Comparison of patient-controlled analgesia in children by i.v. and s.c. routes of administration

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SUMMARY

Sixty children undergoing appendicectomy were allocated randomly to receive one of two PCA regimens with morphine. Group IV received standard i.v. PCA with a bolus dose of morphine 20 μg kg⁻¹ and a background infusion of 4 μg kg⁻¹ h⁻¹ while group SC received PCA by the s.c. route with a bolus dose of morphine 20 μg kg⁻¹ and a background infusion of 5 μg kg⁻¹ h⁻¹. In both groups there was a lockout interval of 5 min. Group SC self-administered significantly less morphine (P < 0.05) and had a significantly (P < 0.01) greater percentage of valid demands for analgesia than group IV. There were no differences in pain scores between the groups at rest or during movement. Group IV suffered significantly (P < 0.01) more hypoxic episodes than group SC. There were no differences between groups in the incidence of postoperative nausea and vomiting or oversedation. S.c. PCA appears to be as effective and safe as i.v. PCA. By giving patients feedback on the occurrence of valid demands for analgesia, s.c. PCA may produce more appropriate and effective use of PCA. (Br. J. Anaesth. 1994; 72: 533-536)

KEY WORDS

Analgesia: paediatric; Analgesia: patient-controlled.

Patient-controlled analgesia (PCA) is now used commonly for the treatment of acute pain in selected children [1-6]. All reported studies have used the i.v. route of administration. The disadvantages of this route include the need for a dedicated i.v. cannula which may be a particular problem in children or the need for a one-way anti-reflux valve in the i.v. tubing, which is more expensive than a dedicated cannula. In children, the use of an anti-reflux valve makes the junction of the i.v. tubing and the cannula bulky and awkward.

The s.c. route of administration is very satisfactory for opioid infusions in acute [7-9] and chronic [10, 11] pain and also for bolus doses [12]. If the s.c. route of administration could be shown to be suitable for PCA, this would offer potential advantages by avoiding the need for either an anti-reflux valve or a dedicated i.v. cannula. These advantages would be particularly marked in children and in patients where veins are at a premium, such as those with extensive burns and those with chronic or terminal pain.

This study was performed to compare the s.c. and i.v. routes of administration for PCA in children. Both groups received a small background infusion which has been shown to be superior to a PCA regimen with no background infusion [13]. The study included assessment of pain during movement which has been shown to be a more sensitive discriminator between analgesic regimens than assessments carried out at rest [14].

PATIENTS AND METHODS

The study was approved by the hospital Ethics Committee and written informed parental consent was obtained for all patients. We studied 60 children aged 6-14 yr undergoing appendicectomy. On the basis of previous work using these methods [14], it was calculated that the study had a 90 % probability of detecting differences in pain scores and side effects which were significant at the 5 % level. Patients were visited before operation when the principles of using PCA were explained to the child and parents. Patients were taught to use the trigger of the PCA machine during this visit. Patients were not studied if they had received analgesia before operation.

All patients received a standard general anaesthetic which comprised a rapid sequence induction with thiopentone 5-7 mg kg⁻¹ and suxamethonium 1 mg kg⁻¹. The trachea was intubated and the patients' lungs ventilated with 67% nitrous oxide and 0.5-2.0% isoflurane in oxygen. Neumuscular block was maintained with vecuronium 0.1 mg kg⁻¹. Morphine 0.1 mg kg⁻¹ was given during operation. At the end of surgery, neumuscular block was antagonized with neostigmine and glycopyrronium in appropriate doses. In the recovery area, patients were titrated to comfort with bolus doses of morphine 50 μg kg⁻¹, if required.

Before patients left the recovery area, the PCA pump was connected (Graseby, PCAS). Patients were allocated randomly (by means of a computer generated list) to receive one of two different PCA regimens. One group received i.v. PCA (group IV) and the other received PCA by the s.c. route (group


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SC). In group IV the solution used contained morphine 1 mg kg\(^{-1}\) diluted to 50 ml with 0.9 % saline to give a concentration of 20 μg kg\(^{-1}\) ml\(^{-1}\). The PCA syringe was attached to the side arm of a Cardiff anti-reflux valve incorporated into the i.v. infusion cannula. This group received bolus doses of 20 μg kg\(^{-1}\) (1 ml) with a lockout interval of 5 min and a background infusion of 4 μg kg\(^{-1}\) h\(^{-1}\) (0.2 ml h\(^{-1}\)).

In group SC, a 22-gauge catheter was sited s.c. over the deltoid muscle of the same (non-dominant) arm as the i.v. cannula. This cannula was flushed with 1 ml of 0.9 % saline and secured with Elastoplast tape. The PCA syringe was attached to this cannula. In group SC the solution used contained morphine 1 mg kg\(^{-1}\) diluted in 20 ml of 0.9 % saline to give a concentration of 50 μg kg\(^{-1}\) ml\(^{-1}\). This group received bolus doses of 20 μg kg\(^{-1}\) (0.4 ml) with a lockout interval of 5 min and a background infusion of 5 μg kg\(^{-1}\) h\(^{-1}\) (0.1 ml h\(^{-1}\)). This background infusion differed from that used in group IV because it was not possible to give the same infusion with the dilution of morphine used.

After operation patients breathed air. A monitoring procedure described previously [15] was used. This involved high dependency nursing care with continuous pulse oximetry and hourly recordings of ventilatory frequency and scores for sedation, pain and nausea. The number of demands made, the number of valid demands and the volume of solution infused were also recorded hourly. Patients were reviewed three times a day by one of the authors. Patients were asked to quantify the delay between pressing the trigger of the PCA pump and the onset of analgesia. Patients were also asked about the presence of pain or discomfort at the cannula site and its relation to pressing the PCA trigger. There was always an anaesthetist available to deal with any problems relating to the PCA regimen. PCA was discontinued when there was a consistent decline in use and patients were able to take oral analgesics. At discontinuation of the s.c. PCA, the cannula was removed and the site inspected.

Pain was scored using a four-point, self-reporting score, which has been validated previously [14, 16], as follows: 1 = no pain; 2 = not really sore; 3 = quite sore; 4 = very sore. Assessments were made both at rest and during a specified movement (vital capacity breath followed by a cough). Children were not wokened from sleep for assessment unless the nurse suspected oversedation and "A" was recorded on the chart at these times. Sedation was scored using a four-point scale as follows: 0 = eyes open spontaneously; 1 = eyes open to speech; 2 = eyes open when shaken; 3 = unrousable. Nausea was scored on a four-point scale: 0 = none; 1 = nausea only; 2 = vomited once in the past 1 h; 3 = vomited more than once in the past 1 h.

If a pain score of > 4, or a sedation or nausea score of 3 was recorded, an anaesthetist was asked to see the patient.

Results were analysed using the Mann-Whitney U test for pain scores and morphine consumption and chi-square tests for comparison of events between groups.

### RESULTS

Patient data are shown in table I. The two groups were similar in age, weight, gender distribution and duration of PCA use. Patients in group IV self-administered significantly more morphine than those in group SC (P < 0.05). Group SC had a significantly greater percentage of valid demands than group IV (P < 0.01).

Pain scores were compared by calculating the median total pain score during each 4-h period after operation and comparing the groups during each of these periods (at rest and during movement). Figure 1 shows the pain scores in the two groups. There were no significant differences between the groups at rest or during movement at any of these times.

There were significantly more Sp\(_O_2\) recordings of less than 94 % in group IV than in group SC (P < 0.01) (table II). Sp\(_O_2\) readings were regarded as valid and recorded only if they persisted over a period of 5 min, if there was a good pulse signal on the oximeter screen and artefacts caused by poor positioning or venous engorgement had been excluded. The least values recorded were 85 % in group IV and 87 % in group SC.

There were no significant differences in the incidence of postoperative nausea and vomiting or of oversedation (sedation score of 2 = eyes open to shake or 3 = unrousable) in the two groups (table II). There were no sedation scores of 3 in any patient.

Twenty-eight patients in group SC were aware of bolus infusions shortly after making a demand. Five

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### Table I. Patient data and details of morphine consumption (mean (SD or range)). *P < 0.05, **P < 0.01

<table>
<thead>
<tr>
<th>Group IV</th>
<th>Group SC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (M/F)</td>
<td>17/13</td>
</tr>
<tr>
<td>Age (months)</td>
<td>128.6 (83-168)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>39.2 (11.4)</td>
</tr>
<tr>
<td>Duration of PCA use (h)</td>
<td>40.5 (11.9)</td>
</tr>
<tr>
<td>Morphine consumption</td>
<td></td>
</tr>
<tr>
<td>Total (including background infusion)</td>
<td>1436 (654)</td>
</tr>
<tr>
<td>μg kg(^{-1}) h(^{-1})</td>
<td>31.2 (11.1)</td>
</tr>
<tr>
<td>Self-administered by PCA</td>
<td>1250 (641)</td>
</tr>
<tr>
<td>μg kg(^{-1})</td>
<td>27.2 (11.1)</td>
</tr>
<tr>
<td>μg kg(^{-1}) h(^{-1})</td>
<td>71.6 (18.6)</td>
</tr>
</tbody>
</table>

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patients in group SC complained of pain at the cannulation site during bolus infusion. In all of these five patients, bolus doses stopped being painful after several hours of PCA use. Four patients in group IV were able to feel bolus infusions. No patients in this group complained of pain during bolus infusions.

When asked to comment on the interval between making a demand and subsequent analgesia, 25 patients in group SC and 15 patients in group IV described this delay as being less than 5 min.

In group SC, nine patients had a localized erythematous flare at the cannulation site which started soon after commencement of PCA. In all cases this faded after several hours. In group SC, no problems were observed at the s.c. site after removal of the cannula.

**DISCUSSION**

This study has shown that s.c. PCA appeared to be as effective and safe for acute postoperative pain as i.v. PCA. It also suggested that the s.c. route may have advantages over the i.v. route. There was a lesser consumption of morphine (in patients undergoing the same procedure) associated with a greater proportion of valid demands for analgesia. This was possibly because of the fact that with s.c. PCA, the patient was aware of bolus infusions and the demand for analgesia had been successful. Because of this, patients expected the demand to produce analgesia and tended not to make further invalid demands during the lockout period. The usefulness of a positive feedback to the patient that a demand has been successful has been noted previously [17, 18] and PCA pumps which produce different sounds after valid and invalid demands for analgesia are being developed. It should be remembered that group SC received a background infusion of 5 μg kg⁻¹ h⁻¹ (compared with 4 μg kg⁻¹ h⁻¹ in group IV) and this may have been partly responsible for a reduced requirement for self-administered morphine in group SC. This would not, however, explain the reduction in total morphine consumption in group SC compared with group IV.

The reduction in hypoxic episodes during s.c. PCA compared with i.v. PCA may reflect two possible mechanisms. The reduction in morphine consumption during s.c. PCA may result in less ventilatory depression than would otherwise be the case. Alternatively, differences in the pharmacokinetics of the two routes of administration may result in lesser peak concentrations of morphine if boluses are given s.c. rather than i.v. Limited data [19] concerning the absorption of morphine during i.v. and s.c. infusions in adults suggest that both routes are equally effective but there are no data concerning absorption after intermittent bolus administration. The fact that there was no difference between the groups in the incidence of oversedation suggests that morphine consumption in group IV was not excessive.

In patients breathing air, pulse oximetry is a sensitive monitor of ventilation [20]. Consideration of the ideal alveolar gas equation shows that with an inspired oxygen concentration of 21%, a small increase in alveolar carbon dioxide tension produces a decrease in alveolar oxygen tension and consequent hypoxaemia. An arterial oxygen saturation of 94% corresponds to an arterial oxygen tension of approximately 10 kPa and is associated with mild ventilatory impairment in healthy patients. This is a non-specific monitor of ventilation and discrimination between the possible causes (excess opioid and pain) requires assessment of opioid consumption and the level of sedation. A patient who is hypoxic because of...
excess opioid will be sedated while a patient in pain will be alert and unwilling to take a deep breath and cough.

Although the s.c. route of administration is very satisfactory for infusion analgesia in chronic and terminal pain and also acute pain, there is concern that absorption of bolus doses is so slow as to make it unsuitable for use with PCA. This proved not to be the case and in all patients the delay in receiving analgesia after a demand was of the order of a few minutes. We did not attempt to assess this interval accurately because of difficulties for patients in judging time accurately during the postoperative period.

In summary, s.c. PCA appears to be as effective and safe as i.v. PCA and it may offer advantages over the i.v. route by providing feedback on successful demands for analgesia and enhancing appropriate use of the machine.

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REFERENCES