A REVIEW OF DEVELOPED INFORMATION SYSTEMS FOR PAIN MANAGEMENT IN PATIENTS WITH SPINAL CORD INJURY

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ABSTRACT

***Introduction**: Pain is one of the most disabling problems in people with Spinal Cord Injury. An interdisciplinary pain management team includes healthcare providers from different disciplines, each of them specialized in various characteristics of pain, and all should be coordinated so that the optimum results will be achieved. Information technology has been used in various domains of medicine. The aim of this study was to review relevant articles and find out power and weak points in pain management developed information systems and technologies used in these systems in the spinal cord injury population.*

***Research method**: A literature review was established to search developed information systems for pain management of patient with spinal cord injury, e-journals collections, and printed journals, books, dissertations, and theses for relevant articles. The search strategy interchangeably used the terms of "spinal cord injury", "pain management system", "expert system" and "clinical decision support system" combined with Boolean operator "AND". Search results (n=184) were adjusted for duplications, screened based on their abstract relevancy and full-text availability (n=93) and then assessed for eligibility (n=47). Eligible articles were included if they had explicitly focused on information systems for pain management, finally, 18 relevant articles included in the study.*

***Results**: Reviewing 18 articles published in English from 2007 to 2016 showed that computerized CDS systems may minimize pain mismanagements by nearly 60%, decrease hospital stay, and optimize co-morbidities' management. The results of the system showed an accuracy of about 78% for the diagnosis of the type of pain in patients with SCI. Different studies indicated positive role of the systems to increase accuracy and improve physician's decision making.*

***Discussion**: Use of Information Systems in medicine aid medical practitioners for better management. To produce such a device, it is necessary to choose methods and algorithms for classification, such as neural network, support vector machine, genetic algorithms, rule-based systems, decision tree, and so forth.*

***Conclusion**: Medical informatics like "Developed Information Systems" should become a powerful member of the team. Although Research on "Developed Information Systems" in chronic pain management is limited. Using medical informatics in medicine would result in 1-minimizing clinical errors (pharmaceutical and diagnostics), 2-optimizing care effectiveness, 3-saving the time, and 4-jump to novel ideas and knowledge in the field of medicine.*

***Keywords**: pain, spinal cord injury, expert systems, clinical decision support systems (CDS System).*

DOI: 10.19193/0393-6384_2017_2_035

***Received** October 30, 2016; **Accepted** January 02, 2017*

Introduction

Spinal cord injury (SCI) is a damage to the spinal cord causing temporary or permanent functional changes[(1)]. Common causes of SCI include trauma (accident, gunshot, falls, sports injuries, etc.) or disease (transverse myelitis, polio, spina bifida, Friedreich's ataxia, etc.). Symptoms can vary widely from pain to paralysis and incontinence depending on the damaged part of the spinal cord and nerve roots[(2)].

Pain is an unpleasant sense and emotional experience associated with damage to bodily tissues[(3)]. Pain is a common problem in medicine and

one of the sources of personal and family sufferings; so that in most cases it goes beyond the individual and becomes a social problem[4].

Pain is one of the main problems in people with SCI[5], and is one of the most common reasons of reduced quality of life after SCI[6]. Several reports have shown that severe pain can occur after SCI[7]. There is little consensus on the nature, terminology and definitions of various types of pain after SCI. This situation led to much differences in reported the incidence and prevalence of pain after SCI[5].

The patients suffer from a chronic condition that often requires long-term treatment to be continuously assessed and adjusted. Although treatment is possible, the pain may recur. Therefore, treatment takes place aiming at pain reduction while improving physical and mental performance[8]. In many medical conditions, pain is a major symptom that is significantly associated with reduced quality of individual's life and his/her overall performance[9].

Today, pain management is a major issue in health care[10]. By creation of the industrial world, chronic pain became a significant and costly problem in the United States and unfortunately there are concerns about effectiveness of conventional medical interventions. Thus, we need to replace treatment strategies of chronic pain by modern intervention strategies[11]. Chronic pain may occur following an illness or injury, but it is likely to become permanent by physical and psychological factors that are far beyond the injury or disease[3].

A study conducted on prevalence of pain in children found that 54% of them experienced pain in the past three months[12]. About 30 million people in the United States suffer from chronic pain(13). Pain is the most common reason for consulting a physician in the United States[13].

Nearly 8.2% of gross national income is spent on direct and indirect treatment of pain in developed countries[14]. Chronic pain in adult patients has imposed heavy costs on patients and governments in western societies. The average cost of treating chronic pain (including direct and indirect costs) for any British teenager has been estimated to be about 8,000 £ per year. Annual expenditure for treating all adolescents with chronic pain in the United Kingdom has been estimated to be about 3,840 million £[15].

Pain management tries to reduce the pain to the extent that the patient can resume his previous activities and provide better living with the patient. First, physicians determine etiology of pain by careful assessment and examination, and then try to reduce pain through a combination of pharmacologic and non-pharmacologic therapies, and if necessary, they change the dose and type of the medications used. If physicians do not obtain the desired result, they will jump to the next step; that is, semi-invasive interventional treatments[16]. These treatments are performed in a sterile operating room with fluoroscopic and radiographic guidance to increase accuracy and safety. After full or partial control of the pain, the patient is introduced to the sports medicine or physical and rehabilitation medicine departments so that physical abilities would improve by receiving the exercise prescriptions. In addition, psychiatrists or clinical psychologists will visit the patient in order to offer necessary therapeutic actions for improving mental-psychological status[16].

Pain management is a branch of medical sciences and is related to various disciplines to reduce pain and improve quality of patients' life[17]. The pain management team usually includes general practitioners, pharmacologists, clinical psychologists, physiotherapists, occupational medicine practitioners, physician assistants and nurses[18]. Moreover, mental health specialists and massage therapists may also work in the team[18]. Such interdisciplinary pain management team includes healthcare providers from different disciplines, each of them are specialized in various characteristics of the pain. the main disadvantage of this approach is that access to all team members is usually limited and we rarely see an effective coordination[8]. Initial screening of the patient by one of the members will determine other required members for optimum management[19]. Roles played by members will be often overlapped which emphasizes the importance of communication between the team members. For example, a professional nurse and pharmacist should normally cooperate with each other in order to monitor patient's response to medical treatment, and management of potential side effects with physician. All team members must coordinate the care so that the patient can return to work, of course, if return to work is one of the objectives of treatment[8].

Health monitoring system has grown rapidly in the past two decades, and has the potential to change the current medical care. Intelligent systems of "health monitoring" have a positive effect on automation of patient monitoring, improvement of

patient treatment process, improvement of medical staff efficiency, reduction of waiting times for health services, and reduction of overall costs of health care(20). Mechanized health information systems would collect and generate information required for integrated support of management decision-making processes[21, 22, 23]. Using information technology in medicine reduces clinical errors (pharmaceutical and diagnostics) and leads to increased care effectiveness and saves time in caring patients[24, 25]. Due to the importance of pain management in patients with SCI, this study deals with the developed information systems such as Clinical Decision Support Systems (CDS System) and expert systems on pain management in this population.

CDS systems are divided into three types:

• They provide information used in a clinical context with the physician and health personnel using online documentation that is called info button.

• They represent patient's condition, certain situational warnings, reminders, a collection of medical orders, and other recommendations for direct actions.

• They provide information to facilitate problem-solving and decision-making as dashboards, graphic displays, documents format and structured reports(26).

Research method

To conduct a literature review on "Developed information systems for pain management of patient with spinal cord injury", we searched peer-reviewed articles in research database including Scopus, Pub Med, IEEE Explore, and Google scholar; and e-journal collections including EBSCO, Science direct, Emerald, Springer Link, and Wiley. Furthermore, printed journals, books, dissertations were hand- searched for relevant studies not captured from the database. The search strategy interchangeably used the terms of "Spinal Cord Injuries", "pain measurement system" , "expert system" and "Clinical decision support system" combined with Boolean operator "AND". Articles were identified by conducting title searches. The search process was limited to articles in English (either printed matter or online journals) and published between 2007 and 2016.

The records were screened for relevance to topic of the study. Articles seemed to be relevant, retrieved and read in full. The lists of references within the relevant articles were also hand-searched. Some articles were excluded due to irrelevancy to the topic or inaccessibility to their full text. Remained full-text articles were assessed for eligibility. Finally, 18 relevant articles entered the study.

Result

Reviewing 18 articles published in English from 2007 to 2016 showed that computerized CDS systems may minimize pain mismanagements by nearly 60%, decrease hospital stay, and optimize co-morbidities' management.

As a crucial issue in pain management, CDS systems can be effectively used to improve accuracy of pain assessment and provide better recommendations for clinical decision-making. Pombo (2014) reviewed papers on computerized systems, including CDS systems for acute or chronic pain from 1992 to 2011. The papers employed rule-based algorithms, neural networks, non-standard set theory and statistical algorithms. The results showed that average accuracy of the methods is 53% to 87.5%. 85% of the research presented the output comparable with the physicians' performance and reported 84% improved performance. This study confirmed clinical performance improvement based on the suggestions provided by the CDS systems[17].

Patient and clinician acceptability ratings of CDS Systems ranged from moderate to high. Using Decision Support Systems increased clinical usefulness, understandability, clinical workflow fit, ease of completing guideline recommended practices, improved care coordination by facilitating division of workload, improved patient education, increased consideration and knowledge of other disciplines, and improved behavioral care, allow sharing and integrating the data, and knowledge reuse.

Results showed that the CDS systems may be used in acute and chronic pain settings. Use of CDS Systems in rapid access chest pain clinics assist diagnosis, providing timely assessment for patients with new onset suspected angina.

Verma et al. designed a CDS system for diagnosing the type of pain of patients with SCI. The results of the system showed an accuracy of about 78% for the diagnosis of the type of pain in patients with SCI. The system was designed using Bayesian networks[27]. Table1 shows systematic reviews in related articles.

Author	year	clinical base	application domain
Thilo Bertsche and others(28)	2009	Pain management	computerized CDS system
	The number of patients with at least one deviation from guidelines at discharge was decreased from 74% to 14%. Duration of hospital stay decreased from 3.0 to 1.5 days. The number of patients treated with co-analgesics increased from 46% to 66%.		
Meredith Y. Smith and others(29)	2007	chronic pain management	Computerized CDS Systems
	Patient and clinician acceptability ratings of CDS Systems ranged from moderate to high. Due to insufficient data, definitive conclusions concerning the impact of CDS Systems on provider performance and patient outcomes were not possible.		
Sneha K. Verma and others(30)	2013	Spinal cord injury, Neurological Classification	Multimedia system, CDSS
	Computer-aided pain classifier tool can be integrated with medical imaging so that if physicians want to compare pain information provided by patients with imaging data, they can do it all at the same time.		
Jodie Trafton and others(31)	2010	Chronic, Noncancer Pain(Opioid Therapy)	Decision Support System
	Increased clinical usefulness, understandability, clinical workflow fit, and ease of completing guideline recommended practices.		
HazmyImanAbas and others(32)	2011	acute postoperative pain management(APPM)	ontology and CDS system
	CDSS Improved APPM management by: Developing guidelines and algorithms, clinical paths, checklists, daily goals. Allow sharing of data, knowledge reuse.		
LEE, SEONAH And others**(33)**	2013	Nursing Practice	Computerized CDS Systems
	The key steps for decision support functions were initial patient assessment, problem identification, care plan, and outcome evaluation.		
Ju-Ling Hsiao and others(34)	2013	nursing staffs-Anesthetist	Decision support systems and modeling
	The critical role of information quality, computer self-efficacy and organizational structure in the development of CDSS are demonstrated.		
InSook Cho and others(35)	2010	EHR, Arden Syntax	standards-based interoperable CDSS architecture
	architecture exhibited good performance and made it easy to integrate patient data		
David Peiris and others(36)	2014	Management of Back Pain	Web-Based Clinical Decision Support
	The tool had acceptable face validity when reviewed by experts. Over a 12 month period there were 7125 website visits with users.		
Kalpana Maria Nair and others(37)	2015	chronic pain, primary care	CDS System, electronic medical record
	System Usability Scale was 81.1 and in iteration was 70.40, Qualitative data from usability testing were valuable in the CDSS Development process.		
Preetvanti Singh(38)	2013	Knee Pain Management	Knowledge-Based Medical Decision Support System
	The developed CDS System will help health care professionals making medical decisions by comparing the effectiveness of various alternate decisions devised with the objective of improving Quality of Life of patients.		
Johnson, Rachel and others(39)	2011	chest pain	CDS Systems
	Use of CDS Systems in rapid access chest pain clinics assist diagnosis, providing timely assessment for patients with new onset suspected angina.		
Pombo, Nuno and others(17)	2014	pain management	machine learning, CDS systems
	The median accuracy ranged from 53% to 87.5%.		
Malaekeh, Sadat Raheleh(40)	2013	Neuropathic Pain	CDS System
	Participants preferred electronic formats than paper.		
Amanda M Midboe(41)	2011	Chronic pain management, Medication management	CDS systems
	Improved care coordination by facilitating division of workload, improving patient education, increasing consideration and knowledge of options in other disciplines, and improving behavioral medicine care for chronic pain.		
Sneha K. Verma and others(27)	2014	spinal cord injury	Bayesian decision theory, Decision Support System
	This tool will be integrated with an imaging informatics system to support a clinical study.		
Timm Hecht and others(42)	2015	adverse drug reactions in chronic pain therapy	CDS systems
	CDS Systems may minimize adverse drug-drug interactions (DDIs) causes an average. According to the pain physicians the CDSS was chosen as the preferred tool.		
Wendy Oude Nijeweme and others(43)	2016	Low Back Pain, Ontology	Decision Tree, Web-Based CDS System
	Based on the results, we developed ontology and a decision tree that models the decision making process of the CDSS.		

Table1: Relevant systematic reviews.

Discussion

CDS systems deliver intelligently professionals' information and knowledge to the physicians, staff, patients and other individuals at the right time that will improve treatment and health care[44]. With regard to specific clinical conditions, such systems provide relevant information, necessary recommendations and analysis of conditions with the physicians, patients, and healthcare centers; however, judgment will be handled by physicians[26].

Like CDS systems and expert systems, developed computerized systems aim to provide a tool for timely and more reliable decision for healthcare providers. According to the studies reviewed in this paper, the first step to produce such a device is to choose methods and algorithms for classification, such as neural network, support vector machine (SVM), genetic algorithms, rule-based systems, decision tree, and so forth[45]. Using clinical computerized systems may improve management of chronic diseases that require multiple visits and return to the healthcare professional centers, monitoring of disease process and treatment, and patient behavior management[46]. According to the pain physicians the CDSS was chosen as the preferred tool[42]. These systems play an important role in pain management. The most important disadvantages of such systems are a lack of integration with mobile devices, lack of use of web-based interfaces and lack of features for entering data by patients[17].

Paper-based systems in the clinic cannot respond to the repeated returns of patients. If information management of pain resulting from SCI is mechanized based on surveys and interviews with medical experts, the following actions seem to be taken:

• Mechanization of the process of data collection, storage and processing, and saving papers;

• Comprehensive and complete review of diagnostics and therapeutic outcomes;

• Ease and accuracy of follow-up during treatment;

•Efficient use of the working time of the health personnel;

•Providing information to make policies for pain management;

• Increased quality of healthcare services through improved interactions;• Increased quality of information received from the patient in terms of accuracy and completeness, precision and relevance;

• Creating a database of patients referring to the pain clinics in the country;

• Improvement of treatment of patients with pain;

• Cost reduction by eliminating unnecessary visits, reduction of repeated referring of the patients to the healthcare centres, reduction of the frequency of Para clinical tests and so forth.

Ideally, CDS system plays five important roles in medicine: providing the right information to the right person in the right format through a good communication context at the right time which are the most important tasks of such systems[47]. CDS systems are widely used in the healthcare process such as triage, early diagnosis, changes in patient's symptoms, extraction of the patient's data from medical records, patient support, treatment assessment and monitoring the treatment process[17].

In one study, 88% of the respondents agreed that using CDS systems would reduce medical errors(48). CDS system is an essential tool for evidence-based medicine[49]. Moreover, implementation of CDS systems increases the possibility of timely management[17].

Gerard et al (2008) used CDS system for influenza vaccination. The results showed that it improved vaccination(50). CDS system in-prescribing (e-Rx) system improved safety, quality, productivity and treatment cost reduction. However, usefulness of the potential benefits has not been recognized. Use and customization of CDS system provides a new approach to expansion of current knowledge, acceleration of the standards implementation, coding of systems and achievement of improved health and healthcare systems[51].

Mechanized support decision systems play an important role in planning associated with symptoms important in pain management. The most important disadvantages of CDS systems are lack of integration with mobile devices, lack of web-based interfaces use and lack of features for entering data by the patients[17].

Ability to interact with the system at any place and time provides a valuable opportunity with physicians, health professionals and patients. This type of access can lead to better and more effective treatment and also ensures monitoring of the patients in a hospital or outpatient settings. The systems will provide scalability and compatibility to monitor the healthcare of patients with acute and chronic pain in short- and long term. Patients may also announce reports, complaints and notes when the pain occurs. In addition, regular collection of patients' data leads to more realistic assessment of their health and minimizes misdiagnosis and wrong decisions(17).

Using CDS systems improves the followings:

• Management of chronic conditions requiring multiple visits and return to the health centres;

• Monitoring disease process and treatment;

• Managing patient's behaviour[52].

Using artificial intelligence in CDS systems helps physicians diagnose disease or choose treatment. Due to the memory limitations, physicians may not examine all symptoms and test results at a time, forget them and or may not seek information about them. However, it is unlikely for the mechanized systems to ignore or forget effective factors (since the relationships between variables are addressed in designing such systems)[46].

Like other intelligent systems, this intelligent CDS system generally consists of five parts:

1. Choosing a classifier system;
2. Choosing effective features in classification;
3. Training;
4. Validation,
5. Assessment[53].

Neural networks are widely used in medical decision support systems[54]. Neural networks are a powerful tool to help physicians. The tools can process a high number of data and minimize errors in ignoring patients' information. They also reduce the time spent on diagnosis. Neural networks strength has been proven in satisfactory diagnosis of various diseases. In addition, they have more reliable diagnose which increases patients' satisfaction. However, neural network is a tool provided for physician and the physician is the one who should make the final decision. Intelligent techniques are steadily changed to assist in accurate and rapid diagnosis[6].

It is evident that further study after implementing all the system changes needed to determine the effectiveness of system refinements(40).

Conclusion

Management of SCI pain requires pain management team, including skilled physicians with diverse knowledge and expertise. Team members play very important roles because they must work together in order to facilitate treatment. CDS systems provide intelligently professionals' information and knowledge to the physicians, staff, patients

and other individuals and present the knowledge at the right time that improves treatment and healthcare. Many studies indicate that CDS systems improve various clinical and medical areas(55).

Application of CDS systems using professionals' information and knowledge causes information to be notified to the right person at the right place and time. Different studies indicated positive role of the systems to increase accuracy and improvement of physician's decision making. If the systems are provided in webs and mobiles, they could be accessed at any place and time and could be more efficient. CDS systems combined with artificial intelligence will have beneficial effects on assisting medical systems, increase accuracy in diagnosing the type of pain and improve treatment of pain in the patients with spinal cord injury.

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Acknowledgments
This study was part of a PhD thesis conducted in Tehran University of Medical Sciences. We also thank Shefa Neuroscience Research Center. The authors wish to thank all people supported this study with their expert opinions. We express our special thanks to all authors whose articles were reviewed in the process of literature review. Their valuable efforts are highly appreciated by the authors

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