REVIEW PAPER (PREGLEDNI RAD)

The importance of MRI in determining the stage o f cervical cancer

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Summary

Cervical cancer is one of the most common malignant tumours in women. The treatment of early and locally advanced stages of this cancer typically involves surgery, chemotherapy, and radiotherapy. However, there is no standardised therapy for metastatic cervical cancer due to the diverse manifestations of the disease. Therefore, timely diagnosis and staging of the carcinoma are crucial for maintaining the quality of life of patients. Imaging during the initial diagnostic evaluation is essential for accurately assessing the extent of the tumour and metastases, and for selecting the optimal therapy, with the FIGO system further emphasising this role. Compared to other imaging techniques, MRI provides detailed information on the location and size of the tumour, invasion into surrounding tissues, and the presence of distant metastases. This allows MRI to facilitate a tailored approach in therapy selection, taking into account the specific characteristics of the tumour. The integration of MRI into the diagnostic and therapeutic process improves clinical outcomes for patients with cervical cancer, enabling effective care. MRI is used alongside other imaging modalities in the diagnosis and treatment planning, and without it, precise staging of the disease and establishing a final diagnosis would not be possible.

Keywords: FIGO staging; cervical cancer; magnetic resonance; PET/CT; US

Abbreviations and acronyms:

CT (Computed Tomography), DWI (Diffusion Weighted Imaging), HPV (Humani Papyloma Virus), MRI (Magnetic Resonance Imaging), PET/CT (Positron Emission Tomography/ Computer Tomography), TRUS (Transrectal Ultrasound), TVUS (Transvaginal Ultrasound), US (Ultrasound)

Introduction

Cervical cancer is the most common gynaecological malignant tumour in the world and one of the leading causes of cancer-related death in women. It develops due to the abnormal growth of cells that have the ability to spread to other parts of the body. One of the main causes of cervical cancer is long-term chronic inflammation of the vagina and cervix caused by the sexually transmitted human papillomavirus (HPV). Imaging methods used for early detection of the cancer itself include CT (Computed Tomography), PET/CT (Positron Emission Tomography and Computed Tomography), ultrasound (US), and MRI (Magnetic Resonance Imaging). MRI is a radiological imaging method used for staging cervical cancer and as a diagnostic imaging method during the initial evaluation of patients with cervical cancer. It is also used for better assessment of tumour spread, localization, and accurate determination of tumour size [1].

Cervical cancer

Cervical cancer is the fourth most common cancer in women, with approximately 660,000 new cases annually [2]. In Croatia, more than 300 women are diagnosed with invasive cervical cancer each year, and around 600 women are diagnosed with localised cancer (Latin: Ca in situ) [3]. Although cervical cancer rates are declining in more developed countries, the incidence and mortality remain high in underdeveloped nations due to inadequate treatment services and a lack of screening programs. Cervical cancer is the third leading cause of death and the second most commonly diagnosed cancer in women in less developed countries, with the main cause being long-term chronic cervical inflammation caused by HPV [4].

Incidence and risk factors

Cervical cancer ranks fourth in both incidence and mortality among women worldwide. According to the latest data,

274 new cases of cervical cancer were recorded in Croatia in 2018, accounting for 2% of all cancer cases in women. The average age of those affected was 55.6 years. In the majority of cases, infection with high-risk types of human papillomavirus (HPV) is considered the primary cause of cervical cancer. Over 99% of precancerous lesions are caused by HPV infection. Factors associated with HPV infection and the development of malignant disease include obesity, smoking, sexually transmitted infections, and coinfection with HIV or herpes simplex virus type 2 [5, 6].

Clinical presentation

Cervical cancer most commonly occurs in women between the ages of 40 and 55. HPV infection is asymptomatic in most cases, although the appearance of condylomas, or genital warts, is possible. Due to its asymptomatic nature, HPV infection can easily be transmitted sexually. The symptoms of cervical cancer depend on the stage of the disease. Early stages of cancer may also be asymptomatic. The first symptom is usually bleeding, accompanied by pain in the lower abdomen, pelvis, and hips, which often occurs as a result of the malignant process spreading to the uterine body, pelvic wall, or around the sciatic nerve [6, 7].

Diagnosis and treatment

A gynaecological examination is of crucial importance for diagnosing cervical cancer, as it helps determine the size and location of the tumour. The main goal is to detect cancer at the earliest possible stage. The most commonly used methods for detecting cervical cancer are the Papa test, HPV test, and colposcopy [7]. Tumour size can also be assessed via transvaginal ultrasound. Other diagnostic methods include CT, MRI, lymphadenectomy, lymphangiogram, diffusion-weighted MRI (DWI), and PET-CT. PET-CT is an excellent method for assessing distant metastases. Chest X-rays and bone scintigraphy can help identify the presence of metastases. Premalignant glandular changes and epithelial lesions can be removed using minimally invasive surgical procedures. In cases of malignant disease, surgical procedures such as hysterectomy, removal of tissues around the uterus along with pelvic lymph nodes, or removal of the uterus along with the ovaries and fallopian tubes are performed [8]. For patients who are not surgical candidates, chemotherapy may be one of the treatment options for primary metastatic cervical cancer. HPV testing and a Pap test should be conducted 12 and 24 months after the procedure [9].

FIGO classification

In 2018, a new FIGO classification for cervical cancer was published, which defines anatomically advanced disease and distinguishes survival outcomes (Table 1). Compared to the previous FIGO system from 2014, the main change is that stage IB now includes three subgroups instead of two [10]. The appropriate diagnostic methods and treatment options for each stage are also summarised. Pathological and imaging assessments of the pelvis, as well as the evaluation of para-aortic and pelvic lymph nodes, have been incorporated into the staging system. This staging system also allows for the comparison of patients and their outcomes. Technological advancements improve diagnosis and treatment, and cancer staging is a process that evolves in response to this progress [11].

Table 1. FIGO tumour classification [10]

FIGO stage	Definition
I (IA, IA1, IA2, IB, IB1, IB2, IB3)	Cervical cancer confined to the uterus
II (IIA, IIA1, IIA2, IIB)	Cervical cancer spread beyond the uterus but without infiltration of the pelvic wall or the lower third of the vagina.
III (IIIA, IIIB, IIIC)	Cancer involves the lower third of the vagina, with possible presence of: infiltration to the pelvic wall, hydronephrosis, or involvement of lymph nodes.
IV (IVA, IVB)	Tumour has spread beyond the pelvis or infiltrates the mucosa of the bladder or rectum.

Aim of the paper

The aim of this paper is to present the role of the latest technological advancements in the use of MRI for more accurate detection and localization of cervical tumours, evaluation of disease staging, and risk factors. It will also highlight the advantages and disadvantages of MRI compared to other imaging modalities, as well as how MRI can influence the identification of tumour characteristics that affect the choice of optimal therapeutic techniques. The literature was searched using key terms on PubMed for the period from 2000 to 2024. A total of 3,413 papers were found, 54 of which are relevant to the topic of this paper. In addition to the database, 5 websites and 1 book were also used.

Discussion

MR imaging of the healthy cervix

MRI as an imaging method provides insight into gynaecological anatomy that is not visible with other techniques. Due to its high contrast resolution for small structures and tissues, as well as multiplanar imaging capabilities, it is possible to differentiate even very small pathological changes [12]. To distinguish pathologically visible structures from anatomical ones, it is essential to understand the anatomically normal appearance of both the uterus and the cervix (Figure 5). Tissue layers within and outside the uterus, cervix, and vagina are displayed in all three planes [13]. The cervix is located at the lower part of the uterus and is cylindrical in shape, protruding partially into the vagina. The average length of an anatomically normal cervix is 3 to 4 cm, with a diameter of 2.5 cm. MRI allows visualisation of all three layers of the uterus: endometrium, myometrium, and perimetrium [14]. The most

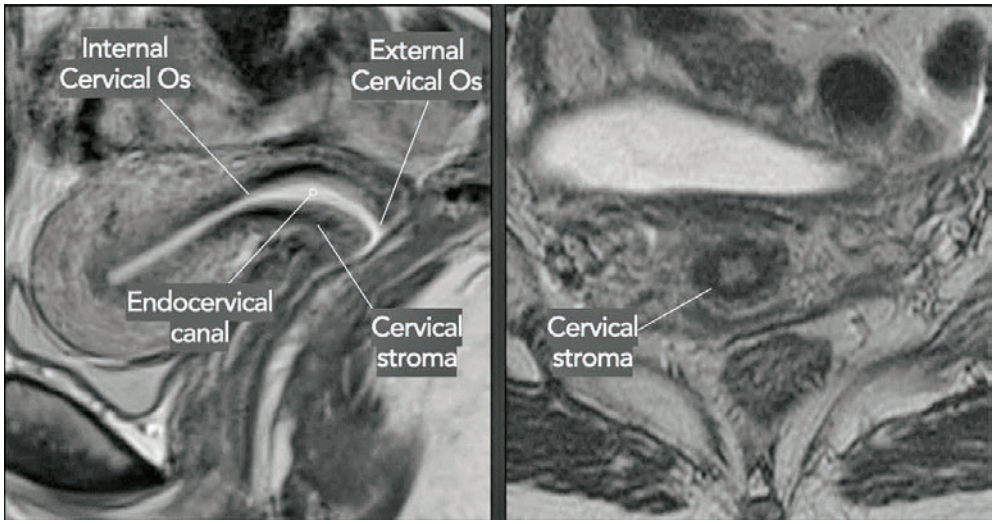

Figure 5. Anatomical MRI of a healthy cervix.
Source: https://radiologyassistant.nl/abdomen/unsorted/mr-in-cervical-cancer-1

common site for cervical tumours is the squamocolumnar junction, which is the boundary between the squamous and columnar epithelium lining the cervix. The cervix is separated from the bladder by the parametrium. The rectum is located posteriorly to the cervix, while the bladder is situated anteriorly. On T2-weighted images, the length and position of the cervix are clearly visible. A healthy cervix has two distinct zones: a central zone with high signal intensity, covered with mucus, and an outer zone with low signal intensity. On T1-weighted images, the surrounding parametrium is displayed with moderate signal intensity and is clearly distinguishable from connective tissue [13, 15].

The anatomy of the uterus and cervix varies with age. During the reproductive years, the different layers of the uterus and cervix are well-defined, and the muscular part of the uterine wall may be highly vascularized. The uterine cavity can be identified as a hypointense structure. In postmenopausal women, the anatomy becomes less visible, with cervical stroma and myometrium appearing hypointense on T2-weighted images. With age, the female reproductive organs gradually decrease in size, with a more pronounced loss of uterine volume compared to the cervix [16].

MR imaging of cervical carcinoma

MRI is the most precise and specific imaging technique used for the initial diagnosis and monitoring of cervical cancer. It provides a detailed assessment of disease and its spread within the cervix, as well as tumour extension into the pelvis, which significantly impacts treatment strategy and disease management [17]. The International Federation of Gynecology and Obstetrics (FIGO) staging system uses imaging and pathological evaluations for diagnosis and staging. The choice of imaging modality is based on the FIGO classification. MRI is considered the imaging modality of choice for assessing local tumour extension. It offers excellent soft tissue resolution, allowing accurate evaluation of tumour size, localization, and local infiltration, and provides insight into pelvic lymph node enlargement. The sequence most commonly used for diagnosing tumours is the Diffusion Weighted Imaging (DWI) sequence. This contrast-enhancing method is based on differences in diffusion. DWI shows the movement of water within tumour tissue. Pathological processes can affect water distribution within the tumour tissue. This characteristic allows insight into the tumour's microstructure, cellularity, and cellular membrane integrity. Cervical cancer tissue appears as restricted diffusion with high signal intensity in the primary tumour and metastatic lymph nodes. Cervical cancer is usually moderately hyperintense on T2-weighted images. The sagittal plane allows assessment of tumour extension to the uterine body or vagina. On T1-weighted non-contrast images, the tumour is typically displayed as isointense relative to the normal cervix. Smaller tumours usually grow homogeneously, while larger tumours may be necrotic and often show an enhanced margin. Large tumour size is a sign of aggressive disease. Isoechoic and hyperechoic tumours are more common in adenocarcinomas, whereas hypoechoic tumours frequently appear in squamous cell carcinomas of the cervix [18]. T2-weighted imaging is the mainstay for assessing cervical tumours on pelvic MRI. Images are acquired perpendicularly to the cervix, with thin slices of 3 to 4 mm recommended. Tumour size, whether greater or smaller than 4 cm, plays a crucial role in therapy selection, and accurate tumour size assessment is generally achieved. However, sometimes lesion size may be inaccurately assessed on T2 images due to the presence of inflammation or edema. Additionally, tumours may exhibit varied morphological characteristics, such as exophytic, infiltrative, or endocervical forms, and different growth patterns, which are essential for planning potential brachytherapy. Preservation of the hypointense fibrous ring on T2-weighted MRI often suggests a lack of parametrial invasion. However, disruption of the stromal ring without a clearly defined parametrial mass may result in microscopic invasion, leading to false-negative findings. Complete disruption of the ring, accompanied by nodular or irregular tumour signal intensity, are reliable indicators of tumour invasion [19] (Figure 6). Alongside diffusion imaging, MR spectroscopy is used as a specialised technique in cervical cancer imaging. It is a functional technique that

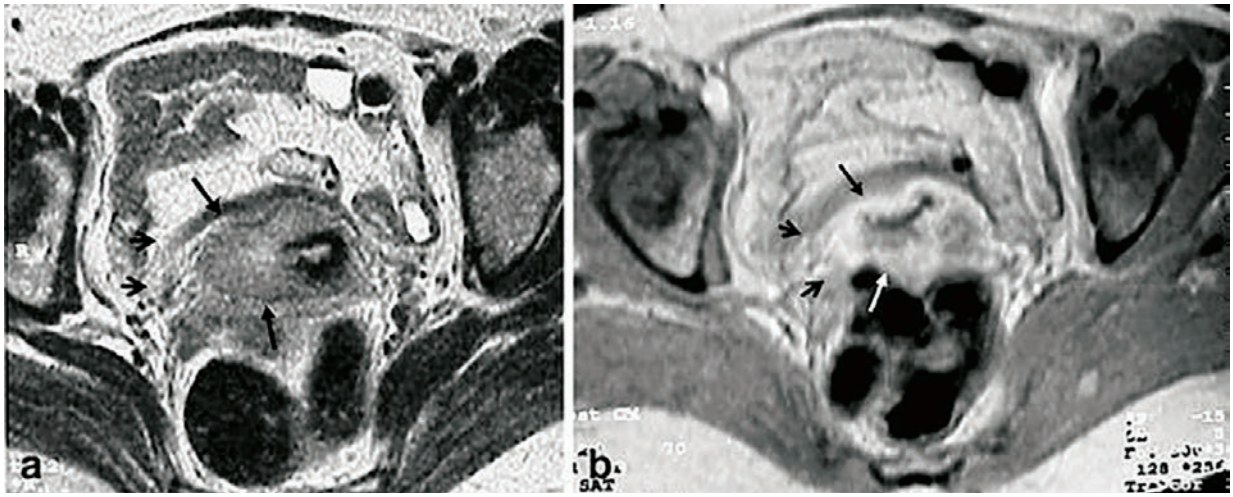

Figure 6. Axial T2 and T1-weighted contrast-enhanced images show a necrotic cervical mass (arrows) with right parametrial invasion (short arrows).
Source: https://link.springer.com/article/10.1007/s00330-005-2804-z/figures/2

detects the presence of small mobile molecules at commonly used MRI strengths of 1.5 T and 3 T [20].

Stage I cervical cancer on MRI

Early detection of cervical cancer with MRI can reduce the need for patients to undergo radical surgery. In the earliest stage of the disease, the tumour is not clinically visible, and diagnosis is made solely through biopsy and pathological analysis. Imaging modalities like conventional MRI cannot detect millimetre-sized changes at this stage and are not recommended for patients with stage IA of this disease. Additionally, the therapeutic options for these patients depend on whether they are in their reproductive years and the involvement of lymphatic and blood vessels. When assessing the stage of cancer in the early stages of the disease, caution is needed due to local inflammatory processes and edema resulting from the biopsy. Inflammation is often accompanied by edema, leading to high signal intensity on MRI and is a common reason for overestimating tumour size and staging the disease higher than it actually is [21].

For stage IB cervical cancer, prognosis depends on tumour volume, type, lymphovascular invasion, and lymph node status (Figure 7). T2-weighted MRI is precise for assessing tumour volume, especially with endovaginal techniques. Squamous cell carcinomas generally have a better response compared to adenocarcinomas, though adenocarcinomas typically have a worse prognosis, especially if poorly differentiated. The presence of tumour cells in vascular channels is a poor prognostic sign. MRI can be used as a prognostic biomarker to differentiate the histological characteristics of tumours in stage I disease [22].

Stage II cervical cancer on MRI

A tumor that has extended beyond the uterus but has not invaded the pelvic wall or the lower third of the uterus is classified as stage II. According to the classification,

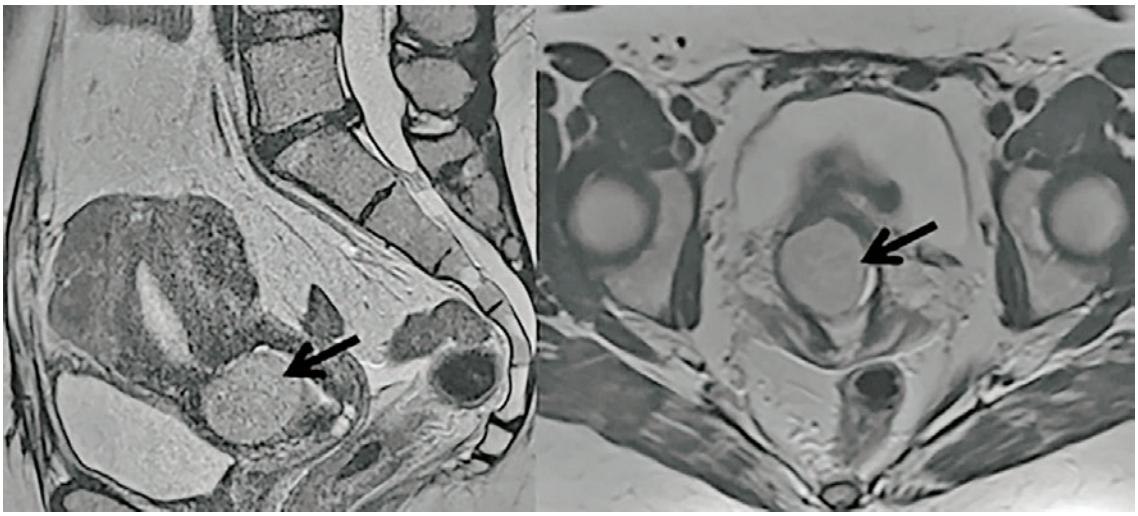

Figure 7. Stage IB cervical cancer on MRI
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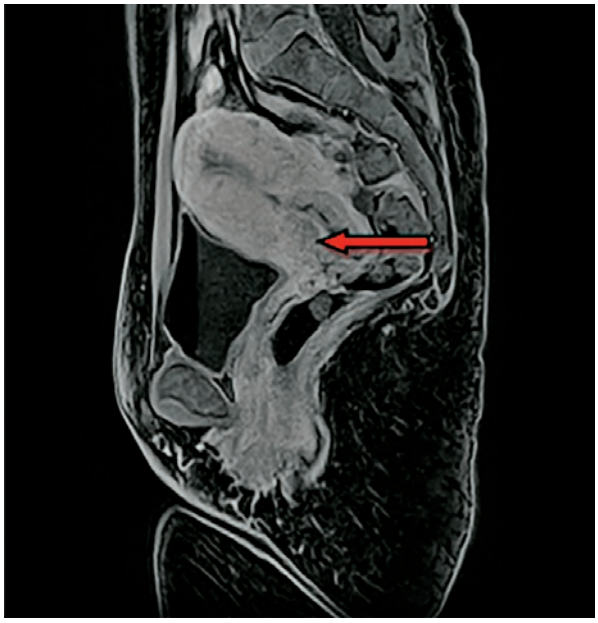

Figure 8. FIGO stage IIA cervical cancer (<4cm) on TI in the sagittal plane
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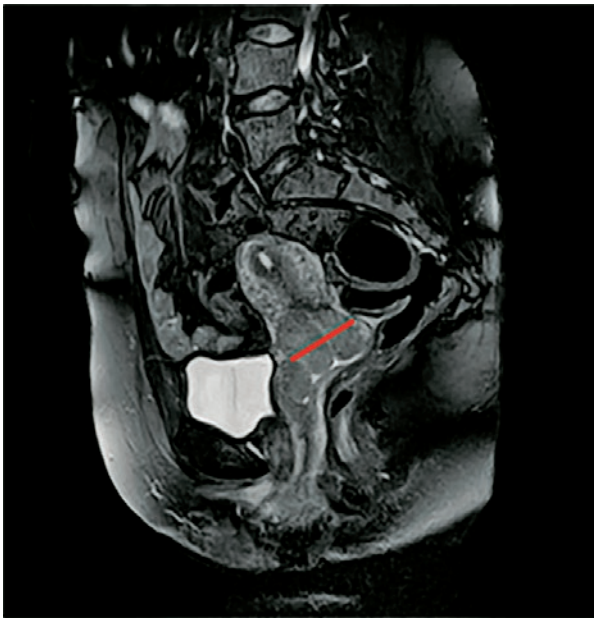

Figure 9. FIGO stage IIA2 cervical cancer (>4 cm) in the sagittal plane on T2-weighted imaging
Source: https://zir.nsk.hr/islandora/object/mef:3661/datastream/PDF/view

tumours with a diameter of <4 cm fall under stage IIA1 tumours (Figure 8), while invasive cancers larger than 4 cm are classified as stage IIA2 (Figure 9). Stage IIB cancer involves parametrial invasion but not invasion of the pelvic wall. Tumours at this stage can be treated with surgery or radiation therapy [24]. On MRI, stage IIA appears as infiltration into the upper two-thirds of the vagina, with loss of the normally hypointense signal and thickening of the vaginal wall. In stage IIB, signs of parametrial invasion are visible, and there is a complete loss of the hypointense signal from the cervical stroma. T2-weighted imaging is justified when assessing parametrial invasion. On T1-weighted images, healthy tissue will give a brighter signal due to the presence of fat, while tumour tissue will appear darker [25].

Stage III cervical cancer on MRI

Stage III disease involves the spread of cancer to the lower third of the vagina or the pelvic wall, changes in the thickness or loss of the normal signal of the vaginal wall, and the presence of hydronephrosis (fluid accumulation in the kidney), as well as involvement of local and regional lymph nodes (Figure 10). Hydronephrosis is best assessed on T2-weighted images in a coronal plane that includes the kidneys [25, 26]. Healthy lymph nodes have an oval shape, with homogeneous intermediate signal intensity on T2-weighted images, hypointense on T1-weighted images, and high signal intensity on DWI images. The primary criterion for distinguishing malignant from benign tumours is size; nodes larger than 1 cm in their shortest

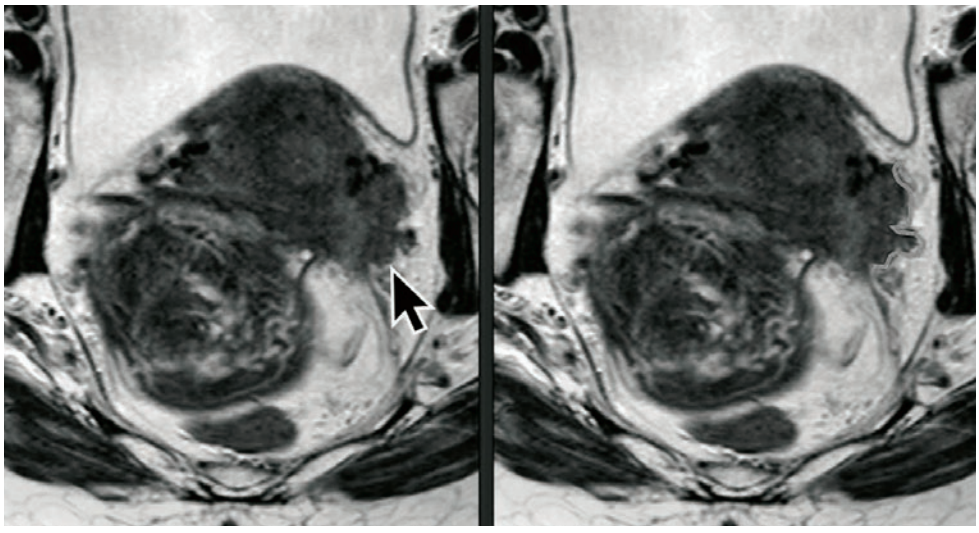

Figure 10. Pelvic lateral wall invasion of stage III cervical cancer
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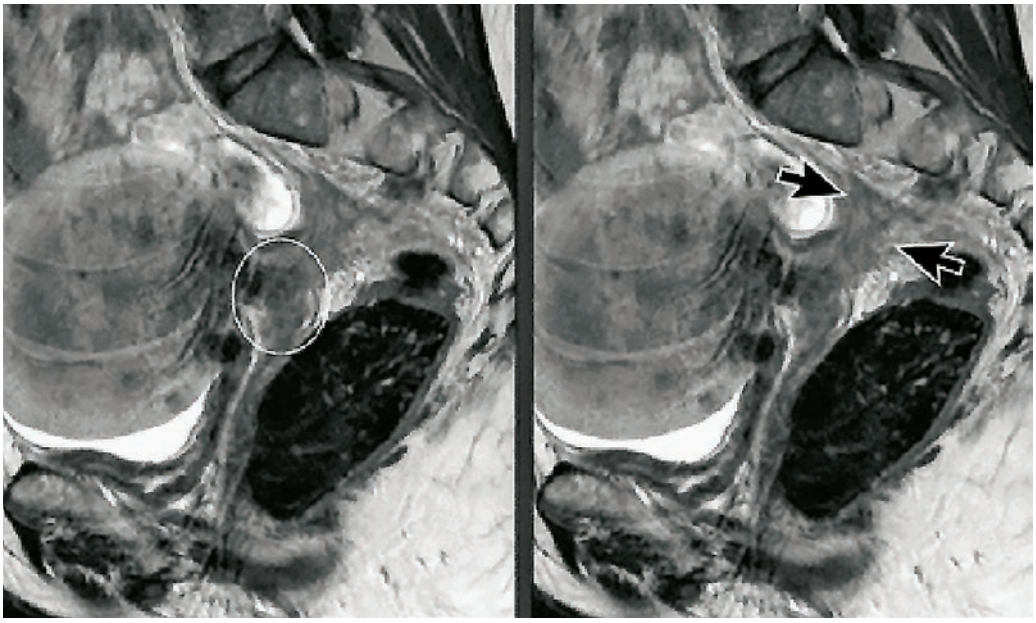

Figure 11. Locally advanced stage III cervical cancer (circle) with extensive invasion of the sacrouterine ligaments (arrows)
Source: https://radiologyassistant.nl/abdomen/unsorted/mr-in-cervical-cancer-1

axis may indicate a malignant process. Detection of positive lymph nodes is easiest on T2-weighted images due to their intermediate intensity compared to the hypointense blood vessels and muscles [27] (Figure 11). Metastases in lymph nodes associated with cervical cancer are linked to a lower survival rate, with a three-year survival rate of 64%, compared to 94% for patients without metastases [25, 27, 28]. The 2022 recommendations from national comprehensive cancer centres for treating stage III cancer suggest concurrent chemoradiotherapy and conventional external beam radiotherapy with doses ranging from 50 to 60 Gy. This dose is sufficient to control smaller metastatic lymph nodes but is inadequate for larger and more extensive lymph nodes. High doses of external brachytherapy and lymph node resections are the main treatment strategies for larger lymph nodes. However, increasing the dose carries the risk of serious and toxic side effects on adjacent organs such as the bladder, rectum, and intestines [26].

Stage IV cervical cancer on MRI

Stage IV is the terminal stage of cervical cancer. At this stage, there is extension of the cancer to adjacent organs, particularly the bladder and rectum, and there may also be metastasis to distant organs. Stage IV is divided into IVA and IVB. Stage IVA indicates metastasis to adjacent organs, while Stage IVB denotes metastasis to distant organs [29] (Figure 12). Concurrent surgical therapy and chemotherapy are approaches used for treating stage IV disease [30]. The overall five-year survival rate for patients with stage IV disease is 15%. MRI has a sensitivity for detecting involvement of soft tissue structures ranging from 71-100%, with specificity between 88-91% [31].

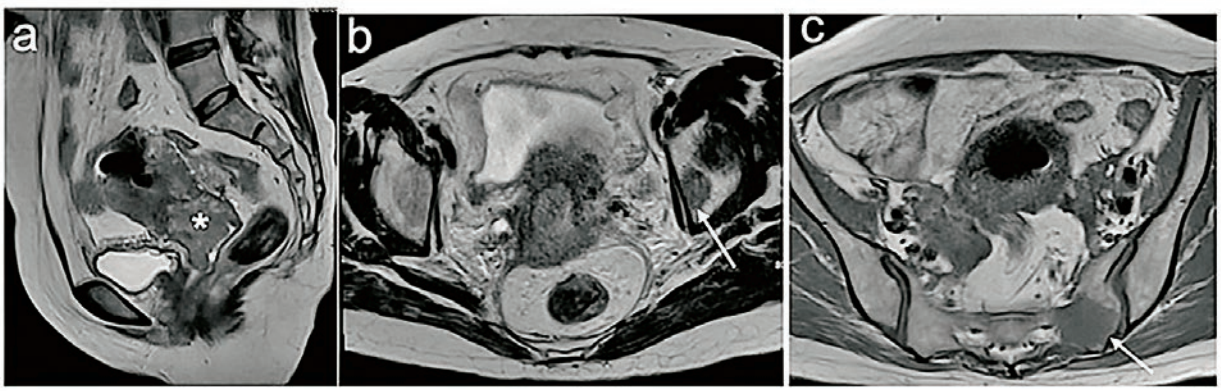

Figure 12. Sagittal T2 (a) shows a cervical tumor of intermediate signal intensity (*). Axial T2 at the mid-pelvic level (b) and sacrum (c) reveals focal regions of irregular low signal intensity within the left acetabulum (arrows) consistent with bone metastases. FIGO Stage IVB .
Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10605640/#B29-cancers-15-05105

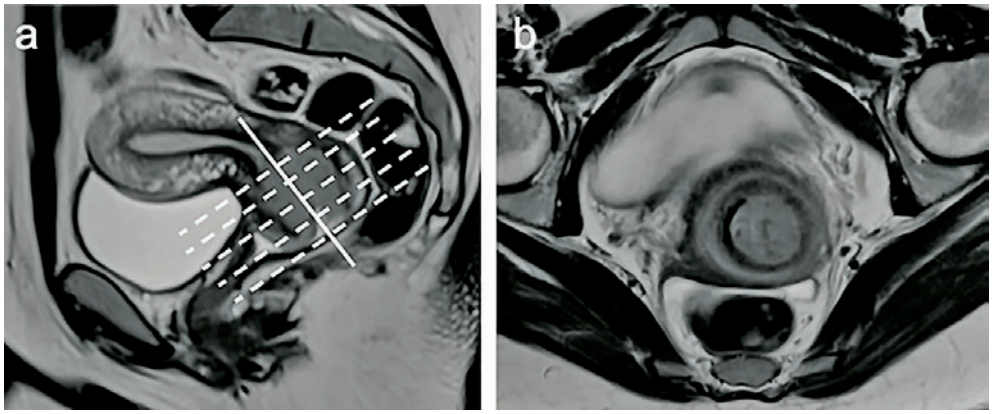

Figure 13. Sagittal T2 (a) highlights the long axis of the cervix (solid white line) and the perpendicular axis to the cervix (dashed white lines) from which (b) axial-oblique slices are obtained.
Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10605640/

The presence of a hyperintense tumour within the bladder and rectum, with wall damage on T2-weighted images, clearly indicates tumour cell expansion. This radiological diagnosis is further confirmed by pathological analysis of tissue samples. Additionally, edema of the bladder mucosa may occur, potentially leading to an incorrect assessment of the posterior wall of the bladder, and can result in false-positive findings on T2-weighted images due to uniform thickening and high signal intensity throughout the wall [27, 32].

Role of MRI in the treatment of patients with cervical cancer

MRI plays a central role in patients with diagnosed cervical cancer and allows for accurate staging, which is crucial for determining the most appropriate treatment. MRI is the best imaging option for assessing tumour size, location, as well as parametrial and lateral wall invasion. A partially filled bladder ensures that the uterus is in an optimal position, so patients are advised to empty their bladder approximately half an hour before the examination to ensure it is partially filled during the scan. Prior to the procedure, an intramuscular medication is administered to calm peristalsis, thereby reducing movement artefacts caused by intestinal peristalsis [33]. In the standard MRI protocol for staging cervical cancer, a broad-field standard T2 image is obtained first. This image is used to plan subsequent imaging with higher resolution along the axis of the cervix, which is crucial for precisely locating the tumour and accurately determining parametrial involvement (Figure 13). The normal anatomy of the cervix is most clearly seen on T2, where the central endocervical glands and mucosa are hyperintense, surrounded by hypointense fibrous stroma and stroma of intermediate signal intensity extending to the parametria. Cervical tumours are best visualised on T2 as lesions of intermediate signal intensity, which clearly differentiate from the hypointense cervical stroma. DWI can assist in detecting tumours when the lesion has the same signal intensity as the cervix [34].

Certain guidelines recommend using a large FOV axial T1 and T2WI from the renal hilum to the pubic symphysis to assess additional associated diseases or pelvic metastases, such as enlarged lymph nodes, bone involvement, and hydronephrosis [35, 36]. Different tissues have

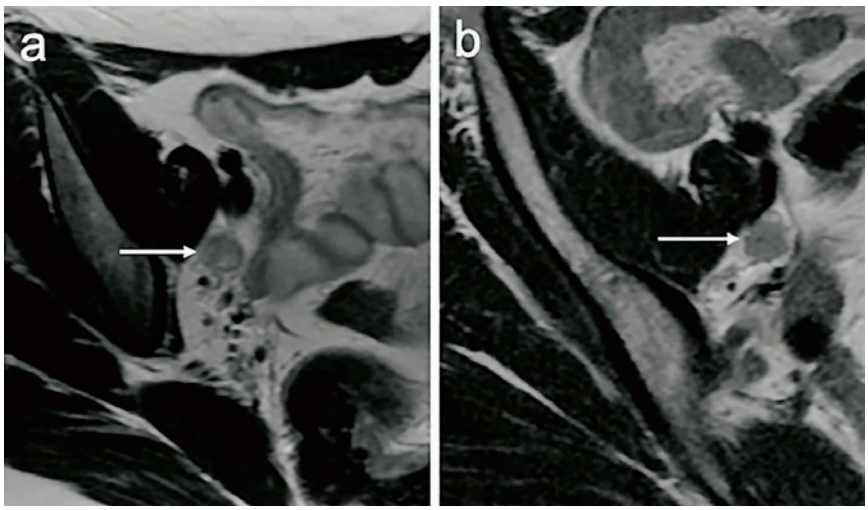

Figure 14. Appearance of metastatic lymph nodes with (a) rounded morphology and central necrosis and (b) irregular spiculated margins on axial T2WI.
Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10605640/

characteristic diffusion properties, and in highly cellular tissues, water molecule diffusion is relatively restricted. This is manifested as high signal intensity on DWI images [37, 38, 39]. DWI facilitates the detection of lymph nodes; however, it is important to note that both physiological and pathological nodes show restricted diffusion. T1 and T2-weighted images can be used for further assessment of lymph node morphology. Suspicious features include rounded morphology, irregular borders, and loss of the fatty hilum (Figure 14). Size criteria for enlarged lymph nodes vary depending on the location [40].

Combined chemoradiotherapy is the treatment of choice for advanced cervical cancer. MRI is performed before and during treatment to enable tailored treatment planning and dose adjustment of radiotherapy, improving local tumour control and reducing treatment toxicity. If initial treatment fails, further therapeutic options are limited. Therefore, early and accurate prediction of treatment response significantly impacts patient prognosis. Many studies have investigated the potential role of contrast-enhanced MRI in staging as a predictor of treatment response. Studies have shown that tumours with poor enhancement (poorly perfused hypoxic tumours associated with increased aggressiveness, higher risk of metastasis, and treatment failure) had a poorer response to therapy and lower survival rates. However, studies have not identified a precise, reproducible value for these parameters, limiting their use in current clinical practice. Some studies have also shown that contrast-enhanced MRI can improve the sensitivity of detecting small isointense tumours, particularly for patients who may be candidates for fertility-sparing treatment. Cervical cancer is treated with curative intent, and FIGO staging aims to classify patients who are suitable for primary surgery and those who will have a better prognosis with chemoradiation. Surgical intervention is considered for patients with tumours smaller than 4 cm and confined to the cervix without parametrial or nodal invasion. For a selected group of patients who desire future fertility, fertility-sparing surgery may be an option. In such cases, tumour size is most accurately depicted by MRI, typically reserved for tumors confined to the cervix measuring < 2 cm (stages IA1, IA2, and IB1). For larger tumours confined to the cervix (> 2 cm) or for patients where fertility preservation is not a priority, surgical options include total abdominal hysterectomy with or without bilateral salpingo-oophorectomy and lymphadenectomy, performed either open or laparoscopically. Patients with FIGO stages IB and IIA may also be offered primary chemoradiotherapy if they are considered less favourable candidates for surgery. Standard treatment for locally advanced cervical cancer (stage IIB and higher) is chemoradiotherapy, which includes external radiation with concurrent chemotherapy, followed by intracavitary brachytherapy. MRI can be used to assess the precise placement of brachytherapy applicators and complications after brachytherapy. MRI during treatment (about 5 weeks after the start of chemotherapy with external radiation and before intracavitary brachytherapy) can help adjust the dose based on residual tumour volume, which can reduce toxicity. MRI is usually performed 3-6 months after chemoradiotherapy, and the regeneration of low-signal intensity cervical stroma on T2WI indicates a complete response. Changes after treatment can persist for up to 9 months after chemoradiotherapy; thus, differentiating residual tumours from post-treatment edema can be challenging, as both will appear as intermediate signal intensities on T2WI. The use of DWI can help distinguish between the two, as only tumours should show restricted diffusion.

Advantages and disadvantages of mri compared to other imaging modalities in cervical cancer

Before initiating treatment, local staging of cervical cancer often involves determining the stage using transvaginal or transrectal ultrasound and/or MRI. This helps assess the precise tumour size, depth of stromal invasion, and parametrial invasion. For evaluating metastases in pelvic and paraaortic lymph nodes and detecting distant metastases in locally advanced cervical cancer, both MRI and CT are widely used [46]. However, both MRI and CT have low sensitivity for detecting metastatic lymph nodes, whereas PET-CT shows better sensitivity. Nonetheless, PET/CT also has low sensitivity for diagnosing small/microscopic metastases [47]. Therefore, negative imaging findings for lymph node metastases based on any imaging modality do not rule out occult lymph node metastases in cervical cancer [48].

MRI and ultrasound in the imaging of cervical cancer

While MRI is considered the primary technique for assessing tumour size and parametrial extension, transvaginal ultrasound (TVUS) or transrectal ultrasound (TRUS) can provide comparable results. Ultrasound can be as accurate as MRI. However, MRI has the advantage of being easily reviewed during multidisciplinary tumor board meetings, whereas ultrasound depends on the operator's skill [49, 50]. Combining MRI with ultrasound can also successfully visualise disturbances in the stromal ring, a specific sign of parametrial involvement, which is typically characterised on MRI by a drastic reduction in T2 hypointensity of the fibrous stromal ring [51] (Figure 15). Recent technical advances in ultrasound have led to its increased use in cervical cancer management. Ultrasound diagnosis has been shown to enhance initial diagnosis and better assess the size of small tumours. Vascularization can be assessed using Doppler, and it is possible to differentiate between precancerous lesions and cervical cancer, improving diagnostic accuracy (Figure 16). The use of Doppler has led to reinterpretation of MRI data in patients with nodular cervical hyperplasia, and ultrasound has proven to be significantly better than MRI in assessing tumour size [52]. The limitation of ultrasound may be that certain factors can interfere with the ultrasound evaluation of some tumour characteristics, such as lesion borders, involvement of the fornices, and vascular patterns. Additionally, ultrasound may overestimate tumour dimensions, which could compromise the opportunity for fertility-sparing surgery in certain patients [53]. A comparison of 3D ultrasound with MRI for assessing parametrial infiltration showed a 79% concordance between the two techniques [54]. MRI and ultrasound have similar diagnostic effectiveness. The advantage of MRI over ultrasound is its greater ability to identify patients with metastatic lymph nodes. The

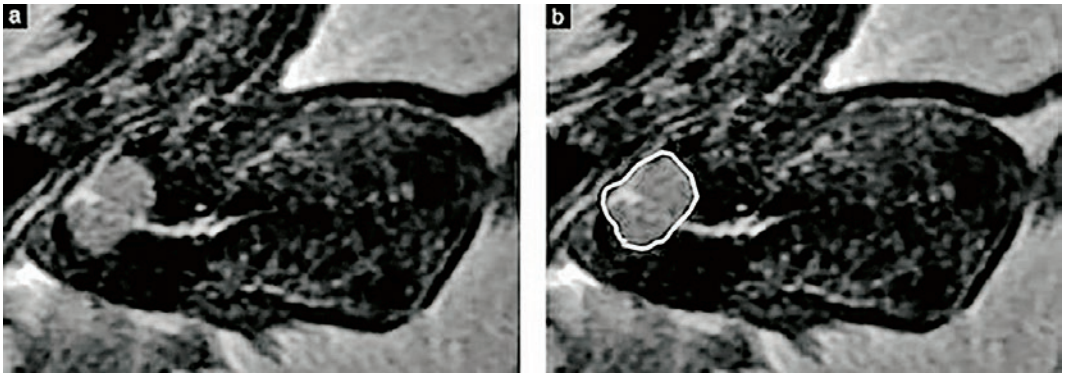

Figure 15. Sagittal T2-weighted MRI of cervical cancer infiltrating less than two-thirds of the stroma (FIGO stage IB). The tumor boundary is outlined, surrounded by free cervical stroma (b) [55].

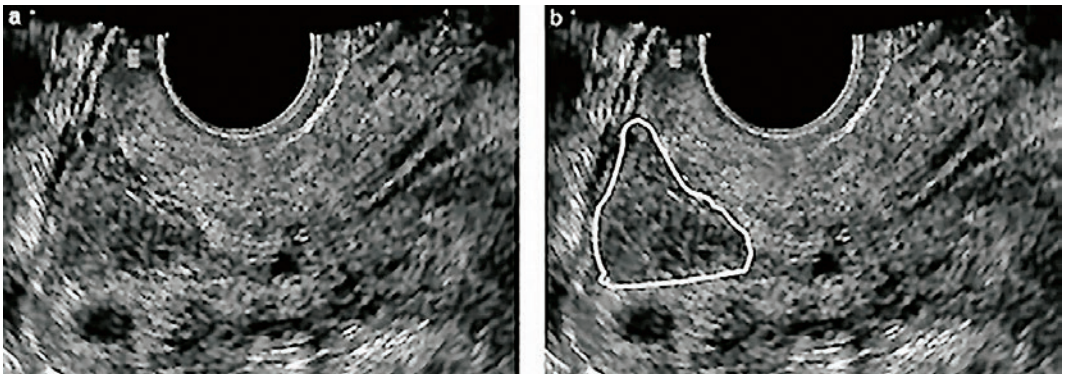

Figure 16. Transvaginal ultrasound image showing a longitudinal section of cervical cancer infiltrating less than two-thirds of the stroma (FIGO stage IB). The tumor boundary is outlined, surrounded by free cervical stroma (b) [55].

drawbacks of MRI include cost and the inability to perform dynamic examinations, as well as the length of the exam [55].

MRI and PET/CT in cervical cancer imaging

MRI and CT are used to assess paraaortic and pelvic lymph nodes in patients with cervical cancer. These methods have only moderate sensitivity and specificity for detecting metastases. A major limitation of these modalities is their inability to identify small lymph node metastases. Although PET has been shown to be superior to CT and MRI for detecting pelvic and paraaortic lymph node metastases due to cervical cancer, PET is limited in terms of anatomical and spatial resolution compared to CT or MRI [56]. However, PET has lower spatial resolution than CT or MRI. MRI and PET/CT are advanced imaging techniques routinely used today for staging and monitoring cervical cancer treatment. MRI provides the best visualisation of the primary tumour and the extent of disease in soft tissues. PET/CT is recommended for evaluating nodal involvement as well as distant metastases. Both MRI and PET/CT are used to monitor patients after treatment to assess recurrence. PET/CT is used before treatment when there is a possibility of tumour spread beyond the cervix or in patients considered for trachelectomy [57]. PET/CT plays a crucial role in depicting and assessing the local extent of the disease and can be helpful in delineating the edges of invasive tumours in cases of superior tumour spread. However, high intensity can excessively overestimate tumour spread into parametrium, as well as involvement of the bladder and rectum. Therefore, MRI should be used alongside PET/CT to avoid overestimation of local invasion into the parametrium, bladder, and rectum [58]. Similar to MRI imaging, PET/CT is evaluated as a functional imaging parameter for predicting disease

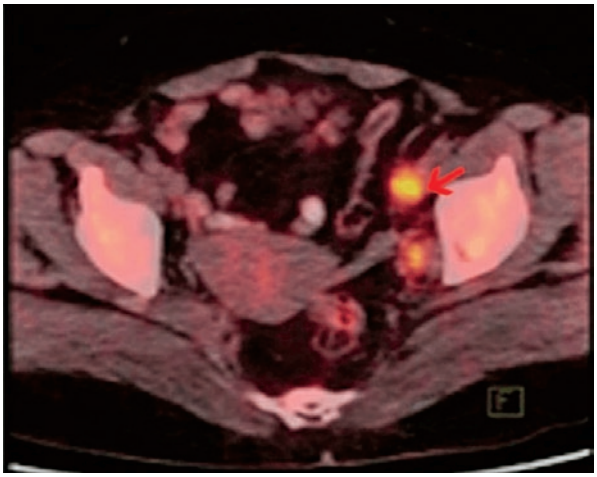

Figure 17. PET/CT image showing involvement of the left pelvic lymph node. The red arrow indicates FDG (Fluorodeoxyglucose) uptake in the left pelvic lymph node of a patient with early-stage cervical cancer.
Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9803860/

response and prognosis, including disease-free survival and overall survival. PET/CT has advantages over MRI in assessing distant metastatic disease. PET is also used to avoid missing lesions at the edges of the MRI field of view. While MRI is useful for detecting enlarged pelvic and paraaortic metastatic lymph nodes, PET/CT is more sensitive than MRI for detecting metastatic lymph nodes from cervical cancer (Figure 17). Combining PET images with MRI images is an emerging technology used for assessing patients with cervical cancer. According to recent studies, the benefits of MRI in evaluating local tumour extension, paired with the strengths of PET in assessing lymph node metastases, result in a synergistic effect on staging accuracy for women with cervical cancer [59, 60].

Conclusion

MRI plays a crucial role in the diagnosis and treatment of cervical cancer, particularly in assessing tumour size, disease spread, and detecting metastases. It provides detailed visualisation of the primary tumour and accurately depicts soft tissues. Combining MRI with other imaging techniques can further enhance diagnostic and treatment accuracy. This includes the use of various imaging methods such as ultrasound, PET/CT, and MRI. Although MRI and CT are commonly used for evaluating metastases, PET/CT offers higher sensitivity but still has limitations in detecting smaller metastases. Additionally, combining MRI with ultrasound can successfully depict parametrial infiltration. While MRI and PET/CT are valuable for assessing disease spread and monitoring treatment, their combination can have a synergistic effect on staging accuracy. Furthermore, MRI plays an important role in surgical planning by allowing precise determination of tumour size and identification of affected adjacent structures. MRI is also used to monitor patients post-treatment to assess for potential disease recurrence. Despite its drawbacks, such as high costs and limitations in dynamic imaging, there is a need for further research and technological development. Nevertheless, its ability to provide detailed visualisation of anatomical structures and detect pathological changes makes it an indispensable diagnostic tool for rapid and accurate diagnosis and treatment monitoring in cervical cancer.

All data in this paper are part of the results of the undergraduate thesis „The role of MRI in the diagnosis and choice of treatment for cervical cancer“ written at the University Department of Health Studies, University of Split [61]. ■

Važnost MR-a u određivanju stadija raka vrata maternice

Sažetak

Rak vrata maternice jedan je od najčešćih malignih tumora koji pogađa žene. Kod bolesnica s ranim stadijem raka vrata maternice i lokalno uznapredovalim rakom vrata maternice princip liječenja je konvencionalan uključujući operaciju, kemoterapiju i radioterapiju, dok kod bolesnica s metastatskim rakom vrata maternice, ne postoji standardno liječenje zbog njegovih heterogenih manifestacija. Zbog svega toga ključno je na vrijeme dijagnosticirati i odrediti stadij karcinoma u svrhu kvalitete života. Snimanje tijekom primarne dijagnostičke obrade ključno je za točnu procjenu proširenosti tumora i metastatske bolesti kao i za odabir najbolje terapijske opcije, a pomoću FIGO sustava njegova je uloga dodatno naglašena. U odnosu na druge tehnike snimanja, MR nam pruža detaljne informacije o lokalizaciji i veličini tumora, invaziji u okolna tkiva, te prisutnost udaljenih metastaza. MR doprinosi individualiziranom pristupu u odabiru terapije, uzimajući u obzir specifične karakteristike tumora. Integracija MR-a u dijagnostički i terapijski proces poboljšava kliničke ishode pacijenata s karcinomom vrata maternice, omogućujući učinkovitu skrb. MR se nadopunjuje sa ostalim modalitetima snimanja kod dijagnostike i planiranja liječenja, te bez MR-a nije moguće utvrditi stadij bolesti i postaviti konačnu dijagnozu.

Ključne riječi: FIGO stadij; karcinom vrata maternice; magnetska rezonancija; PET/CT; UZV

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