The Development of Clinical Decision Support System for Diagnosing Neurogenic Bladder

Nyambat Batmunh[a] and Young M. Chae[b]

[a] *International Vaccine Institute*
Shillim-dong, Kwanak-gu, Seoul, Korea 151-600
Tel: +82-2-872-2801, Fax: +82-2-872-2803, E-mail: bnyam@ivi.int

[b] *Graduate School of Health Science and Management,*
Yonsei University, C.P.O.Box 8044, Seoul, Korea
Tel: +82-2-361-5048, Fax: +82-2-392-7734, E-mail: ymchae@yumc.yonsei.ac.kr

Abstract

In this study, we have developed a prototype of clinical decision support systems (CDSS) for diagnosing neurogenic bladder and compared its predicted diagnoses with the actual diagnoses using 92 patient's Urodynamic study cases. The CDSS was developed using a Visual Basic based on the evidence-based rules extracted from guidelines and other references regarding a diagnosis of neurogenic bladder. To compare with the 92 final diagnoses made by doctors at the Yonsei Rehabilitation Center, we classified all diagnoses into 5 groups. The predictive rates of the CDSS were: 48.0% for areflexic neurogenic bladder; 60.0% for hyperreflexic neurogenic bladder in a spinal shock recovery stage; 72.9% for hyperreflexic neurogenic bladder, and 80.0% for areflexic neurogenic bladder in a spinal shock stage, which was the highest predicted rate. There were only 2 cases for hyperreflexic neurogenic bladder in a well controlled detrusor activity, and its predictive rate was 0%.
The study results showed that CDSS for diagnosing neurogenic bladder could provide a helpful advice on decision-making for doctors. The findings also suggest that physicians should be involved in all development stages to ensure that systems are developed in a fashion that maximizes their beneficial effect on patient care, and that systems are acceptable to both professionals and patients. The future studies will concentrate on including more comprehensive rules and more data for developing and validating the system.

Keywords: Decision support system, Expert system, Neurogenic bladder

Introduction

Spinal cord injury (SCI) is an uncommon condition. More than half of the persons injured are under 30 years of age and 85% are in the labor force at the time of their injuries. The incidence figures range from 29.4 cases per 1 million to 50 cases per 1 million. The majority of persons with SCI are male, with the male-to-female ratios in the literature ranging from 2.4:1 to 4:1. The common causes of SCI can vary in different geographical regions. Overall, vehicle crashes are the most common cause (45.4%), followed by falls (16.8%), sports injuries (16.3%), and violence [1]. Upper tract urinary complications have been reported in about 20-30% of SCI patients.

A neurogenic bladder is the loss of normal bladder function caused by damage to part of the nervous system and most common dysfunction among patients with SCI. A neurogenic bladder may result from a disease, an injury (spinal cord injury) or a birth defect affecting the brain, spinal cord, or nerves leading to the bladder, its outlet (the opening into the urethra from the bladder), or both. A neurogenic bladder can be underractive, in which it is unable to contract (hyporeflexic) and unable to empty well, or it can be overactive (hyperreflexic), emptying by uncontrolled reflexes. An underactive bladder usually results from interruption of local nerves supplying the bladder. An overactive bladder usually results from an interruption of normal control of the bladder by the spinal cord and brain. A common cause is an injury or a disorder, such as multiple sclerosis, affecting the spinal cord, which may also result in paralysis of the legs (paraplegia) or the arms and legs (quadriplegia).

Various bladder management techniques have been promulgated over the years and they have risks and benefits from a medical standpoint, in addition to affecting the day-to-day lives of spinal cord-injured patients. Main goals are to preserve function of the kidney and then to obtain full urinary continence between in urination which is most often assisted with catheterizations if catheterization is required.

As new medical technology and knowledge are introduced everyday, there is a particular need for the computer

systems that will help doctors make timely decisions on diagnosis and treatment with new and up-to-date knowledge [2]. Computerized decision support systems are consultation systems that use artificial intelligence techniques for encoding knowledge and solving problems with that knowledge. They are designed to aid clinical decision-making, assist in diagnosis and make management decisions, based on individual patient data [3]. Computers may assist in medical decision-making and improve the quality of diagnosis or the efficiency of therapy. Computerized decision support systems have potential to drive reminders, provide alerts for prescribing interactions or test results, interpret complex investigations, predict mortality on the basis of epidemiological data, aid diagnosis and calculate drug doses [4]. Table 1 shows the functions of CDSS:

Table 1 - Functions of Computer-Based CDSS

Function	Example
Alerting	Highlighting out-of-range laboratory values
Reminding	Reminding the clinician to schedule a mammogram
Critiquing	Rejecting an electronic order
Interpreting	Interpreting the electrocardiogram
Predicting	Predicting risk of mortality from a severity-of-illness score
Diagnosing	Listing a differential diagnosis for a patient with chest pain
Assisting	Tailoring the antibiotic choices for liver transplantation
Suggesting	Generating suggestions for adjusting the mechanical ventilator

One of the most difficult parts for the neurogenic bladder management is to make a final diagnosis for a given patient and give an appropriate recommendation for the treatment. Until now, there are very few scientific papers published on this field. In Rehabilitation practice, every year has been introduced a new methodology for evaluation and testing patients with neurogenic bladder and new generation of drugs. Symptoms and signs referable to a spinal injury are depends on the alertness of the patient. It makes some difficulties to the doctor's decision making.

So in this study we concentrated on diagnosing part and we have constructed knowledge base for developing the Clinical Decision Support System (CDSS) of neurogenic bladder and develop a prototype of computerized system. CDSS for neurogenic bladder will provide help on decision-making procedure for diagnosing neurogenic bladder. In other words, this system will help for diagnosing the stage, type, level and other specific characteristics. Decision support systems must not be perceived as interfering with physician's freedom in prescribing treatments, which is very important to them. In any case, making the appropriate decision is the physician's duty. CDSS should first be developed in areas where knowledge is clearly identified and generally agreed upon. This will prevent professionals from perceiving the advice as a constraint or a limitation on their activity.

Approach and methods

In this study we have developed a prototype of CDSS for diagnosing neurogenic bladder. These are four stages for this research:

- Construction of database and knowledge base for diagnosing neurogenic bladder
- Development of Graphic User Interface and CDSS for diagnosing neurogenic bladder
- Comparison of the final diagnosis and results from CDSS
- Future consideration and suggestion of CDSS for neurogenic bladder management

Subjects and design of the study

The study population is 100 out and inpatients at Rehabilitation Center, Severance Hospital diagnosed as SCI and with neurogenic bladder dysfunction who had taken the urodynamic studies from September 2000 through April 2001. Patient's urodynamic studies are used as a primary data for this study and for constructing the database. These data are used and helped for comparison of the final diagnosis and results from CDSS for diagnosing neurogenic bladder. Figure 1 shows the framework of the study.

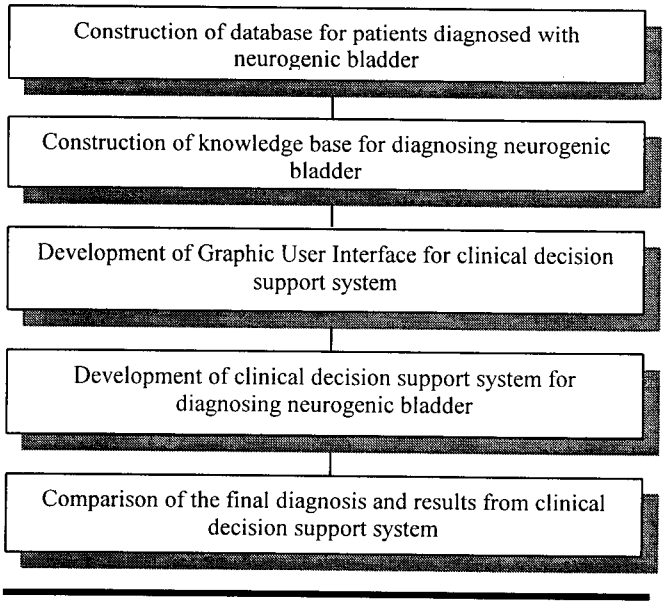

Figure 1 - Framework of the study

Construction of Neurogenic Bladder Patient's Database

Using the Urodynamic Study Report received from Rehabilitation Center, we have constructed the database in Microsoft Access 2000. This database does not include full clinical and laboratory information for 100 patients with

Spinal Cord Injury and it makes a limitation for constructing knowledge based system and comparison of the final diagnosis and results from CDSS. Some missing data are neurological level, medication before urodynamic studies and some of the records do not have information for gender. And we reviewed medical records retrospectively at Severance Hospital to get those missing data.

An Analysis of the Decision-making Procedure

This figure shows the steps for diagnosing neurogenic bladder and what kind of clinical and laboratory information are used to assist in making a diagnosis for neurogenic bladder. Because of some difficulties faced in making the knowledge base for the treatment (data we have are insufficient and complex variables for the treatment), we did not include the rule base for neurogenic bladder treatment. According to constructed rule base the urodynamic study results and some patient's basic information are the most important data for the analysis and decision-making procedures (Figure 2).

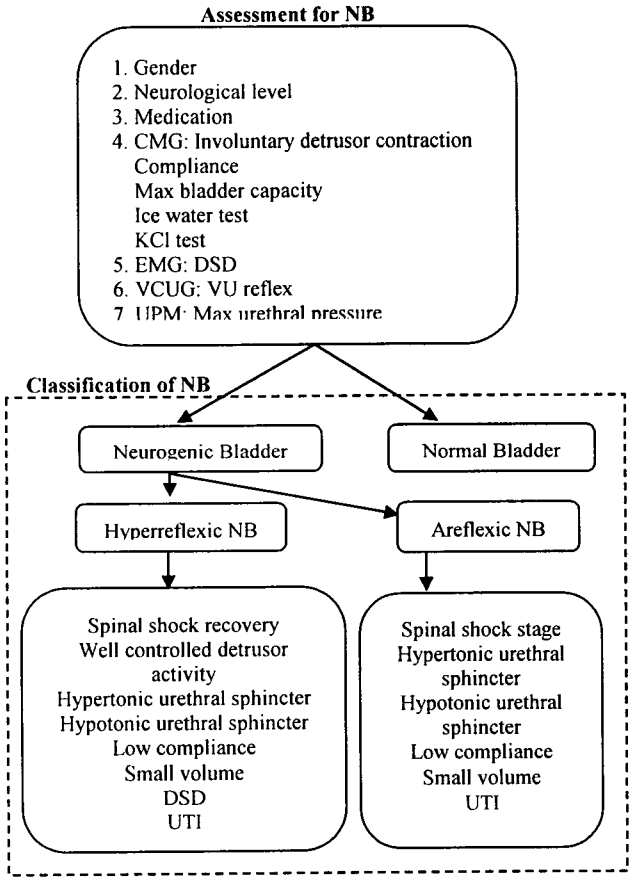

Figure 2 - Framework of the Decision-making Procedure

Selection of Items for the Decision-making Procedure

Using the Clinical Practice Guidelines and other resources for diagnosing neurogenic bladder we developed a rule-based system by prediction method. In medical practice, for assessing the neurogenic bladder the most essential and valuable testing methods are urodynamic studies including cystometrogram (CMG). According to the results of CMG physician can make a final diagnosis for neurogenic bladder. All urodynamic test results are recorded in Urodynamic Study Report at Rehabilitation Center, Severance Hospital (in MS Word file).

Interpretation of the diagnosis for neurogenic bladder

After entering the patient ID number, our system will be able to show all related (demographic, clinical and laboratory) information for a given patient and will analyze those data and give the appropriate diagnosis for neurogenic bladder. According to the constructed rulebase, our system will be able to check, whether is hyperreflexic or areflexic and then check out is there spinal shock (shock stage or recovery) or well controlled detrusor activity. After that the system will check the subdiagnoses (compliance, bladder volume, pressure of urethral sphincter, etc).

Results

Characteristics of the Study Population

Table 2 - Patient's Basic and Clinical Information

Measure	Value	Count (n)	Proportion (%)
Gender	Male	66	71.7
	Female	26	28.3
	Total	92	100
Neurological Level	Suprasacral	74	80.4
	Infrasacral	17	18.5
	Mixed	1	1.1
	Total	92	100
From Clinical Diagnosis	Paraplegia	48	52.2
	Tetraplegia	44	47.8
	Total	92	100
Detrusor Activity	Hyperreflexic	54	58.7
	Areflexic	32	34.7
	Normal Bladder	3	3.3
	Others	3	3.3
	Total	92	100

The 92 test cases concerned 66 male (71.7%) and 26 female patients (28.3%). Most of the cases have had suprasacral lesion (80.4%) and 17 cases (18.5%) have had infrasacral lesion. Forty-eight cases (52.2%) were with paraplegia and 44 (47.8%) cases with tetraplegia. Fifty-four cases (58.7%) have had hyperreflexic type of neurogenic bladder and 32 (34.7%) cases have had areflexic neurogenic bladder.

Table 3 - Patient's Urodynamic Results

Measure	Value	Count (n)†	Proportion (%)
Max Bladder Capacity	Small Volume	24	26.4
	Normal Volume	67	73.6
	Total	91	100
Compliance	Low compliance	19	20.9
	Normal or High	72	79.1
	Total	91	100
Involuntary Detrusor Contraction (IDC)	Positive	39	42.9
	Negative	52	57.1
	Total	91	100
Ice Water Test (IWT)	Positive	50	55.0
	Negative	38	41.8
	Unknown	3	3.2
	Total	91	100
Detrusor Sphincter Dyssynergia (DSD)	Present	3	3.2
	Absent	88	96.8
	Total	91	100

According to urodynamic studies 24 cases (26.4%) were with small volume of the bladder and 67 (73.6%) were normal. Nineteen cases (20.9%) have had low compliance and cases with normal or high compliance were 72 (79.1%). Involuntary Detrusor Contraction (IDC) was positive in 39 (42.9%) cases and 52 cases (57.1%) have had negative result. Fifty cases (55.0%) had Ice Water Test (IWT) positive and 38 cases (41.8%) had negative test. Detrusor Sphincter Dyssynergia (DSD) has appeared in 3 cases (3.2%) only.

Knowledge Base for Diagnosing Neurogenic Bladder

Using the prediction method, we have constructed a simple rule base for assistance on diagnosis of patients with neurogenic bladder. This rule base is used in the analysis stage to classify neurogenic bladder into 5 groups and make diagnosis (Figure 3). As shown in figure 4, this rule base used for analyzing subconditions (subdiagnosis).

1. If IDC = "yes" and (Ice = "(+)" or Ice = "(-)") and (Med = "(-)" or Med = "(+)") and Neur_lev = "Suprasacral" or "Infrasacral" Then *Hyperreflexic NB*
2. If IDC = "no" and Ice = "(-)" and Med = "(-)" and Neur_lev = "Infrasacral" Then *Areflexic NB*
3. If IDC = "no" and Ice = "(+)" and Med = "(+)" and Neur_lev = "Suprasacral" Then *Hyperreflexic NB, Well controlled detrusor activity*
4. If IDC = "no" and Ice = "(-)" and Med = "(-)" and Neur_lev = "Suprasacral" Then *Areflexic NB, Spinal shock stage*
5. If IDC = "no" and Ice = "(+)" and (Med = "(-)" or Med = "(+)") and Neur_lev = "Suprasacral" or "Infrasacral" Then *Hyperreflexic NB, Spinal shock recovery*

Figure 3 - Rule for the Diagnosis

If Compl ≤ 15 Then *Low compliance*
End If
If Capac < 350 Then *Small volume*
End If
If DSD = "yes" Then *DSD*
End If
If (Gender = "male" and MUP > 80) or (Gender = "female" and MUP > 40) Then *Hypertonic urethral sphincter*
Else If (Gender = "male" and MUP < 40) or (Gender = "female" and MUP < 20) Then *Hypotonic urethral sphincter*
End If
If KCl (+) Then *UTI*
End If
If VUR = "yes" Then *VUR*
End If

Figure 4 - Rule for the Subdiagnosis

Clinical Decision Support System for Diagnosing Neurogenic Bladder

CDSS for diagnosing neurogenic bladder is the knowledge-based system that is capable to make a simple analysis on clinical and laboratory results and help on doctor's decision-making procedure on diagnosis. We designed a total of 6 three-tabbed dialogue-box screens, where the user with mouse-click can enter and store data for a given patient (Figure 5-6). After entering data for a given patient, physician can easily get the output (diagnosis).

† Out of 92 cases we excluded 1 case due to missing variables in CMG records.

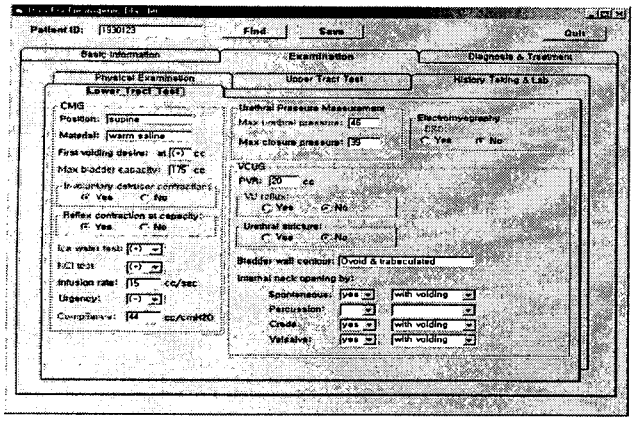

Figure 5 - Screen for Lower Tract Test

This screen designed for entering and showing information for urinary lower tract test results. This is most important screen and variables are the key indicators for diagnosing neurogenic bladder.

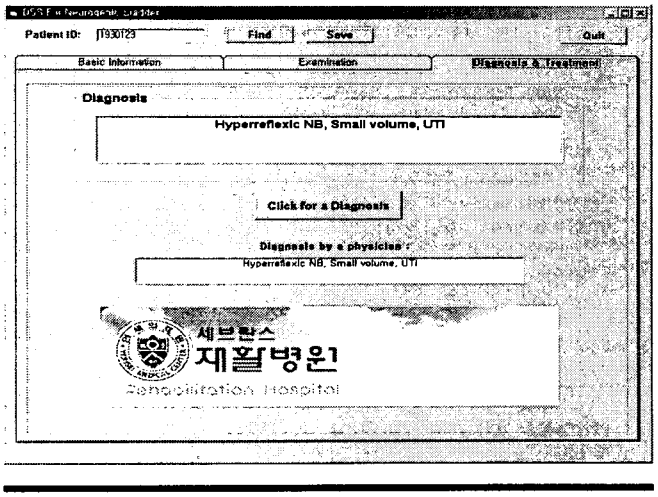

Figure 6 - Screen for Diagnosis (example)

This screen shows the result of CDSS for diagnosing neurogenic bladder. Also screen shows diagnosis made by doctor to compare with results from CDSS.

Comparison of the Final Diagnosis and Results from Clinical Decision Support System

Results of the Comparison

A critical part of developing and implementing decision support system is validating. Validation has been given many definitions, however, one summary definition is that validation is building the right system. As mentioned before, it did not allow us to validate this system and just limited on comparison of the final diagnosis and results from CDSS. For determining whether DSS is valid or not valid, we used all 92 test cases and then calculated a percentage for the system's predictive rate. Because of small data and limited time we could not make a more additional sampling for more advanced comparison and limited in few data.

Table 4 - Predictive Rates for Outputs

Main conditions	Final Diagnosis by Doctor (n)†	Results from CDSS (n)	Predictive Rate (%)
Hyperreflexic NB	48	35	72.9
Hyperreflexic NB, Spinal shock recovery	5	3	60.0
Hyperreflexic NB, Well controlled detrusor activity	2	0	0
Areflexic NB	25	12	48.0
Areflexic NB, Spinal shock stage	5	4	80.0
Total	85	54	63.5

Compared a total of 92 final diagnoses made by doctors at Rehabilitation Center, Severance Hospital. In comparison study we classified all diagnoses into 5 groups as shown in Table 4. The significant variables for assessment of 6 groups were: IDC (Involuntary detrusor contraction), IWT (Ice water test), previous medication and neurological level. There were 48 cases diagnosed by doctors with hyperreflexic neurogenic bladder, 25 cases with areflexic neurogenic bladder, 5 cases each with hyperreflexic neurogenic bladder, spinal shock recovery and areflexic neurogenic bladder, spinal shock stage. And only 2 cases with hyperreflexic neurogenic bladder, well controlled detrusor activity were found. On diagnoses (conditions) like low compliance, small volume, DSD, hypertonic urethral sphincter doctor can easily make decision considering on the single variables. In other side, the borderline of those variables in clinical practice is unsettled or inconstant. So we did not compare those conditions. Seven excluded cases were patients with such diagnosis: Normal bladder; Uncheckable reflex activity; Bilateral VUR, etc.

As seen in Table 4, the predictive rate for areflexic neurogenic bladder was 48.0%, for hyperreflexic neurogenic bladder, spinal shock recovery (60.0%), for hyperreflexic neurogenic bladder (72.9%), and for areflexic neurogenic bladder, spinal shock stage (80.0%) was the highest. For hyperreflexic neurogenic bladder, well controlled detrusor activity, there were only 2 cases and predictive rate was 0.

An Analysis of the Inconsistent Cases

During the comparison we found some inconsistent cases. Inconsistent cases are cases that different in final diagnosis and result of CDSS or when system is unable to make decision due to insufficient and missing variables. Two

† Out of 92 diagnoses we excluded 7 outputs due to unknown or different diagnoses

cases with diagnosis areflexic neurogenic bladder were predicted by our CDSS as hyperreflexic neurogenic bladder. Our system has picked those cases as hyperreflexic neurogenic bladder, because according to urodynamic study, involuntary detrusor contraction (IDC) was present and negative Ice water test (IWT). CDSS could not make decision for 8 cases due to missing variables (missing data for IDC, IWT, Medication and Neurological level). Also eight cases with diagnosis areflexic neurogenic bladder were predicted by our CDSS as areflexic neurogenic bladder, spinal shock stage. As stated in the rule base, for those two conditions the only difference is neurological level. And because of the level is suprasacral output was areflexic neurogenic bladder, spinal shock stage. Two cases with diagnosis hyperreflexic neurogenic bladder were predicted as areflexic neurogenic bladder, spinal shock stage. And 9 cases have picked as hyperreflexic neurogenic bladder, spinal shock recovery.

Discussion

This study described the development of a clinical decision support system (CDSS) that is intended to provide advice for diagnosing neurogenic bladder. Compared a total of 92 final diagnoses made by doctors at Rehabilitation Center, Severance Hospital and results from the system. In comparison study we classified all diagnoses made by doctors into 5 groups. The predictive rate for areflexic neurogenic bladder was 48.0%, for hyperreflexic neurogenic bladder, spinal shock recovery (60.0%), for hyperreflexic neurogenic bladder (72.9%), and rate for areflexic neurogenic bladder, spinal shock stage (80.0%) was the highest. For hyperreflexic neurogenic bladder, well controlled detrusor activity, there were only 2 cases and predictive rate was 0.

Diagnosis and therapeutic planning of neurogenic bladder are a multifactorial process involving the assessment of personal and clinical characteristics, physical examinations and especially laboratory tests. There have been many studies on clinical aspects so far, but very few studies on development of CDSS and expert system on rehabilitation medicine. There are several reasons. First, borderline of laboratory test variables for assessment of neurogenic bladder is still various and changing frequently which makes difficult to construct knowledge based system, in other words, the lack of a gold standard. Second, management of neurogenic bladder may be complicated by other sequelae of urological disease, such as effects on cerebral functioning and on the patient's mobility and very difficult to choose appropriate treatment for given dysfunction. Third, management depends on the ability of the patient to corporate with the treatment.

The number and quality of studies for CDSSs are increasing and in certain clinical areas, such as drug use and preventive medicine, these systems have been shown to improve physician performance and, less frequently, improve patient outcomes. Unfortunately, these studies cover a small fraction of all CDSSs currently marketed. As the number of new companies developing CDSS products increases, clinicians may be bewildered by the number of different vendors with slick program demonstrations, some of which may have exaggerated and unsubstantiated claims. Aside from prompting skepticism on the part of practicing physicians, the extreme variability in quality and amount of evaluation of these systems underscores the need for all health centers to conduct in-house evaluation of any system before it is purchased and installed. Whereas a mistake in banking software may misplace several million dollars, a mistake in a CDSS may lead to the death of a patient [3].

CDSS's have become an established component of medical technology and their use will continue to grow, fueled by electronic medical records and autonomic data capture. Computer systems can improve the quality of decisions made in clinical practice and may have an important role in enabling doctors and patients to increasingly share the role of the decision-making process. A survey of general practitioners suggested that over 80% would use computer decision support system if available, although there is some evidence that doctors may feel that their decision-making is undermined by their introduction. Nurses are more likely to accept decision support from computers especially when it relates to diagnostic support. These systems may improve the quality of medical care. The United Kingdom has the most extensively computerized primary healthcare sector in the world and has a unique opportunity to develop and evaluate this technology [4]. The development of national standards for coding and information exchange, and the latest generation of medical systems will enable the development of more sophisticated computerized decision support systems that improve the outcome for patients and lead to a more efficient and cost-effective primary health service.

There are some studies on development of CDSSs in diagnosis have been evaluated. These evaluated a variety of systems designed to assist in the management of pediatric patients or patients presenting with chest or abdominal pain. In addition, they tested a system that identified patients at high risk of respiratory tract complications postoperatively so that physiotherapy could be selectively provided. This was the only study to find a benefit with the CDSS. Positive effects were noted for both timely referral of patients for physiotherapy and reduced risk of postoperative complications [5].

During the development of these systems, it is particularly important that physicians are involved at all stages, to ensure that systems develop in a fashion that maximizes their beneficial effect on patient care, and that systems are acceptable to both professionals and patients [6]. The user interface is an important component of the effectiveness of a CDSS. The CDSS interface should be developed on the basis of potential users' capabilities and limitations, the users' task, and the environment in which those tasks are performed [7]. To ensure user acceptance, users must feel that they can depend on the system to be available whenever they need it.

A total of 68 prospective trials using concurrent control groups have reported the effects of using CDSSs on drug using, diagnosis, preventive care and active medical care.

Forty three (66%) of 65 studies showed that CDSSs improved physician performance. These included 9 of 15 studies on drug dosing systems, 1 of 5 studies on diagnostic aids, 14 of 19 preventive care systems, and 19 of 26 studies CDSSs for active medical care. Six (43%) of 14 studies showed that CDSSs improved patient outcomes, 3 studies showed no benefit and the remaining studies lacked sufficient power to detect a clinically important effect [8]. Even if the study is valid and a positive effect is shown, CDSSs have special applicability issues that must be considered.

There were some limitations that should be dealt with to further enhance a capability of CDSS. First, number of cases was insufficient to the construction of knowledge bases and comparison of outputs. Second, we could not validate the system due to various problems faced during the study. Third, the computer based CDSS that we used was limited to only diagnosing advice; other aspects of neurogenic bladder such as treatment was not included. Fourth, managing the patient with a diagnosis of neurogenic bladder is a frequently encountered and difficult problem due to complexity of the underlying etiology of the neurogenic bladder.

However, the current systems are able to respond only to a limited set of rules as well as our system. Most doctors do not want a system that will diagnose a patient's illness, but instead a system that will suggest alternative diagnoses, investigations, or highlight areas of particular risk. Much work is needed to develop this technology so that these potential benefits can be realized, and that the systems respond to local priorities.

Conclusion

The CDSS will most surely be time-saving and since time is the most crucial resource in clinical practice, this should be regarded as a benefit. The CDSS can also be used in education and act as an audit instrument. CDSSs offer the potential to improve the quality and reduce the cost of care by influencing medical decisions at the time and place decisions are made.

A more comprehensive system would require data from many more patients and a lot more rules to be developed. So there is a need to integrate with a hospital information system to have direct access to the medical database. In addition, to further strengthen the capability of the medical decision support system, recommendation for the treatment can also be added. Decision support systems that are able to retrieve information effectively and comprehensively and then present the clinician with a useful conclusion from the data are likely to be readily accepted and used. However, considerable work is needed to ensure that their introduction is not detrimental to the quality of the relationship between the doctor and patient in the consultation, and to make the systems adaptable to local priorities. The systems need to be acceptable to both professionals and patients.

In clinical practice proper evaluation of the neurogenic bladder remains the cornerstone for accurate management of the neurologically impaired patients. Given the success of other specialists (physical medicine and rehabilitation, orthopedics and neurology) at improving and prolonging the lives of the neurologically injured patients, the urologist has an increasing responsibility to evaluate and treat the neurogenic bladder effectively over a life span that is approaching that of the normal population.

As a result, study on development of CDSS for diagnosing neurogenic bladder is a long-haul project requiring multi-faceted approaches. Also developers of computer based CDSSs should remember that as well as technological development, clinical understanding of the recommendations made by such systems are required and important.

Only through careful application and objective assessment based on outcome data will the potential for computer-based CDSSs to advance clinical practice and improve the quality of care be realized. Physicians and other health professionals have come to accept CDSS value and limitations. The research and development in the field of health informatics is also emphasized to enhance the progress of medicine and health in general in the new era of knowledge based society. In the future, CDSS for neurogenic bladder can be further improved by constructing more advanced knowledge based system. Finally, computer based CDSSs which combine diagnosing and treatment, in other words, whole management of neurogenic bladder require further development and evaluation.

Acknowledgements

I would like to thank my supervisor and professor Young Moon Chae, for his firm support throughout the period of my study in Korea. In the upset waters of the present day scientific community he always stood as a calm and rational guiding light that reached well beyond my own horizon.

References

[1] Gary M, Yarkony GM, Chen D. Rehabilitation of Patients with Spinal Cord Injuries. 1994

[2] Chae YM, Jang TY, Park IY, Chung SK, Park M. 1992. The Development of a Decision Support System for Diagnosing Nasal Allergy. *Yonsei Medical Journal,* 33, 72-80

[3] Hunt D, Haynes DJ, Hanna S, Smith K. 1998. Effects of Computer-based Clinical Decision Support System on Physician Performance and Patient Outcomes. *JAMA,* 280; 1339-1346

[4] Delaney BC, Fitzmaurice DA, Riaz A, Richard Hobbs FD. 1999. Can Computerized Decision Support Systems Deliver Improved Quality in Primary Care? *BMJ,* 319:1281

[5] Chase CR, Vacek PM, Shinozaki T, Giard AM, Ashikaga T. 1983. Medical information management:

improving the transfer of research results to presurgical evaluation. *Med Care.* 21:410-424

[6] Thornett AM. Computer decision support systems in general practice. *International Journal of Information Management,* 21 (2001); 39-47

[7] Salvemini AV. 1998. Improving the human-computer interface: a human factors engineering approach. *MD Comput* 15:311-315

[8] Johnston ME, Langton KB, Haynes RB, Mathieu A. 1994. Effects of computer-based clinical decision support systems on clinician performance and patient outcome. *Ann Intern Med.* 120:135-142

[9] Bradley WE, Teague CT. Spinal cord organization of micturitional reflex afferents. *Exp Neurol* 1968; 22: 504-516

[10] Carson ER, Hovorka R, Roudsari AV. Modeling and decision support in physiology and medicine: a methodological framework with illustration. *J Math Comput Model Dynamic Syst* (1998)

[11] Degoulet P, Fieschi M. 2000. Introduction to clinical informatics. *Masson*, Editeur, Paris, 1996 Elliott DS, Boone TB. Recent advances in the management of the neurogenic bladder. *Elsevier Science* 56:76-81

[12] Fletcher TF, Bradley WE. 1978. Neuroanatomy of the bladder-urethra. *J Urol* 119: 189-191

[13] Lundsgaarde H. 1987. Evaluating medical expert system. *Soc Sci Med* 24:805-19

[14] Montgomery AA, Fahey T, Peters TJ, Sharp DJ. 2000. Evaluation of computer based clinical decision support system and risk chart for management of hypertension in primary care: randomized controlled trial. *BMJ.* 320:686-90

[15] Randolph AG, Haynes RB, Wyatt JC, Cook DJ, Guyatt GH. Users guides to the medical literature XVIII. How to use an article evaluating the clinical impact of a computer-based clinical decision support system. *JAMA,* 1999; 282:76-74

[16] Scally G, Donaldson LJ. 1998. Clinical governance and the drive for quality improvement in the new NHS in England, *BMJ* 317:61-5

[17] Seung Hee Ho. 2000. Development and evaluation of decision support system for hypertension management using data mining technique. PhD diss., Dept. of Health Management and Information System, Yonsei Univ.

[18] Tanago EA. Anatomy of the lower urinary tract. In: Walsh PC, Gittes RF, Perlmutter AD, Stamey TA, eds. *Cambell's urology, 5th ed.* Philadelphia: WB Sanders, 1986; 46-61