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# eXiTCDSS: A framework for a workflow-based CBR for interventional Clinical Decision Support Systems and its application to TAVI

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ABSTRACT

Clinical Decision Support System (CDSSs) should form an important part of the field of clinical knowledge management technologies through their capacity to support the clinical process and use of knowledge, including knowledge maintenance and continuous learning, from diagnosis and investigation through surgery, treatment and long-term care. The work presented shows a workflow-based CDSS designed to give case-specific assessment to clinicians during complex surgery or Minimally Invasive Surgery (MISs). Following a perioperative workflow, the designed software will use a Case-Based Reasoning (CBR) methodology to retrieve similar past cases from a case base to provide support at any particular point of the process. The graphical user interface allows easy navigation through the whole support progress, from the initial configuration steps to the final results organized as sets of experiments easily visualized in a user-friendly way. The eXiTCDSS tool is presented giving support to a recent complex minimally invasive surgery which is receiving growing attention lately, the Transcatheter Aortic Valve Implantation (TAVI). The results obtained are presented on a basis of a real TAVI case base of 82 patients operated at Rennes University Hospital.



## 1. Introduction

Nowadays, medicine and health fields are getting more and more involved with computer science. Among all branches, the main focus of the current research points towards Artificial Intelligence (AI) to improve the performance of Clinical Decision Support System (CDSSs). In a general term, CDSSs comprise a large spectrum of systems which provide clinicians, staff, patients, and other individuals with knowledge and person-specific information, intelligently filtered and presented at appropriate times, to enhance health and health care (Berner, 2009). Although the first attempts to supply health services with computerized systems appeared in late 1950s (Ledley & Lusted, 1959), CDSSs have been used in clinical practice since 1970 with the appearance of the first clinical advisory systems (Dombal, Leaper, Staniland, McCann, & Horrocks, 1972; Shortliffe, 1976; Warner, 1979). Since then, several CDSSs based on AI algorithms have been designed and are widely used in hospitals and medical centers, shifting from merely administrative systems to the actual CDSSs and they are proved to be very useful not only to help the clinical staff in making decision but for patients also.

CDSSs should form an important part of the field of clinical knowledge management technologies through their capacity to support the clinical process and use of knowledge,including knowledge maintenance and continuous learning, from diagnosis and investigation through surgery, treatment and long-term care. Arguments for and against the value of CDSSs have been discussed over the years. Among its potential benefits, as stated in Coiera (2003), CDSSs could improve patient safety through reduced medication errors and adverse events. Also, they should improve quality of care by increasing pathways, guidelines and documentation available for patients. Another advantage is that CDSSs may improve efficiency in health care delivery, reducing costs through faster order processing and avoiding test duplication. As drawbacks, clinicians may see CDSSs as a threat to clinical judgment and sometimes too inflexible, with difficulties to depart from ordered, pre-prepared paths. Also, computer-supported decision systems promote overreliance on software decisions which may limit clinicians' freedom to think at some point. In the same way, bad designed systems can create extra work or extend clinical procedures more than necessary. Finally, maintenance costs, professional support and training needed by the medical staff in order to use the software properly could also be seen as arguments against the utilization of CDSSs.

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Despite several successes, their impact on routine clinical practice has not been as strong as expected, specially due to the barriers to their implementation, which still remain in place. Therefore, up to the date, CDSSs have not been largely tested and, given their fast evolution and the limited range of clinical settings in which they have been used, it is mandatory that CDSSs should be rigorously evaluated before widespread introduction into clinical practice (Evans, Pestotnik, & Classen, 1998).

Decision support can be provided at various stages in the care process, from preventive care through diagnosis and treatment to monitoring and follow-up. As detailed in Perreault and Metzger (1999), computer CDSSs can be designed to support four basic clinical functions. First, giving administrative support, aiding in clinical coding and documentation, authorization of procedures, and referrals. Second, managing clinical complexity, keeping patients on research and chemotherapy protocols, tracking orders, referrals follow-up, and preventive care. The third function deals with cost control, programming CDSSs to monitor medication orders with the objective of avoiding duplicate or unnecessary tests. A fourth stage of application, which represents the focus of this work, involves CDSSs with low level decision support, helping in clinical diagnosis and treatment plan processes, giving case-specific support in highly complex surgery operations as in Minimally Invasive Surgery (MISs), promoting use of best practices and guidelines based on population case management.

CDSSs are classified into two main groups, depending on whether they are knowledge-based systems, or non knowledge-based systems (Berner, 2009). The knowledge-based CDSSs are the most common type of CDSSs used in clinics and hospitals. Many of today's knowledge-based CDSSs arose out of earlier expert systems research, where the aim was to build a computer program that could simulate human thinking (Miller, Pople, & Myers, 1982; Shortliffe, Axline, Buchanan, Merigan, & Cohen, 1973). They are structured around rules mostly in the form of IF-THEN statements. Most of knowledge-based systems consist of three parts, the knowledge base, inference engine, and mechanism to communicate (Wyatt & Spiegelhalter, 1991). The rules are associated with compiled data extracted from a knowledge base. The inference engine combines the rules from the knowledge base with the patient's data. The communication mechanism will allow the system to show the results to the user as well as have input into the system. Non knowledge-based CDSSs use AI through machine learning techniques, which allows the computer to learn from past experiences and to recognize patterns in the clinical data (Marakas, 1999). Artificial Neural Network (ANN) (Baxt, 1995; Holst, Astrom, & A.J., 2000; Olsson, Ohlsson, Ohlin, & Edenbrandt, 2002) and genetic algorithms (Laurikkala, Juhola, Lammi, & Viikki, 1999) are two common types of non knowledge-based systems. The fusion of a knowledge base with non knowledge-based machine learning techniques results into an hybrid system. Hybrid systems extract the best from both methodologies, finally resulting into an overall improvement of the system performance and thus providing an optimal solution for Clinical Decision Support Systems (Demmer-Fushman & Lin, 2007). This paper will focus on this kind of hybrid systems, presenting a software framework for CDSS which uses a well-known *lazy learning* technique called Case-Based Reasoning (CBR) (Aamodt & Plaza, 1994) and a past patients case base to asses clinicians. Although rule-based approaches can be used to implement CDSS, rules for these systems would become very complex and difficult to compile (Wills & Watson, 2004). Storing experience lends itself well to a case-based approach, whereas encoding experience knowledge in rules is not as intuitive. In fact cases can also be seen as rules (one case one rule) specific for each case. CBR systems also automatically adapt with experience, while rule-based approaches may need more user-interaction and understanding.

From a software oriented point of view, a CBR-based CDSSs is designed to directly aid in clinical decision making in which characteristics of individual patients are matched to a computerized knowledge base for the purpose of generating patient-specific assessments or recommendations that are then presented to clinicians for consideration (Hunt, Haynes, Hanna, & Smith, 1998). CBR is the process of solving new problems based on the solutions of similar past problems. In the clinical field, CBR has been specifically used in successful CDSSs. An integration of CBR and rule-based reasoning was used in systems for the planning of ongoing care of Alzheimer's patients (Marling & Whitehouse, 2001) and for the management of Diabetes patients (Bellazi, Montani, Portinale, & Riva, 1999).

The eXiTCDSS tool is presented giving support to a recent complex minimally invasive surgery which is receiving growing attention lately, the Transcatheter Aortic Valve Implantation (TAVI) (Webb & Cribier, 2011). In TAVI, a synthetic valve is transported to the heart through a small hole made in groin. This procedure can be compared to that performed when placing a stent, or performing balloon angioplasty. Nowadays, there are two current market leaders whose devices have earned CE Mark approval in Europe and are available to physicians for TAVI in appropriate patients; the CoreValve device (a self-expanding valve prosthesis consisting of a Nickel–titanium frame with a tri-leaflet valve fashioned out of porcine pericardium mounted within) and the SAPIEN device by Edwards Lifesciences (a balloon-expandable tubular metal stent with a tri-leaflet valve fashioned out of bovine pericardium mounted within). This technique was first developed in Europe, where it was initially performed in 2002. Since then, more than 10,000 patients have benefited from it and the results have shown the procedure to be effective in improving functioning in the patients with severe aortic stenosis. In the recent years TAVI is assuming a major role in the routine management of patients with aortic stenosis and now TAVI is considered the standard in patients who are not candidates for conventional surgical Aortic Valve Replacement (AVR). On the basis of almost 10 years of experience TAVI also appears to be a reasonable option for some operable, but high-risk patients. Nevertheless considerable work needs to be done before TAVI is expanded into lower risk groups.

This work presents a workflow-based CDSS designed to give case-specific assessment to clinicians during complex surgery. For this purpose, a real TAVI case base of 82 patients operated at Rennes University Hospital is used as case base. The article is structured as follows. In Section 2 a description of the workflow management during an intervention is detailed. Also, recent applications of CDSS for surgical processes are reviewed. Section 3 introduces the eXiTCDSS framework. Also, this section describes the components and functionalities of the application. In Section 4, the TAVI MIS is described. The application of eXiTCDSS is applied to the TAVI procedure. In Section 5, experimental results with a real TAVI patient case base are presented. Finally, conclusions and future work are included in Section 6.

## 2. CDSS integration with clinical workflow

Recent introduction of new clinical techniques such as MIS has led to several technological innovations inside the Operation Room (OR). All these advances, however, create new difficulties, such as inadequate information transparency, limited access, and poor visualization. Therefore, clinicians must rely on advancements in medical imaging technology (Dugas, Schauer, Volk, & Rau, 2002). These limitations in MIS are constantly giving rise to new research and development in the area of CDSSs. Such systems are providing realtime image guidance and task automation support while the clinician is performing the intra-operative tasks (Wood et al., 2007).