Technical Report

Modification of IVAC 530 infusion pump for patient controlled analgesia

C.P. Bates MD FRCPC, J.A. McEwen PH D P ENG,
K.M. Leighton MB FRCPC

This article describes an inexpensive device for delivering patient-controlled analgesia. Details of the necessary modifications of a standard IVAC 530 infusion pump are included. The total cost of the modified pump was $2200.

Patient-controlled intravenous narcotic analgesia (PCA) has been gaining acceptance as a safe and effective means of treating patients with postsurgical pain since its introduction in the early 1970's.[1-5]

The method employs an infusion pump which responds to the patient's request for analgesia by delivering a small dose of a narcotic analgesic intravenously. Integral to the safety of any PCA system is a "lockout interval" following each dose, during which the pump will not respond to additional requests by the patient. Potential benefits of PCA include a more precise tracking of the patient's changing requirements for analgesic medication than is possible with continuous analgesic infusions or intermittent intramuscular injections.[6] A number of PCA pumps are available from commercial suppliers, at prices up to $5000. In some cases, expensive special-purpose disposable accessories are also required. The relatively high cost of such devices and accessories may prevent widespread acceptance of PCA, particularly with increasing constraints on hospital budgets.

We would like to report the successful low-cost modification of a widely available intravenous infusion pump for use as a patient-controlled device. Our requirements were: simplicity of operation by patients and nurses, a dose range of 0.5 to 3 mg morphine, a lockout interval adjustable from one to 60 minutes, a recording device and protection against tampering.

Key words
ANALGESIA: instrumentation, methods; EQUIPMENT AND SUPPLIES, HOSPITAL: economics.

From the Departments of Anaesthesia and Biomedical Engineering (JAM), Health Sciences Centre Hospital, University of British Columbia, Vancouver, British Columbia, V6T 2B5.

The pump

Our PCA pump is an integrated system consisting of a modified IVAC Model 530 infusion pump and a custom control device. Figure 1 shows a functional block diagram of the system, including the modified infusion pump and added control device. Figures 2 and 3 show the front panels and operator controls of the integrated system. The information contained in the figures should enable a skilled biomedical engineer to construct a replica; further detailed technical information is available from the authors. Briefly, the system allows the monitoring of self-administered drugs and incorporates safeguards to prevent accidental overdosage. The control device performs four primary functions:

- Electronically turns the IVAC 530 pump on and off;
- Allows a programmable volume of solution to be infused by the pump;
- Disables pump activation for a programmable period of time after each injection; and
- Prints elapsed time whenever the patient control switch is depressed, along with a symbol indicating whether or not a dose was given in response.

The dosing interval is controlled by the patient, who triggers the device by depressing the patient control switch. A lockout period follows each injection of drug and may be varied from one to 99 minutes. The dose is controlled by the physician and can be varied from 1 to 99 drops.

Dose monitoring is achieved by the PCA controller's drop counting circuitry, which monitors the status of the IVAC's drop detection circuit. When the IVAC's drop sensor detects a drop, a signal is produced by the IVAC that increments the PCA controller's drop counter. When the drop count equals the programmed dose, the control-

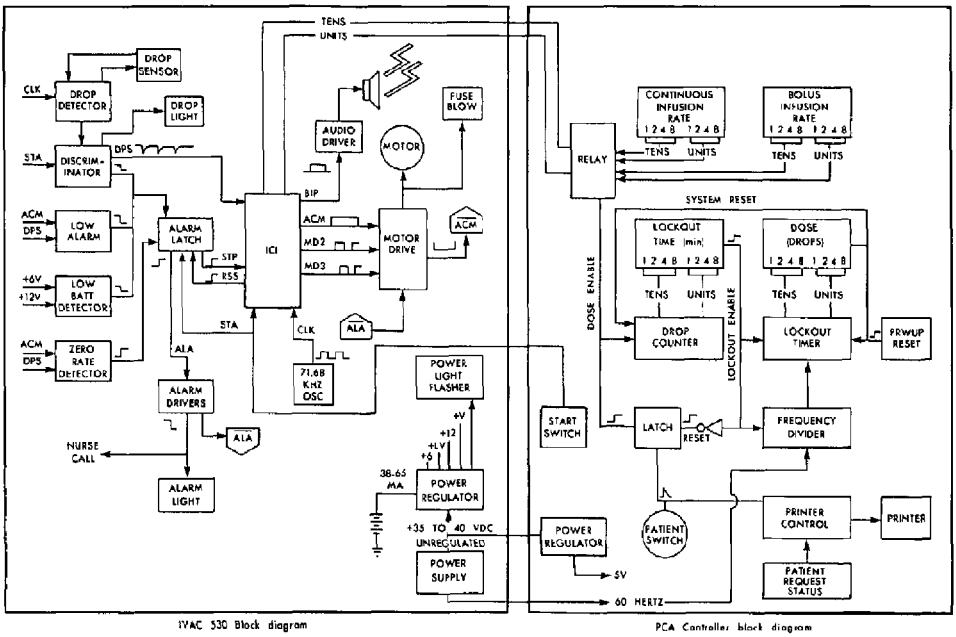

FIGURE 1 PCA functional block diagram.

ler turns the pump off and initiates the lockout period. When the lockout period has elapsed, the entire system is reset and is ready to deliver a new dose.

To provide a clinically acceptable level of safety, a number of modifications to the IVAC pump were performed. One such modification disabled the "power" and "reset" switches on the pump to prevent inadvertent pump activation. The IVAC's door, which acts as a clamp preventing free flow of solution through the device, was fitted with a lock to discourage its being opened accidentally. In addition, a clear plastic door was installed on the PCA controller. This door can also be locked to prevent unauthorised tampering with the dose and lockout settings. None of these modifications affects other safety features of the IVAC pump such as the low battery alarm and high and low drop-rate alarm.

The modifications described above were designed and implemented by staff of the U.B.C. hospital's Biomedical Engineering Department, in accordance with established standards and policies concerning the modification of medical devices and in conjunction with review by the University's human experimentation committee.

The total cost of the modification described above was approximately $900, consisting of $200 for components and $700 for design and fabrication. A surplus IVAC 530 pump, with an initial purchase price of $1300, was used in the prototype system. Modification of the pump prevents its use as a standard infusion pump while modified, but if required for normal usage the pump can be restored to its original, unmodified condition within two hours by biomedical engineering staff.

Conclusion

Our early experience with this device has been promising. A safe, effective and low-cost PCA pump has been developed by modifying an IVAC Model 530 infusion pump, the most common model of infusion pump in use today. This PCA pump uses standard intravenous tubing sets and thus is inexpensive to operate, in contrast to the PCA pumps which are commercially available. The demonstrated feasibility of inexpensive PCA pump systems such as this may encourage wider evaluation, acceptance and use of PCA techniques despite increasing constraints on hospital budgets. Two clinical points deserve emphasis:

- Since this device delivers each dose of analgesic solution as a prescribed number of drops, the drop size is of crucial importance to its success. Our system uses a drop counter and morphine concentration (0.5 $mg \cdot ml^{-1}$)

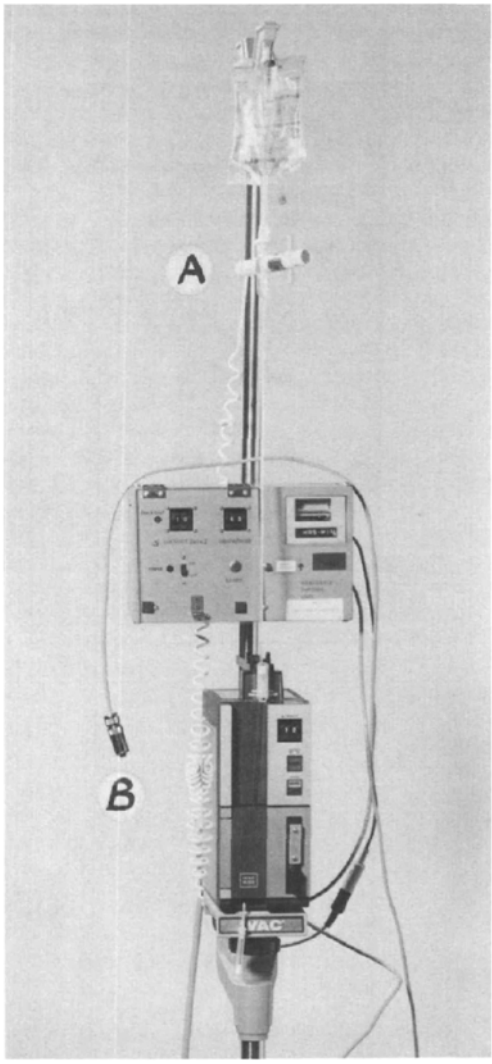

FIGURE 2 The PCA system, showing the modified IVAC 530 infusion pump and the custom control device. Also shown are the drop counter (A) and the patient control switch (B).

suited to a drop size of 0.1 ml; if a paediatric drip set is used instead, drop size and dose are reduced by a factor of six and satisfactory analgesia is impossible.

– Some patients using our PCA pump have complained of night-time sleep disturbance because of frequent return of pain. How this compares with the experience of patients receiving intramuscular narcotics, we have yet to determine, but in any case it suggests that night-time PCA might be made more effective by adding a slow continuous infusion of the narcotic. This can be achieved by a further modification of the IVAC 530 pump.

One final cautionary note should be added: for reasons of safety, quality-assurance and medico-legal liability, modification of any medical device such as the infusion pump described above should only be performed by an experienced biomedical engineer who is familiar with pertinent standards and regulations.

References

1 *Forrest WH, Smethurst PWR, Kienitz ME.* Self-administration of intravenous analgesics. Anesthesiology 1970; 33: 363–5.

2 *Keeri-Szanto M.* Apparatus for demand analgesia. Can Anaesth Soc J 1971; 18: 581–2.

3 *Keeri-Szanto M, Heaman S.* Postoperative demand analgesia. Surg Gynecol Obstet 1972; 134: 647–51.

4 *Tamsen A, Hartvig P, Fagerlund C, Dahlström B, Bondesson U.* Patient-controlled analgesic therapy: clinical experience. Acta Anaesthesiol Scand 1982; Suppl 74: 157–60.

5 *Rosen M.* Patient controlled analgesia. Editorial. Br Med J 1984; 289: 640–1.

6 *Mather LE.* Parenteral opiates for postoperative analgesia. Regional Anesthesia 1982; 7: 144–8.

Résumé

On décrit dans cet article un appareil économique pour l'administration de l'analgésie à demande. Les détails nécessaires pour modifier les pompes à infusion IVAC 530 sont donnés. Le coût total de la pompe modifiée est de $2,200.

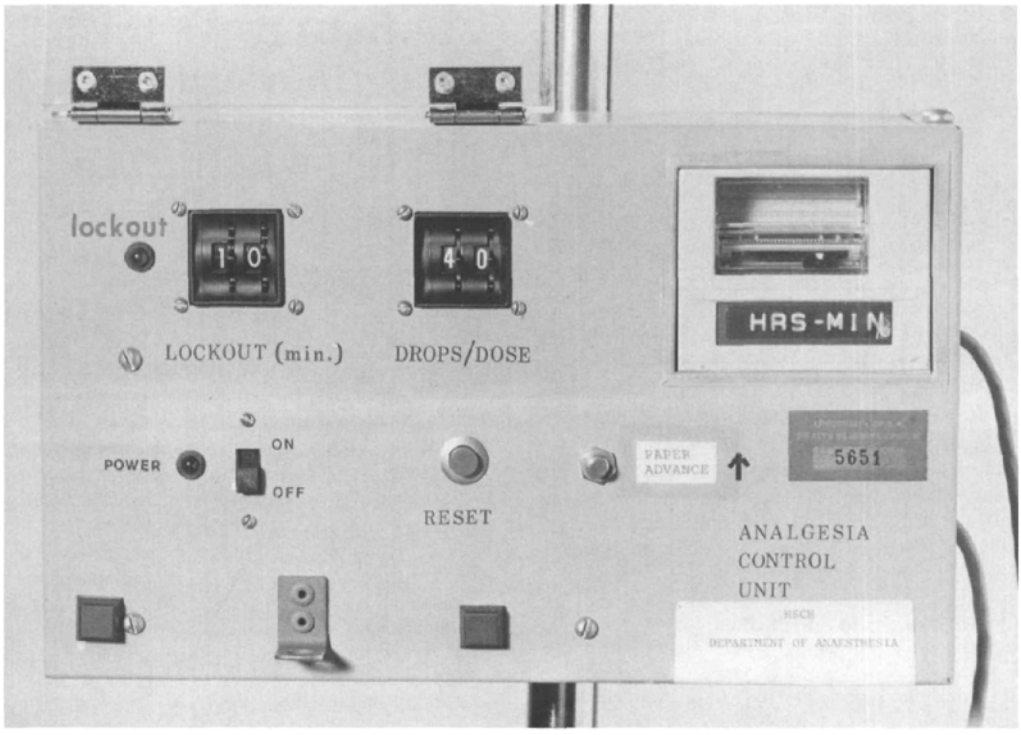

FIGURE 3 The custom control device.