Eur Radiol (2011) 21:1301–1310
DOI 10.1007/s00330-010-2018-x

UROGENITAL

Indeterminate adnexal masses at ultrasound: effect of MRI imaging findings on diagnostic thinking and therapeutic decisions

Bianka Chilla · Nik Hauser · Gad Singer · Mafalda Trippel · Johannes M. Froehlich · Rahel A. Kubik-Huch

Received: 30 August 2010 / Revised: 20 October 2010 / Accepted: 15 November 2010 / Published online: 21 December 2010

Abstract
Objective To determine the impact of MRI including DWI on therapeutic decision-making and costs in the work-up of patients with a indeterminate adnexal mass on ultrasound.
Methods Thirty-eight patients with indeterminate ovarian lesions scheduled for surgery were included in this prospective study. In a questionnaire, the surgeon characterised the lesions based on a morphological score and determined the surgical procedure. The assessment was re-evaluated knowing MR findings and correlated with the final diagnosis. A cost-benefit analysis of MRI was performed. The impact of including DWI in the MR protocol was assessed.
Results MRI provided major diagnostic information in 11/38 cases (28.9%) resulting in abstention from surgery in 5 cases; moderate additional information was recorded in 10/38 (26.3%) patients. Overall a net cost saving (3'676 EUR) was achieved. DWI did not show a significant difference between benign and malignant lesions. Teratomas yielded significantly lower mean ADC values (0.597×10^{-3} mm^2/s) compared with all other adnexal lesions (1.812×10^{-3} mm^2/s); the mean ADC values in endometrioma (1.387×10^{-3} mm^2/s) were significantly lower than in other cystic lesions (2.372×10^{-3} mm^2/s).
Conclusion Inclusion of MRI in the diagnostic algorithm of the indeterminate adnexal mass allows better differentiation of ovarian lesions resulting in a change of therapeutic decision-making with net cost savings.

Keywords Adnexal lesion · Diagnostic efficacy · Ultrasound · MRI · Diffusion-weighted imaging · Cost-effectiveness

B. Chilla · J. M. Froehlich · R. A. Kubik-Huch
Department of Radiology, Kantonsspital Baden, CH-5404, Baden, Switzerland

N. Hauser
Department of Gynecology, Kantonsspital Baden, CH-5404, Baden, Switzerland

G. Singer · M. Trippel
Department Pathology, Kantonsspital Baden, CH-5404, Baden, Switzerland

B. Chilla (✉)
Institute of Radiology, Kantonsspital Baden, CH 5404, Baden, Switzerland
e-mail: bianka.chilla@ksb.ch

Introduction

In patients with an adnexal mass, there are two major diagnostic challenges: the determination of malignancy and the evaluation of tumour extent (staging), if a malignancy is suspected or confirmed. Diagnostic studies that allow accurate characterisation of a lesion might reduce unnecessary surgery in benign masses and will help to determine surgical and chemotherapeutic planning in malignant lesions [1].

Transvaginal ultrasound (TVUS) is the first-line investigation of suspected adnexal masses, being very sensitive in the detection of ovarian tumours, widely available and generally well accepted by patients [1–5]. There have been persisting concerns, however, about the ability of this technology to differentiate benign from malignant adnexal tumours [2, 6–8].

Magnetic resonance imaging was shown to be the most appropriate investigation for patients with an indeterminate adnexal mass on ultrasound, i.e. pelvic lesions in which either the organ of origin is uncertain or it remains unclear whether the nature is benign or malignant [1, 6, 9, 10].

Recently, a diagnostic algorithm was proposed according to which all women with indeterminate adnexal masses

should undergo MRI before therapeutic decision-making. It was postulated that the adjunct of MRI in this setting might reduce the number of women undergoing unnecessary surgery [6]. Often recommendations are based on the experience of experts or habits rather than evidence. Despite the acknowledgement of the importance of MRI by experts in female imaging and the great interest of best practice guidelines for diagnostic evaluation to the medical community, surprisingly little work has been done to determine the therapeutic effect of MRI, although its technical and diagnostic performance has been assessed extensively [2, 6].

The standard imaging protocol for adnexal lesions in our institutions incorporates the recommendations of the ESUR Womens' Imaging Subcommittee [6]. In addition, a diffusion-weighted sequence of the pelvis has been implemented. Diffusion-weighted imaging (DWI), well established for intracranial imaging, is a functional imaging technique whose contrast derives from the random motion of water molecules within the extracellular tissue. Because of recent technical advances allowing for much faster data acquisition, DWI can be successfully implemented for pelvic and abdominal applications and was shown to show potential in female pelvic tumours, i.e. to differentiate benign from malignant lesions or for preoperative lymph node characterisation [11–23].

The purpose of our study was to determine the impact of MR imaging on therapeutic decision-making and costs in the work-up of patients with an indeterminate adnexal mass on ultrasound. A subsidiary aim was to determine the value of DWI in the evaluation of adnexal masses, especially to distinguish between malignant and benign tumours.

Materials and methods

Patients

Thirty-eight female patients (mean age of 48.33 years; age range of 19–85 years; 23 pre-, 1 peri-, 14 postmenopausal) with indeterminate adnexal lesions at transvaginal ultrasound (TVUS), who were scheduled for laparoscopy or laparotomy, were included. This prospective clinical study was approved by our local institutional ethics review board and written informed consent was obtained from all patients.

Eligible patients were all consecutive women over the age of 18 years presenting at the Department of Gynecology between November 2008 and November 2009 with an indeterminate adnexal lesion at TVUS who were scheduled for laparoscopy or laparotomy and willing to participate in the study. An indeterminate adnexal mass on ultrasound was defined as a lesion with complexity that cannot be confidently classified as benign or malignant; or one of which the site of origin, from the ovary, uterus or another pelvic structure, remains to be established [6].

Excluded from the study were cases that already had a high index of suspicion for ovarian cancer based on results of ultrasound diagnostics or patients with contraindications for MRI as well as patients not eligible for surgery.

Transvaginal ultrasound

Transvaginal ultrasound was performed by the referring gynaecologist using a high-resolution endovaginal transducer (Voluson 730 expert, transvaginal probe RIC 5/9D; GE Healthcare, Milwaukee, WI, USA). The ultrasound images were evaluated prospectively in the knowledge of all clinical findings. The rationale for including the medical history as part of the ultrasound evaluation was to reproduce circumstances most similar to clinical reality.

Following the examination, a standardised questionnaire was filled out by the gynaecologist. Based on the sonomorphological findings, a score published by Kawai et al. [24] ranging from 1 (solitary cyst without internal echoes) to 12 (homogeneous solid pattern) was assigned to each lesion. A score of 9 or higher indicates malignancy.

A preliminary diagnosis, based on clinical findings including TVUS results, was determined and consecutive therapeutic consequences were decided before for MRI diagnostics.

MR imaging protocol

Magnetic resonance imaging examinations were all performed within 2 weeks after ultrasound examination on an 1.5-T MRI (Avanto, Siemens Medical Systems, Erlangen, Germany).

The standardised MR protocol consisted of the following pulse sequences: a cine steady-state free precession sequence (TrueFisp) in the coronal and axial plane as well as an axial T1-weighted 2D gradient echo sequence covering the entire abdomen (FOV 370 mm).

Subsequently, intestinal motion was reduced by intravenous (i.v.) administration of 1.0 mg of glucagon (Glucagen®, Novo Nordisk, Switzerland; [25]) and a diffusion-weighted echoplanar MR sequence of the pelvis with three b-values (50, 400, 800 mm^2/s) was acquired (2D DWI SPAIR: TR 4,700 ms, TE 94 ms, slice thickness 4 mm/gap 20%, matrix 192×144, FOV 250 mm, bandwith 1,042 Hz/pixel, 6 NEX, grappa factor 2, time of acquisition 4.28 min.). Isotropic ADC maps were automatically generated using all b values and a monoexponential fitting. These sequences were followed by additionalT1- and T2-weighted sequences focused on the small pelvis: Sagittal T2-weighted 2D TSE (TR 4,650 ms, TE 101 ms, slice thickness 4 mm/gap 30%, matrix 512×256, FOV 250 mm), axial T2-weighted STIR

(TR 6,650 ms, TE 77 ms, slice thickness 7 mm/gap 20%, matrix 256×256, FOV 350 mm), axial T1-weighted 2D TSE (TR 532 ms, TE 11 ms, slice thickness 4–7 mm/gap 20%, matrix 512×256, FOV 350 mm). Additional axial-oblique T2-weighted or fat-saturated precontrast T1-weighted sequences were tailored to the abnormal adnexal features seen on the initial sequences.

A single-dose of gadolinium (0.1 mmol/kg body-weight of Gd-DOTA, gadoterate meglumine, Dotarem®, Roissy, Guerbet, France) was administered i.v. at a rate of 3 ml/s and fat-saturated T1-weighted sequences (TR 492 ms, TE 10 ms, slice thickness 4–7 mm/gap 20%, matrix 256×192, FOV 350 mm) were acquired.

MR image analysis

All image data sets were transferred to a PACS workstation for image analysis (Centricity®-PACS Picture Archiving and Communicating System, GE Healthcare, Milwaukee, WI, USA). The MR images were evaluated prospectively in consensus by two radiologists , who were blinded to TVUS, other imaging results and medical history. Lesions were characterised and defined based on criteria previously published in the literature [26]. The presence of additional findings such as enlarged lymph nodes, organ metastases or ascites was assessed.

On the diffusion imaging, lesion evaluation was performed qualitatively on the high b=800 images. Lesions with high signal on high b-value images and low signal on the corresponding ADC maps were regarded as malignant. In addition a quantitative measurement of ADC values was attempted by manually placing a region of interest (ROI) as large as possible (mean ROI size 383 mm^2, range 14–3,245 mm^2) in regions of restricted diffusion. In addition, quantitative ADC measurements were also obtained separately for solid and cystic adnexal lesion components.

A specific diagnosis, i.e. mature teratoma or endometrioma was determined, if certain features like fat signal or the T2-shading sign were present [27]. In all cases, based on the criteria mentioned above, the likelihood of malignancy was assessed using a four-point-scale.

Evaluation of the impact of MRI on therapeutic decision making

Before surgery a second evaluation concerning the therapeutic impact was performed. MRI findings were discussed with the gynaecological surgeon and its impact was rated on a 4-point scale from nil to major (nil=no additional information by MRI, TVUS alone sufficient; major= important additional information influencing diagnosis and/or therapy).

Cost-effectiveness analysis

The costs of a contrast-enhanced MRI of the abdomen and pelvis charged to an outpatient were calculated based on the Swiss tariff system for ambulatory services [28]. Furthermore, the mean total costs of laparoscopic surgery including hospital stay were determined based on the hospital bill of patients with compulsory health insurance undergoing laparoscopic surgery for an adnexal lesion.

Histopathological analysis

Results were correlated with histopathological diagnoses in those cases where surgery was performed. The intraoperative specimens were fixed in 10% formalin. Dissection consisted of 5–10-mm slicing of the whole lesion. Slices were embedded in blocks and processed for haematoxylin-eosin staining in 5-μm sections.

Statistics and diagnostic efficacy analysis

The reference standard consisted of either histopathological information retrieved from the patient files or of clinical follow-up covering at least 6 months in those cases where surgery was not performed.

Therapeutic decisions before and after MR diagnostics were compared, and confirmation of, or any change in diagnosis was determined. Receiver operating characteristic curves were constructed for the initial combined clinical and TVUS assessment versus the MR-based diagnosis for presence of benign or malignant lesions with calculation of the area under the ROC curves (AUCs) using a SPSS software syntax (PASW® statistics 18, IBM, Chicago, IL, USA). Confidence intervals were calculated defining the number of bootstrap replicates equal to 30,000. Comparison of the 2 AUCs occurred with a number of bootstrap replicates of 10,000 calculated using the R package.

In 2 patients (both benign pathological conditions) diffusion-weighted sequences could not be performed. Therefore 36 cases were included in the statistical analysis of DWI. The significance of the contingency between diffusion restriction of lesions resulting in high b-value images and their malignancy were rated using the two-tailed Fisher's exact test.

A two-sided Student's t-test for independent variables was used to compare ADC values of the different pathological conditions. A p value of less than 0.05 was considered statistically significant. Analyses were performed using Excel software (Microsoft, Redmond, WA, USA).

Results

There were 6 malignant and 32 benign final diagnoses available for statistical analysis: Malignant diagnoses included:

- 2 endometrial uterine tumours with ovarian metastases (1 clear-cell carcinoma with direct extension to the left ovary and metastasis in the right ovary; 1 malignant mixed Mullerian tumour with a liver metastasis first detected by MRI)
- 1 endometrioid uterine carcinoma with simultaneous endometrioid adenocarcinoma of the left ovary arising from an endometrioma
- 1 cystadenoma of the right ovary with simultaneous endometrial adenocarcinoma first detected by MRI
- 1 serous low-grade carcinoma of the ovary
- 1 borderline tumour classified as malignant for statistical purposes

On ultrasound the borderline tumour had been defined as benign (morphological score 4) whereas MRI attributed a high likelihood of malignancy. The endometrial adenocarcinoma in the patient with cystadenoma was not detected by TVUS but by MRI.

The remaining three cases were classified as indeterminate as the origin of the lesions remained to be established by TVUS, while all uterine tumour manifestations were correctly diagnosed by MRI.

In 4 patients with an indeterminate adnexal lesion at initial ultrasound, MRI as well as repeat TVUS failed to reveal a pathological lesion and surgery was cancelled.

In 2 patients with indeterminate adnexal lesions at TVUS, laparoscopic surgery confirmed the MRI diagnoses of intraligamental and subserosal leiomyomas, respectively (Fig. 1). In 1 additional patient MRI revealed subserosal leiomyoma and the patient decided against surgery.

Final diagnoses in 6 patients were mature teratoma. A specific diagnosis of teratoma was correctly made by MRI in all but one case of small recurrent disease. On ultrasound one malignant diagnosis (Kawai score 11) was suspected and a specific diagnosis had only been made in two cases.

In 8 cases histology revealed endometriomas (Fig. 2). In five cases, both methods established the correct diagnosis, while in 2 cases both methods classified benign lesions without specific diagnosis. In the remaining 1 case, MRI diagnosed endometrioma . This was also the most likely diagnosis at TVUS, however, with a Kawai score of 12, malignancy could not be excluded.

In 8 cases histopathology revealed cystadenomas or follicular cysts which all had been correctly classified by TVUS and MRI as most likely benign entities. In 1 case

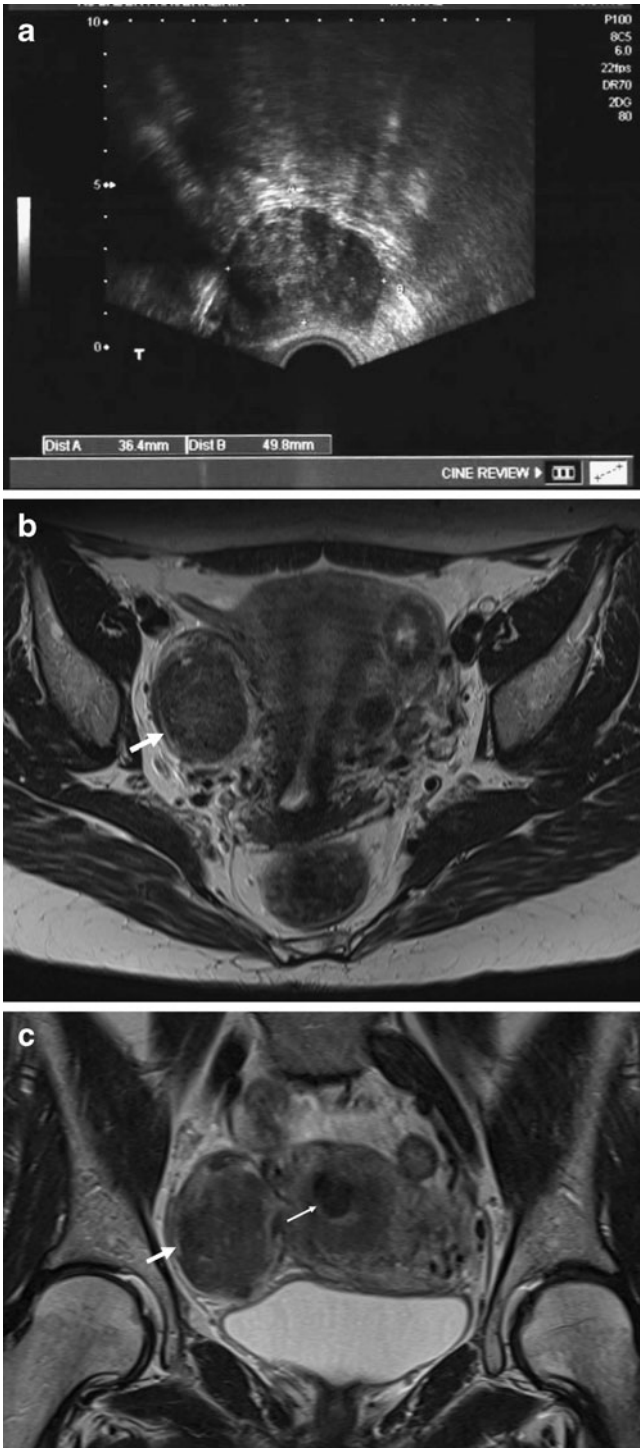

Fig. 1 A 48-year-old patient. **a** Transvaginal US image showed indeterminate adnexal lesion with a morphological score of 12, classified as malignant. MRI, axial **b** and coronal **c** T2-weighted FSE images of the pelvis showed pedunculated subserosal leiomyoma (*arrow*); a second smaller submucosal leiomyoma (*small arrow*) was also detected. Diagnosis was confirmed by histopathology. Additional diagnostic information from MRI was rated as major by the surgeon. In this case, alternative therapeutic options might have been discussed if MRI had been available before initial therapeutic decision-making

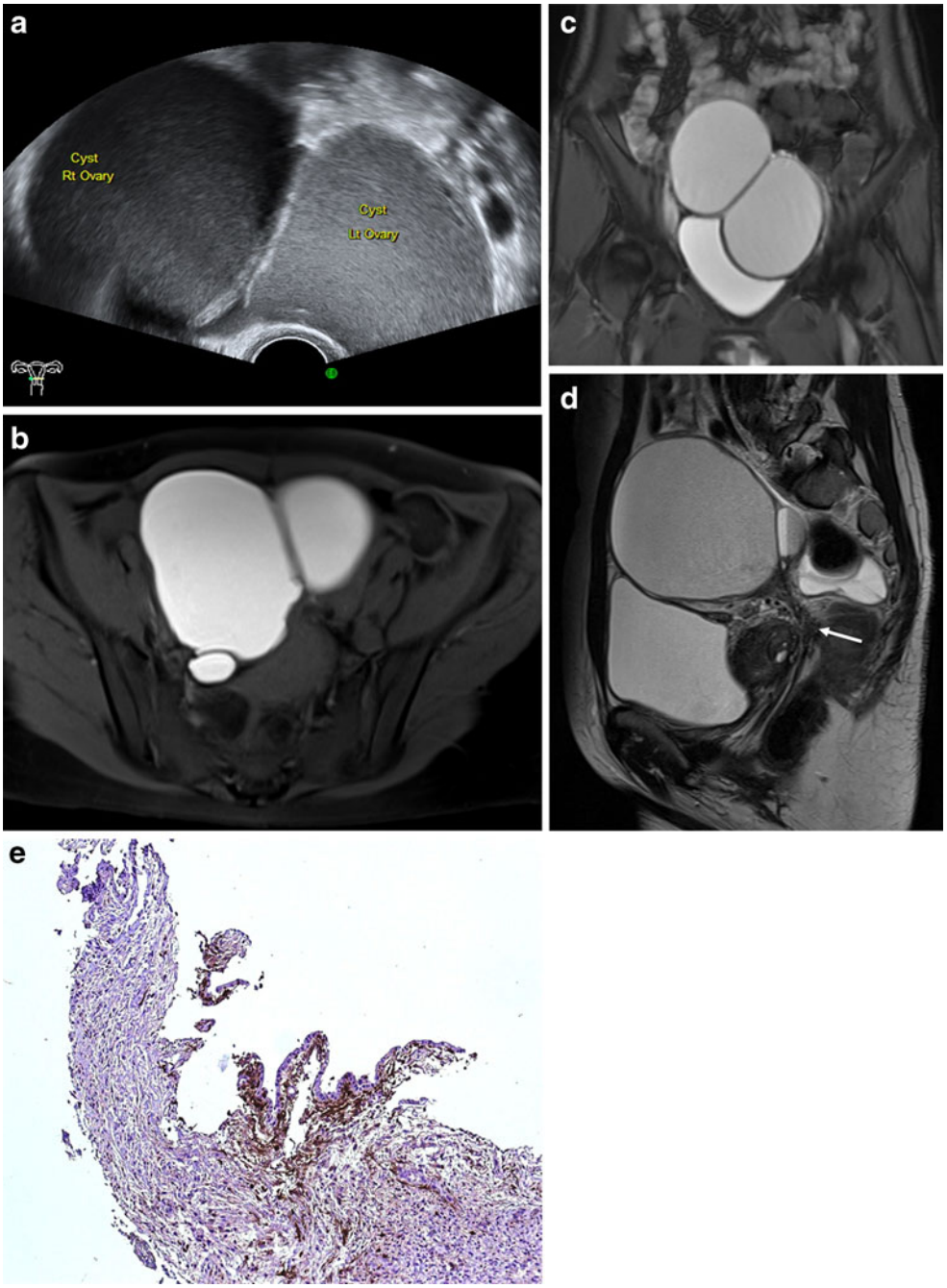

Fig. 2 A 32-year-old patient. **a** Transvaginal US image correctly diagnosed a large ovarian endometrioma. MRI **b** axial fast-saturated T1-weighted unenhanced FSE image, **c** coronal Truefisp image, **d** sagittal T2-weighted FSE image: MRI gave no significant additional information, but showed a good topographic overview demonstrating the cystic lesions with partial T2-shading as well as fibrotic changes in the cul-de-sac (arrow). **e** Microscopy shows part of an endometriotic cyst with immunohistochemically stained endometriotic stroma (CD10, magnification 200×)

TVUS was inconclusive while MRI correctly suspected sactosalpinx (Fig. 3).

In 2 cases of fibrothecomas, MRI correctly made a specific diagnosis, whereas TVUS was inconclusive in one case and malignancy (Kawai 11) was suspected in the other (Fig. 4).

Results comparing the diagnostic potential of TVUS versus MRI are displayed in a ROC curve and AUCs resulted in a significant difference ($p=0.005$; number of bootstrap replicates=10,000) with TVUS equal to 0.615 (95% CI: 0.364–0.852) and MR equal to 0.848 (95% CI: 0.667–1.000) (Fig. 5).

Influence of MRI on therapeutic decision-making

In 5 cases surgery was cancelled following MRI and therefore the patients were discharged the same day: in 4 patients MRI failed to reveal a pathological lesion and in 1 patient a subserosal leiomyoma was diagnosed.

In 6 further cases, MRI provided major additional diagnostic information: in one patient, ovarian carcinoma was diagnosed by TVUS, whereas MRI suspected benign fibrous lesions; multiple fibrothecomas were confirmed (Fig. 4). In another patient, TVUS suspected benign cystadenoma, whereas MRI revealed a high likelihood of

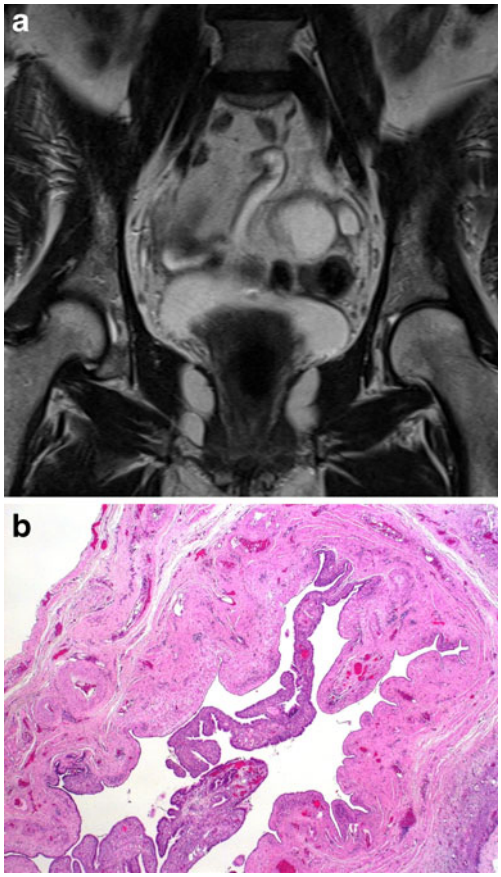

Fig. 3 A 49-year-old patient with an indeterminate lesion at ultrasound. MRI, **a** coronal T2-weighted MRI image of the pelvis shows a tubular hyperintense structure in the left adnexal region indicative of the diagnosis of sactosalpinx, which was confirmed by subsequent surgery. Additional information from MRI was rated as moderate. Microscopy **b** shows part of a cystically dilated Fallopian tube (H&E stain, magnification 25×)

malignancy. Histology showed a borderline tumour. In another patient with correctly suspected cystadenoma by TVUS, MRI was the first to suspect additional endometrial carcinoma, which was confirmed by histology.

In 2 patients with indeterminate adnexal masses on ultrasound MRI revealed subserosal leiomyomas that could be confirmed by laparoscopy (Fig. 1). A 24-year-old patient with unexplained pelvic pain and normal ultrasound was scheduled for laparoscopy. MRI was performed and demonstrated bilateral teratomas.

Therefore, MRI provided major additional diagnostic information in 11/38 cases (28.9%).

Moderate additional information from MRI was seen in 10/38 patients (26.3%) (Fig. 3).

Cost-effectiveness analysis

The cost of a contrast-enhanced MRI of the abdomen and pelvis is 658 EUR. This results in a total cost of 25'000 EUR for MR imaging in the 38 patients included in our study. For patients with compulsory health insurance, a flat rate ("Fallkostenpauschale") of 5'735 EUR is charged for the laparoscopic surgery including hospitalisation. Therefore, 28'677 EUR was saved in those 5 patients where surgery and hospitalisation were avoided because of the MR findings. This means that the use of MRI in our study population resulted in a net cost saving of 3'676 EUR.

Diffusion-weighted MRI

By visual analysis comparing b800 with ADC maps, areas of diffusion restriction were observed in 3/6 patients with malignant lesions and in 7/30 patients with benign lesions ($p=0.31$).

Of the 7 benign cases with diffusion restriction, 4 teratomas, 1 endometrioma, 1 haemorrhagic cyst and 1 fibrothecoma were encountered. None of the 3 leiomyomas showed restriction on high b-value images.

On a patient level, using the lowest ADC value in each case independent of its solid or cystic character, there was no statistical significant difference ($p=0.09$) between malignant ($0.937\pm0.069\times10^{-3}$ mm^2/s) and benign ($1.807\pm0.977\times10^{-3}$ mm^2/s) lesions.

Of the 6 patients with histological diagnosis of teratoma, 1 was a recurrent disease that was not detected by MRI at all. In the remaining 5 cases, one patient presented with bilateral teratomas and DWI sequence was not available in one 25-year-old patient. Mean ADC values of teratomas ($0.597\pm0.345\times10^{-3}$ mm^2/s; n=5 lesions/4 patients) differed significantly ($p=0.001$) in comparison to all other adnexal lesions (all lesions $1.812\pm0.837\times10^{-3}$ mm^2/s; cystic components only $2.233\pm0.602\times10^{-3}$ mm^2/s; solid components only $0.865\pm0.188\times10^{-3}$ mm^2/s) (Fig. 6).

Mean ADC values of endometrioma ($1.387\pm0.542\times10^{-3}$ mm^2/s; n=7) differed significantly ($p<0.0001$) from all other cystic components ($2.372\pm0.512\times10^{-3}$ mm^2/s; n=28).

Discussion

Our results demonstrate that the inclusion of MRI in the diagnostic algorithm for the pretherapeutic work-up of the indeterminate adnexal mass at ultrasound is beneficial in a clinical setting and therefore support the recommendations of the ESUR guidelines in a prospective study [3, 6]. The additional use of MRI in our study not only provided major or moderate additional diagnostic information in 55.3% of the patients, but even resulted in an abstention from surgery in five cases. Therefore a net cost saving was achieved over the entire study population.

Magnetic resonance imaging was shown to be superior to clinical findings combined with TVUS in the character-

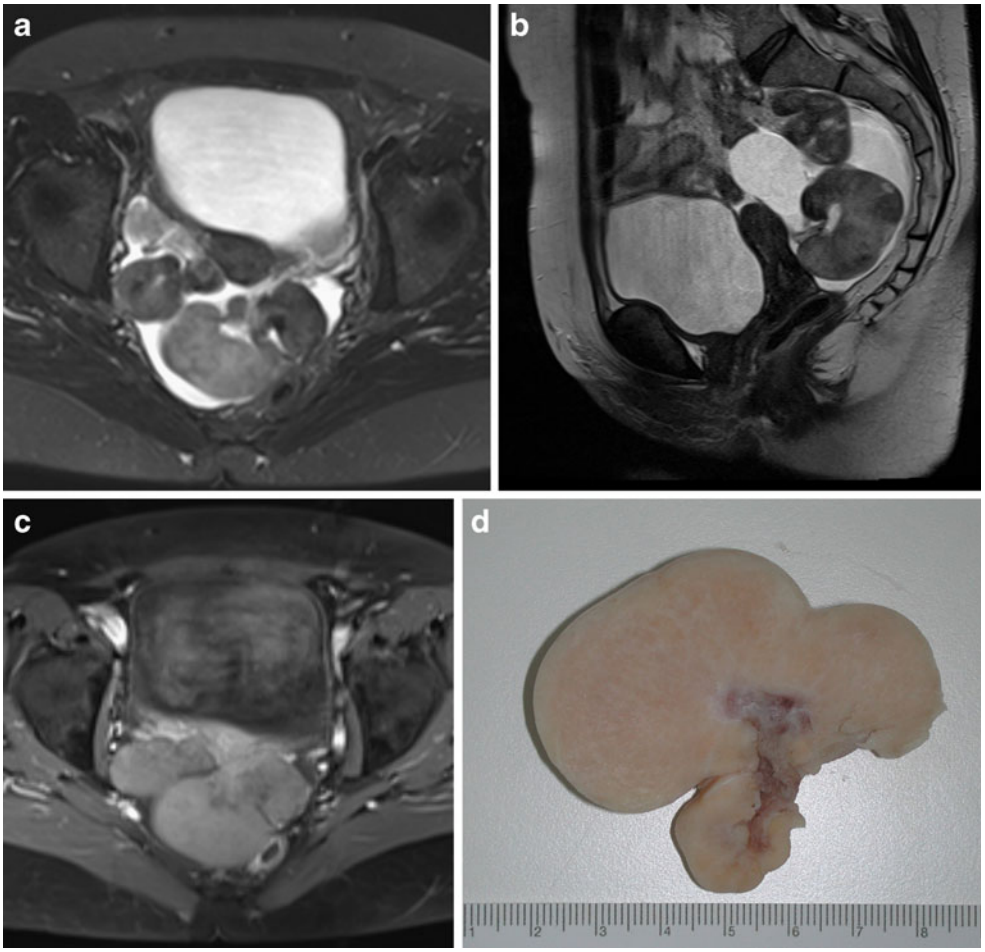

Fig. 4 A 53-year-old patient. Transvaginal US image indicated a high suspicion of ovarian carcinoma (morphological score 11). MRI, **a** axial STIR image, **b** sagittal T2-weighted FSE image, **c** axial contrast-enhanced T1-weighted FSE image. Multiple solid, T2-hypointense fibrous lesions with the differential diagnosis of fibrothecomas or subserosal/ligamental leiomyomas were demonstrated by MRI. Free fluid in the pouch of Douglas in this postmenopausal patient may also be associated with benign uterine or ovarian disease. **d** Macroscopic findings of solid tumour of the ovary with yellowish cut surface. Microscopically, a fibrothecoma was diagnosed (*not shown*). Impact of MRI was rated as major

isation of benign vs. malignant lesions (Fig. 5). MRI provided correct diagnosis in all 6 patients with malignancies including the ovarian borderline carcinoma. Providing a good overview of the anatomical pelvic and abdominal structure MRI might be helpful in determining the surgical approach. Furthermore, it allows detection of extra-pelvic metastases such as a liver metastasis [29].

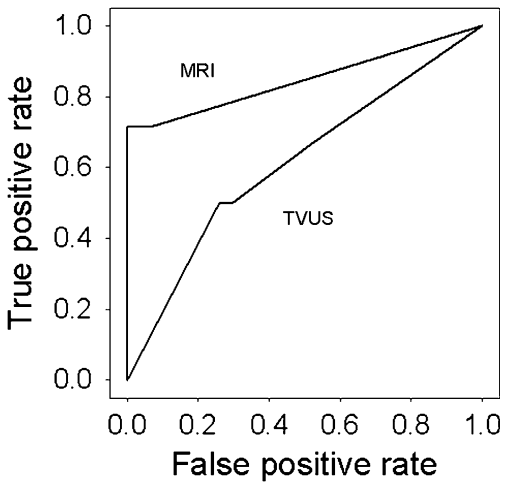

Fig. 5 Receiver-operating characteristic curve comparing the diagnostic potential of TVUS versus MRI: the curve demonstrates a significantly higher accuracy of MRI (p=0.005) in the characterisation of ovarian lesions

A further strength of MRI is its ability to determine the origin of a mass. Because fibrous tumours of the ovary have imaging features similar to those of fibroids, the recognition of the stalk and the identification of separate normal ovaries can help to confirm the diagnosis of fibroid [8] (Fig.1). In our study, 3 indeterminate adnexal masses at TVUS turned out to be uterine fibroids.

For complex ovarian pathological conditions, MRI is more likely to allow a specific diagnosis as corroborated by the patients with mature teratomas or fibrothecoma.

In none of the cases in which TVUS suspected cystadenomas was MRI able to provide additional information, advocating when excluding a corpus luteum cyst for direct referral to laparoscopic surgery.

In patients with endometrioma, MRI bears the advantage of also detecting smaller peritoneal implants for example in the cul-de-sac. However, in patients with endometriosis the decision to carry out laparoscopic surgery is usually based on clinical symptoms rather than on imaging findings [30–33].

DWI was implemented as a new approach to the work-up of lesions in the female pelvis. Although we did not evaluate DWI for the detection and characterisation of iliac

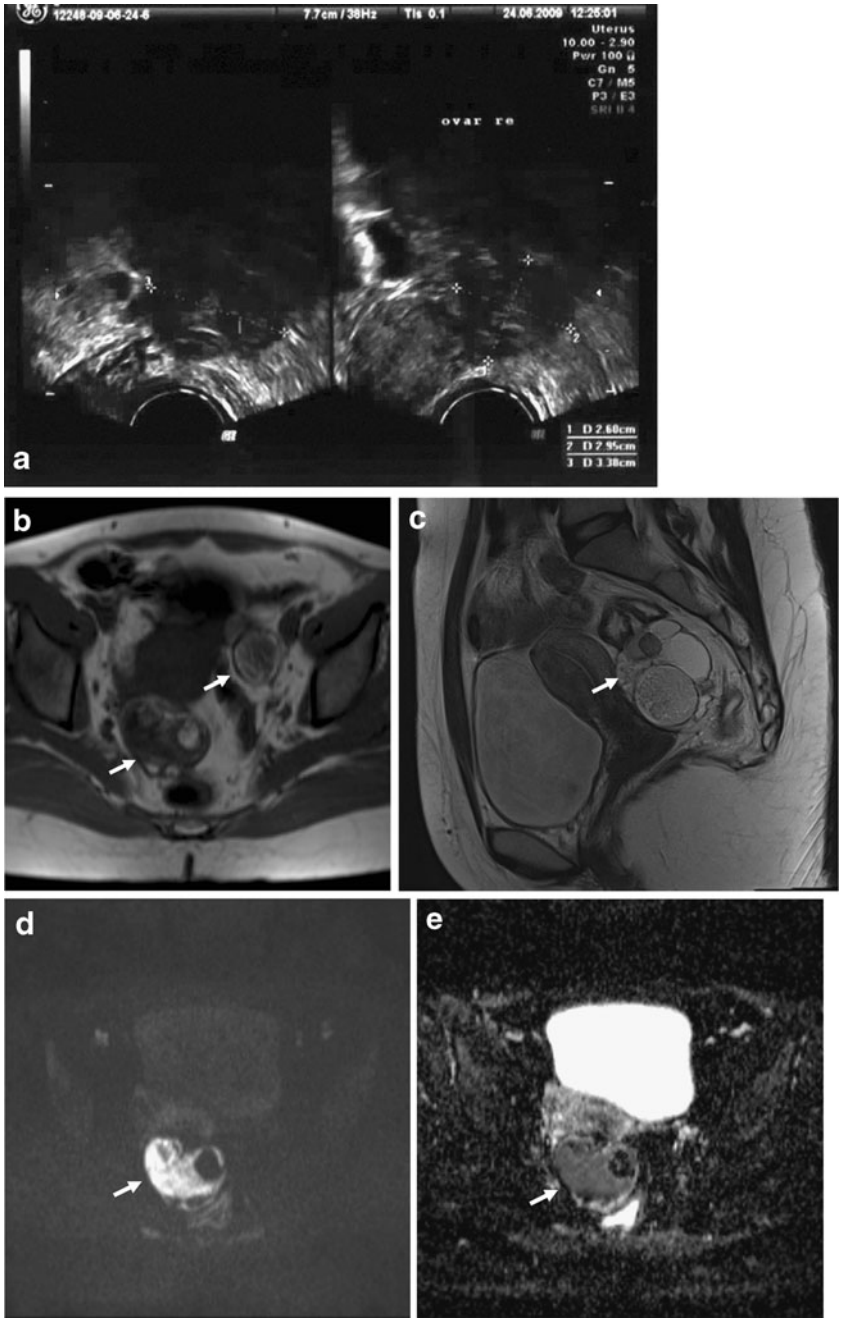

Fig. 6 24-year-old patient with severe pelvic pain. **a** Transvaginal US image did not reveal any ovarian lesions, but was impaired by bowel structures and therefore judged as inconclusive; the patient was scheduled for laparoscopy. MRI **b** axial T1-weighted unenhanced FSE image, **c** sagittal T2-weighted FSE images, **d**, **e** DWI, b800 and ADC map. MRI showed bilateral fat-containing lesions (*arrows*) with restriction on DWI (ADC of the right side $0.920 \pm 0.089 \times 10^{-3}$ mm^2/s; left side $0.788 \pm 0.179 \times 10^{-3}$ mm^2/s; only right lesion is shown on DWI images) allowing the specific diagnosis of bilateral mature teratomas, confirmed by subsequent surgery. The diagnostic information was rated as major

lymph nodes on a systematic basis, we found that it was superior to our standard morphological approach for the delineation of iliac lymph nodes and distinction from iliac vasculature structures [11, 12, 34–36].

In the present study there was no significant difference with regard to the presence of diffusion restriction in benign versus malignant lesions. This lack of significance may be attributed to the rather small number of patients with malignant ovarian lesions as well as inclusion of several cases of mature teratomas presenting low mean ADC values. Based on DW-MRI alone, teratoma cannot be distinguished from malignant tumours. This is however of little clinical relevance since accurate diagnosis is easily possible using conventional MRI (Fig. 6).

In patients with endometriosis, the mean ADC values of endometrial cysts differed significantly from all other cystic lesion components due to the presence of blood and hemosiderin [12, 15, 37–40]. Again, in this entity, specific diagnosis can usually be made based on clinical findings and morphological imaging showing the presence of haemorrhage and the T2 shading sign [33].

Further studies including a larger number of selected pathological conditions focusing in particular on solid lesions are warranted to explore for which entities DWI

might be advantageous with regard to adnexal lesion characterisation [41].

In this age of market-driven health care, medical decision analysis incorporating new imaging technologies under consideration of cost-effectiveness becomes essential to the design of disease-specific diagnostic algorithms [42, 43]. Therefore a further issue elucidated within the study was the cost-effectiveness of the diagnostic algorithm proposed by the ESUR guidelines for the work-up of indeterminate adnexal lesions [6, 10]. Cost savings in this study were only calculated in patients in whom surgery had been cancelled. Given that scheduled surgery was an inclusion criterion, threshold for cancelling surgery was rather high. Follow-up instead of surgery or other therapeutic strategies such as fibroid embolisation in the case of leiomyoma are probably underestimated. This might have further reduced the therapeutic costs. In addition, in all patients in whom MRI had a major or moderate diagnostic impact, but surgery was nevertheless performed (in 42.1% of all patients), potentially further economic benefit was not part of this cost-effectiveness analysis. Our cost-effectiveness analysis was based on patients with compulsory health insurance. Calculations are based on the Swiss national reimbursement system and cannot be directly translated to other countries. Nevertheless, abstention from surgery will most likely result in cost savings in most health care systems [43]. As documented in this study and others, new technologies such as MRI may not only improve medical care but also may decrease expenses [43].

There are certain limitations to our study. In this study, all TVUS had been performed by the referring gynaecologist, not by the radiologist, reflecting our local routine practice.

Although the inclusion criteria were clearly defined at the beginning of the study, there might be a selection bias because the gynaecologists chose their patients based on clinical and ultrasound findings. Therefore, TVUS was not an independent variable. However, this reflects the typical clinical setting.

Finally, our study population consists of patients with a large variety of pathological conditions of the female pelvis and a rather low number of malignant cases, thus hampering the analysis of subgroups, e.g. with regard to the value of DWI.

Conclusion

Inclusion of MRI into the diagnostic algorithm of adnexal masses that were indeterminate on TVUS does not only allow a better differentiation between benign and malignant ovarian lesions and improved organ attribution, but also results in a change in therapeutic decision-making in a substantial number of patients and in net cost savings. Therefore, the use of MR imaging before the final decision of conservative or surgical treatment is highly recommended.

Acknowledgements We would like to thank Alex Peters for his valuable technical assistance during the study. Moreover, the authors would like to thank Nicole Graf, MSc, for providing statistical support. We are grateful for the assistance from our colleagues of the Department of Gynecology in patient care.

This study was in part supported by a research grant from Guerbet Switzerland. Authors maintained full control of the data and there is no conflict of interest concerning the funding of this study and the addressed subject. Froehlich JM works as a consultant for Grebert. This had no implications for our research project.

References

1. Kurtz AB, Tsimikas JV, Tempany CM et al (1999) Diagnosis and staging of ovarian cancer: comparative values of Doppler and conventional US, CT, and MR imaging correlated with surgery and histopathologic analysis–report of the Radiology Diagnostic Oncology Group. Radiology 212:19–27
2. Kinkel K, Hricak H, Lu Y, Tsuda K, Filly RA (2000) US characterization of ovarian masses: a meta-analysis. Radiology 217:803–811
3. Spencer JA, Forstner R, Hricak H (2008) Investigating women with suspected ovarian cancer. Editorial Gynecol Oncol 108:262–264
4. Lucidarme O, Akakpo JP, Granberg S et al (2010) A new computer-aided diagnostic tool for non-invasive characterisation of malignant ovarian masses: results of a multicentre validation study. Eur Radiol 20:1822–1830
5. Outwater EK, Dunton CJ (1995) Imaging of the ovary and adnexa: clinical issues and applications of MR imaging. Radiology 194:1–18
6. Spencer JA, Forstner R, Cunha TM, Kinkel K, ESUR female imaging sub-committee (2010) ESUR guidelines for MR imaging of the sonographically indeterminate adnexal mass: an algorithmic approach. Eur Radiol 20:25–35
7. Sohaib SA, Mills TD, Sahdev A et al (2005) The role of magnetic resonance imaging and ultrasound in patients with adnexal masses. Clin Radiol 60:340–348
8. Adusumilli S, Hussain HK, Caoili EM et al (2006) MRI of sonographically indeterminate adnexal masses. AJR Am J Roentgenol 187:732–740
9. Iyer VR, Lee SI (2010) MRI, CT, and PET/CT for ovarian cancer detection and adnexal lesion characterization. AJR Am J Roentgenol 194:311–321
10. Spencer J, Ghattamaneni S (2010) MR Imaging of the sonographically indeterminate adnexal mass. Radiology 256:677–694
11. Whittaker CS, Coady A, Culver L, Rustin G, Padwick M, Padhani AR (2009) Diffusion-weighted MR imaging of female pelvic tumors: a pictorial review. Radiographics 29:759–774
12. Namimoto T, Awai K, Nakaura T, Yanaga Y, Hirai T, Yamashita Y (2009) Role of diffusion-weighted imaging in the diagnosis of gynecological diseases. Eur Radiol 19:745–760
13. Xue HD, Li S, Sun F et al (2008) Clinical application of body diffusion weighted MR imaging in the diagnosis and preoperative N staging of cervical cancer. Chin Med Sci J 23:133–137
14. Sala E, Priest AN, Kataoka M et al (2010) Apparent diffusion coefficient and vascular signal fraction measurements with magnetic resonance imaging: feasibility in metastatic ovarian cancer at 3 Tesla. Technical development Eur Radiol 20:491–496

15. Moteki T, Ishizaka H (2000) Diffusion-weighted EPI of cystic ovarian lesions: evaluation of cystic contents using apparent diffusion coefficients. J Magn Reson Imaging 12:1014–1019
16. Naganawa S, Sato C, Kumada H, Ishigaki T, Miura S, Takizawa O (2005) Apparent diffusion coefficient in cervical cancer of the uterus: comparison with the normal uterine cervix. Eur Radiol 15:71–78
17. McVeigh PZ, Syed AM, Milosevic M, Fyles A, Haider MA (2008) Diffusion-weighted MRI in cervical cancer. Eur Radiol 18:1058–1064
18. Tamai K, Koyama T, Saga T et al (2007) Diffusion-weighted MR imaging of uterine endometrial cancer. J Magn Reson Imaging 26:682–687
19. Inada Y, Matsuki M, Nakai G et al (2009) Body diffusion-weighted MR imaging of uterine endometrial cancer: is it helpful in the detection of cancer in nonenhanced MR imaging? Eur J Radiol 70:122–127
20. Tamai K, Koyama T, Saga T et al (2008) The utility of diffusion-weighted MR imaging for differentiating uterine sarcomas from benign leiomyomas. Eur Radiol 18:723–730
21. Fujii S, Matsusue E, Kanasaki Y et al (2008) Detection of peritoneal dissemination in gynecological malignancy: evaluation by diffusion-weighted MR imaging. Eur Radiol 18:18–23
22. Roussel A, Thomassin-Naggara I, Darai E, Marsault C, Bazot M (2009) Value of diffusion-weighted imaging in the evaluation of adnexal tumors. J Radiol 90:589–596
23. Low RN, Sebrechts CP, Barone RM, Muller W (2009) Diffusion-weighted MRI of peritoneal tumors: comparison with conventional MRI and surgical and histopathologic findings—a feasibility study. AJR Am J Roentgenol 193:461–470
24. Kawai M, Kano T, Kikkawa F, Maeda O, Oguchi H, Tomoda Y (1992) Transvaginal Doppler ultrasound with color flow imaging in the diagnosis of ovarian cancer. Obstet Gynecol 79:163–167
25. Froehlich JM, Daenzer M, von Weymarn C, Erturk SM, Zollikofer CL, Patak MA (2009) Aperistaltic effect of hyoscine N-butylbromide versus glucagon on the small bowel assessed by magnetic resonance imaging. Eur Radiol 19:1387–1393
26. Hricak H, Chen M, Coakley FV et al (2000) Complex adnexal masses: detection and characterization with MR imaging—multivariate analysis. Radiology 214:39–46
27. Outwater E, Schiebler ML, Owen RS, Schnall MD (1993) Characterization of hemorrhagic adnexal lesions with MR imaging: blinded reader study. Radiology 186:489–494
28. TARMED Suisse Tariff release 1.07.01 in effect since 1.4.2010, positions 39.5110 and 39.5010; accessed on 15 August 2010 www.tarmedsuisse.ch/87html
29. Booth SJ, Turnbull LW, Poole DR, Richmond I (2008) The accurate staging of ovarian cancer using 3T magnetic resonance imaging—a realistic option. BJOG 115:894–901
30. Patel MD, Feldstein VA, Chen DC, Lipson SD, Filly RA (1999) Endometriomas: diagnostic performance of US. Radiology 210:739–745
31. Bazot M, Darai E, Hourani R et al (2004) Deep pelvic endometriosis: MR imaging for diagnosis and prediction of extension of disease. Radiology 232:379–389
32. Zanardi R, Del Frate C, Zuiani C, Bazzocchi M (2003) Staging of pelvic endometriosis based on MRI findings versus laparoscopic classification according to the American Fertility Society. Abdom Imaging 28:733–742
33. Gougoutas CA, Siegelman ES, Hunt J, Outwater EK (2000) Pelvic endometriosis: various manifestations and MR imaging findings. AJR Am J Roentgenol 175:353–358
34. Lin G, Ho KC, Wang JJ et al (2008) Detection of lymph node metastasis in cervical and uterine cancers by diffusion weighted magnetic resonance imaging at 3T. J Magn Reson Imaging 28:128–135
35. Lin G, Ng KK, Chang CJ et al (2009) Myometrial invasion in endometrial cancer: diagnostic accuracy of diffusion weighted 3.0-T MR imaging—initial experience. Radiology 250:784–792
36. Park SO, Kim JK, Kim KA et al (2009) Relative apparent diffusion coefficient: determination of reference site and validation of benefit for detecting metastatic lymph nodes in uterine cervical cancer. J Magn Reson Imaging 29:383–390
37. Katayama M, Masui T, Kobayashi S et al (2002) Diffusion-weighted echo planar imaging of ovarian tumors: is it useful to measure apparent diffusion coefficients? J Comput Assist Tomogr 26:250–256
38. Nakayama T, Yoshimitsu K, Irie H et al (2005) Diffusion-weighted echo-planar MR imaging and ADC mapping in the differential diagnosis of ovarian cystic masses: usefulness of detecting keratinoid substances in mature cystic teratomas. J Magn Reson Imaging 22:271–278
39. Silvera S, Oppenheim C, Touzé E et al (2005) Spontaneous intracerebral hematoma on diffusion-weighted images: influence of T2-shine through and T2-blackout effects. AJNR Am J Neuroradiol 26:236–241
40. Maldjian JA, Listerud J, Moonis G, Siddigi F (2001) Computing diffusion rates in T2-dark hematomas and areas of low T2 signal. AJNR Am J Neuroradiol 22:112–118
41. Padhani AR, Liu G, Koh DM et al (2009) Diffusion-weighted magnetic resonance imaging as a cancer biomarker: consensus and recommendations. Neoplasia 11:102–125
42. Hricak H, Powell CB, Yu KK et al (1996) Invasive cervical carcinoma: role of MR imaging in pretreatment work-up—cost minimization and diagnostic efficacy analysis. Radiology 198:403–409
43. Parker RG (1993) The “cost-effectiveness” of radiology and radiologists. Radiology 189:363–369