EFFECTS OF A MEDICAL EXPERT SYSTEM ON DIFFERENTIAL DIAGNOSIS OF RENAL MASSES: A PROSPECTIVE STUDY

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Abstract—A medical expert system, RMDS, was used to prospectively evaluate patients undergoing nephrectomy for suspected renal masses. The effects of a medical expert system on differential diagnosis of renal masses were investigated. After RMDS consultation, three chief residents and one junior attending physician changed their preoperative diagnosis and significantly increased their diagnostic accuracy. The results indicate that the medical expert system may have an useful role in preoperative diagnosis of renal masses.

Key Words: Medical expert system, Renal mass

INTRODUCTION

Expert system is a computer-based consultation system using artificial intelligence techniques to emulate the decision-making behavior of an expert in a specialized, knowledge-intensive field (1, 2). ILIAD is a medical expert system for internal medicine, dermatology, obstetrics/gynecology, and psychiatry (3–5). The ILIAD expert system shell was used here to develop a preoperative renal mass diagnosis system, or RMDS. The RMDS makes use of functions of consultation and simulation to provide physicians with tools for doing preoperative differential diagnosis of renal masses.

It is difficult to differentiate preoperatively some benign renal diseases such as xanthogranulomatous pyelonephritis, renal abscess and benign tumors from other malignant renal tumors. However, the diagnostic process is necessary because the method of management is different in benign renal lesions, malignant renal parenchymal tumors and malignant renal pelvic tumors. Usually, partial nephrectomy or simple nephrectomy is the method of management for benign renal lesion; radical nephrectomy is the primary treatment for malignant renal parenchymal tumor (6) and nephroureterectomy is the standard therapy for malignant renal pelvic tumor (7, 8). Therefore, the RMDS expert system was tried for prospective evaluation of patients undergoing nephrectomy for suspected renal mass, then examined the effects of the RMDS expert system on physicians' differential diagnoses of renal masses.

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MATERIALS AND METHODS

ILIAD is a medical expert system which uses knowledge frames to teach medical students about differential diagnosis (3). It is written in C for the Macintosh computer. A Windows version of ILIAD has also been developed for IBM PC-compatibles. From September 1991, the ILIAD system shell was used to develop a preoperative renal mass diagnosis system, RMDS for IBM-compatible microcomputers.

The RMDS expert system contains 18 renal mass probabilistic frames, each containing findings to be expected in the disease. These clinical findings were processed sequentially, using Bayes theorem, which permits use of sensitivities and specificities to describe the relationship of a disease to its manifestations, and provides a basis for explaining its conclusions. Seven intermediate diagnoses were built as deterministic frames. Deterministic frames were Boolean decision frames which adopt conditionally dependent information and represent valuable clinical, specific combinations of information. This is a function inherently implemented in the ILIAD system shell (3, 4).

RMDS can provide a preoperative differential diagnosis for renal masses by utilizing: (1) basic personal data; (2) medical history; (3) symptoms and signs; (4) laboratory data; and (5) specific diagnostic procedures including ultrasonography (US), intravenous urography (IVU), retrograde urography (RU), computed tomography (CT) scanning, renal angiography and magnetic resonance imaging (MRI).

From March 1993 to April 1994, 123 consecutive patients were admitted to our hospital with suspected diagnosis of renal mass. After a complete history was taken and a physical examination performed, urinalysis and a plain film of the abdomen followed. All patients underwent the usual preoperative diagnostic evaluation for renal masses. One patient expired before operation, and 59 patients had a definite preoperative diagnosis. The remaining 63 patients who had no definite preoperative diagnosis constituted the study population. Patient age ranged from 21 to 82 years, with an average age of 62 years. There were 34 men and 29 women. Of these 63 patients, 56 patients received IVU and 53 patients, US. Fifteen patients had RU study because of poor visualization of IVU. All patients had CT scan, eight patients had renal angiography and four patients had MRI. Details of the screening modality are shown in Table 1.

In this study, 18 diagnostic categories were considered including benign lesions, malignant renal parenchymal tumors and malignant renal pelvic tumors. The preoperative patient characteristics considered important in differential diagnosis of renal mass are described in Table 2. The characteristics included clinical and radiographic parameters. The diagnosis made by RMDS was considered as "preoperative diagnosis" if the likelihood of this diagnosis was predicted as greater than 50%, and the diagnosis appeared at the top of the differential diagnosis list of RMDS.

Table 1. Detail of the screening modality in 63 patients

Screening modality	No.
IVU + CT	5
US + CT	7
IVU + RU + CT	5
IVU + US + CT	24
IVU + US + RU + CT	10
IVU + US + CT + Angiography	8
IVU + US + CT + MRI	4
Total	63

IVU = intravenous urography; US = ultrasonography; CT = computerized tomography; RU = retrograde urography; MRI = magnetic resonance imaging

Before surgical exploration of the kidney, one junior urologic attending physician and three urologic chief residents (numbered as CR-1, CR-2 and CR-3) were asked to state the most likely diagnosis for each case. Clinical findings of patients were then input into RMDS by another physician, preoperatively. The diagnosis made by RMDS was then shown to all physicians, and they were asked whether they would like to change their diagnosis.

Surgical exploration of the kidney was done on each patient, and frozen section during operation was performed for histological examination if diagnosis was uncertain. The preoperative diagnoses made by RMDS and physicians were compared with the final histological diagnosis to test the validity of the expert system and examine the effects after RMDS consultation on physicians' diagnoses of renal masses.

McNemar's test was used to measure the statistical significance of the difference between RMDS and physicians' diagnoses. The paired t test was used to measure any statistical difference in physicians' diagnoses before and after RMDS consultation.

RESULTS

Of the 63 patients with uncertain preoperative diagnosis, who underwent surgical exploration of the kidney, 55 had renal parenchymal tumors, eight had renal pelvic tumors. The RMDS correctly categorized the renal mass in 57 of the 63 patients, yielding a 90% overall preoperative diagnostic accuracy. The average overall diagnostic accuracy for renal masses of the three chief residents was 72% and the diagnostic accuracy of junior attending physician was 83%. All were less accurate than RMDS to a significance level of $p<0.05$.

After RMDS expert system consultation, the three chief residents changed their diagnosis, increasing the average overall diagnostic accuracy for renal masses to 85%. The diagnostic accuracy of the three chief residents after RMDS consultation is significantly better than those before RMDS consultation ($p<0.01$). The diagnostic accuracy of the junior attending physician also had significant difference before and after RMDS consultation. The number of correct preoperative diagnoses of renal masses made by RMDS and physicians' diagnoses before and after RMDS consultation are shown in Table 3.

In these 63 test cases, IVU, US and CT were the modalities most widely utilized. Forty-six patients received IVU as a initial study and were evaluated

Table 2. Preoperative characteristics of patients with renal masses

No. of patients	Total cases ($n=63$)	R. Parenchymal T. Mal. (%) ($n=46$)	R. Parenchymal T. Ben. (%) ($n=9$)	R. pelvic T. Mal. (%) ($n=6$)	R. pelvic T. Ben. (%) ($n=2$)
Male	34	27(59)	3(33)	4(67)	0
Female	29	19(41)	6(67)	2(33)	2
Age <50yr	18	12(26)	3(33)	2(33)	1
Age ≥50yr	45	34(74)	6(67)	4(67)	1
Smoking history	38	29(63)	3(33)	6(100)	0
General malaise	28	24(52)	1(11)	3(50)	0
Body weight loss	16	15(33)	0	1(17)	0
Abdominal distention	20	18(39)	1(11)	1(17)	0
Anemia	8	8(17)	0	0	0
Hypertension	14	12(26)	1(11)	1(17)	0
D.M.	15	13(28)	1(11)	1(17)	0
Azotemia	3	2(4)	0	1(17)	0
Gross hematuria	30	20(43)	3(33)	6(100)	1
Microscopic hematuria	23	18(39)	4(44)	0	1
Pyuria	10	5(11)	3(33)	2(33)	0
Urine culture (+)	10	5(11)	3(33)	2(33)	0
Flank pain	45	33(72)	7(78)	4(67)	1
CVA tenderness	40	31(67)	6(67)	3(50)	0
Flank mass	33	29(63)	3(33)	1(17)	0
Fever and chills	6	3(7)	2(22)	1(17)	0
Urine cytology (+)	3	0	0	3(50)	0
Lesion <10cm	42	28(61)	7(78)	5(83)	2
Lesion ≥10cm	21	18(39)	2(22)	1(17)	0
Smooth margins	15	6(13)	8(89)	1(17)	0
Irregular margins	48	40(87)	1(11)	5(83)	2
Homogeneous	7	1(2)	6(67)	0	0
Inhomogeneous	39	36(78)	3(33)	0	0
Combined renal calculi	5	3(7)	2(22)	0	0
Central calcification	3	3(7)	0	0	0
Cystic-like lesion	1	0	1(11)	0	0
Solid mass	62	46(100)	8(89)	6(100)	2
Round in shape	6	4(9)	2(22)	0	0
Intraluminal filling defect	12	3(7)	1(11)	6(100)	2
Collect system distortion	36	27(59)	4(44)	4(67)	1
Poor function kidney	26	21(46)	3(33)	2(33)	0
Hypovascular	2	2(4)	0	0	0
A-V fistula	3	2(4)	1(11)	0	0
Neovascularity	6	5(11)	1(11)	0	0
Central bleeding	4	2(4)	2(22)	0	0
High fat content	4	0	4(44)	0	0
Renal pelvis soft mass	11	3(7)	0	6(100)	2
Perirenal LN enlargement 5	4(9)	0	1(17)	0	
Retroperitoneal contiguous LN masses	2	2(4)	0	0	0
Bone metastasis	5	4(9)	0	1(17)	0
Lung metastasis	3	2(4)	0	1(17)	0
Liver metastasis	3	2(4)	0	1(17)	0

R. Parenchymal T. = Renal Parenchymal Tumor, R. Pelvic T. = Renal Pelvic Tumor, Mal. = Malignant, Ben. = Benign

further by US and CT scan. Of the 46 patients, additional RU study in 10 patients, renal angiography in eight patients and MRI in four patients were performed. Ten patients had IVU and CT scan without US study. In five of these 10 patients, additional RU studies were performed. Seven patients received US and CT scan without IVU or RU study (Table 1).

In diagnosis of renal parenchymal tumors, the diagnostic accuracy of the three chief residents and junior attending physician had significant difference ($p<0.01$) between, before and after RMDS consultation (Table 4). In diagnosis of renal pelvic tumors, the number of patients was too small to be compared.

The diagnostic accuracy for differentiating malignant renal tumors from benign lesions by RMDS was 92%. After RMDS consultation, the diagnostic accuracy for differentiating malignant renal tumors from benign lesions by physicians significantly increased ($p<0.01$). The number of correct preoperative diagnoses of benign and malig-

Table 3. Diagnosis before and after RMDS consultation

	CR-1	CR-2	CR-3	Attend.	RMDS	Total
A. R. Parenchymal T.	(40)45	(39)43	(41)46	(44)46	47	51
Angiomyolipoma	(2)3	(3)3	(2)3	(3)3	3	4
Hemangiopericytoma	0	0	0	0	0	0
Juxtaglomerular cell tumor	0	0	0	0	0	0
Lipoma	0	0	0	0	0	0
Lymphoblastoma	(1)2	(1)2	(2)2	(1)2	2	2
Metastatic tumor	(2)2	(2)2	(2)2	(2)2	2	3
Oncocytoma	(0)1	(0)0	(1)1	(0)0	1	1
Renal cell carcinoma	(34)36	(33)36	(34)37	(37)38	38	39
Sarcoma	(1)1	(0)0	(0)1	(1)1	1	2
Wilms' tumor	0	0	0	0	0	0
B. XGP	(2)3	(1)2	(2)3	(2)3	3	4
C. R. Pelvic T.	(3)6	(3)6	(5)6	(6)7	7	8
Benign papilloma	(1)2	(1)2	(1)2	(2)2	2	2
Transitional cell ca.	(2)4	(2)3	(3)3	(3)4	4	4
Squamous cell ca.	(0)0	(0)1	(1)1	(1)1	1	1
Adenocarcinoma	(0)0	(0)0	(0)0	(0)0	0	1
Total no.	(45)54	(43)51	(48)55	(52)56	57	63
Percentage	(71)86	(68)81	(76)87	(83)89	90	
Average from three chief residents	(72%)85%					
p value	<0.01	<0.01	<0.01	<0.01		

( ): The data before RMDS consultation
Attend. = attending physician
R. Parenchymal T. = Renal Parenchymal Tumor
R. Pelvic T. = Renal Pelvic Tumor
XGP: Xanthogranulomatous pyelonephritis
*After RMDS consultation, the overall diagnostic accuracy of physicians is significantly better than those before RMDS consultation with $p<0.01$.

nant renal tumors before and after RMDS consultation are shown in Table 5.

DISCUSSION

None of the previous studies used a medical decision support system to evaluate the patient with renal masses, prospectively. For some renal mass cases, preoperative diagnosis is not easily made. Herein the possibility of computer-assisted preoperative diagnosis for patients undergoing surgical exploration for renal masses was evaluated. Analysis was restricted to patients undergoing operation without a definite preoperative diagnosis.

Although many sophisticated radiological techniques are available for performance of a diagnostic workup in patients with a suspected renal mass. IVU and US are still the recommended initial studies. If a renal solid mass is identified on IVU and US, CT scanning has been widely accepted as the diagnostic procedure of choice (11). In this study, we had the same preoperative workup, IVU, US and CT were most widely utilized, especially CT scanning which was performed in all patients except those with renal cyst (Table 1).

Table 4. Diagnostic accuracy in renal parenchymal and renal pelvic masses before and after RMDS consultation

	Renal parenchymal masses		Renal pelvic masses	
	Before	After*	Before	After**
CR-1	40(78%)	45(88%)	3(38%)	6(75%)
CR-2	39(77%)	43(84%)	3(38%)	6(75%)
CR-3	41(80%)	46(90%)	5(63%)	6(75%)
Attending	44(86%)	46(90%)	6(75%)	7(88%)
RMDS	50(91%)	7(88%)		
Total	55	8		

*$p<0.02$ compared to the accuracy before RMDS consultation.
**$p<0.05$ compared to the accuracy before RMDS consultation.

Table 5. The number of correct preoperative diagnoses of benign and malignant renal masses before and after RMDS consultation

	Malignant renal masses		Benign renal masses	
	Before	After*	Before	After**
CR-1	40(77%)	45(87%)	5(46%)	9(82%)
CR-2	38(73%)	44(85%)	5(46%)	7(64%)
CR-3	42(81%)	46(88%)	6(55%)	9(82%)
Attending	45(87%)	48(92%)	7(64%)	8(73%)
RMDS	48(92%)	9(82%)		
Total	52	11		

*$p<0.01$ compared to the accuracy before RMDS consultation.
**$p<0.05$ compared to the accuracy before RMDS consultation.

The preoperative characteristics of patients with renal masses were selected from clinical observations here. We do not contend that these characteristics are the only ones of important factors for malignancy. However, all of them are necessary in the knowledge frames of RMDS (Table 2). RMDS used estimated statistical associations between diseases and these preoperative characteristics.

RMDS was developed using a Bayesian probabilistic approach. Bayesian theory has been used in many successful medical decision support system (12, 13). The decision-making information in RMDS was based on the knowledge and experience of urologists and scientific clinical literature in the field of urology(14). In a previous report, RMDS was able to correctly diagnose 83.3% cases, which is better than chief residents and is not significantly different from the diagnostic accuracy of the junior attending physician (15). Recently, with a revision of this system, the overall diagnostic accuracy has increased to 90% (Table 3). Therefore, RMDS was used for prospectively evaluating patients to categorize renal masses as benign or malignant lesions and as renal parenchymal or renal pelvic tumors. The positive predictive value and negative predictive value for RMDS were calculated on the basis of correct identification of the renal mass category. In differential diagnosis of renal parenchymal tumors and renal pelvic tumors, the sensitivity was 91% and the specificity, 88%. For differential diagnosis of malignant and benign renal masses, the positive predictive value was 92% and the negative predictive value was 82%. The utility of RMDS is supported by the high sensitivities and specificities of the results. After RMDS expert system consultation, three chief residents and the junior attending physician changed their diagnoses and their diagnostic accuracy significantly increased (Table 3). Physicians changed their diagnoses because the RMDS expert system reminded physicians of patient conditions which need attention.

The common finding in patients with renal pelvic tumor is a filling defect in the renal pelvis, often seen on early films of the IVU. In about one-third of the patients with renal pelvic tumor, the only finding is that defect (9). A preoperative differential diagnosis of renal pelvic tumor usually is not difficult. However, in a few cases, the renal pelvic tumor has extended beyond the kidney. It is difficult to differentiate this kind of renal pelvic tumor from renal parenchymal tumor. In this study, RMDS was able to differentiate seven of the eight cases of renal pelvic tumor and 50 of the 55 cases of renal parenchymal tumor (Table 4).

In renal parenchymal tumors, benign renal lesions were frequently detected in preoperative diagnosis after the use of CT and MRI. Physicians will increasingly be required to differentiate benign from malignant renal parenchymal tumors (11). In this series, benign renal lesions included renal cyst, renal abscess, xanthogranulomatous pyelonephritis, angiomyolipoma and oncocytoma. Most benign renal lesions were diagnosed preoperatively by RMDS, except for one xanthogranulomatous pyelonephritis and one angiomyolipoma. The diagnostic accuracy for malignant renal masses was 92%. Physicians changed their diagnoses after RMDS consultation, and the diagnostic accuracy for benign and malignant renal masses also significantly increased. However, one malignant renal pelvic tumor-adenocarcinoma was diagnosed as transitional cell carcinoma. In renal pelvic tumor, benign papillomas account for approximately 15–20% of cases, and will eventually develop carcinomas (10). It was difficult to differentiate benign from malignant renal pelvic tumors. In our series, the benign renal pelvic tumor diagnosed by RMDS was based on radiological findings, and a negative test of urine cytology.

It appears that better preoperative renal mass diagnosis will result in fewer unnecessary frozen sections during operation, and shorter surgical times. Thereafter fewer postoperative complications and a reduced length of hospital stay will be expected. This study was not used to influence physician's behavior or make physicians change their management techniques, but the results indicate that the medical expert system RMDS may have an important role in preoperative diagnosis of renal masses.

SUMMARY

The RMDS expert system was used to prospectively evaluating patients undergoing nephrectomy for suspected renal masses. From March 1993 to April 1994, 123 consecutive patients underwent the usual preoperative diagnostic evaluation here, for renal masses. One patient expired before operation and 59 patients had a preoperative diagnosis. The remaining 63 patients without a definite preoperative diagnosis constituted the study population. The overall preoperative diagnostic accuracy of RMDS was 90%; the average overall preoperative diagnostic accuracy of three chief residents was 72% and the overall diagnostic accuracy of a junior attending physician was 83%. The diagnostic accuracy for differentiating malignant renal masses from benign lesions by RMDS was 92%, and the diagnostic accuracy for differentiating renal parenchymal tumors from renal pelvic tumors by RMDS was 91%. After RMDS expert system consultation, three chief residents and the junior attending physician changed their preoperative diagnosis, and significantly increased their diagnostic accuracy to 85% and 89%. This study has not been used to influence physician's behavior and/or preoperative management, but the results indicate that the medical expert system may have a useful role in preoperative diagnosis of renal masses.

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