The Pain Visual Analog Scale: Is It Linear or Nonlinear?

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The visual analog scale (VAS) is a tool widely used to measure pain, yet controversy surrounds whether the VAS score is ratio or ordinal data. We studied 52 postoperative patients and measured their pain intensity using the VAS. We then asked them to consider different amounts of pain (conceptually twice as much and then half as much) and asked them to repeat their VAS rating after each consideration (VAS_2 and VAS_3, respectively). Patients with unrelieved pain had their pain treated with IV fentanyl and were then asked to rate their pain intensity when they considered they had half as much pain. We compared the baseline VAS (VAS_1) with VAS_2 and VAS_3. The mean (95% confidence interval) for $VAS_{2:1}$ was 2.12 (1.81–2.43) and $VAS_{3:1}$ was 0.45 (0.38–0.52). We conclude that the VAS is linear for mild-to-moderate pain, and the VAS score can be treated as ratio data. **Implications:** A change in the visual analog scale score represents a relative change in the magnitude of pain sensation. Use of the VAS in comparative analgesic trials can now meaningfully quantify differences in potency and efficacy.

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The visual analog scale (VAS) is a tool widely used to measure pain. A patient is asked to indicate his/her perceived pain intensity (most commonly) along a 100 mm horizontal line, and this rating is then measured from the left edge (=VAS score). The VAS score correlates well with acute pain levels (1–4), but it does have an error of about 20 mm (1,5,6).

There is controversy regarding whether the VAS score is ratio or ordinal data (7–9). Ludington and Dexter (10) have recently suggested that VAS scores are ratio data because 0 mm represents a true zero (indicating absence of pain). They implied that the VAS score has linear scale properties (i.e., the difference in pain between each successive increment is equal) (10). Thus, a VAS pain score of 60 mm indicates twice as much pain as a VAS score of 30 mm, and the difference between a VAS score of 30 and 40 mm would be of the same magnitude as the difference between VAS scores of 70 and 80 mm. To our knowledge, there is no evidence to support the notion that VAS data lie on a linear scale.

Whether or not the VAS is linear has implications for the interpretation of anesthetic, surgical, or pain studies that use the VAS score as an assessment of outcome. For example, if a VAS score is halved in a group comparison study, then the interpretation would either be a halving of pain (if a linear scale) or less pain (if a nonlinear scale). The latter interpretation makes no conclusion regarding the amount of pain relief. We therefore tested the hypothesis that the VAS score is a linear pain measurement.

Methods

After ethics committee approval, we approached surgical patients postoperatively and obtained written, informed consent. We excluded patients who had severe pain (because we considered they could not provide informed consent) and also those who had no significant pain. Patients who were expected to be unable to complete the VAS (e.g., confusion, frailty, visual impairment, psychological disturbance) were also excluded.

Each patient had their pain assessed by one of the investigators on the first (Day 1) or the second day (Day 2) after surgery. After obtaining demographic and perioperative data, we assessed each patient's postoperative status using a 9-item instrument used to measure quality of recovery, the QoR score (11), a validated score that rates aspects of recovery out of a possible score of 18. We measured the patient's current level of postoperative pain using the VAS. We used an unmarked 100 mm VAS that had ends marked with "no pain" and "worst pain ever." We called this existing pain rating VAS_1.

Patients were asked to consider different amounts of pain before repeating his/her VAS rating. It was

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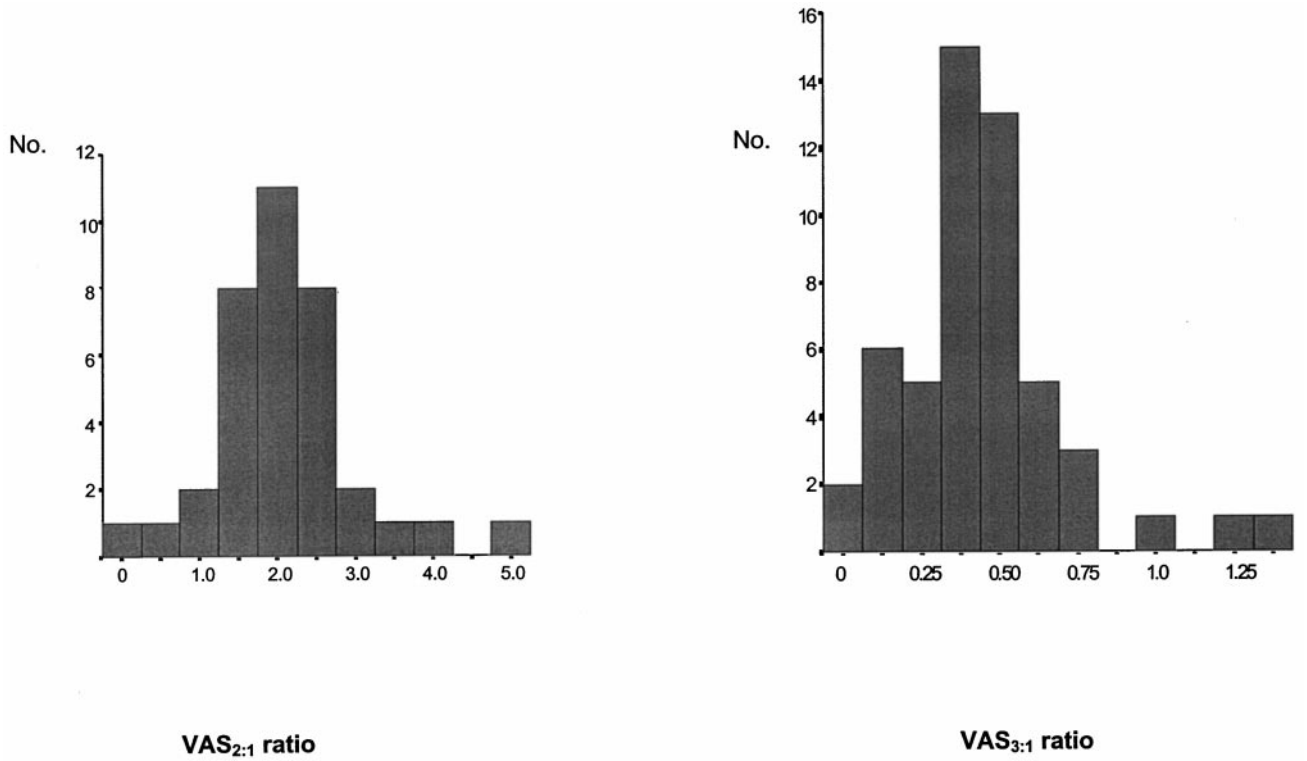

Figure 1. Frequency distributions of the Visual Analog Scale (VAS) ratios, where $VAS_{2:1}$ ratio = VAS_2/VAS_1 and $VAS_{3:1}$ ratio = VAS_3/VAS_1.

accepted that patients would be influenced by their first VAS recording. So each successive rating was concealed after completion.

If their VAS_1 was less than or equal to 50 mm, they were asked to consider how they would feel if they had *twice* as much pain. After allowing some time for this deliberation, they were asked to rate their conceived pain state with another VAS (VAS_2).

Patients who stated they would like to have immediate pain relief were then given an IV dose of fentanyl, titrated to relieve their pain. These patients were asked to rate their pain when they considered their initial pain intensity had halved. This provided another objective assessment of the VAS. All other patients were asked to consider how they would feel if they had *half* as much pain. After allowing some time for this deliberation, they were asked to rate their conceived pain state with a third VAS (VAS_3). Both the VAS_2 and the VAS_3 were presented on separate sheets.

Patients had their pain management adjusted at the completion of the study if they desired.

We anticipated a mean (SD) VAS ratio ($VAS_{2:1}$) of 2.0 (0.4) for patients considering twice as much pain. A preliminary estimate of sample size was based on a 95% confidence interval (CI) for the $VAS_{2:1}$ ratio, excluding this value (<1.9 or >2.1). Accepting a Type I error of 0.05 and a Type II error of 0.20, the required number was calculated at 21 patients per group (Clinical Trials Design Program v1.0, Biosoft, Cambridge, UK). This assumes a normal distribution of the data and so 50 evaluable patients were included in this study.

The VAS scores are presented as mean (SD) and median (interquartile range; IQR). The ratios of baseline to twice and half pain states are presented as the mean (95% CI) to determine if the VAS score is linear (i.e., does or does not include the value 2.0 or 0.5, respectively).

Testing for whether the data were consistent with sampling from a normal distribution was done using visual inspection of the sample frequency distributions (Fig. 1) and the Kolmogorov-Smirnov test ($VAS_{2:1}$ ratio, $P = 0.58$; $VAS_{3:1}$ ratio, $P = 0.21$). Logarithmic transformation did not alter the variance:mean relationship (i.e., uniform variance) between groups (12). These procedures supported treating the VAS ratio as normally distributed data. All statistical analyses were performed using SPSS for Windows v8.0 (SPSS Ltd., Chicago, IL).

Results

We approached 53 eligible patients, and 52 were recruited (31 males, 21 females). They had a mean (SD) age of 42 (15) years. Patients were assessed at 25.0 (8.6) h after their surgery. Demographic and perioperative data are presented in Table 1. Five patients requested immediate analgesia (IV fentanyl) before rating a halving of pain intensity; the individual total doses given were 20, 25, 30, 40, and 50 μg.

Table 1. Demographic and Perioperative Data

Variable	
Age (yr)	42 (15)
Male/female	31/21
ASA physical status	
I	18 (35%)
II	16 (31%)
III	16 (31%)
IV	2 (4%)
Time to assessment (postoperative) (h)	25.0 (8.6)
QoR score	14 (3)
Extent of surgery	
Minor	2 (4%)
Intermediate	32 (62%)
Major	18 (35%)
Type of surgery	
General	19 (37%)
Orthopedic	9 (17%)
ENT/faciomaxillary	5 (10%)
Cardiothoracic	5 (10%)
Other	14 (27%)

Values are means (SD) or number (%). QoR score = quality of recovery score; ENT = ear, nose, and throat. The extent of surgery was rated by the anesthesiologist researcher.

The mean (SD) and median [IQR] VAS_1 scores were 42 (20) mm and 41 [27–57] mm, respectively, indicating most patients had moderate pain. Their mean (SD) QoR score was 14.0 (2.5).

The mean (SD) and median [IQR] VAS_2 and VAS_3 scores were 59 (23) mm and 65 [44–73] mm, and 14 (11) and 12 [8–29], respectively. The mean (95% CI) for $VAS_{2:1}$ was 2.12 (1.81–2.43) and for $VAS_{3:1}$ was 0.45 (0.38–0.52). The VAS ratios are presented in Fig. 2.

Patients who were given IV fentanyl before rating their VAS when they felt their pain intensity had halved did not have a significantly different $VAS_{3:1}$ from those who had been asked to consider a halving of pain intensity ($P = 0.32$).

Exploratory univariate analyses found no significant association between the VAS ratios ($VAS_{2:1}$ and $VAS_{3:1}$, respectively) and investigator ($P = 0.84$, $P = 0.35$), patient age ($P = 0.21$, $P = 0.17$), patient gender ($P = 0.084$, $P = 0.068$), ASA status ($P = 0.74$, $P = 0.78$), extent of surgery ($P = 0.70$, $P = 0.82$), time of assessment after surgery ($P = 0.19$, $P = 0.64$), and QoR score ($P = 0.15$, $P = 0.89$).

Discussion

We have shown that the VAS has properties consistent with a linear scale, at least for patients with mild-to-moderate pain, and thus VAS scores can be treated as ratio data. This supports the notion that a change in the VAS score represents a relative change in the magnitude of pain sensation. This enhances its clinical application. If a VAS score is halved after a clinical intervention (e.g., administration of analgesia), then the patient's pain has been halved. Likewise, in comparative analgesic trials, we can now meaningfully quantify differences in potency and efficacy.

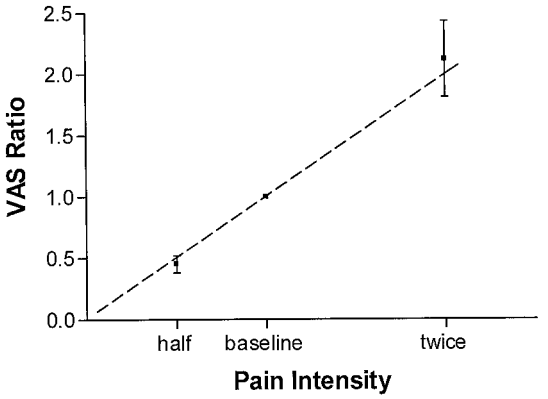

Figure 2. Visual Analog Scale (VAS) ratios with different levels of pain intensity from baseline (VAS ratio = 1.0). Dashed is the line of equality, and error bars are 95% confidence interval.

There are several limitations of this study. First, the participants may have intuitively believed that the pain VAS is a linear scale and, therefore, attempted to try to double or halve their scores based on their recollections of their first VAS assessment. We sought to minimize this potential source of bias by clear patient explanation and concealment of their previous responses. Carlsson (13) has demonstrated that patients are not necessarily influenced by previous ratings when asked to repeat measurements. Some patients requested pain treatment (and actually achieved a halving of their pain intensity), and they had equivalent $VAS_{3:1}$ ratios. We found no evidence of observer bias or confounding. We included only patients who had mild-to-moderate acute (postoperative) pain, and thus it is possible that extremes of the VAS are nonlinear. Collins et al. (14) concluded that a VAS score of at least 54 mm could be equated with a rating of severe pain; 17 (33%) of our patients rated their initial VAS at 54 mm or greater. We chose to derive our 95% CI based on parametric method, after demonstration of normality. This approach could be criticized, but nonparametric methods would result in wider confidence intervals and would not alter our conclusion of linearity. The VAS is a unimodal measure of pain intensity and cannot adequately represent all aspects of pain perception. The extremes of pain—"no pain" and "worst pain ever"—may not truly represent absolute limits of perception. Despite these limitations, it remains a widely used, validated measure of pain.

Price et al. (15) have considered the scaling properties of the VAS in patients with chronic and experimental pain. They used noxious thermal stimuli to derive a regression line and subsequently verified its linear properties with repeat application of different levels of thermal stimuli.

DeLoach et al. (5) found that a single VAS has an imprecision of ±20 mm when measuring acute pain and suggested that clinically significant changes in pain sensation would require a change in VAS score of similar magnitude. This information should be considered along with the results of our study when interpreting changes in VAS scores in clinical practice.

There has been some controversy in the literature regarding which statistical tests should be used when analyzing VAS data (9,16–18). Parametric tests, such as Student's *t*-test and analysis of variance, assume that sample data have been taken from a normally distributed population. Mantha et al. (17) surveyed the anesthesia literature and found that approximately 50% used parametric tests. Philip (16) argued cogently that use of parametric tests will lower the risk of Type II error (false-negative conclusion). Dexter and Chestnut (18) used a multiple resampling (of VAS data) method to demonstrate that parametric tests had the greater power to detect differences among groups without increasing the Type I error. Our study demonstrates that VAS data have ratio scale properties for mild-to-moderate pain and supports use of parametric tests when analyzing VAS scores.

We have shown that, in postoperative patients with acute mild-to-moderate pain, the VAS score is a linear scale. Changes in the VAS score represent a relative change in the magnitude of pain sensation.

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