Prospective Study of Postoperative Pain Following Adult Inguinal Hernia Repair by Transabdominal Preperitoneal Approach Versus Anterior Approach

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Abstract

[Objective] We performed a prospective comparative study of early postoperative pain in adult patients with inguinal hernia treated by the transabdominal preperitoneal approach (TAPP) or the anterior approach (AA).

[Patients and Methods] The participants comprised 89 adult patients with inguinal hernia operated on from August 2015 to March 2017. The patients were divided into two groups, the TAPP group (n=46) and the AA group (n=43). We assessed the intensity of postoperative pain using the current perception threshold (CPT) measured by a perceptual pain sensation analyzer (PainVision PS-2100; Sanyo Seiko, Yamanashi, Japan). We measured the minimum perceived current and pain-compatible current (PCC) preoperatively and calculated the innate pain intensity (IPI). Postoperatively, we measured the wound PCC, calculated the wound pain intensity (WPI), calculated the adjusted wound pain intensity (AWPI) from the IPI and WPI, and compared postoperative pain in the two groups based on the surgical technique used.

[Results] The AWPI values were 193.2 ± 27.9 and 200.4 ± 32.9 in the TAPP and AA groups, respectively, on postoperative day (POD) 1 (P=0.86), then 160.0 ± 23.5 and 138.7 ± 17.1, respectively, on POD 2 (P=0.47), with no significant differences observed.

[Conclusion] We observed no significant difference in the intensity of pain measured by PainVision between the TAPP and AA groups during early postoperative period.

Key words
PainVision, inguinal hernia, postoperative pain

Introduction

Adult inguinal hernia is a universal and common condition that has been recognized since ancient times, with approximately 140,000 Japanese people diagnosed with the condition annually¹. However, curative forms of treatment have undergone constant modification and improvement since the time of Cornelius Celsus of Ancient Rome, known as the “father of the hernia.” The anterior approach (AA) became a popular option from the late 1980s, when polypropylene mesh was developed². Meanwhile, laparoscopic hernia repair was also developed in the 1990s to decrease invasiveness and improve cosmesis³. This included a technique known as transabdominal preperitoneal repair (TAPP). Compared to AA, postoperative pain after TAPP is usually reported to be less intense⁴; however, there was no comparative study about the current perception threshold (CPT) between the two surgical techniques.
The main purpose of this study was to verify whether TAPP causes less postoperative pain than AA. Therefore, the null hypothesis was that there would be no difference in postoperative pain between TAPP and AA, and the alternative hypothesis was that TAPP would cause less postoperative pain than AA. To test the hypothesis, we conducted a prospective study to assess the intensity of postoperative pain after TAPP and AA using a pain sensation analyzer (PainVision PS-2100; Sanyo Seiko, Yamanashi, Japan). The PainVision made it possible to quantitatively measure pain by replacing the intensity of pain with the magnitude of the sense of pain (heterogeneous sensation) elicited by electrical stimulation without causing actual pain.

Patients and Methods

This clinical study was reviewed and approved by the St. Marianna University School of Medicine ethical review board (Approval No. 2980). The participants were adult patients who underwent elective unilateral inguinal hernia from August 2015 to March 2017. This study was conducted at St. Marianna University School of Medicine, St. Marianna University School of Medicine Yokohama City Seibu Hospital, and St. Marianna School of Medicine Toyoko Hospital.

Adult inguinal hernia surgery was performed in our facilities on about 100 people/year, and about 160 participants were expected to participate during the study period. We mainly performed AA, followed by TAPP, and patients were assigned to TAPP or AA by their personal choice. Criteria for participation included all three of the following: the patient could undergo either AA or TAPP, had sufficient cognitive function, and the patient understood the significance of this study and gave his/her written informed consent to participate at his/her own discretion. Exclusion criteria included the following: no electronic implants such as a pacemaker, a history of lower abdominal surgery, and being unable to walk independently. The type of surgery was selected by each patient after they were provided sufficient information about the two procedures and this study.

All of the patients received general anesthesia induced with propofol and maintained with inhaled desflurane and continuous intravenous infusion of remifentanil. Administration of analgesics postoperatively was not performed on a fixed schedule, and non-steroidal anti-inflammatory drugs or acetaminophen was administered orally or intravenously according to patients’ request when they experienced pain. Acetaminophen was used for patients with asthma and renal dysfunction.

The PainVision measurements were taken three times: on admission, on postoperative day (POD) 1, and on POD 2. We measured the minimum perceived current (MPC) and pain-compatible current (PCC) preoperatively and calculated the innate pain intensity (IPI) at the time of admission. We measured the wound PCC (WPCC) on POD 1 and 2 and then used it to calculate wound PI (WPI). The adjusted WPI (AWPI) was derived from the IPI and the WPI. The AWPI compares predetermined electrical pain stimuli to actual pain stimuli to determine pain severity.

Patients were also requested to complete a postoperative pain evaluation sheet, the Modified Prince Henry Pain Score (MPHPS), to provide a subjective evaluation of their postoperative pain (Table 1). This was performed as a self-evaluation at a fixed time during the morning each day until the first outpatient visit after discharge (POD 14). The following items were included in the statistical analysis of the AA and TAPP groups: age (years), sex (M/F), and body mass index (BMI, kg/m²) as patient background factors and number of years surgical experience of the surgeon (years) and duration of surgery (minutes) as surgical factors. The AWPI on POD 1 and 2 was analyzed as the pain-related factor. To determine the sample size, we first collected data from 5 cases in both groups as a pilot study. The standard deviation for POD 1 adjusted wound pain was 208.9, and the average difference between the two groups was 171.8. The alpha error was 0.05 and the detection power was 0.8, resulting in a required sample size of at least 49 patients. However, we included as many

<p>| Table 1. Modified Prince Henry Pain Scale Shows Four Stages for Subjective Evaluation of Postoperative Pain |</p>
<table>
<thead>
<tr>
<th>Scale</th>
<th>Severity of pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No pain on coughing or sneezing</td>
</tr>
<tr>
<td>2</td>
<td>No pain on movement, but pain on coughing or sneezing</td>
</tr>
<tr>
<td>3</td>
<td>No pain at rest, but pain on movement</td>
</tr>
<tr>
<td>4</td>
<td>Cannot sleep without pain killer</td>
</tr>
</tbody>
</table>
patients as possible who participated during the scheduled study period. We used one-way analysis of variance (ANOVA) and Student t-tests for statistical analysis. A P value <0.05 was considered statistically significant. All statistical analyses were performed by use of JMP ver. 12 (SAS Institute, Cary, NC, USA).

During a supplementary analysis, we also determined the relationships between the duration of surgery and AWPI, BMI and AWPI, and age and AWPI.

**PainVision principles and measurement method**

**PainVision principles**

This apparatus performs a quantitative evaluation that compares pain intensity to the sensation after delivery of a painless electrical stimulus (heteresthesia). Specifically, pulsed-current waveforms (low-frequency waves, 50 Hz, 0–150 μA, pulse width: 0.5 ms) were used to stimulate Aβ and Aγ fibers. An electrical stimulus was transmitted to the skin, and the stimulus quantity was measured as it was gradually increased. The PI was calculated by measuring the MPC (μA), which is the smallest electrical stimulus that could be perceived, and the PCC (μA), which is the current perceived that corresponds to the actual intensity of the patient’s pain. This provides an objective evaluation of pain. The PI was defined as the value derived from the MPC and PCC according to the following formula from previous reports:

$$\text{PI} = \frac{(\text{PCC} - \text{MPC})}{\text{MPC}} \times 100.$$  

**PainVision measurement method**

Bipolar electrodes are attached to the medial surface of the patient’s dominant and non-dominant forearms while the patient is holding a hand switch with the dominant hand (Fig. 1). The patient presses a start button, and the electric current is gradually increased over time. The patient presses the hand switch the moment he/she perceives the electrical stimulus. This process is repeated three times to obtain the mean MPC (μA). To measure PI, we also induce pain by attaching a weighted (100 g) compression device to the palmar surface of the second fingertip of the non-dominant hand to use as a fixed stimulus. The patient is then required to compare the gradually increasing electrical stimulus to the pain felt in his/her fingertip and press the stop switch when these two are perceived as equivalent. This process is repeated three times to obtain the mean PCC (μA). We derived individual IPI from the MPC and PCC.

We also measure the PCC (μA) for wound pain during the morning of POD 1 and 2. If the patient was taking analgesics, we performed measurements ≥6 hours after their administration. After the patient had rested for approximately 10 minutes, they were required to stand and have the PCC measured while pain was induced, as described above. This process was repeated three times to obtain the wound PCC (WPCC, μA). We derived WPI from the MPC and WPCC and AWPI from the IPI and the WPI. We derived the AWPI to minimize the individual differences in pain sensitivity when performing statistical analysis because the CPT value is the result of an individual’s internal comparison between the perception of pain and the perception of electrical current. To do so, we divided the WPI by the IPI, which is based on individual pain sensitivity, and showed this as the factor of wound pain in response to a fixed pain stimulus:

$$\text{AWPI} = \frac{(\text{WPI} / \text{IPI})}{100}.$$  

**TAPP and AA surgical procedures**

**TAPP**

The patient is placed in the Trendelenburg position, and the abdomen is insufflated to 10 mmHg. We use a size L 3D MAX Light mesh (Bard, Murray Hill, NJ, USA) or size M anatomical mesh (Covidien, Dublin, Ireland). Fixation is achieved using the SorbaFix (Bard) or AbsorbaTack (Covidien) fixation devices. We use three ports: a 12-mm umbilical XCEL blunt-tip trocar (Ethicon, New Brunswick, NJ, USA) and two 5-mm E-Z trocars (Hakko Medical, Tokyo, Japan) in either flank (Fig. 2A). After inserting the mesh, we perform tacking at six locations: the Cooper ligament, both inferior epigastric vessels, and along the most medial and lateral points of the mesh. We create continuous sutures in the peritoneum by use of a V-Loc 180 Absorbable Wound Closure De-
Figure 2. Skin incision wounds. A: TAPP port placement (from the patient’s right side). B: AA skin incision (from the patient’s right side).

Table 2. Patient Background Factors and Surgical Factors

<table>
<thead>
<tr>
<th></th>
<th>TAPP</th>
<th>AA</th>
<th>P value</th>
</tr>
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<tbody>
<tr>
<td>Number of patients</td>
<td>46</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>64.9±11.6</td>
<td>65.3±13.3</td>
<td>0.65</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>40/6</td>
<td>41/2</td>
<td>N.S.</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>22.9±3.1</td>
<td>23.9±2.2</td>
<td>0.06</td>
</tr>
<tr>
<td>Number of years of surgical experience</td>
<td>15.2±7.3</td>
<td>6.1±1.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Duration of surgery (min)</td>
<td>118±22.1</td>
<td>82±21.9</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

TAPP: transabdominal preperitoneal approach; AA: anterior approach; BMI: body mass index; N.S.: not significant

vice (3-0, 15 cm, Covidien). The abdominal wound is closed with 2–0 Vicryl sutures and 4–0 Vicryl Plus (both, Ethicon). The 5-mm port wounds are then closed with 4–0 Vicryl Plus sutures.

AA
The patient is placed in the supine position. We use the same method for closing external and internal inguinal hernias and the same skin incision method. A 5-cm long incision is made along Langer’s line medial to a point at the center of a line connecting the anterior superior iliac spine and the edge of the pubic tubercle on the affected side (Fig. 2B). When we identify the spermatic cord structure, we also confirm the ilioinguinal and iliohypogastric nerves, which must be preserved. When treating an external inguinal hernia, we insert the mesh into the retroinguinal space via the internal inguinal ring. When treating an internal inguinal hernia, we create concentric circles in the distended transversalis fascia forming the posterior wall and insert the mesh into the retroinguinal space via these openings. We then suture the posterior wall. Continuous sutures are used to close the aponeurosis of the abdominal external oblique muscle, Scarpa’s fascia is sutured, and the wound is closed with buried subcuticular sutures. Both surgical techniques are performed using 4–0 Maxon sutures (Covidien) for this purpose. We also use M-size Direct Kugel Patch mesh (Bard).

Results
During the study period, 175 patients with inguinal hernia were recruited. Of these, 86 were excluded, and the remaining 89 patients were subsequently assigned to the TAPP group (n=46) or the AA group (n=43).

Approximately 80% of the patients excluded were admitted with a history of lower abdominal surgery. Other reasons included the presence of electronic implants, impaired cognitive function, and refusal to participate in the test itself.

During this study, all patients underwent elective surgery with the technique of their choice. There were no intraoperative modifications or additions to the surgical techniques. Table 2 shows the patient background and surgical factors. There were no sig-


68

Hisatsune Y Koizumi S et al
significant differences in terms of any patient background factors, although the surgical factors of years of surgical experience and duration of surgery differed significantly between the two groups. Table 3 shows the results for pain-related factors. The AWPI values were 193.2 ± 27.9 and 200.4 ± 32.9 in the TAPP and AA groups, respectively, on POD 1 (P=0.86) and 160.0 ± 23.5 and 138.7 ± 17.1, respectively, on POD 2 (P=0.47), and they were not significantly different between the two groups on either POD (Fig. 3). The response rate to the MPHPS was 63%. It took 7.4 ± 2.8 days for patients in the TAPP group and 8.7 ± 3.4 days for those in the AA group (P=0.23) to report feeling no pain during coughing or sneezing (MPHPS: 1). There was no significant difference between the two groups in this regard, and postoperative pain persisted for approximately the same amount of time (TAPP: 7.4 ± 2.8 days, AA: 8.7 ± 3.4 days, P=0.23). Our supplementary analysis also showed no significant relationships between the duration of surgery and AWPI, BMI and AWPI, and age and AWPI in either group (Figs. 4–6).

**Discussion**

We assessed the intensity of postoperative pain of TAPP and AA using PainVision. The main purpose of the study was to verify whether TAPP causes less postoperative pain than AA. However, we could not prove that TAPP caused less postoperative pain than AA. The EU Hernia Trialists Collaboration has stated in several reports that greater chronic postoperative pain occurs after AA than after TAPP, although none of these reports provide information about early postoperative pain. The reports by Symeonidis et al and Mahon et al are representative of early postoperative pain reports, although there are a few other reports stating that there is less postoperative pain after AA than TAPP, based on the result of the frequency of analgesic use, Visual Analogue Scale (VAS), and the number of days required for rehabilitation into society. Certainly, it is highly likely that the frequency of use of analgesics and the number of days taken to reintegrate are directly related to the pain experienced. However, the possibility of including other confounding factors cannot be denied. VAS, numerical rating scales, and verbal rating scales are self-rating assessments for the measurement of pain intensity in general clinical and research settings. However, Kim et al reported that it is difficult to compare the intensity of pain in patients because the VAS measures the experienced value of pain sensation based on past personal experiences. Hence, we considered that the use of CPT would minimize this flaw of VAS and used the PainVision to assess the intensity of postoperative pain in this study.

PainVision provided quantitative evaluation by comparing PI to the sensation experienced after a painless electrical stimulus (heteresthesia) and facilitated an evaluation of postoperative pain. All of the previous studies measuring pain using the PainVision have performed comparative investigations using PI derived from MPC and PCC. However, this value is often subject to differences in the reaction time taken to press the hand switch for measurement, which makes the PI unsuitable for comparing between different patients. Thus, we devised the

**Table 3. Pain-related Factors**

<table>
<thead>
<tr>
<th></th>
<th>TAPP n=46</th>
<th>AA n=43</th>
<th>P value</th>
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</thead>
<tbody>
<tr>
<td>Minimum perceived current (μA)</td>
<td>9.9±2.9</td>
<td>9.7±2.4</td>
<td>0.77</td>
</tr>
<tr>
<td>Pain compatible current (μA)</td>
<td>23.1±2.6</td>
<td>19.7±1.4</td>
<td>0.26</td>
</tr>
<tr>
<td>Innate pain intensity</td>
<td>128.5±18.8</td>
<td>94.2±12.5</td>
<td>0.13</td>
</tr>
<tr>
<td>POD 1 PCC (μA)</td>
<td>23.4±2.2</td>
<td>21.7±1.8</td>
<td>0.55</td>
</tr>
<tr>
<td>POD 2 PCC (μA)</td>
<td>19.2±1.1</td>
<td>19.7±1.8</td>
<td>0.81</td>
</tr>
<tr>
<td>POD 1 WPI</td>
<td>148.9±22.8</td>
<td>130.6±18</td>
<td>0.53</td>
</tr>
<tr>
<td>POD 2 WPI</td>
<td>102.8±11.4</td>
<td>105.3±15.4</td>
<td>0.89</td>
</tr>
<tr>
<td>POD 1 AWPI</td>
<td>193.2±27.9</td>
<td>200.4±32.9</td>
<td>0.86</td>
</tr>
<tr>
<td>POD 2 AWPI</td>
<td>160.0±23.5</td>
<td>138.7±17.1</td>
<td>0.47</td>
</tr>
</tbody>
</table>

TAPP: transabdominal preperitoneal approach; AA: anterior approach; POD: postoperative day; PCC: pain-compatible current; WPI: wound pain intensity; AWPI: adjusted wound pain intensity.
Green line: average report in one way analysis

**Figure 3.** One-way ANOVA results for the AWPI on POD 1 and 2 in the TAPP and AA groups. There were no significant differences in the results between the two groups.

The method used in this study in which we digitized individual patient sensitivity by performing preoperative PI measurements (IPI) using a fixed stimulus to minimize the effects on the calculation formula. We also divided the WPI by the IPI, which is based on individual pain sensitivity to a fixed stimulus, and showed this as a factor of wound pain in response to a fixed pain stimulus. Calculation of this value, the AWPI, negated the differences in pain levels due to individual differences in pain sensitivity, thus facilitating the quantitative evaluation and statistical analysis of postoperative PI in different patients.

There were no significant differences in early postoperative pain between the TAPP and AA groups in terms of the AWPI values on POD 1 and 2. However, Li et al reported that PI was greater after AA than TAPP due to greater injury resulting from the inguinal incision and because peripheral nerve injury occurs more commonly during AA\(^{(13)}\). There are two possible reasons why our results differ from those reported by Li et al. First, the greatest contributor to postoperative pain after AA is reported to be injury to the sensory inguinal nerves, namely the ilioinguinal nerve, iliohypogastric nerve, and genital branch of the genitofemoral nerve\(^{(14)}\). However, the technique used to perform AA at our hospital does not cause peritoneal injury as a rule, so we have been able to reduce postoperative pain by ensuring the preservation of these sensory inguinal nerves. Second, TAPP is associated with injury at the trocar insertion site and fascia forming the posterior wall of the inguinal region and necessitates peritoneal suturing after both trocar removal and mesh insertion. Even though it is temporary, peritoneal inflammation is caused by
A study of postoperative pain for adult inguinal hernia

Figure 4. Duration of surgery and AWPI. We found no obvious relationship between the duration of surgery and AWPI in either group.
We found no obvious relationship between BMI and AWPI in either group. We also analyzed each group to determine whether there was a relationship between age and AWPI because we suspected that age might influence postoperative pain, but we also found no relationship between these two factors in either group. It appears that age and postoperative pain are not necessarily related in patients who undergo inguinal hernia repair. According to the MPHPS, patients in both the TAPP and AA groups recovered to the extent that they experienced no pain when coughing or sneezing within one week postoperatively. On the basis of the above, we believe that there are no differences between TAPP and AA in terms of postoperative pain.

There are several limitations in this study. First is the lack of double blinding, which is, however, difficult for a study using different surgical incisions. Second, the surgical procedure was selected by the participants, which could introduce selection bias and affect the results of pain intensity compared with a randomized allocation. Third, several different surgeons were involved in the present study, which could also cause bias. However, it is difficult for surgeries to be performed by the same surgical team in teaching hospitals during a study period. Finally, there was a lack of numerical or unidimensional measurement such as NRS and VAS, but as mentioned previously, CPT was selected to minimize the influence of past personal experience on the intensity of pain.

**Conclusion**

We used PainVision to perform an evaluation of early postoperative pain after inguinal hernia repair by TAPP or AA. However, we observed no significant difference in the intensity of pain measured by CPT between the two surgical techniques during the early postoperative period.

**Acknowledgement**

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Figure 6. Age and AWPI. We found no obvious relationship between age and AWPI in either group.


