ROBUST PID CONTROL FOR CLOSED-LOOP PROPOFOL INFUSION IN CHILDREN

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Background: Individual responses to propofol infusion in children are highly variable [1]. A closed-loop controlled system for anesthesia can reduce the effect of this variability, by automatically adjusting the drug infusion using feedback from a measure of the clinical effect. A robust controller design takes the interpatient variability into account, and is expected to provide adequate and safe closed-loop control of depth of hypnosis (DOH) regardless of the variability. In this study, a robust proportional-integral-derivative (PID) controller [2] is designed that automates both induction and maintenance of anesthesia. The designed system is clinically evaluated in a pilot study.

Methods: The WAVcns index [3] was used as measure of DOH. A PID controller was tuned to provide adequate robustness margins for a set of 14 identified models of the effect of propofol infusion on the DOH [4]. Following REB approval, and informed consent/assent, 23 children aged 6-15 (12y±3, 46kg±13, 154cm±15), ASA I-II, requiring anesthesia for elective upper or lower gastrointestinal endoscopic investigations were enrolled for clinical evaluation. Remifentanil was administered as a bolus (0.5 µg/kg) prior to propofol administration followed by continuous infusion (0.03 µg/kg/min).

Results: Automated induction of anesthesia was completed in an average (SD) of 4min10s (±80s) and the WAVcns index decreased to mean (SD) 39 (±5). During maintenance of anesthesia, the WAVcns index was stable and within 10 units of the setpoint for median (range) 90% (22-100%) of the time. Spontaneous breathing was maintained in all subjects. The limited overshoot during induction of anesthesia indicates sufficient robustness margins for all 23 subjects. One patient showed a strong response to stimulation (change of WAVcns index > 40).

Conclusion: Automated induction of anesthesia in children using a robust PID controller provides a stable level of anesthesia, maintains spontaneous breathing and limits overshoot in measured WAVcns. Maintenance of anesthesia during moderately painful procedures was adequate. In future work, the controller will be optimized to improve the speed of induction and the response to stimulation.

References
2. K.J. Åström and T. Hägglund, Advanced PID Control. ISA. 2006

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