Editor’s key points

- Transversus abdominis plane (TAP) block is a promising approach for postoperative analgesia after abdominal surgery.
- This randomized control trial of 93 children tested the ability of bilateral TAP blocks to reduce morphine consumption after laparoscopic appendicectomy.
- TAP blocks plus local anaesthesia and paracetamol did not reduce patient-controlled morphine use compared with local anaesthesia and paracetamol alone.

Background. The effect of adding transversus abdominis plane (TAP) blocks to local anaesthetic infiltration on morphine consumption and postoperative pain in children undergoing laparoscopic appendicectomy is unknown.

Methods. After random allocation, 93 children aged 7–16 were randomized to receive ultrasound-guided TAP blocks placed before surgery or not (control). All subjects had port sites infiltrated with ropivacaine and were prescribed i.v. patient-controlled analgesia (PCA) with morphine and oral paracetamol for postoperative pain. The primary outcome was the proportion of subjects using >200 μg kg⁻¹ morphine. Secondary outcomes included PCA morphine use, pain scores, time intervals to the first use of PCA and other analgesics, sedation scores, postoperative nausea or vomiting, and time to hospital discharge.

Results. The procedure duration was longer in the TAP group (111 compared with 97 min for controls, P=0.03). The duration in the recovery ward and that of the hospital stay were similar. There was no difference in the proportion of subjects requiring >200 μg kg⁻¹ of PCA morphine [control 31/45 (69%), TAP 29/42 (69%), P=0.99]. There was no significant difference in PCA morphine use, time intervals to the first use of PCA or other analgesics, or amounts of other analgesics. More patients in the TAP group had complicated appendicitis [TAP 13/42 (31%), control 5/45 (11%), P=0.02]. Pain scores were reduced for the TAP group in the recovery ward only (median score 0 vs 2, 95% confidence interval 0–3, P=0.03).

Conclusions. TAP blocks increased anaesthesia time by 14 min on average but offered no clinically important benefit over local anaesthetic port-site infiltration to paediatric patients undergoing laparoscopic appendicectomy.

Keywords: appendicectomy; nerve block; pain, postoperative; ultrasonography, Doppler

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Safe and effective regional anaesthesia requires local anaesthetics to be placed in close proximity to target nerves without injury to target nerves or adjacent structures. A promising approach to the provision of postoperative analgesia after abdominal surgery is to block the sensory nerve supply to the anterior abdominal wall by placing a local anaesthetic in the transversus abdominis plane (TAP).

Pain after surgery for acute appendicitis is caused by the surgical wound and visceroperitonitic pain due to peritoneal inflammation and infection.¹ The TAP block was first described in 2004 by McDonnell and colleagues,² and an ultrasound-guided technique was subsequently described by Hebbard and colleagues.³ The abdominal wall has three muscle layers: external and internal obliques, and transversus abdominis. They are innervated by mixed somatic nerves that course between the transversus abdominis and the internal oblique muscles.⁴ Blocking the sensory nerve supply to the anterior abdominal wall has been reported to provide effective postoperative analgesia after both open appendicectomy and laparoscopic cholecystectomy.⁵–⁸

The standard care for laparoscopic appendicectomy in our children's hospital involves general anaesthesia, tracheal intubation, i.v. opioid, local anaesthetic infiltration of laparoscopic port sites, and patient-controlled analgesia (PCA) in
the postoperative period. In this study, we aimed to examine the effect of adding TAP blocks to this regimen on opioid consumption and postoperative pain.

Methods

After obtaining approval from the institutional human research ethics committee, we enrolled ASA physical status I–II children aged 7–16 yr undergoing laparoscopic appendicectomy. The study was approved by the Human Research Ethics Committee of the Northern Hospital Network, Prince of Wales Hospital (Ref. 08/002) and registered with the Australian and New Zealand Clinical trials registry (Ref. ACTRN 1260800314325). We aimed to include all patients where the parents or the guardian consented. Patients were excluded only if there was a known allergy or intolerance to morphine, an approved health-care interpreter was unavailable when required, or the patient was assessed as unable to use a PCA device.

Subjects were enrolled at Sydney Children's Hospital between July 2008 and September 2009. After written informed consent was obtained from parents or legal guardians (for the subjects more than 13 yr old), patients were allocated to either the treatment (TAP) or control groups using a randomized central computer-generated sequence held by an investigator not involved with the clinical management or data collection (M.B.). Before emergence from anaesthesia, all subjects in both the TAP and control groups had opaque sticking plasters placed at the site of a TAP block in order to enable patients, parents, and the data collectors to remain blinded to allocation. There was no placebo injection in the control group.

All subjects received a standard general anaesthetic involving rapid sequence induction with propofol (3 mg kg\(^{-1}\)) and succinylcholine (1.5–2 mg kg\(^{-1}\)) and continued paralysis with atracurium. Anaesthesia was maintained with nitrous oxide in oxygen and sevoflurane. All subjects received i.v. fentanyl (1 µg kg\(^{-1}\)) at the commencement of surgery and ondansetron (200 µg kg\(^{-1}\)) to a maximum of 4 mg i.v. towards the end of anaesthesia, a 38 mm, 6–13 MHz linear array ultrasound transducer (Sonosite Micromaxx™ SonoSite, Inc., Bothell, WA, USA) was placed on either flank with the probe orientated on an imaginary line joining the umbilicus and the L3–L4 vertebrae. A needle was advanced under aseptic conditions from an injection point on the anterolateral abdominal wall, at about the level of the umbilicus, in the plane of the ultrasound until the tip lay between the transversus abdominis and the internal oblique muscles (the transversus abdominis plane). Ropivacaine (0.5 ml kg\(^{-1}\) of 0.2%) was injected in either side of the abdomen (2 mg kg\(^{-1}\) total of ropivacaine). The competence of anaesthetists performing the TAP blocks was assessed by the first author.

Each subject was prescribed i.v. PCA morphine as per Sydney Children’s Hospital Standard protocol (no background infusion; bolus dose of 15 µg kg\(^{-1}\) with 5 min lock out and no 4 hourly limit) and regular oral paracetamol 15 mg kg\(^{-1}\). No other analgesics were prescribed during the first 16 h after operation unless commenced by the Acute Pain Service. Patients were also prescribed ondansetron 200 µg kg\(^{-1}\) (to a maximum of 4 mg) eighth hourly as required.

On the basis of pilot data from our institution, the primary outcome was the proportion of subjects who used more than 200 µg kg\(^{-1}\) of morphine in the first 16 h from arrival in the recovery ward (see the sample size calculation below). Secondary outcomes included: PCA morphine consumption from 0 to 8 and >8 to 16 h after operation; pain measured by 0–10 cm self-reported visual analogue score (VAS) in the recovery ward and at 2–4, 6–8, 10–12, and 14–16 h after operation (if the subject was asleep, the VAS was recorded as zero); time to the first non-PCA supplemental analgesia; time to the first dose of morphine administered by PCA (first button press); sedation scores at the time of recovery ward discharge, at 6–8 h, and at 10–12 h (from 0=awake to 2=unrousable); post-operative nausea and vomiting (PONV) measured by the total number of antiemetic administrations and the documented number of vomits during the first 16 h; and time to hospital discharge.

We also recorded adverse effects of TAP blocks including bleeding, swelling, or bruising at the injection site and sedation requiring medical review or removal of the PCA button. To examine any effect of major known confounders for the primary outcome, we also recorded the duration of anaesthesia, preoperative analgesic administration, and sedative premedication. All time intervals in the study were taken from the commencement of anaesthesia (T\(_0\)) or from arrival in the recovery ward (T\(_r\)).

Sample size and statistical methods

Pilot data demonstrated a bimodal distribution of PCA morphine consumption after laparoscopic appendicectomy. Approximately 60% of the subjects without TAP block consumed modest amounts of morphine via PCA after operation (>200 µg kg\(^{-1}\)), whereas the remainder of subjects used very little morphine. We estimated that a halving of the high PCA use group from 60% to 30% of the subjects...
would represent a clinically significant benefit from the TAP block that might modify our institutional practice of post-operative PCA opioids. We calculated that 84 subjects would be required to have an 80% power to detect a reduction to 30% at a significance level of <0.05. Because of anticipated dropouts, we planned to recruit 45 subjects into each arm of the study.

Analyses were made using StatsDirect (StatsDirect Pty Ltd, version 2.7.8, 2010, Altrincham, Cheshire, UK). We accepted statistical significance as a probability that the observed difference was <5% likely due to chance (P<0.05). For continuous outcomes, we compared groups using Student’s t-test or Mann–Whitney U-test, depending on the data distribution. For categorical outcomes, we used χ2 test or Fisher’s exact test as appropriate.

Results

Two hundred and twenty-eight patients underwent laparoscopic appendicectomy in the study period (Fig. 1). Of these, 112 were not invited to participate because investigators were unavailable to obtain informed consent, leaving 116 patients invited to participate in the study, of whom 23 refused consent. A total of 93 patients between the ages of 7 and 16 agreed to enter the study. Among them, 46 subjects were randomized to the TAP group with one dropout after transfer to another hospital before surgery and three exclusions because of conversion to an open procedure, leaving a total of 42 subjects. Of the total, 47 subjects were randomized to the control group with one dropout after a surgeon declined to follow the study protocol and one exclusion because of conversion to an open procedure, leaving 45 subjects.

Subjects in the TAP and control arms were similar in ASA status, weight, age, and the proportion in each group receiving analgesics within 6 h before the start of the procedure. The procedure duration (T1 to T3) was significantly longer in the TAP group consistent with the time taken to perform the TAP block (111 vs 97 min, P=0.03). The duration in the recovery ward and that of the hospital stay were similar (Table 1).

There was no difference in the proportion of patients requiring more than 200 μg kg⁻¹ of PCA morphine in the first 16 h from arrival in the recovery room [control 31/45 (69%) compared with TAP 29/42 (69%), χ²=0.0003, P=0.99]. PCA morphine use was not statistically different for the TAP compared with control groups at either time interval. Neither was there any significant difference in time to the first use of PCA, time to administration of other analgesics, amount of fentanyl administered during the operation, or of the amount of paracetamol administered during the first 16 h from arrival in the recovery ward (Table 2).

There were no reported cases of bleeding, swelling, or bruising at the TAP block injection site, nor were there episodes of excess sedation requiring medical review or removal of the PCA button. There was no difference in the number of subjects in each group that received anti-emetic or in the number of episodes of vomiting.

Although all subjects in both groups had the appendix removed, significantly more patients in the TAP group had either free pus or fluid present, or a perforated appendix [TAP 13/42 (31%) compared with control 5/45 (11%), χ²=5.2, P=0.02; Table 1]. A curious finding was a trend for those with free pus or fluid or a perforated appendix to use less morphine in the first 16 h (median 210 μg kg⁻¹ compared with 320 μg kg⁻¹), although this was not statistically significant (P=0.19, 95% confidence interval (CI) for difference between medians=-0.067 (−0.035 to 0.170)). Owing to inadequate power, we did not explore this with subgroup analysis.

Median pain scores were reduced for the TAP group in the recovery ward (median score 0 compared with 2, 95% CI 0–3, P=0.03). Pain scores were similar at all other time intervals (Fig. 2).

Discussion

There was no difference in the proportion of patients requiring moderate-to-high doses of morphine after laparoscopic appendicectomy with or without a TAP block. Similarly, the total dose of PCA morphine consumed in the first 16 h was not different between the groups. This is in contrast to other publications where 33–74% reductions have been reported when a TAP block was compared with systemic analgesia only.

In our study, the VAS in recovery was lower in the TAP group compared with control. At all other time periods, there were no differences in the pain scores. The improved score in recovery was of negligible benefit when considered in the context of longer anaesthesia time, similar time to...
the first morphine administration, approximately equal morphine consumption, and similar time to discharge from the recovery ward. A TAP block placed at the completion of the procedure may have altered these outcomes by extending the postoperative time during which the block would have been working.

The time to the first press of the PCA button was not different between the groups. Although this could reflect similar pain levels in both groups, despite the measured difference in recovery VAS, it is also possible that some unrelated factor such as curiosity influenced the time at which subjects pressed the button. Some adult studies have shown a modest increase in time to the first PCA use of up to about 3 h.9 There was also no significant difference between the two groups in time to non-PCA supplemental analgesic use.

Sedation scores were different between the two groups in the recovery room only. The control group was 23% more likely to have a sedation score of zero compared with the TAP group. This is different from other studies where lower sedation scores were reported in the TAP group for up to 6 h after operation;11 presumably because the TAP group had lower opioid use. In our study, the TAP and control groups received the same dose of opioids intraoperatively and it is probable that the TAP group was displaying an unopposed opioid effect.

Our study has a number of limitations of importance to interpretation. First, our control group did not receive a placebo injection, but rather a sham intervention in the form of a dressing only. We considered that a placebo was inappropriate as it would have required an invasive procedure with the potential for harm.10 Although it is possible that lack of a placebo influenced the result, we believe that the likely bias would be to increase any apparent difference in favour

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**Table 1** Patient characteristics, anaesthetic, and surgical factors

<table>
<thead>
<tr>
<th></th>
<th>Control (n=45)</th>
<th>TAP (n=42)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASA I (number)</td>
<td>41</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>Mean weight (kg)</td>
<td>41</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>Mean age and range (yr)</td>
<td>11 (7–16)</td>
<td>11 (7–16)</td>
<td></td>
</tr>
<tr>
<td>Patients receiving analgesics in 6 h preop (number)</td>
<td>13</td>
<td>16</td>
<td>0.36 ($\chi^2$ test)</td>
</tr>
<tr>
<td>Mean paracetamol in 6 h preop (mg kg$^{-1}$)</td>
<td>15</td>
<td>15</td>
<td>0.9 (t-test)</td>
</tr>
<tr>
<td>Mean morphine in 6 h preop ((\mu g) kg$^{-1}$)</td>
<td>90</td>
<td>64</td>
<td>0.2 (t-test)</td>
</tr>
<tr>
<td>Mean duration of procedure (min)</td>
<td>97</td>
<td>111</td>
<td>0.03 (t-test)</td>
</tr>
<tr>
<td>Mean intraoperative fentanyl ((\mu g) kg$^{-1}$) ((\mu g))</td>
<td>1.4 (0.67)</td>
<td>1.2 (0.52)</td>
<td>0.10 (t-test)</td>
</tr>
<tr>
<td>Median paracetamol administration 0–16 h postop (mg kg$^{-1}$) and range</td>
<td>17.8 (0–67.5)</td>
<td>28 (63.3)</td>
<td>0.65 (MWUT)</td>
</tr>
<tr>
<td>Mean time admission to induction anaesthesia (min)</td>
<td>1017</td>
<td>872</td>
<td>0.4 (t-test)</td>
</tr>
<tr>
<td>Appendix removed (number) (%)</td>
<td>45 (100)</td>
<td>42 (100)</td>
<td></td>
</tr>
<tr>
<td>Free pus, fluid, or appendix perforated (number) (%)</td>
<td>5 (11)</td>
<td>13 (31)</td>
<td>0.02 ($\chi^2$ test)</td>
</tr>
</tbody>
</table>

**Table 2** Outcomes. *Mann–Whitney U-test used to compare medians, and unpaired t-test used to compare means

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Control (n=45)</th>
<th>TAP (n=42)</th>
<th>P-value (MWUT, t-test, or $\chi^2$)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCA morphine consumption $&gt;200$ (\mu g) kg$^{-1}$ (%) 0–16 h post-op</td>
<td>31 (69%)</td>
<td>29 (69%)</td>
<td>0.99 ($\chi^2$ test)</td>
</tr>
<tr>
<td>Median morphine PCA consumption 0–8 h postop ((\mu g) kg$^{-1}$) and range</td>
<td>141 (0–679)</td>
<td>123 (0–506)</td>
<td>0.52</td>
</tr>
<tr>
<td>Median morphine PCA consumption &gt;8–16 h postop ((\mu g) kg$^{-1}$ and range)</td>
<td>142 (0–594)</td>
<td>179 (0–875)</td>
<td>0.19</td>
</tr>
<tr>
<td>Median time to first PCA use (min) and range</td>
<td>26 (0–510)</td>
<td>50 (3–525)</td>
<td>0.32</td>
</tr>
<tr>
<td>Mean time to first non-PCA analgesia (min) ((\mu g))</td>
<td>580 (416)</td>
<td>483 (486)</td>
<td>0.33</td>
</tr>
<tr>
<td>Time in recovery ward (min)</td>
<td>60</td>
<td>67</td>
<td>0.06</td>
</tr>
<tr>
<td>Time in hospital (min)</td>
<td>2340</td>
<td>2670</td>
<td>0.1</td>
</tr>
</tbody>
</table>

**Fig 2** Visual analogue pain scores for control and TAP block groups (median and inter-quartile range). *Statistically significant difference between groups ($P=0.03$).
of the TAP group. Secondly, we did not record preoperative pain scores and it is possible that those allocated to the TAP group had more preoperative pain and therefore might be expected to exhibit more postoperative pain as a result. Although we relied on randomization to reduce the likelihood of this situation, we also demonstrated no difference in the preoperative analgesia administered between the two groups, nor any difference in time from hospital arrival to commencement of surgery.

Conclusion
TAP blocks increased anaesthesia time by 14 min on average but offered very little clinical benefit over local anaesthetic port-site infiltration with morphine PCA and paracetamol to paediatric patients undergoing laparoscopic appendicectomy. Where local infiltration is in use, the TAP block confers no benefit and we cannot recommend its routine use in this patient group.

Conflict of interest
None declared.

References
1 Aida S, Baba H, Yamakura T, Taga K, Fukuda S, Shimoji K. The effectiveness of pre-emptive analgesia varies according to the type of surgery: a randomized, double-blind study. Anesth Analg 1999; 89: 711–6