Magnetic resonance hysterosalpingography in the evaluation of tubal patency in infertile women: an observational study

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Summary

The purpose of this study was to evaluate the ability of magnetic resonance hysterosalpingography (MR-HSG) to demonstrate fallopian tube patency in infertile women and to improve the MR-HSG technique. Sixteen consecutive infertile women were recruited for this trial. All subjects underwent clinically indicated MR-HSG: 10-15 ml of 1:10 solution of gadolinium and normal sterile saline (0.9%) was gently hand-injected intracervically through a 7 French balloon catheter while seven consecutive flash-3D dynamic (FL 3D DY) T1-weighted MR sequences were acquired. Two readers independently assessed image quality as well as anatomic and pathologic correlations. Patient comfort was evaluated using a specific score questionnaire. MR-HSG was successfully completed in all patients. In 14/16 (87.4%) patients, MR-HSG showed bilateral tubal patency with symmetric contrast agent diffusion and a regular tubo-ovarian relationship. One patient (6.3%) with monolateral hydrosalpinx presented no contrast agent diffusion in the affected side (monolateral tubal occlusion); in another patient (6.3%) the fallopian tube was displaced upward causing loss of the tubo-ovarian anatomical relationship resulting in asymmetric and inadequate contrast agent diffusion. Eight women (50%) were found to have abnormalities on MR imaging; these abnormalities included multi follicular ovaries (5 cases 31.1%), endometrioma (1 case, 6.3%), leiomyoma (1 case / 6.3%) and endometrial polyp (1 case / 6.3%). The average time required for the study was 25-30 minutes. Analysis of the questionnaires administered to the patients showed that 15/16 patients (93.7%) were fully satisfied with the procedure. All examinations were judged to be of high diagnostic quality and the two readers made similar diagnoses. In conclusion, MR-HSG is a feasible, useful and well tolerated tool for the assessment of the uterus, fallopian tubes, ovaries and extra-uterine structures. MR-HSG is a new promising imaging approach to female infertility.

Key words: Femal infertility; Tubal factor; Magnetic resonance hysterosalpingography.

Introduction

The current trend to defer childbirth to a later age has resulted in an increasing number of couples presenting with infertility problems. Approximately 15% of couples of reproductive age are confronted with infertility, which is defined as the failure to conceive after one year of unprotected intercourse [1-2]. In about half of these cases infertility is caused by female factors, and abnormalities of the reproductive tract are commonly detected. The etiology of female infertility can be found in several factors (tubal, ovulatory, cervical, uterine, endometriosis, age and lifestyle) that may be isolated or combined [3-6].

Tubal pathology is one of the main causes of infertility. It is estimated to account for 12%-33% of cases [7-9]. This figure is probably underestimated, as most aspects of tubal dysfunction escape observation.

Tubal pathology is usually associated with peritubal adhesions and tubal occlusion. In routine fertility work-up, the ability to evaluate tubal function is limited and the degree of tubal damage is judged mainly by tubal patency and the extent of peritubal adhesions [10].

Hysterosalpingography (HSG) is a radiographic method used in routine infertility evaluation.

It is used in many infertility centers as a preliminary investigation tool and it is considered the gold standard for assessing fallopian tube patency. HSG is a reproducible examination, easily and rapidly performed at a reasonable cost [10-15].This procedure allows diagnosis of congenital uterine abnormalities, acquired alterations of the uterine cavity and stenosis or occlusion of the fallopian tubes [11]. HSG shows a good diagnostic accuracy (sensitivity 81.8%, specificity 77.1%) in the evaluation of fallopian tube patency while sensitivity and specificity are low in the evaluation of abnormalities of the uterine cavity. HSG is considered mainly a diagnostic tool, but there may also be a possible therapeutic benefit in connection with this procedure due to the flushing effect [12-15]. However, conventional HSG exposes the reproductive organs of young potentially fertile woman to ionizing radiation, and moreover, the procedure can be uncomfortable or painful [16-18].

For these reasons, the scientific community's attention has in recent years been focused on alternative methods such as hysterosalpingo-contrast-sonography (HyCoSy) and magnetic resonance imaging (MRI) which would allow a full assessment of the potential causes of infertility in women without administration of ionizing radiation [15, 19-23].

MRI is gradually gaining importance in the investigation of the female reproductive tract [19-23] for its ability to display soft tissue contrast. Gadolinium-based con-

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Table 1. — *MR-HSG protocol*.

Sequence	Plane	TE (ms)	TR (ms)	Interval (mm)	Matrix	NEX	FoV	Thickness (mm)
T2 HASTE	sagittal	88	1000	5	384 x 252	1	307 x 309	5
T2 HASTE	coronal	88	1000	5	384 x 252	1	307 x 309	5
T2 HASTE	axial	88	1000	5	384 x 252	1	307 x 309	5
FL3D DYNAMIC	3D	1.14	2.78	0.76	320 x 320	1	380 x 380	1.2
T1 TSE FS	axial	9.7	688	1.5	320 x 256	3	200 x 200	5
T2 TSE FS	axial	90	4161	0	448 x 274	2	380 x 380	3

TSE: turbo spin echo; HASTE: half-Fourier acquired single-shot turbo spin-echo; FS: fat suppressor; TE: echo time; TR: repetition time; NEX: number of excitations; FoV: field of view; ms: milliseconds.

trast agents have furthermore been developed that can safely be introduced into the uterine cavity and allow examination of the fallopian tubes. Modern fast 3D gradient echo sequences allow dynamic imaging during intracavitary injection of contrast agent, so MRI can offer a comprehensive anatomic survey permitting simultaneous evaluation of tubal patency [24-29].

The aim of the present study was to evaluate the feasibility of MR-HSG in the demonstration of fallopian tube patency in infertile women and to optimize the MR-HSG technique.

Materials and Methods

This prospective observational study was approved by the local ethics committee and written informed consent was obtained from all patients. The sample was built up from December 2010 to March 2011 at the Department of Radiological Sciences, University of Rome "Sapienza" among women with primary or secondary infertility. Absence of pregnancy after 12 months of unprotected intercourse, exclusion of male infertility and hormonal disorders provided the indication for MR-HSG.

Exclusion criteria were refusal or inability to sign the informed consent form, age < 18 years, clinical history of intolerance to gadolinium-based contrast agents, vaginal or cervical infections, cervical stenosis, insufficient cervical seal and an abnormal uterine position that would prevent catheterization or make it difficult, as well as contraindications to MRI such as cardiac pacemakers, cochlear implants, and severe claustrophobia.

The examination was preceded by a preliminary phase during which the patient's clinical history was assessed again for contraindications with respect to the MRI study and gadolinium administration, and the rationale of the study was explained. All patients subsequently underwent a complete pelvic examination.

A sterile 24.5 cm hysterometer (RAMISTER/RI.MOS; Italy) was inserted through the cervical os into the cervical canal to exclude cervical stenosis, insufficient cervical seal or anomalies in the course of the cervical canal that might prevent catheterization or make it difficult.

Transvaginal ultrasound was performed in all patients by the same radiologist who subsequently performed MR-HSG to determine the degree of bending of the uterus. MR-HSG was performed with the bladder full or empty according to the position of the uterus. In case of antiversion and antiflexion, the examination was performed with a full bladder, while examination was performed with an empty bladder in case of retroversion and retroflexion. In case of stenosis of the external orifice of the uterus a Hegar dilator size 4 was used to test for reversibility; in case of irregularities detected in the course of the cervical canal, the patients were informed about the possibility of pulling the cervix forward during MR-HSG using Collins uterine forceps.

Only patients meeting the following selection criteria were recruited: 1) non-stenotic and non-gaping external orifice of the uterus; 2) external orifice of the uterus with reversible stenosis after dilation using Hegar dilator size 4; 3) a regular course of the cervical canal; 4) the patient's consent to pulling the cervix during MR-HSG if the course of the cervical canal was irregular.

Microbiological analysis was performed in all patients to detect genital infections (exclusion criteria). Antibiotics (amoxicillin and clavulanate) were administered one day before and for five days after the examination, 1 g twice a day for six days. The patients were told to refrain from unprotected sexual intercourse from the first day of their period until the investigation to be certain that there was no risk of pregnancy. MR-HSG was scheduled early in the follicular phase of the menstrual cycle, between the 7th and the 12th day.

Two hours before the procedure, 40 mg of N-butyl scopolamine was administered orally to reduce intestinal peristalsis in the small pelvis and discomfort during intrauterine injection of the contrast agent. One hour before MR-HSG and after exclusion of contraindications all patients received oral administration of 300 ml of Lumirem (Ferumoxsil 175 ml/l, Laboratoire Guebert, France).

MRI examination was performed on a 1.5T MRI unit (Avanto, Siemens Medical Solutions, Germany) using a four-element phased-array surface coil (Body Matrix Coil; Siemens Medical Systems; Germany).

For the catheterization a 7 French balloon catheter (PBN Medicals Denmark A/S, Stenlose, Denmark) was used. Catheterization was performed on a non-magnetic stretcher in the medical center next to the MRI room under sterile conditions and adequate privacy. The patients were placed in a gynecological position, the vagina was dilated by a gynecological dilator and the external orifice of the uterus was catheterized. A balloon catheter was inflated with 2-3 ml of normal sterile saline and its stability was verified by gentle traction in the caudal direction.

The speculum was removed and circa 5-10 ml of sterile saline (0.9%) was injected into the uterine cavity through the catheter. The patients were transported to the MRI room on a non-magnetic stretcher and placed in the supine position on the mobile MRI bed.

Before the procedure, the correct position of the balloon catheter was verified using a sagittal T2-weighted half-Fourier acquired single-shot turbo spin-echo (HASTE) sequence. Subsequent standard imaging of the pelvis consisted of axial and coronal T2-weighted HASTE sequences performed in order to

Table 2. — *Analysis of the questionnaires administered to the patients 7 days after MR-HSG examination*.

Parameters	Score (mean values)
Pain during catheterization	2.97
Execution time	2.73
Pain during contrast injection	2.74
Lumirem palatability	2.15
Total score	10.59

study the morphology of the uterine cavity which was hyperintense due to injection of saline and the field of view (FoV) for the subsequent dynamic sequences was set. FoV was oriented parallel to the major axis of the uterus and was large enough to also cover the ovaries.

Subsequently, approximately 10-15 ml of a 1:10 mixture of Dotarem (Acidumgadoteras, 0.5 mmol/ml; Laboratoire Guerbert, France) diluted with normal sterile saline (0.9%) was gently hand-injected through the catheter into the uterine cavity when the acquisition of dynamic sequences was started. All patients were told to inform the radiologist if pain occurred during the injection.

For the dynamic MR-HSG, seven consecutive fat-saturated T1-weighted gradient echo FLASH 3D DYNAMIC (FL 3D DYN) sequences were acquired during intrauterine injection of contrast solution.

One of the following two findings led to the diagnosis of tubal patency: 1) contrast enhancement in the periovarian region and 2) evidence of contrast agent in the pouch of Douglas.

Following an axial T1-weighted turbo spin-echo (TSE) sequence with fat saturation (FS), an axial T2- weighted TSE sequence was performed to visualize the distribution of contrast solution in the peritoneal cavity. The MR-HSG protocol is reported in Table 1. All patients were kept under observation for about half an hour after the examination and they were given a telephone number to contact in case of complications.

Seven days later when the patients came to collect the MRI report, a questionnaire was administered to assess the degree of satisfaction with the examination. The parameters were: pain during catheterization (mild, moderate, severe); pain during injection of contrast medium (mild, moderate, severe); execution time (short, acceptable, long); palatability of Lumirem (good, acceptable, poor).

Each parameter was assigned a score from 1 to 3. The score (range 4-12) was evaluated as follows: 4-6 = examination is not satisfactory; 7-9 = examination is satisfactory; > 10 = examination is considered very satisfactory. In the same questionnaire the patients were asked to state possible onset of bleeding, vaginal discharge, vaginal itching/burning and pelvic pain in the days following the examination.

A set of dynamic subtraction images was reconstructed and evaluated similar to the MRI angiographic procedure. Both the subtracted series and the anatomic images were reviewed independently on a PACS system (Infinitt Healthcare Ltd, Korea) by two expert readers. The readers evaluated image quality, the different parts of the pelvic anatomy, unilateral or bilateral fallopian tubes as well as the uterine cavity with regard to congenital anomalies or pathologies such as fibroids, adenomyotic lesions and uterine polyps. The subtracted images were viewed by manually scrolling through the series on the PACS workstation and were not viewed in cine mode. Assessment of functional aspects included fallopian tube patency in general, localization and extent of filling defects as well as spillage and distribution of contrast agent into the peritoneal cavity.

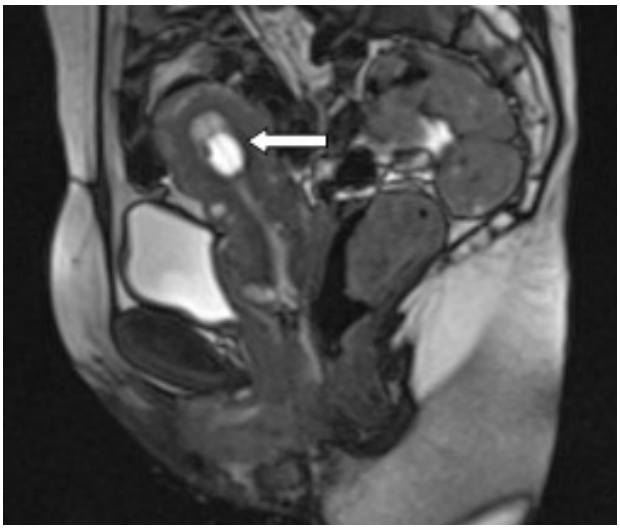

Figure 1. — Sagittal T2-weighted HASTE. Correct intracervical position of the inflated balloon (arrow).

Results

A total of 16 infertile women (mean age 35.5; range 28-44 years) were recruited for this study. Indications were primary infertility in 12 patients (75%) and secondary infertility in four patients (25%).

MR-HSG was successfully completed in all patients: positioning of the catheter was feasible in all patients and no complication occurred during cervical cannulation. In one (6.3%) patient with moderate stenosis of the external orifice of the uterus, dilation was performed using a Hegar dilator size 4; another patient (6.3%) whose cervical canal was bent consented to caudal traction of the cervix using Collin's uterine forceps in order to straighten the cervical canal and thereby facilitate the introduction of the catheter. In all cases T2-weighted HASTE sequences showed correct positioning of the catheter (Figure 1) using the scans in the sagittal plane.

Manual injection of 5-10 ml sterile saline (0.9%) made the uterine cavity hyperintense and T2 HASTE sequences in the coronal plane showed the regularity of the profile in 15/16 (93.7%) cases and a slightly arched uterine fundus in the remaining cases (6.3%).

Analysis of dynamic sequences, subtraction images and maximum intensity projection (MIP) reconstructions confirmed tubal patency in 14/16 (87.4%) cases. The images showed sequential opacification of the uterus and intramural portion of the tubes as well as bilateral spillage of contrast agent into the peritoneal cavity permitting also evaluation of diffusion time and symmetry (Figure 2 a). In eight cases (50%) the ampullary portion of the tube was depicted (Figure 2 b), while it was possible to identify the intramural portion in only two cases (12.5%) (Figure 2 c).

In 14/16 (87.4%) cases contrast agent diffusion was symmetrical and comparison of base-line and dynamic images using dedicated software confirmed the regularity

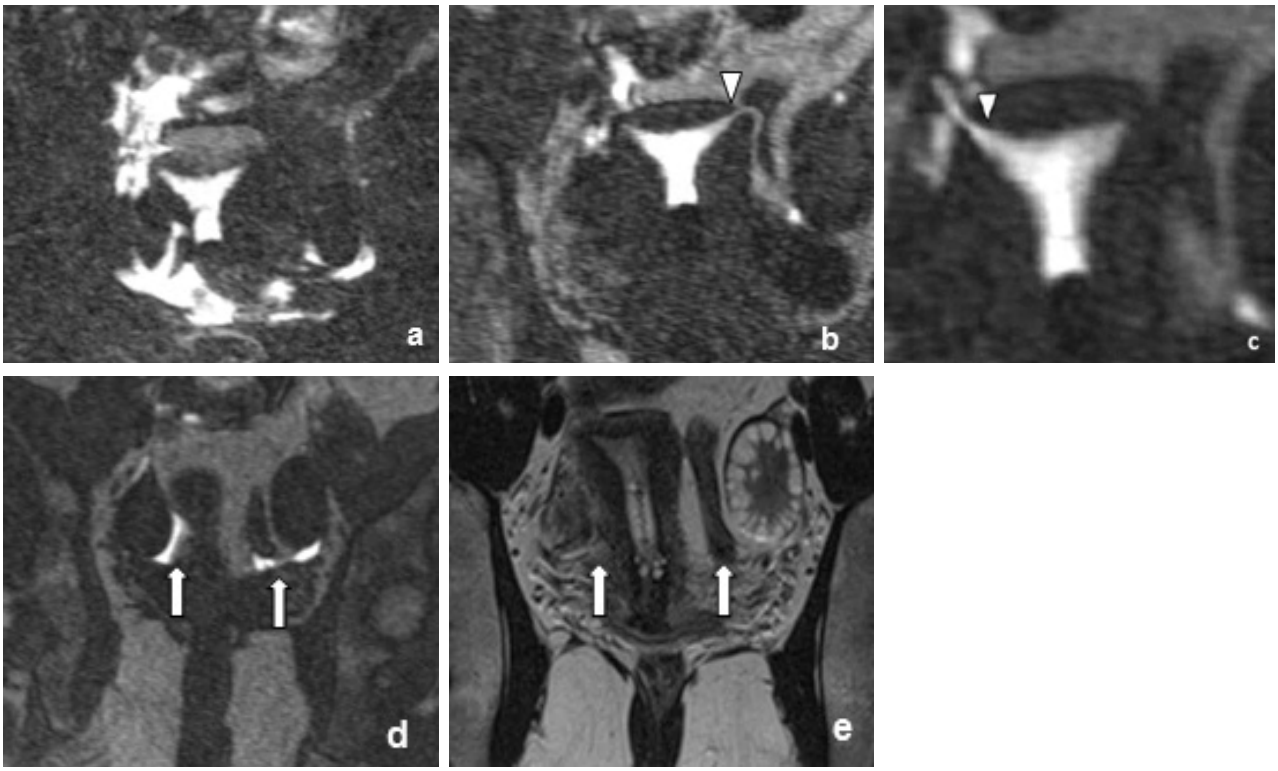

Figure 2. — FLASH 3D DYN T1-weighted images after intrauterine contrast injection (MIP). Accumulation of contrast solution in the uterine cavity appears regular and there is initial filling of the intramural portion of the tubes with bilateral and simultaneous spilling of contrast medium into the peritoneal cavity: bilateral tubal patency (a). Initial non subtracted FLASH 3D DYN T1-weighted images from series of 7 sequences after intrauterine contrast injection reveal the ampullary portion of the left tube (arrowhead) (b) and the intramural portion of the right tube (arrowhead) (c). Comparative analysis of final non subtracted FLASH 3D DYN T1-weighted images from the same series (d) and baseline T2-weighted TRUE FISP (e) shows the symmetrical spillage of contrast agent in the periovarian region on the left and in the periuterine region on the right (arrows).

of the tubo-ovarian relationship (Figure 2 d/e). In one case (6.3%) hydrosalpinx of the left tube with unilateral tubal occlusion were detected. In another case (6.3%), the right fallopian tube was cranially displaced resulting in loss of the anatomical relationship with the ipsilateral ovary and inadequate contrast agent diffusion.

The endometrium, myometrium, ovaries and pelvic ectopic structures were studied using T2-weighted HASTE, TSE and T1-weighted TSE FS sequences.

Eight patients (50%) were found to have abnormalities on MRI including multifollicular ovaries: five patients (31.1%) had multiple small follicular cysts surrounded by thickened and luteinized theca suggestive of polycystic ovarian syndrome [29-32]; one had endometrioma (6.3%), one had small intramural myoma (6.3%) and one had an endometrial polyp (6.3%) that appeared as a small filling defect in the dynamic sequences. Average time required to perform the examination was 25-30 min: balloon catheter positioning 5-10 min and MRI data acquisition 20-25 min.

Analysis of the questionnaires administered to the patients one week after the procedure showed that 15/16 patients (93.7%) were satisfied with the procedure resulting in an average score of 10.59 (Table 2). Catheter implantation and MRI examination were generally well tolerated and only 1/16 patients (6.3%) indicated "severe pain". Lumirem palatability was considered poor by most of the patients 11/16 (68.7%) and one patient had adverse reactions such as nausea and diarrhea. This event did not affect the outcome of the examination but it significantly reduced the score assigned by the patient in question (score 8). There were no cases of bleeding, vaginal discharge, symptoms related to bacterial vaginosis or pelvic pain in the days following the procedure. All examinations were judged to be of high diagnostic quality, and the two readers provided similar diagnoses.

Discussion and Conclusions

To our knowledge, this is the first Italian experience with MR-HSG in infertile women. The purpose of the present study was to evaluate the ability of MR-HSG to depict tubal patency and to optimize the technique in order to reduce complications and failure rate. At present HSG is the method of choice for the evaluation of tubal patency in infertile women. However, the most important

limitations of HSG are the insufficient evaluation of other causes of infertility, such as myometrial abnormalities and extrauterine diseases, and the exposure to ionizing radiation [5-7]. Ovarian doses range from 3.1 mGy in analog systems to 0.5 mGy in digital systems [16-18] and the procedure usually involves at least two radiographic exposures in addition to fluoroscopic exposure. Furthermore, although HSG is a relatively quick outpatient procedure, it is uncomfortable and often painful to the patient due to osmotic irritation of the endometrial and peritoneal tissue caused by iodinated contrast agents [9, 10].

Over the years, MRI has become an increasingly used diagnostic tool [19-25] and this method has the potential to become useful also for evaluating pelvic disorders associated with female infertility. Women affected by infertility are often referred to MRI for the diagnosis of possible uterine and extrauterine abnormalities, and simultaneous assessment of tubal patency would therefore be beneficial, as this would permit the patient to avoid administration of ionizing radiation [19, 20, 30-32]. The MR-HSG procedure performed in this study clearly demonstrated the anatomy of the reproductive organs including the myometrium and ovaries allowing at the same time assessment of tubal patency and the study of the extrauterine pelvic structures. MR-HSG may thus provide a more accurate diagnosis of all the possible causes of female infertility.

Assessment of diffusion time and symmetry as well as spillage of contrast agent into the pelvic cavity makes it possible to evaluate the functional aspects of the tubal factor assuming that delayed and/or asymmetrical contrast agent diffusion is suggestive of functional abnormalities of the fallopian tubes. The tubal factor includes also loss of a tubo-ovarian anatomical relationship mainly due to peritubal adhesions caused by inflammation and/or endometriosis [8]. This aspect was studied using dedicated software which allowed a combined analysis and comparison of baseline and dynamic sequences in order to establish the relationship between the uterine tubes and ovaries. MR-HSG thus allows an overall assessment of the tubal factor by studying both morphological and functional aspects.

The most important disadvantages of MR-HSG are the high costs and the duration. However, these disadvantages are largely weighed up by the advantage of obtaining more information about all the organs of the pelvis and especially by the fact that exposure to ionizing radiation is avoided [28]. All patients enrolled in this study stated that they were satisfied with the duration of the examination.

In the present study the attention was focused on certain aspects of the procedure and the attempt to improve the technique in order to avoid the difficulties reported in the literature. MR-HSG was performed in the early follicular phase of the menstrual cycle after exclusion of infections. The endometrium is thin during this proliferative phase and this facilitates a better image interpretation and should also ensure that the patient is not pregnant. Later in the cycle, focal contour irregularities of the endometrium may be mistaken for small polyps or focal areas of endometrial hyperplasia and may cause a false-positive diagnosis of corneal occlusion [14]. The absence of post-procedure infectious complications in the present study population may be related to the microbiological screening and antibiotic prophylaxis administered before the examination.

Winter *et al*. [28] studied 37 patients and reported an incidence of malpositioning of the catheter in 5.4% of the patients and displacement during injection of contrast medium in 8.1%; moreover, in 5% of cases the examination was not concluded due to strong pain during contrast injection. Sadowski *et al*. [29] performed MR-HSG in 17 patients and reported a failure rate of 5.4% caused by excessive patient movement due to strong pain felt during the automatic injection of contrast agent.

To reduce the incidence of such events, the anatomy of the external orifice of the uterus and the cervical canal was studied in each patient to detect possible anatomical abnormalities which might prevent positioning and/or stability of the catheter during injection of contrast medium.

The absence of complications related to catheterization (malpositioning or dislocation of the catheter) seems to confirm the importance of preliminary assessment to determine the possible need for procedures in addition to the standard protocol such as dilation of the cervical canal using a Hegar dilator and/or traction using Collin's uterine forceps. Ultrasound determination of the position of the uterus performed by the same radiologist, who carried out MR-HSG, led to the decision to perform the examination with a full or empty bladder in order to reduce the flexion of the cervical canal and thereby facilitate the introduction of the catheter. To avoid pain during injection of contrast agent, muscle relaxant medication was orally administered two hours before the procedure, and injection of contrast agent was carried out manually. Instead of intravenous medication as administered by Winter *et al*. [28] oral medication was preferred as it is more easily accepted and better tolerated by the patients. In our opinion, the use of an automatic injector device is not beneficial because the inability to control and modulate the quantity, pressure, and timing of injection of contrast agent increases the likelihood that the patient feels pain. Moreover, a fast and continued distention of the uterine cavity may cause a reflex spasm of the intramural portion of the tube leading to a false-positive diagnosis of proximal occlusion.

The ability to adjust injection speed in order to avoid pain is essential to the good outcome of the examination, as the response of the myometrium during the introduction of contrast agent is highly subjective and influenced by pain. Also the fact that only a small quantity of contrast agent is injected (10-15 ml) has a positive effect on the patient's perception of pain. Finally, manual injection may reduce the risk of dislocation of the catheter in the vagina.

Lumirem is a negative, superparamagnetic contrast agent that has so far mainly been orally administered for

bowel contrast in MRI intestinal exploration. The rationale for its use in this study lies in the ability to reduce signals coming from the intestinal contents and to prevent artifacts on MR-HSG images. In all cases the images were of excellent diagnostic quality, but due to the poor palatability of Lumirem, the real utility of this product and its use in future examinations will be subject to evaluation.

In this study preliminary assessment of the cervix and position of the uterus, oral intake of muscle relaxant medication and manual injection of contrast agent produced excellent results. Also the fact that all examinations were completed, unlike other studies [28, 29], allows us to assert that the above procedures are useful and can be recommended

In conclusion, this study has provided proof of the utility of dynamic MR-HSG assessment of the uterus, extrauterine pelvic structures and tubal factor in a "one-stop shop" session without exposure to ionizing radiation. MR-HSG was furthermore well tolerated by the patients, but further research is required to determine if this technique can become an alternative to conventional HSG.

References

[1] Hornstein M.D., Schust D.: "Infertility". In: Berek J.S., Adashi E.Y., Hillard P.A. (eds.). Novak's Gynecology. 12th edition, Baltimore, MD, Williams & Wilkins, 1996, 915.

[2] Hammond C.B., Stillman R.J.: "Infertility and assisted reproduction". In: Scott J.R., DiSaia P.J., Hammond C.B., Spellacy W.N. (eds.). Danforth's Obstetrics and Gynecology. 8th edition, Philadelphia, PA, Lippincott Williams & Wilkins, 1999, 649.

[3] Taylor E., Gomel V.: "The uterus and fertility". *Fertil. Steril.,* 2008, *89,* 1.

[4] ESHRE Capri Workshop Group: "Fertility and ageing". *Hum. Reprod.*, 2005, *11,* 261.

[5] teVelde E.R., Pearson P.L.: "The variability of female reproductive ageing". *Hum. Reprod.*, 2002, *8,* 141.

[6] Homan G.F., Davies M., Norman R.: "The impact of lifestyle factors on reproductive performance in the general population and those undergoing infertility treatment: a review". *Hum. Reprod.*, 2007, *13,* 209.

[7] Speroff L., Glass R.H., Kase N.G.: "Investigation of the infertile couple". In: Clinical Gynecological Endocrinology and Infertility. 5th edition, Baltimore, MD, Williams & Wilkins; 1994.

[8] Watrelot A., Hamilton J., Grudzinskas J.G.: "Advances in the assessment of the uterus and fallopian tube function". *Best. Pract. Res. Clin. Obstet. Gynaecol.,* 2003, *17,* 187.

[9] Cheong Y.C., Li T.C.: "Evidence-based management of tubal disease and infertility". *Curr. Obstet. & Gynaecol.,* 2005, *15*, 306.

[10] Anguissola R., D'Andrea F., Firullo A., Moro G., Pavesi M., Di Maggio E. *et al.*: "Current role of hysterosalpingography in the assessment of female infertility: review of a series of cases". *Radiol. Med.*, 1991, *82,* 303.

[11] Krysiewicz S.: "Infertility in women: diagnostic evaluation with hysterosalpingography and other imaging techniques". *Am. J. Roentgenol.*, 1992, *159*, 253.

[12] Hossam O.H., Ahamed Y.S., Aly M.E.: "Hysterosalpingo-contrast sonography versus radiolographic hysterosalpingography in the evaluation of tubal patency". *Int. J. Gynaecol. Obstet.,* 2009, *107,* 23.

[13] Eglé Tvarijonavičiené, Rūta Jolanta Nadišauskiené: "The value of hysterosalpingography in the diagnosisof tubal pathology among infertile patients". *Medicina* (Kaunas), 2008, *44*, 439.

[14] Chalazonitis A., Tzovara I., Laspas F., Porfyridis P., Ptohis N., Tsimitselis G.: "Hysterosalpingography: technique and applications". *Curr. Probl. Radiol.*, 2009, *29,* 1353.

[15] Exacoustos C., Zupi E., Carusotti C., Lanzi G., Marconi D., Arduini D.: "Hysterosalpingo-contrast sonography compared with hysterosalpingography and laparoscopic dye pertubation to evaluate tubal patency". *J. Am. Assoc. Gynecol. Laparosc.,* 2003, *10,* 29.

[16] Perisinakis K., Damilakis J., Grammatikakis J., Theocharopoulos N., Gourtsoyiannis N.: "Radiogenic risks from hysterosalpingography". *Eur. Radiol.*, 2003, *13,* 1522.

[17] Gregan A.C., Peach D., McHugo J.M.: "Patient dosimetry in hysterosalpingography: a comparative study". *Br. J. Radiol.*, 1998, *71,* 1058.

[18] Calicchia A., Chiacchiararelli L., De Felice C., Gigliotti T., Indovina P.L., Mazzei F., Porfiri L.M.: "Assessment of radiation dose to patients in hysterosalpingography". *Radiol. Med.,* 1998, *95,* 93.

[19] Woodward P.J., Wagner B.J., Farley T.E.: "MR imaging in the evaluation of female infertility". *Radiographics,* 1993, *13,* 293.

[20] Imaoka I., Wada A., Matsuo M., Yoshida M., Kitagaki H., Sugimura K.: "MR imaging of disorders associated with female infertility: use in diagnosis, treatment, and management". *Radiographics*, 2003, *23*, 1401.

[21] Carrington B.M., Hricak H., Nuruddin R.N., Secaf E., Laros R.K., Hill E.C.: "Mullerian duct anomalies: MR imaging evaluation". *Radiology*, 1990, *176*, 715.

[22] Fedele L., Dorta M., Brioschi D., Giudici M.N., Villa L.: "Magnetic resonance imaging of unicornuate uterus". *Acta Obstet. Gynecol. Scand.*, 1990, *69*, 511.

[23] Fielding J.R.: "MR imaging of the female pelvis". *Radiol. Clin. North Am.*, 2003, *41,* 179.

[24] Freeman-Walsh C.B., Fahrig R., Ganguly A., Rieke V., Daniel B.L.: "A hybrid radiography/MRI system for combining hysterosalpingography and MRI in infertility patients: initial experience". *Am. J. Roentgenol.*, 2008, *190,* W157.

[25] Frye R.E., Ascher S.M., Thomasson D.: "MR hysterosalpingography: protocol development and refinement for simulating normal and abnormal fallopian tube patency – feasibility study with a phantom". *Radiology,* 2000, *214,* 107.

[26] Wiesner W., Ruehm S.G., Bongartz G., Kaim A., Reese E., De Geyter C.: "Three-dimensional dynamic MR hysterosalpingography: a preliminary report". *Eur. Radiol.,* 2001, *11,* 1439.

[27] Unterweger M., De Geyter C., Frohlich J.M., Bongartz G., Wiesner W.: "Three-dimensional dynamic MR-hysterosalpingography; a new, low invasive, radiation-free and less painful radiological approach to female infertility". *Hum. Reprod.,* 2002, *17*, 3138.

[28] Winter L., Glücker T., Steimann S., Fröhlich J.M., Steinbrich W., De Geyter C., Pegios W.: "Feasibility of dynamic MR-hysterosalpingography for the diagnostic work-up of infertile women". *Acta Radiol.,* 2010, *51*, 693.

[29] Sadowski E.A., Ochsner J.E., Riherd J.M, Korosec F.R., Agrawal G., Pritts E.A., Kliewer M.A.: "MR hysterosalpingography with an angiographic time-resolved 3D pulse sequence: assessment of tubal patency". *Am. J. Roentgenol.,* 2008, *191,* 1381.

[30] Ascher S.M., Agrawal R., Bis K.G., Brown E.D., Maximovich A., Markham S.M. *et al.*: "Endometriosis: appearance and detection with conventional and contrast enhanced fat-suppressed spin-echo techniques". *J. Magn. Reson.,* 1995, *5,* 251.

[31] Dudiak C.M., Turner D.A., Patel S.K., Archie J.T., Silver B., Norusis M.: "Uterine leiomyomas in the infertile patient: preoperative localization with MR imaging versus US and hysterosalpingography". *Radiology,* 1988, *167,* 627.

[32] Troiano R.N., McCarthy S.M.: "Mullerian duct anomalies: imaging and clinical issues". *Radiology,* 2004, *233*, 19.

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