Urol Res (1991) 19:349–352

Urological Research

^{31}P MR spectroscopy and ^{1}H MR imaging of the human prostate using a transrectal probe*

F. Hering[1], and S. Müller[2]

[1]Urology Clinic, University Hospital and [2]MR center of the University, Basel, Switzerland

Accepted: June 1, 1991

Summary. ^{1}H magnetic resonance imaging and ^{31}P magnetic resonance spectroscopy of the human prostate using transrectal surface coild are discussed. ^{1}H MR images were characterized by a high sensitivity, revealing many details in the prostate. Localized ^{31}P spectra acquired during the same investigation showed phosphorous metabolites, which may help differentiate between benign prostatic hyperplasia and prostate carcinoma. An endoscopic transmit-receive radio frequency (RF) antenna is also described which can be used with very low RF power.

Key words: Human prostate – ^{31}P magnetic resonance Spectroscopy – ^{1}H magnetic resonance imaging

Conventional magnetic resonance imaging (MRI) of the prostate used strictly non-invasively by means of volume coils or surface coils operating at the periphery of the body often lacks the ability to predict in correct tumour stage, especially in distinguishing tumour infiltration of the capsule or infiltration of the seminal vesicles. Stimulated by the work of Narayan and Hricak [2], who recently reported differences in metabolic concentrations of benign prostate hyperplasia (BPH) and prostate carcinomas (PC) using a transrectal probe for ^{31}P spectroscopy, we developed a transrectal probe designed for ^{31}P MR spectroscopy and ^{1}H MRI.

Materials and methods

Twenty-one patients (11 with BPH and 10 with PC) were investigated in this study. Fourteen patients were evaluated with ^{1}H imaging, and in 7 patients ^{31}P spectra were acquired; in 2 patients both imaging and spectroscopy were performed. Ten patients suffered PC; in 4 cases MRI was performed before radical prostectomy. Eleven patients with BPH served as controls.

All in vivo measurements were performed with a Siemens whole body Magneton (Helikon type) operating at 1.5 T. The patients were placed in the prone position, with the head pointing towards the centre of the magnet. After a digital palpation, the probe was positioned under the prostate, and its position was verified using ^{1}H imaging with the endoscopic coil.

^{31}P spectroscopy, ^{1}H shimming and ^{1}H imaging were carried out with the same endorectal transmit-receive surface coil. The coil was protected by a smoothly rounded cover made of hard plastic (length 12 cm, outer diameter 2 cm), surrounded by a condom and lubricated with jelly (Instillagel®), for slight local anaesthesia. The tuning and matching circuit of the probe was placed in a Faraday shielded box close to the coil and could be manipulated in situ from outside the magnet (Fig. 1). Switching between the ^{31}P and ^{1}H frequency

* A preliminary account of this work was presented at the 9th Annual Meeting of the Society of Magnetic Resonance in Medicine, New York, 18–24 August 1990

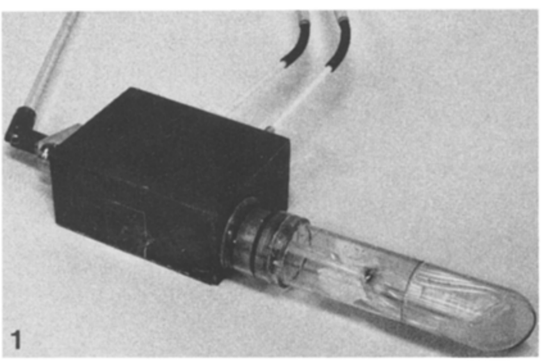
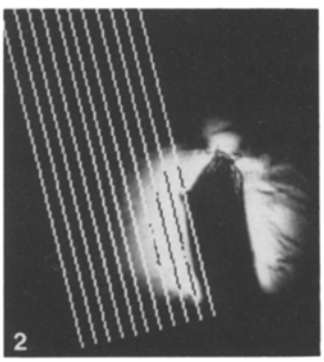



Fig. 1. Radiofrequency coil used in this study for the transrectal investigation of human prostate. The coil can be used in situ for ^{1}H imaging and ^{31}P spectroscopy. The outer diameter of the insert is 2 cm. Electronic tuning and matching devices and the switch for the frequency change (^{1}H to ^{31}P) are seen on top and on the left side of the instrument. The RF cable is not connected

Fig. 2. ^{1}H scout images obtained with the endoscopic coil. Sagittal orientation showing the prostate on the left side of the image (ventral to the coil insert). Using such images the subsequent paracoronal imaging planes are selected, producing the graphical overlays (*white stripes*) at the position on the slices

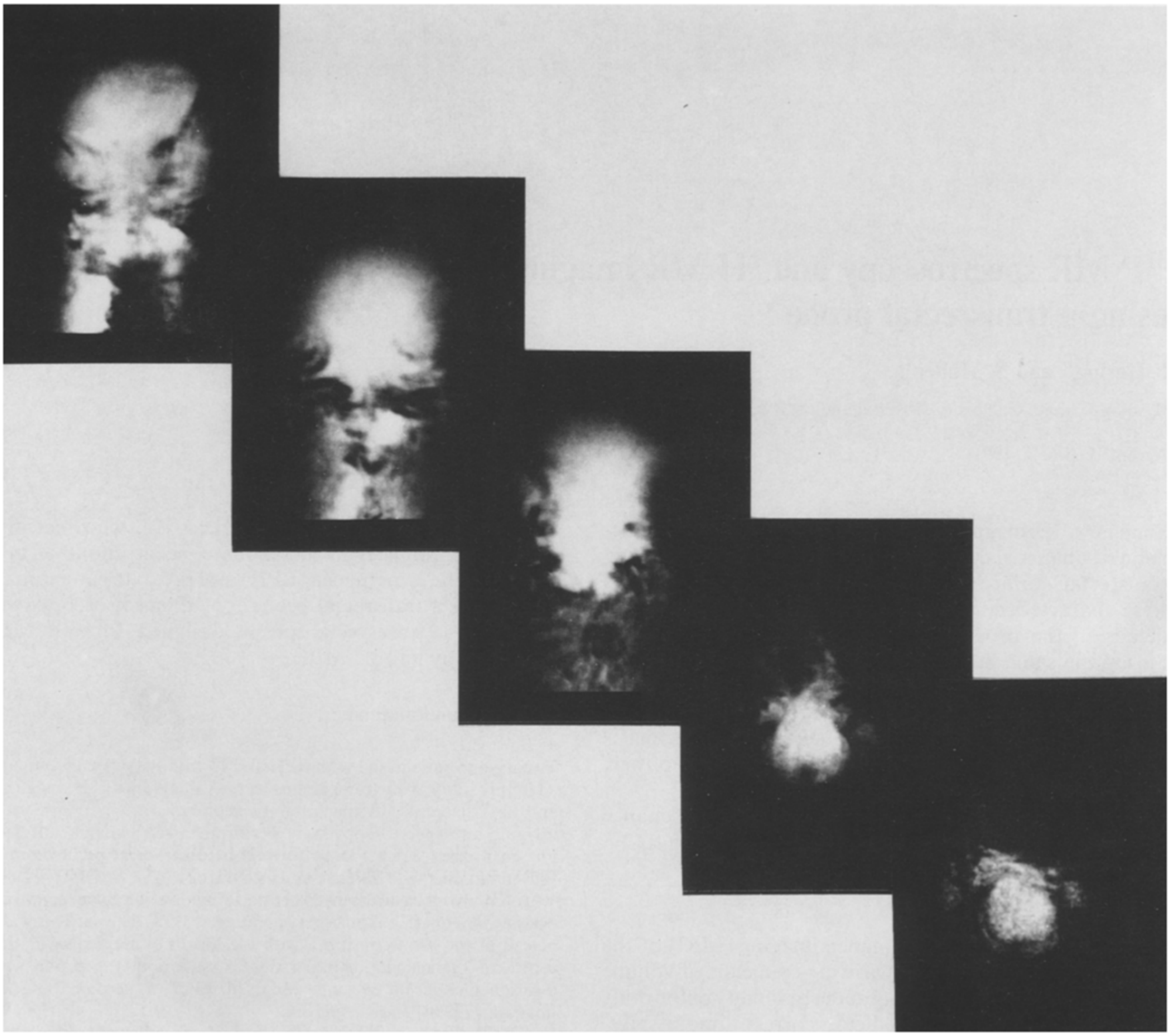


Fig. 3. Five parallel cross-sectional images selected from the set of images in Fig. 2. On the left side images close to the RF coil are shown and on the right side the zones further away from the coil are displayed

was realized with a second tuning capacitor which could be turned on and off and allowed tuning of the probe to either frequency [1]. ^{1}H images were obtained with conventional two- dimensional FISP [3] sequences and slice orientations parallel to the radiofrequency (RF) coil plane. A sagittal scout view through the region of interest is shown in Fig. 2. Based on such an image, paracoronal cross-sections through the prostate can be defined and measured as shown in Fig. 3. Typical imaging parameters were repetition time (TR) = 0.3; s, echo time (TE) = 11 ms; slice thickness = 3 mm; number of slices = 10. Peak voltage of the RF pulses was always below 20 V.

^{31}P spectra of the peripheral part of the prostate were measured using a pulse-acquire experiment (200 μs rectangular pulse, 1 ms delay before acquisition) generating a flip angle of approximately 180° at the centre of the coil. TR in spectroscopy was 1.5 s; typically 256 FIDs were acquired, resulting in about 7 min of measurement time. Magnet shimming was performed with the same coil tuned to ^{1}H. Water linewidths of 20–50 Hz at 65 MHz were also obtained.

Including the scout view and local shimming, a total examination time of 20–25 min was required.

PCA extracts of PC tissue obtained after transurethral resection (TUR) were measured in vitro and compared with the in vivo results. ^{31}P specta of the extracts were measured in a Bruker MSL 400 system at a phosphorus frequency of 162 MHz.

Results

The ^{31}P spectra of a patient with BPH, a patient with PC stage T4 N2, and the in vitro spectrum of the tissue of the latter patient obtained by TUR are displayed in Fig. 4. There were no obvious differencies in adenosine triphosphate (ATP) concentrations, but generally a higher phosphomonoester/ATP ratio in patients with PC. The same observation was made by Thomas, et al. [4], who reported similar ^{31}P spectra using a transrectal probe.

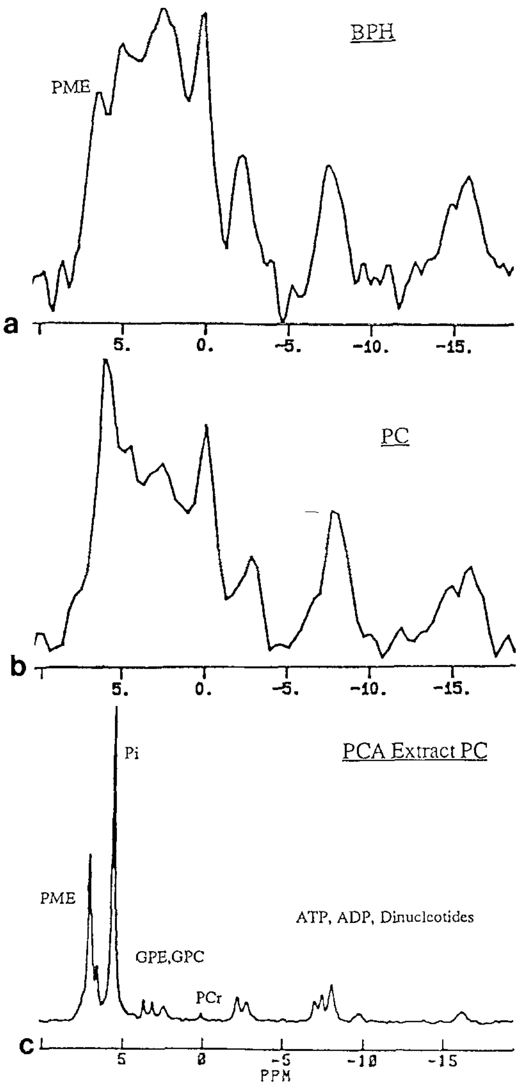


Fig. 4a–c. Comparison of ^{31}P spectra of a patient with benign prostate hyperplasia (**a**), prostate carcinoma (**b**) and tissue obtained after transurethral resection for PC (p **c**). Note the differences in the PME intensity between the BPH and the PC patient

Figures 5 and 6 show typical ^{1}H images of a patient with BPH. the probe was positioned in the rectum surrounded by air, stool and lubricating jelly. Ventrally to the probe the prostate is seen with a smooth capsule and a regular inner structure. In Fig. 6a longitudinal image is shown with parts of the os pubis.

Figures 7 and 8 show a patient who underwent radical prostatectomy for a pT3 pNo carcinoma. The pathohistological report described an infiltration of periprostatic fat without involvement of the seminal vesicles. On both sides, the border between the prostate and the capsule is lost. Moreover, the inner structure of the gland has a somewhat irregular pattern. The hole in the prostate corresponds to the urethra.

Discussion

The aim of this preliminary study was to investigate whether clinical staging of prostate carcinoma can be improved by means of transrectal MRI. Computed tomography and non-invasive MRI using RF coils operating at the periphery of the body are often restricted in predicting the correct local tumour stage, especially in detecting tumour spread in the so-called prostate capsule as well as infiltrating the seminal vesicles. The error in conventional imaging is as high as 50%.

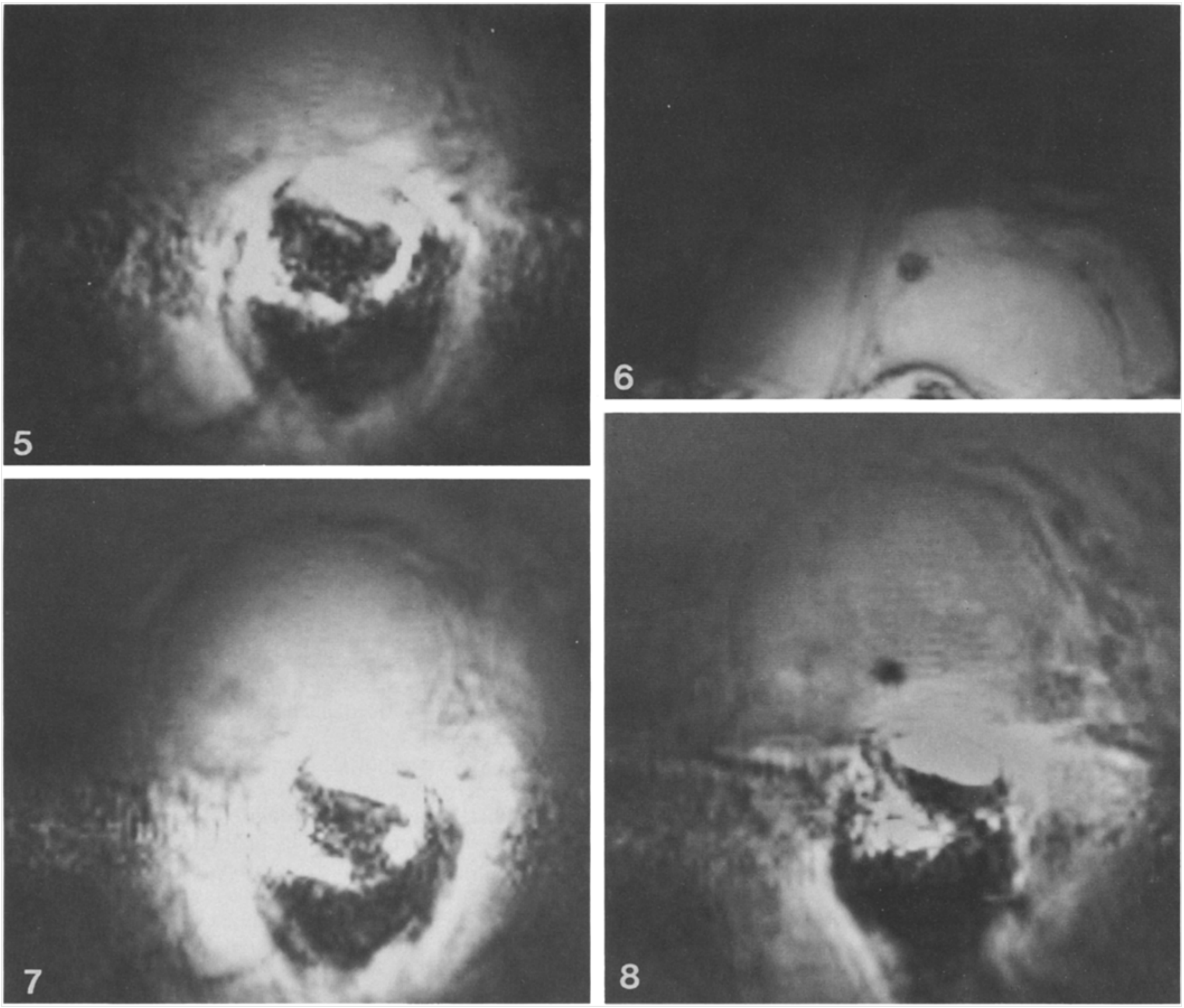
In contrast, endoscopic imaging enables the demonstration of tumour infiltration of surrounding strutures. Therefore, transrectal investigation of the human prostate with MRI was implemented in this study. MR data of high sensitivity were obtained by using a small local surface coil, straightforward probe handling, and a high filling factor.

When measuring with endoscopic RF coils local heating is important. Conventional MRI based on receive-only surface coils and a larger volume coil as the transmitter could provide hot spots unless special precautions are taken. In addition, the performance of a receive-only surface coil is difficult to monitor and control in situ. In our study we therefore used the endoscopic surface coil in a transmit and receive mode. In this way only very low power is required for the excitation of the MR signals and the power deposition can be calculated, controlled and adjusted at will.

One drawback of this approach was reduced image homogeneity throughout the field of view, especially if transaxial images were required. Different imaging schemes were therefore tested, including adiabatic numerically optimized NOM RF pulses [5] which provide a spatially homogeneous excitation as soon as a certain threshold RF pulse power is reached. These pulses are not slice selective, and three-dimensional volume imaging was therefore implemented for this case. For prostate imaging, however, intense motion artefacts in both phase-encoding directions were observed which were caused by peristaltis of the bowels and spontaneous motion of the patient. Therefore, image quality was insufficient in this case. Better results were obtained with two-dimensional gradient echo imaging, especially for imaging planes oriented parallel to the RF coil plane. Investigations of the human prostate, where infiltration of a carcinoma into seminal vesicles if of interest, can easily be conducted with this special image plane orientation.

The results obtained so far have demonstrated the feasibility and reliability of this new approach for the investigation of the human prostate. In the future it should be possible to detect suspicious areas more or less confined to the prostate by ^{1}H imaging and to distinguish benign from malignant tissue by means of ^{31}P spectroscopy using the same probe.

In conclusion, we propose the use of transrectal ^{31}P MR spectroscopy and ^{1}H MR imaging for investigating the human prostate. Phosphomonoester/ATP ratios found in BPH and carcinomas may help distinguish between these prostatic diseases. Infiltration of the seminal vesicles or capsular penetrations may be detected with



Figs. 5, 6. ^{1}H-imaging of prostates with benign hyperplasia. The "capsule" is clearly visible. The homogeneous structure of the gland is typical for the benign prostate hypertrophy

Figs. 7, 8. ^{1}H imaging of a patient who underwent radical prostatectomy for a pT3 tumour. *Darker areas* and a somewhat irregular pattern of the prostate are typical for PC. In Fig. 8 the left part of the capsule cannot be differentiated from the prostate

^{1}H MRI. The heterogenous structure in case of carcinoma, again in combination with the spectrum, can help to establish the diagnosis. The problem of local heating with the RF probe is avoided by using the proposed set-up.

References

1. Müller S, Aue WP, Seelig J (1985) NMR imaging and volume selective spectroscopy with a single surface coil. J Magn Reson 63:530
2. Narayan P, Hricak H (1987) Promising areas of research explored at Veterans Administration Medical Center, vol 5. VA Medical Center, p 11
3. Oppelt A, Graumann R, Barfuss H, Fischer H, Hartl W (1986) FISP, a new fast pulse sequence for nuclear magnetic resonance. Electromedica 54:15
4. Thomas MA, Kurhanewicz J, Jajodia P, James TL, Narayan P, Weiner MW (1990) Transrectal localized 31-Phosphorous MR Spectroscopy of human prostate in vivo. Proceedings of the 9th Annual Meeting of the Society of Magnetic Resonance in Medicine, New York, 18–24 August, p 965
5. Ugurbil K, Garwood M, Rath AR (1988) Optimization of modulation functions to improve insensitivity of adiabatic pulses to variations of B1 magnitude. J Magn Reson 80:448

Priv.-Doz. Dr. F. Hering
Urologische Klinik
Kantonsspital
CH-5404 Baden
Switzerland