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Automated control of end-tidal inhalation anaesthetic concentration using the GE Aisys Carestation™†

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Editor's key points

- New anaesthetic machines can automatically control the concentrations of volatile agents and fresh gas flow.
- This study compared the ETControl™ with manual adjustment of fresh gas flow by the anaesthetist in clinical practice.
- Time spent at low gas flows was significantly greater and volatile agent usage and costs were lower when using the automated system.
- Further studies are needed to confirm these findings.

Background. Automated control of end-tidal inhalation anaesthetic concentration is now possible. The EtControl™ module of an Aisys Carestation Anaesthetic machine digitally adjusts fresh gas flow and plenum vaporizer output to achieve a target end-tidal concentration.

Methods. We evaluated EtControl in clinical practice by measuring volatile agent consumption and the need for user input. We compared these values with contemporaneous controls using manual control of fresh gas flow rates.

Results. A total of 321 patients were anaesthetized with EtControl and 168 with manual control of fresh gas flow. The mean [95% confidence interval (CI)] sevoflurane usage for cases of 20–40 min duration was 14 (13–16) ml h^{-1} with EtControl and 30 (26–35) ml h^{-1} with manual control. For cases of the same duration, the mean (95% CI) desflurane consumption was 27 (21–33) ml h^{-1} with EtControl and 45 (29–62) ml h^{-1} with manual control. The average number of keypresses per case was 6.5 with EtControl and 13.6 during manual control of fresh gas flow.

Conclusions. Automatic implementation of low-flow anaesthesia using EtControl allows the user to set and maintain a desired end-tidal volatile concentration while using less volatile agent.

Keywords: anaesthesia, inhalation/economics; anaesthesia, inhalation/instrumentation; drug costs; drug utilization; humans

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Demands for increased efficiency in health expenditure have led to a renewed interest in promoting low-flow anaesthetic techniques to reduce the quantity of inhalation anaesthetic agents used. Such techniques require repeated adjustment of the concentration of volatile vapour added to the fresh gas flow as flow rates are reduced, with the anaesthetist acting as a controller in a negative feedback loop, comparing information from end-tidal gas monitoring with the desired value. This process has been automated by adding servo-motors to adjust both the analogue rotameter and vaporizer controls simultaneously,[1] but this has never been developed commercially. The Zeus anaesthesia machine (Draeger Medical, Lubeck, Germany) was the first anaesthetic machine to offer automated control of volatile delivery, using a system of direct vapour injection into the breathing circuit, combined with a turbine-driven ventilation circuit.[2] The FELIX AInOCanesthetic station (Air Liquide Medical Systems, Brescia, Italy) uses a conventional Selectatec vaporizer turned to the maximum output, with automated delivery of volatile controlled using an electronic mixing system.[3] The GE Aisys Carestation™ (GE Healthcare, Madison, WI, USA) has digital control of both fresh gas flow and plenum vaporizer output together with a compact breathing circuit to reduce the time to equilibration. In April 2010, an optional EtControl™ module was introduced which automatically adjusts gas flow and vaporizer output to achieve the target end-tidal concentration. A multiplexing system diverts gas monitoring to sample machine output every 3 min to confirm that fresh gas and vapour concentrations agree with values set by the software.

The aim of our study was to evaluate the EtControl module in clinical practice by measuring inhalation

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anaesthetic usage and the need for user intervention and comparing this with contemporaneous cases undertaken using manual control of fresh gas flow.

Methods

End-tidal control (EtControl) hardware and software was fitted to five GE Aisys machines in the Gynaecology Theatres of the Liverpool Women's Hospital in April 2010. In the fresh gas control mode, anaesthetists use three controls to manually set the oxygen mixture, fresh gas flow, and percentage volatile output as required throughout the case. Where the EtControl mode is used, anaesthetists set targets for end-tidal oxygen concentration, minimum flow rate, and end-tidal volatile concentration. The system uses an algorithm to adjust both fresh gas flow and vaporizer to achieve the set values via a negative feedback control system, although the precise details of the algorithm are uncertain. Fresh gas flow automatically reduces down to the minimum set value, although this can be increased during the case to compensate for system leaks.

We performed a service evaluation between June 2010 and October 2010 to observe fresh gas flow rates and inhalation anaesthetic usage in clinical practice where the anaesthetist had used either EtControl or fresh gas control. The project was approved by the Trust audit committee.

No patient identification information was collected during the audit. All information was collected from the log files stored within the Aisys anaesthetic machine. EtControl data were analysed from the files generated for each case that store breath-by-breath information about 114 variables derived from raw and processed data obtained from the Aisys machine, with an average time interval of 5.0 s. Data log files were obtained from each of the machines by our senior Biomedical Engineer using a Compact Flash card. Information from each log file was imported into a Microsoft Excel 2010 spreadsheet template [Microsoft (2010), Redmond, WA, USA], which contained formulae described in the Appendix, to calculate each of the variables described in the Results. The accuracy of control and bias were measured during conditions of steady state, defined as >300 s after a change in target concentration.

Fewer data were available for patients who received anaesthesia using fresh gas control as the Aisys software does not currently output data about flow rates or vaporizer settings. Instead, the keypress logfile was analysed, to determine user settings of fresh gas flow and vaporizer output during each case.

All patients received sevoflurane or desflurane. Patients with a duration of anaesthesia of <10 min were excluded, as there were insufficient data to perform a full analysis of the system performance in the maintenance phase of anaesthesia.

For comparison, Dr Ross Kennedy (Department of Anaesthesia, Parkside, Christchurch Hospital, University of Otago, Christchurch, New Zealand) kindly supplied us with original data from his 2006 and 2009 studies of the changing patterns of fresh gas flow rates.[4]

Data were analysed with Graphpad Prism version 5.01 for Windows (GraphPad Software, San Diego, CA, USA, www.graphpad.com) using the Spearman correlation and *t*-tests.

Results

During the evaluation period, we observed routine anaesthetic practice, leaving the choice of inhalation anaesthetic, fresh gas flow rate, and method of flow rate adjustment to the discretion of the individual anaesthetist. A total of 321 patients were anaesthetized using EtControl of fresh gas flow, 181 receiving sevoflurane and 140 receiving desflurane. Data were also obtained from 168 patients who had manual control of fresh gas flow during the same time period; of whom, 143 received sevoflurane and 25 received desflurane.

The time spent at each gas flow rate during the first 10 min of anaesthesia is shown in Figure 1. The gas flow profile for the total duration of anaesthesia is shown in Figure 2, together with data from Kennedy and French.[4] The average fresh gas flow during EtControl decreased significantly with increased duration of anaesthesia (Spearman $r=-0.88$, $P=0.0016$). The average fresh gas flow and rate of liquid volatile agent usage, categorized by duration of anaesthesia, is shown in Table 1. The cost of anaesthesia in £ h^{-1} is shown in Figure 3, using prices from the BNF.[5]

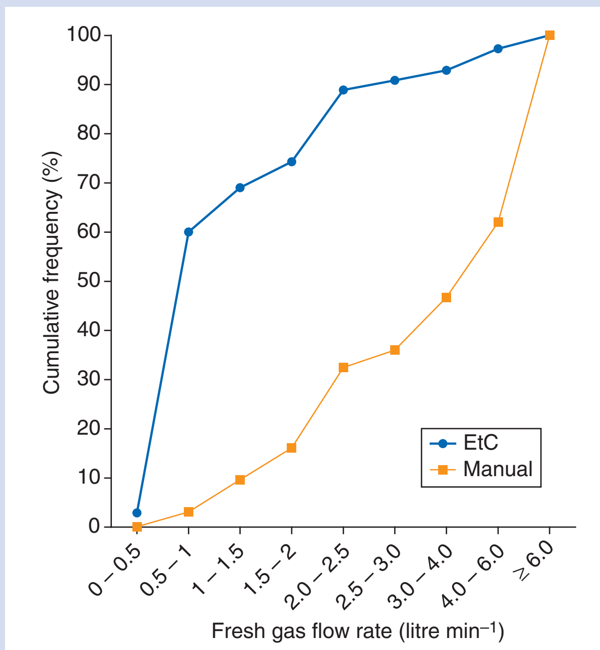

Fig 1 Cumulative frequency graph showing the amount of time spent in each fresh gas flow range during the first 10 min of end-tidal control and manual control of anaesthesia.