neurological symptoms, MRI without contrast agent is the preferred imaging modality.[56]

STAGING OF DIFFERENT MALIGNANT DISEASES

Cancer during pregnancy is a relatively rare phenomenon, with an incidence of 1 in 1000–1500 pregnancies.[68] Diagnosis and treatment should be optimised towards the maximal benefit for the mother while avoiding harm to the child as much as possible. The incidence of malignancies in pregnant women is similar to that in non-pregnant women of the same age.[1] The most frequently diagnosed malignancies are listed in table 3.

Breast cancer

Breast US with reported high sensitivity and specificity is the standard method for the evaluation of a palpable breast lesion during pregnancy.[30] Breast US allows a confident diagnosis of clearly benign lesions, such as simple cysts. After identifying a solid lesion, controversial recommendations have been reported concerning further work up. Biopsy is warranted without delay,[56] and—if the lesion demonstrates suspicious features—mammography is recommended to evaluate for suspicious calcifications that extend further than the lesion visible on US. Furthermore, with adequate abdominal shielding, bilateral mammography in two planes delivers a dose of <0.06 Gy to the fetus and, thus, presents a negligible risk.[31 56 69] Initially, one mediolateral oblique view should be acquired. In case of suspicious findings in addition to those discovered on US, craniocaudal as well as mediolateral oblique views of both breasts are needed to evaluate the patient for multicentric and bilateral disease.[30 56] Owing to the necessity for gadolinium-based contrast agent and its inherent risks to the fetus, breast MRI cannot be recommended during pregnancy, and it should only be used with the utmost caution if US and mammography are deemed inadequate, and if essential diagnostic information is expected.

Along with the lungs, the bones and liver are the most common sites of metastatic spread. Chest X-ray or CT, US of the liver and MRI, without contrast agent, for the detection of osseous lesions are recommended for staging in locally advanced disease or in case of symptoms suggestive of distant metastases.[1] If the risk for distant metastases is low, imaging for distant disease should be postponed until after pregnancy, if performed at all.[30]

Table 3 Incidence rates of the most frequently diagnosed malignancies during pregnancies

Incidence of malignant tumours per pregnancies or deliveries	
Tumour type	**Incidence**
Breast cancer	1:3000–10 000
Cervical cancer	1:2000–10 000
Hodgkin's lymphoma	1:1000–6000
Melanoma	2–5:100 000
Leukaemia	1:75 000–100 000
Ovarian cancer	4–8:100 000
Colorectal cancer	1:13 000
Thyroid cancer	14:100 000
Brain and spine	3.6:1 000 000
Gestational trophoblastic tumour	1:20 000–1:160 000

Modified from references[1 56 83] and[84].

Cervical cancer

Abdominopelvic staging is usually performed by MRI without contrast agent using mainly T2-weighted sequences that provide information about local extent (including hydronephrosis as a sign of parametric invasion), lymphatic spread and distant metastases to the abdomen.[56 70] For the evaluation of distant metastases to the lungs and bones, the same guidelines as those for breast cancer should be followed.

Haematological malignancies

Hodgkin's disease is a more frequent occurrence during pregnancy than non-Hodgkin's lymphoma, due to a peak in incidence in young adults. An unusual presentation of a haematological malignancy that is associated with pregnancy is bilateral lymphoma of the breast.[56 71] Bilateral breast involvement with acute lymphoblastic leukaemia has also been described.[72]

In newly diagnosed lymphoma in the non-pregnant patient, PET-CT of the neck, chest, abdomen and pelvis is recommended, but this hybrid imaging modality is generally not recommended during pregnancy.[73 74] Instead, US of the neck, abdomen and pelvis, as well as MRI without contrast of the neck, chest and abdomen, are preferable. CT of the chest may be added if MRI is insufficient for the evaluation of pulmonary parenchymal disease. If available, PET/MRI might be a reasonable option, offering high soft tissue contrast and functional information.[54] In the diagnosis and staging of leukaemia, a disease conceptualised as a disseminated malignancy of the haematopoietic system, there is no role for imaging-based staging as in other malignancies.[75] Whenever imaging is warranted, non-ionising imaging modalities are preferred over X-rays and CT, as a general rule, if a high degree of diagnostic accuracy can be obtained with these modalities.

Melanoma

The indication for staging examinations in melanoma depends on the depth of invasion of the primary skin lesion and on regional lymph node status or clinically evident signs of distant metastases. Routine radiological staging is recommended in patients with stage III and IV disease only.[76] In patients with a low risk for distant metastases, if imaging is requested at all, chest X-ray and US of the liver and the regional lymph nodes may be used. If the melanoma is located on the lower extremities or lower body, MRI may be warranted to evaluate for pelvic lymphadenopathy.[56] Evaluation for pulmonary

or brain metastatic disease follows the aforementioned recommendations.

Ovarian cancer

US is usually the first—and often the only—imaging modality to evaluate ovarian masses. In case of suspicious features, MRI without contrast agent may be helpful to further characterise the lesion and to evaluate the abdominal cavity for any sign of malignancy or metastases. In the presence of suspicious features on US or MRI, surgical evaluation is usually required.[56]

Thyroid cancer

US is usually the first-line imaging modality to evaluate the thyroid and cervical lymph nodes. In case of suspicious findings, histological diagnosis rather than thyroid scintigraphy may be attempted.[56 77] Especially in cases of poorly differentiated aggressive types of thyroid cancer, chest imaging may be warranted, because the lungs are the most common sites of distant metastases. Therefore, native CT or MRI of the chest may be performed, with CT having the highest sensitivity for small pulmonary nodules, which are often seen in thyroid cancer.[58–61]

Malignant tumours of the brain and spine

MRI is the imaging modality of choice in suspected primary tumours of the brain and spine. In the characterisation of a central nervous system tumour, contrast-enhanced MRI and perfusion MRI play essential roles and should not be withheld if the information gained is expected to affect treatment.[56] Advanced MRI sequences, such as arterial spin labelling, which may identify malignant gliomas based on hyperperfusion without the use of gadolinium-based contrast agents, may obviate the need for contrast administration.[78]

Gestational trophoblastic tumour

Gestational trophoblastic tumours arise as a direct consequence of pregnancy. They comprise hydatiform moles, placental site trophoblastic tumours and choriocarcinoma, with choriocarcinoma being the most malignant form.[56 79] For the assessment of local tumour extent, US and MRI without contrast can be used. MRI allows assessment of the entire abdomen for metastatic lesions.[75] Pulmonary metastases are a frequent occurrence and should be evaluated using chest radiography or chest CT.[80]

COUNSELLING AND INFORMED CONSENT

The pregnant patient, probably even more than the non-pregnant patient, will have doubts about the risks posed by diagnostic imaging. The objective of informed consent is to address the patient's questions, and to provide information about the possible risks and benefits of diagnostic imaging.[4 9 19] The oncologist, together with the radiologist, is encouraged to make every effort to explain to the patient—in a way that the patient is able to understand and follow—the reasons for imaging, the imaging procedures, and the risks and benefits of the imaging method chosen. Although some imaging methods may increase the risks of teratogenesis or carcinogenesis, the patient should be informed about the comparatively small absolute risks even after completing imaging.[4 9 19] It is also essential that the patient understands the potential benefits of the planned examination and knows why she might need to be exposed to radiation or other imaging. The referring clinician may also be encouraged to help explain to the patient that imaging is required in order to obtain necessary diagnostic information. Written, informed consent should be obtained from all patients.[4]

CONCLUSION

Diagnostic imaging for staging pregnant patients with cancer is a challenging task that must be addressed by a multidisciplinary team of physicians. As a first step, the team has to consider the possible benefits imaging may provide the individual patient for overcoming her disease. The multidisciplinary team must make the most useful choice of imaging modalities, to obtain information needed to offer the patient the most effective treatment for the disease stage. The radiologist is a crucial player in this process, as he or she must guide the choice of imaging modalities in such a way that will accurately answer the clinicians' questions, keeping in mind that not only the patient, but also the unborn child, must be protected from excess radiation and risk. Finally, the team of physicians should involve and counsel the patient in such a way that she does not have to fear harm to herself or the fetus from single, well-planned imaging studies.

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