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Predicting Postoperative Pain by Preoperative Pressure Pain Assessment

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Background: **The goal of this study was to evaluate whether preoperative pressure pain sensitivity testing is predictive of postoperative surgical pain.**

Methods: **Female subjects undergoing lower abdominal gynecologic surgery were studied. A pressure algometer was used preoperatively to determine the pressure pain threshold and tolerance. A visual analog scale (VAS) was used to assess postoperative pain. A State-Trait Anxiety Inventory was used to assess patients' anxiety. Subjects received intravenous patient-controlled analgesia for postoperative pain control. The preoperative pain threshold and tolerance were compared with the postoperative VAS pain score and morphine consumption.**

Results: **Forty women were enrolled. Their preoperative pressure pain threshold and tolerance were 141 ± 65 kPa and 223 ± 62 kPa, respectively. The VAS pain score in the postanesthesia care unit and at 24 h postoperatively were 81 ± 24 and 31 ± 10, respectively. Highly anxious patients had higher VAS pain scores in the postanesthesia care unit ($P < 0.05$). Pressure pain tolerance was significantly correlated with the VAS at 24 h postoperatively ($P < 0.001, r = -0.52$). Pressure pain tolerance after fentanyl administration (mean, 272 ± 68 kPa) correlated significantly with morphine consumption in the first 24 h postoperatively ($P < 0.002, r = -0.48$).**

Conclusions: **Assessment of preoperative pressure pain tolerance is significantly correlated with the level of postoperative pain. Pain tolerance assessment after fentanyl was administered and fentanyl sensitivity predicted the dose of analgesics used in the first 24 h after surgery. The algometer is thus a simple, useful tool for predicting postoperative pain and analgesic consumption.**

POSTOPERATIVE pain, a complex sensory and emotional experience, is influenced by physiologic, sensory, affective, cognitive, sociocultural, and behavioral factors.[1,2] It can only be communicated through verbal descriptors or by use of a visual analog scale (VAS). The experience of pain is extremely private and varies widely from individual to individual, even after similar types of surgery.[3] Part of the difficulty lies in individual variation in opioid sensitivity, a situation for which a genetic cause has recently been identified.[4] This is one factor that may have a major impact on postoperative analgesic consumption. Improvement in perioperative analgesia may not only improve patient satisfaction but may also reduce the duration of hospital stay and decrease the risk of pulmonary and cardiovascular complications.[5–9]

Previous studies have indicated that several factors assessable preoperatively may predict the level of postoperative pain, including age, sex, anxiety, preoperative pain, and type of surgery.[10–14] Human experimental pain models play an important role in the study of pain mechanisms and the assessment of analgesic efficacy. Preoperative assessment of pain induced by heat and cold has been shown to predict the level of postoperative pain.[12,15,16] Most such studies of pain prediction have used a heat pain model.

Pressure pain measurement using an algometer to quantify the pain threshold and tolerance has been validated by several studies.[17–26] Heat stimuli and pressure stimuli are processed by the nervous system in a very different fashion. Neuroanatomical evidence has shown they involve multiple ascending pathways, different functional projections to thalamus, and a cortical circuit comprising areas.[27] Therefore, they may have differing efficacy in predicting different types of postoperative pain. Preoperative experimental pressure pain assessment to predict the level of postoperative pain has not been studied thus far. Therefore, we designed this study to evaluate the relation between preoperative experimental pressure pain and postoperative surgical pain, including looking for an association between pain sensitivity and postoperative analgesic consumption.

This article is featured in "This Month in Anesthesiology." Please see this issue of Anesthesiology, page 5A.

Materials and Methods

Patients

Patients scheduled to undergo abdominal total hysterectomy or myomectomy with general anesthesia were eligible to participate in this study. The study was approved by our institutional review board (Mackay Memorial Hospital, Taipei, Taiwan), and signed informed consent was obtained from all subjects. Patients with a history of psychiatric disease, alcohol or drug abuse, chronic nonsteroidal antiinflammatory drugs use, chronic pain, or use of opioids preoperatively were excluded. Forty women, aged 20–55 yr and having an

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American Society of Anesthesiologists physical status of I or II, were enrolled.

Preoperative Assessment of Anxiety

A Chinese version of the State-Trait Anxiety Inventory (STAI) was used in the preoperative holding area to assess patients' anxiety before they entered the operating room. The STAI is a 40-item self-reported questionnaire that measures trait (20 items) and state anxiety (20 items). The latter is the transitory emotional state induced by a particular situation. For the purposes of this study, only the state anxiety portion of the STAI was used to assess preoperative anxiety. Raw scores (20–80) from the STAI were transformed to percentiles (0–100) for further analysis.[28] The anxiety level was classified using the highest quartile of percentile ranks,[29] with 1 = mildly anxious (≤ 75th percentile) and 2 = highly anxious (> 75th percentile). Stratification was based on Spielberger's manual.[28]

Assessment of Pain Sensitivity

An electronic pressure algometer (Somedic AB, Sollentuna, Sweden) was used to determine the pain threshold and pain tolerance pressure. A probe with a surface area of 1 cm^2 was applied to the pulp of the third finger of the right hand, and the pressure was increased at a speed of 30 kPa/s. Patients were asked to press a button on a patient-operated switch when they started to feel pain (pain threshold) and when they could no longer stand the pain (pain tolerance). The algometer recorded the pressure at each point. To familiarize the patients with the assessment method, a training session was given in the preoperative holding area. After patient was transferred to the operating room, the baseline pain threshold and tolerance pressures were recorded with the patient lying on the operating table with eyes closed. Fentanyl, 2 μg/kg, was then administered intravenously, and the pressure pain assessment was repeated 4 min after the injection. Fentanyl sensitivity was defined as the percent increase in the pressure pain tolerance after fentanyl administration.

Anesthetic Technique

Standard monitoring, including noninvasive blood pressure monitoring, electrocardiography, pulse oximetry, and capnography, was begun when patients entered the operating room. An auditory evoked potential monitor, A-Line® (Danmeter A/S, Odense, Denmark), was used to monitor the depth of anesthesia. No premedication was given because it might have interfered with the preoperative pain sensitivity testing. After completing the postfentanyl pain assessment, general anesthesia was induced with 0.5 mg/kg lidocaine, 2%, and 1.5–2 mg/kg propofol. Tracheal intubation was facilitated with 0.8 mg/kg rocuronium. After intubation, 8 mg dexamethasone and 4 mg ondansetron were given to prevent postoperative nausea and vomiting. During the operation, general anesthesia was maintained with 7–10% desflurane, 0.5 l/min air, and 0.5 l/min oxygen. No more fentanyl was given. The depth of anesthesia was maintained at an auditory evoked potential index value of 15–20 by titration of the inspired desflurane concentration in 1–2% increments. No local anesthetic was given for skin closure.

Assessment of Postoperative Pain

A handheld slide rule–type VAS with values from 0 to 100 was used to assess the immediate postoperative pain as soon as the patient arrived in the postanesthesia care unit (PACU). If the patient had difficulty manipulating the VAS slide rule, she was asked to state the degree of pain using a numeric rating scale from 0 to 100.[30,31] The pain assessment was repeated using the VAS 24 h postoperatively with the patient at rest in the ward. All subjects received morphine by intravenous patient-controlled analgesia (PCA) for postoperative pain control. The PCA pump (Abbott APM; Abbott Laboratories, Chicago, IL) was programmed to give a loading dose of 3 mg, a bolus dose of 1 mg, a lockout interval of 5 min, and a 4-h limit of 20 mg. The PCA pump recorded the time when the patient activated it. The number of analgesic requests (demand) made and the number of those requests that resulted in successful deliveries (delivery) were recorded. The demand/delivery ratio was used to measure the quality of analgesia.[32] This detailed record was downloaded from the PCA pump to a personal computer for further analysis.

Statistics

Statistical analysis was performed with SPSS software (version 11.5; SPSS Inc., Chicago, IL). Data distribution was evaluated for normality by the Kolmogorov-Smirnov test. The relation between preoperative pain threshold and tolerance and the postoperative VAS pain score and morphine consumption was analyzed with the Pearson correlation test. The Bonferroni correction was used for multiple comparisons, and statistical significance was set at $P < 0.016$ when preoperative data were compared with postoperative data in the PACU and at 24 h in the ward. The Student *t* test was used to compare postoperative pain and analgesic consumption in highly anxious and mild anxious patients. Stepwise multiple regression analysis was used to determine the independent variables age, body weight, duration of operation, STAI Anxiety score, pain sensitivity, and fentanyl sensitivity that were predictive for the dependent variables VAS pain and morphine consumption in the PACU and at 24 h in the ward. Values are reported as mean ± SD. $P \leq 0.05$ was considered to be statistically significant.

Table 1. Demographic Data

	Mean ± SD	Range
Age, yr	41 ± 6	23–52
Body weight, kg	55 ± 6	46–69
Duration of operation, min	122 ± 42	60–235
Pain threshold, kPa	141 ± 65	32–311
Pain tolerance, kPa	223 ± 62	108–354
VAS pain score at 24 h	31 ± 10	15–56
Morphine consumption in the first 24 h, mg	21 ± 6	9–34

VAS = visual analog scale.

Results

The 40 consecutive patients enrolled in this study had a mean body weight of 55 ± 6.1 kg and mean age of 41 ± 6.2 yr. The average operation time was 122 ± 42 min, with an estimated blood loss of 405 ± 342 ml (table 1). Procedures performed included either abdominal total hysterectomy or myomectomy. The incisions were made on the low abdominal transverse line. All subjects had approximately the same size surgical wound in the same location.

Preoperative Pain Assessment

The mean preoperative pressure pain threshold and pain tolerance were 140 ± 65 kPa and 223 ± 62 kPa, respectively. After fentanyl, the pressure pain threshold increased to 171 ± 67 kPa, and the pain tolerance increased to 272 ± 68 kPa.

Postoperative Pain Assessment

The VAS pain score in the PACU before morphine administration was 81 ± 24. At 24 h postoperatively, it was 31 ± 10. The mean morphine consumption was 20.6 ± 6.0 mg (range, 9–34 mg) in the first 24 h postoperatively.

Preoperative Pain Assessment and Postoperative Pain and Morphine Consumption

Twenty-eight of 40 patients (70%) rated their pain as 70 or greater on the VAS in the PACU after emergence from general anesthesia. There was no statistically significant relation between the preoperative pain threshold and tolerance levels and the immediate postoperative VAS pain score ($P > 0.05$). However, the preoperative pressure pain tolerance was significantly correlated with the VAS result 24 h postoperatively ($P < 0.001$, $r = -0.52$; fig. 1). Pressure pain tolerance after fentanyl administration was significantly correlated with the total PCA morphine consumption in the first 24 h after surgery ($P < 0.002$, $r = -0.48$; fig. 2).

Effect of Preoperative Anxiety Status on Postoperative Pain and Analgesic Consumption

The mean raw STAI score for state anxiety before surgery was 49 ± 11, equivalent to the 66th percentile ± 23. Of the 40 patients, 21 were classified as highly anxious, and the remaining 19 patients were classified as mildly anxious. The immediate postoperative mean VAS pain score of the highly anxious patients was 87 ± 25, significantly higher than that of the mildly anxious patients, 65 ± 28 ($P < 0.05$). The highly anxious patients also had a significantly higher demand/delivery ratio than the mildly anxious patients (8.8 ± 6.6 *vs.* 4.7 ± 2.6). However, at 24 h postoperatively, the mean VAS pain scores did not differ significantly between the two groups, nor was there a significant correlation between preoperative anxiety status on morphine consumption either immediately after surgery or at 24 h ($P > 0.05$; table 2).

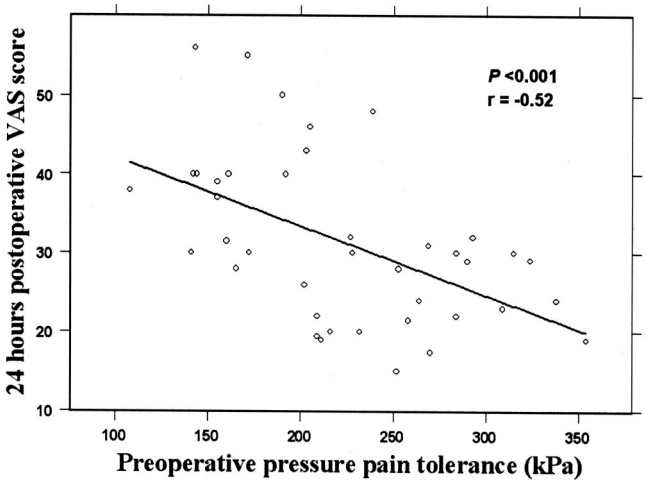

Fig. 1. Correlation between preoperative pressure pain tolerance and 24 h postoperative visual analog scale (VAS) score.

Preoperative Variables and Postoperative Pain and Morphine Consumption

Multiple linear regression analysis has shown that postoperative pain in the PACU can be estimated by using

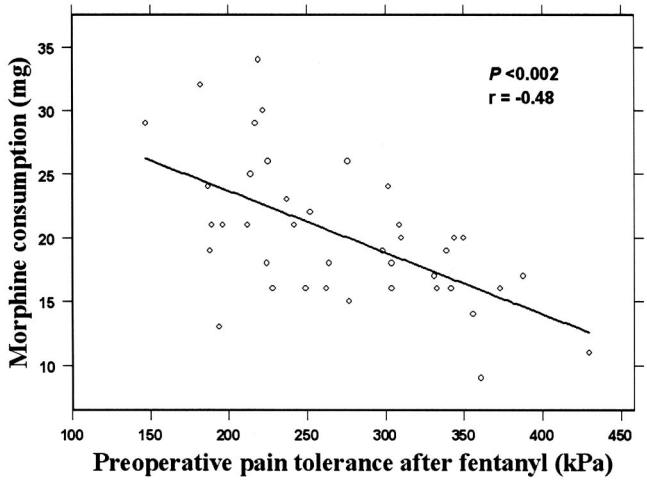

Fig. 2. Correlation between preoperative pressure pain tolerance after fentanyl administration and morphine consumption in the first 24 h after surgery.

Table 2. State Anxiety and Pressure Pain Measurement, Postoperative Pain, and Analgesic Consumption

Variable	Highly Anxious	Mildly Anxious	*P* Value
Number of subjects	21	19	—
Raw STAI score	59 ± 8	41 ± 6	< 0.0001
Pressure pain threshold	133 ± 66	149 ± 64	0.43
Pressure pain tolerance	222 ± 68	225 ± 57	0.56
D/D ratio in PACU	8.8 ± 6.6	4.7 ± 2.6	0.01
D/D ratio at 24 h	2.9 ± 4.1	3.2 ± 2.7	0.83
VAS score in PACU	87 ± 25	65 ± 28	0.005
VAS score at 24 h	31 ± 9	32 ± 12	0.72
Morphine consumption in first hour in PACU	7.0 ± 1.8	6.9 ± 1.3	0.92
Morphine consumption in first 24 h	19 ± 7	22 ± 5	0.20

Values are presented as mean ± SD.

D/D = demand/delivery; PACU = postanesthesia care unit; STAI = State-Trait Anxiety Inventory; VAS = visual analog scale.

STAI percentile rank ($\beta = 0.67$, $P < 0.0001$) and postoperative pain at 24 h in the ward by pain tolerance ($\beta = -0.09$, $P = 0.01$). Postoperative morphine consumption at 24 h in the ward can be estimated by using pain tolerance after fentanyl ($\beta = -0.49$) and fentanyl sensitivity ($\beta = -0.23$, $P = 0.00006$; table 3).

Discussion

This study demonstrates that preoperative pressure pain assessment may predict the level of postoperative pain. Our results show that preoperative pressure pain tolerance after fentanyl analgesia and fentanyl sensitivity may predict the amount of morphine consumption. We also found that patients with higher anxiety levels reported more pain in the immediate postoperative period.

Acute postoperative pain is most often caused by tissue and nerve damage, which may lead to prolonged central and peripheral hyperexcitability in the nociceptive pathways.[33] Human experimental pain models cannot mimic the clinical circumstance of extensive tissue damage or the emotional component of pain related to the threat of disease. However, pain models are useful in that they generate a painful stimulus under fully controlled and standardized conditions. This allows for semiobjective investigation of an admittedly subjective experience.

Several groups have used the pressure pain model to study pain mechanisms and the effect of analgesics.[17–24] However, ours is the first investigation of the relation between preoperative pressure pain levels and postoperative pain. Clinical application of the pressure pain model using algometers has been validated for evaluating pain sensitivity.[25,34] Although different nerve fibers transmit different type of painful stimuli, such as heat, cold, and pressure, measurement of pressure has been shown to be an adequate surrogate to evaluate the results of pain-relieving modalities such as anesthetic blocks, heat, manipulation, and antiinflammatory agents as well as documenting the long-term effectiveness of treatment.[25] Algometers also have the advantage over heat pain or cold pain models of being portable.

To explore the relation between pressure pain assessment and postoperative surgical pain, it is necessary to control for other factors that may influence postoperative pain, such as sex and type of surgery. That is why we designed our study to include only female patients undergoing lower abdominal gynecologic surgery. We excluded patients with cancer because they have been shown to have higher preoperative anxiety than patients with benign disease.[35]

The VAS is the most commonly used tool in clinical research to assess pain in the perioperative period and to evaluate outcome.[36] In general, VAS scores of 70 or more are regarded as indicative of severe pain.[30] In our study, 28 of 40 patients (70%) rated their pain as 70 or greater on the VAS immediately after they emerged from general anesthesia using the short-acting anesthetic desflurane. Previous investigation has shown that the relation between increments in noxious stimuli and VAS pain scores is best described by an exponential function.[37] It is possible that immediate postoperative pain was so severe that it skewed the distribution of VAS scores in our subjects to the right, so that we could not find a correlation between preoperative pressure pain

Table 3. Multiple Regression Model for Predicting Postoperative Pain and Morphine Consumption

Dependent Variable	Predictor	Coefficient (β)	Intercept	R^2	*P* Value
Postoperative pain					
VAS score in PACU	STAI percentile rank	0.67 (0.16)	29.5 (10.7)	0.39	< 0.0001
VAS score at 24 h	Pain tolerance	−0.09 (0.02)	50.1 (5.5)	0.27	0.01
Postoperative morphine consumption					
Morphine consumption in 24 h*	Pain tolerance after fentanyl	−0.049 (0.01)	39.7 (4.0)	0.46	0.00006
	Fentanyl sensitivity†	−0.23 (0.06)			

Values in parentheses are standard errors.

* Morphine consumption in 24 h = 39.7 − (0.049 × pain tolerance after fentanyl) – (0.23 × fentanyl sensitivity). † Fentanyl sensitivity = percentage of pain tolerance increase after fentanyl administration.

PACU = postanesthesia care unit; STAI = State-Trait Anxiety Inventory; VAS = visual analog scale.

assessment and immediate postoperative VAS pain scores. However, the preoperative pressure pain tolerance was predictive of morphine consumption in the first 24 h after surgery. Our results are comparable to those of Granot *et al.*,[15] who used a heat pain model. Our study also shows that pain tolerance is more reliable in assessing analgesic effects than is pain threshold. This is consistent with previous notions that experimental pain thresholds are not increased by opioids to the same extent as is pain tolerance. The thresholds are therefore of limited utility in defining pain sensitivity.[38–40] Although pain tolerance is sensitive in assessing analgesic effects, it is highly dependent on the motivation of the subject. Coghill and Eisenach[41] have suggested the use of a psychophysical rating of a fixed intensity stimulus to include in the study of pain sensitivity if devices are capable of delivering stimulus in a well-controlled fashion.

Several studies have examined the relation between preoperative state anxiety and postoperative pain, but their findings are contradictory. Some investigators have found that increased preoperative state anxiety is associated with increased postoperative pain, increased analgesic requirements, or both,[42–44] whereas others have found no such effect.[45,46] Our study supports the contention that preoperative state anxiety is associated with immediate postoperative pain level. The difference in the demand/delivery ratio suggests that highly anxious patients have different coping behaviors when they experience a stressful, painful situation. Although we found that preoperative state anxiety affected immediate postoperative pain, there was no correlation with VAS pain scores 24 h after surgery. This difference may relate to where and when both state anxiety and VAS pain scores were assessed. Subjects were isolated both when they were reporting their anxiety scale in the holding area and when they were recovering in the PACU. The 24-h postoperative pain assessment was performed after they had settled back into a room in the ward. It is somewhat surprising that we found no significant differences between highly and mildly anxious groups in terms of pressure pain threshold and tolerance. However, the anxiety questionnaire was given in a different location than the pain sensitivity testing, which may have influenced the results.

Patient-controlled analgesia generally provides adequate postoperative pain control with minimal side effects. The flexibility of PCA allows patients to titrate their own opioid dose. There can be considerable interpatient variability in PCA morphine doses. Macintyre and Jarvis[47] found up to 10-fold differences in PCA morphine consumption. Our patients' morphine use in the first 24 h ranged from 9 to 34 mg, approximately a 3-fold difference. The total dose consumed correlated with pressure pain tolerance and the reported level of postoperative pain. Although PCA is designed to be easily titrated by the patient, small changes in the dose available with each press of the button may result in inadequate analgesia. One implication of our study is that individual assessment of pressure pain tolerance might be useful in individualizing the PCA protocol, although this theory must be tested.

In conclusion, we have demonstrated that preoperative pressure pain assessment can be a predictor of postoperative pain and analgesic consumption in women undergoing lower abdominal gynecologic surgery. However, conclusions from this study should be drawn with caution because a significant part of variability cannot be explained by our model. Efforts must continue to be made to improve the pain prediction model, and whether the pressure pain model can be generalized to all surgical patients remains to be studied. We believe it is worth pursuing, because the assessment is simple to perform with an easily available, portable algometer.

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