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A hybrid hierarchical decision support system for cardiac surgical intensive care patients. Part II. Clinical implementation and evaluation

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Summary

Objective: Patients emerging from cardiac surgery can display varying degrees of cardiovascular instability arising from potentially complex, multi-factorial and inter-linked causes. Stabilization and control of the cardiovascular system are currently managed by healthcare experts using experiential knowledge, and, in some centers, manually inputted decision pathway algorithms. This paper describes a clinical trial undertaken to determine the basic functioning of a clinical decision support system (CDSS) designed and constructed by the authors to facilitate the control of the major cardiovascular components in the early post-operative phase. Part II follows Part I's description of the software and simulation testing of the CDSS, and describes the hardware setup of a patient monitoring and CDSS. The system is evaluated on three post-cardiac surgery intensive care patients whom had all undergone cardio-pulmonary bypass.

Methods: The study was approved by the Sheffield Teaching Hospitals National Health Service (NHS) Foundation Trust Research Ethics Committee and conducted at the North Trent cardio-thoracic surgical unit and cardiac intensive care unit (CICU), Northern General Hospital, Sheffield (UK).

Patients considered as 'very likely' to require active intervention to support the cardiovascular function following routine cardiac surgery were recruited during pre-operative surgical and anesthetic assessment, giving written informed consent when admitted for their operation. These patients underwent routine induction and maintenance of anesthesia by a non-study consultant anesthetist and the operation performed. There were no restrictions placed on the types of invasive monitoring used, on the use of trans-oesophageal echocardiography, drug selection, or the

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anesthetic agents selected by the clinicians performing the operations. All patients had full, routine invasive and non-invasive monitoring applied, including electrocardiography, central venous and peripheral arterial catheterisation, urine outputs and central temperature. After chest closure the patients were transferred to the CICU, sedated and ventilated, and the study commenced by the study anesthetist (1st author). The patients were in a clinically stable condition when admitted to the unit, and were attended by the treating clinicians until the handover to the study anesthetist occurred.

The LiDCO*plus*® (lithium dilution cardiac output) monitor (LiDCO Limited, Flowers Building, Granta Park, Cambridge CB1 6GU, United Kingdom) was calibrated after attachment to the patient's arterial line, and the patient's beat-to-beat hemodynamic data transferred to the host laptop computer. The CDSS graphical interface displays the patient's clinical details and specific cardiovascular data and prompts the anesthetist to input the target ranges for each parameter, and select a suitable advisor frequency. This is the frequency with which the therapeutic advice is displayed on screen with an audible prompt for a control inputs from the anesthetist. In each case this was selected to be 30 s. When the study anesthetist agreed with the CDSS advice (administration of fluid, commencing a drug, altering the drug infusion rate) the syringe motif on the "Advisor Infusion Rates" panel of the graphical interface was 'clicked' on and the infusion rate immediately and manually inputted to Graseby® 3400 pumps. If any disagreement between the anesthetist and the computer's advice arose, the syringe motif on the "Expert Infusion Rates" panel of the preferred drug was 'clicked' on and the expert's therapeutic decision (e.g. infusion rate) was entered in the corresponding data field and then applied to the pump. During all trials, data was stored for off-line analysis.

Results: The CDSS successfully selected suitable drug therapies for each case and advised reasonable and appropriate infusion rates such that the study anesthetist did not have to override the suggested CDSS instructions and infusion rates. Under differing clinical conditions the system was able to maintain clinically appropriate and stable control of the cardiovascular system (CVS), with good profiles under noisy physiological measurements, and was readily able to regain control following transient deterioration of the patient hemodynamic parameters (coughing, or during blood sampling).

1. Introduction

In the immediate phase following cardiac surgery utilising cardio-pulmonary bypass (CPB), patients are characterised by cardiovascular instability resulting from many different possible causes, which may be present singly and cause direct disturbance, or be multiple and interlinked. Also, a systemic inflammatory response syndrome (SIRS) is triggered in 25% of patients undergoing cardiac surgery on CPB [1,2]. In this patient sub-population, this form of circulatory failure has a wide variation in rate of severity and in progression. Management involves the co-ordination of multiple drug infusions to maintain multiple monitored patient variables within accepted bounds [3]. Patients' responses in time and magnitude are notoriously non-linear, which, allied to cross-couplings, inter- and intra-patient parameter variability as well as outcome uncertainties, make the therapeutic management of these patients a complex environment.

A computerised CDSS to assist the clinician's decision-making would be potentially beneficial in this challenging control environment. CDSSs are typically designed to integrate a clinical knowledge-base, patient data and a reasoning engine to generate case specific recommendations as shown in Fig. 1.

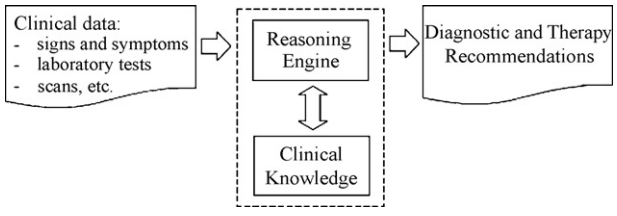

Figure 1 Structure of a CDSS.