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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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.

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

We anticipated a mean (sd) VAS ratio (VAS$_2$ to VAS$_1$) 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$_2$ to VAS$_1$ 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$_2$ to VAS$_1$ ratio, $P = 0.58$; VAS$_3$ to VAS$_1$ 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.
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 VAS2:1 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 VAS3:1 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 (VAS2:1 and VAS3:1, 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.

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 VAS3:1 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 non-linear. 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 non-parametric 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.

References