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The visual analogue thermometer and the graphic numeric rating scale: A comparison of self-report instruments for pain measurement in adults with burns

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ARTICLE INFO

Article history:
Accepted 5 July 2014

Keywords:
Pain
Measurement
Self-report
Cutpoints
Burns
Adults
Nursing

ABSTRACT

To evaluate the adequacy of pain management in burn care, pain measurement is essential. The visual analogue thermometer (VAT) and graphic numeric rating scale (GNRS) are frequently used self-report instruments for burn pain. To legitimise their interchangeable use in research and practice, we aimed to compare self-reports obtained by the VAT and GNRS, the ability of the scales to differentiate background from procedural pain, and to compare potential cutpoints. Adults with acute burns ($N = 319$) participated in the study (67% male, mean age 40.3 years (SD 16), mean TBSA 9.9% (SD 10.4). Correlation coefficients between VAT and GNRS were 0.64 and 0.55 for, respectively, morning and afternoon background pain and 0.51 for procedural pain ($p < 0.01$). VAT scores were lower than GNRS scores for all pain types ($p < 0.01$). Both scales could differentiate background from procedural pain: procedural pain was higher ($p < 0.01$). The standardized response mean was moderate (0.518 for VAT and 0.571 for GNRS). Self-reported thresholds for 'unacceptable pain' by GNRS were higher than by VAT ($p < 0.001$). ROC analyses showed that the highest sensitivity was reached for pain score 2 for both scales. The results suggest that the instruments cannot be used interchangeably without taking their differences into account.

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http://dx.doi.org/10.1016/j.burns.2014.07.002
0305-4179/

1. Introduction

Acute pain is an important complication of burn injuries. Researchers continue to report that burn pain is a worldwide, unresolved problem [1]. In particular, pain experienced during wound care procedures, with highly fluctuating patterns, is difficult to control and complicated to investigate because of its unique characteristics, its multiple components, and its changing patterns over time [2–5]. But also background pain, caused by inflammation and experienced at rest, varies widely in intensity [6]. Health care professionals in burn care are confronted with pain on a daily basis. The multidisciplinary burn care team has an important role in pain management: not only regarding the treatment of pain, but also with regard to the assessment of pain. To evaluate the adequacy of the treatment, pain should be measured.

An essential requirement of outcome measures is that they have appropriate clinimetric properties [3], meaning that they measure in a reproducible fashion and that they measure what they are intended to measure in a specific patient population. Furthermore, the clinical usability, i.e. the speed and ease of use, are important criteria. The commonly used method of pain assessment in adults with burns is by patients' self-reports. However, different self-report measures are used in the global burn field and this may hamper the comparison of pain scores across study reports. This may be particularly relevant for pain intervention studies that received increasing attention in recent years [7–11]. Also for daily practice, to evaluate the adequacy of pain treatment, it may be useful if different measures could be offered to patients to match with their preference for a specific instrument.

One of the frequently used patient self-report instruments for the measurement of background and procedural pain in adults with burns is the visual analogue thermometer (VAT) [4,12–14]. The VAT (Fig. 1) has good clinimetric properties and is specially developed for clinical use in burn care. Another frequently used self-report pain measure is the 0 to10 graphic numeric rating scale (GNRS) (Fig. 2) [15–18]. While pain on the VAT is expressed by the perceptible extent of a red coloured band, pain on the GNRS is expressed by a series of numbers. Up to now, it is unclear whether the VAT and the GNRS can be used interchangeably.

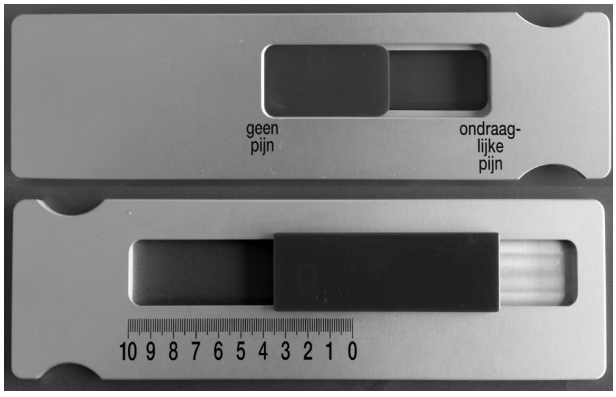

Fig. 1 – Frontside and backside visual analogue thermometer.

Background pain
Please rate your pain by circling the number that best describes your pain at this moment

0 No pain 1 2 3 4 5 6 7 8 9 10 Pain as bad as you can imagine

Fig. 2 – Graphic numeric rating scale.

Another issue relates to cutpoints of the VAT and GNRS: it is unknown what the cutpoints are for both scales and whether the two instruments have similar cutpoints. This is a relevant question for both clinical practice and research. Cutpoints are useful for treatment guidelines by connecting pain ratings to a pain management protocol. Furthermore, cutpoints may help evaluating changes in pain in daily practice and determining effects in intervention studies [19].

To legitimise interchangeable use, the aim of this study was to compare self-reports obtained by the VAT with those obtained by the GNRS, to compare their ability to differentiate background from procedural pain, and to compare cutpoints of both scales.

2. Methods

This study is part of a multicentre longitudinal prospective cohort study into the extent, course and influencing factors of clinical pain. Data were collected between April 2010 and October 2012. Approval of the local medical ethics committees of the three participating Dutch hospitals provided with a burn centre (the Red Cross Hospital in Beverwijk, the Maasstad Hospital in Rotterdam and the Martini Hospital in Groningen), and of the official regional medical ethics committee was obtained. The study was conducted according to the principles of the Declaration of Helsinki.

2.1. *Inclusion criteria*

Inclusion criteria were: adult patients (18 years and older) with acute burns, with a minimal length of stay of 48 h and a minimal total burned body surface area (TBSA) of 1%. Patients had sufficient Dutch proficiency and had no acute or chronic psychotic pathology, nor did they have cognitive impairments that prevented reliable data collection. Patients requiring artificial ventilation were invited to participate as soon as they were extubated and able to provide self-reports. Patients unable to provide self-reports due to sedation or unconsciousness were excluded.

2.2. *Measurement instruments*

2.2.1. *Visual analogue thermometer*

The VAT is a frequently used instrument for self-reports of pain in patients with burns and is an adapted version of the visual analogue scale (VAS). The VAT is developed by Choinière et al. [3]. The VAT (Fig. 1) is an aluminium and plastic endurable tool that can be easily disinfected, which allows reusability in the burn centre [3]. The left and right extremities of the device are marked by the anchor words 'no pain' and 'unbearable pain.' A red band can slide from left to

right. As the band is moved from the left to the right, an increasing intensity of pain is shown. The more intense the pain, the more the red band lengthens towards the anchor 'unbearable pain.' On the back is a 10-cm ruler corresponding to the red band, where the numerical value can be read by the nurse. Construct validity in patients with burns was assessed by comparing the VAT to a verbal numeric rating scale (VNRS) (0–10) and an adjective pain scale. Significant correlations were seen for all scales (Spearman's rho ≥ 0.71, $p = 0.001$) for background and procedural pain. Also, the VAT was able to differentiate background from procedural pain (mean background pain scores were 41% lower than mean procedural pain) [3].

2.2.2. *Graphic numeric rating scale*

The 0 to 10 GNRS (Fig. 2) is a brief, simple and easy to use tool for the assessment of several types of pain in both clinical and research settings. Pain on the GNRS is expressed by the numbers 0 to 10 that are placed at equal distance. The anchor words are 'no pain' and 'pain as bad as you can imagine'. The GNRS is part of the brief pain inventory (BPI), developed by Cleeland and Ryan [20]. Construct validity of the BPI is assessed by using confirmatory factor analysis [21]. However, for the GNRS as an isolated scale, clinimetric properties for the use in burn care were not located in the literature. A 10-point GNRS is used in research into burn pain by several researchers [7,15–17,22,23], but the focus of these studies was not on the clinimetric properties.

2.3. *Assessment of cutpoints*

Cutpoints can be determined by asking patients how they define pain categories [24]. In this study, we first asked patients to classify whether their pain scores were 'unacceptable' before comparing these classifications of the two scales with each other and with cutpoints that were used in the pain literature.

2.4. *Data collection procedure*

During the first week of admission, local researchers invited patients who met the inclusion criteria to participate in the study. The procedure was explained orally and in writing. When patients agreed to participate, written informed consent was obtained. Patients were assured that standard medical and pain treatment remained unchanged and that they could withdraw at any time for any reason without consequences. The baseline characteristics gender, age, cause of the burn, TBSA, length of hospital stay and number of surgical operations were retrieved from the patient file by the researchers.

Since the VAT measurements are part of routine daily nursing care, nurses were already trained in the use of the VAT by a standardized educational programme about pain and pain assessment. To introduce the study, an extra one-hour educational session was organized to explain the purpose of the study and to focus on the appropriate use of the VAT. Besides, an information flyer was handed out. Burn pain is divided into background pain (caused by inflammation, experienced at rest, without rehabilitation sessions or wound care) and procedural pain (caused by inflammation and manipulation, experienced during wound care procedures). Nurses assigned to the patient recorded background pain at least 1 h before wound care, and in the afternoon (or at least 1 h after wound care), by asking the patient to indicate her or his current pain. They assessed procedural pain directly after wound care by asking the patient to indicate overall pain of the whole wound care procedure. Nurses asked the patient to slide the red band to the point where pain was experienced. Subsequently, nurses read the score from the backside of the device and recorded the score on the data collection form.

The researchers asked the patients to categorise the obtained VAT pain scores into 'acceptable' or 'unacceptable'. This was limited to twice a week and to procedural and afternoon background pain only, in order to protect patients against overcharging and to avoid bias. Patients were also given a diary to register their pain scores and categorization of the score obtained with the GNRS. Patients were asked to draw a circle around one of the numbers on the scale that corresponded with their pain. When patients were unable to write, due to bandages, the researchers assisted the patient. An overview of the data collections points is shown in Table 1.

2.5. *Data analysis*

The statistical package IBM SPSS Statistics 20 (release 20.0.0) was used for data analyses except for receiver-operating characteristic tests (ROC). ROC analyses were calculated by MedCalc Software version 12 (release 12.5.0).

Patient baseline characteristics were calculated by using descriptive statistics (means (SD) for gender, age, TBSA, length of hospital stay and number of surgical operations, and medians (range) for the extent of pain). To compare the VAT to the GNRS, Spearman's rho was used to calculate correlation coefficients, since data frequencies were not normally distributed. Because of non-normality of pain scores and because measurements were obtained from the same patients, Wilcoxon signed ranks tests were used to compare VAT with GNRS scores and to compare 'unacceptable pain' scores obtained with both scales. Wilcoxon signed ranks tests were also calculated to detect differences between background and procedural pain mean scores per scale. Furthermore, a standardised response mean (SRM) was calculated to

Table 1 – Data collection points per type of pain.

Measure	Type of pain	Data collection	
VAT	Background	Nurse	Twice daily
	Procedural	Nurse	Once daily
	Unacceptable background	Researcher	Twice weekly
	Unacceptable procedural	Researcher	Twice weekly
GNRS	Background	Patient	Twice daily
	Procedural	Patient	Once daily
	Unacceptable background	Patient	Twice daily
	Unacceptable procedural	Patient	Once daily

compare the ability of the scales to differentiate background from procedural pain. The value of an SRM can be considered as an effect size index. An acceptable effect size should be $d \geq 0.5$ [25,26], which corresponds with a moderate effect.

Finally, receiver-operating characteristic tests (ROC) were carried out to compare potential cutpoints. The ROC test expresses the quality of the scales (%, confidence interval, standard error). 100% indicates that the scale is able to perfectly identify 'unacceptable' pain [27]. The ROC also expresses sensitivity (correct classification 'unacceptable': the probability that 'unacceptable' pain is indeed 'unacceptable' pain) and specificity (the probability that the scale detects 'unacceptable' pain while this is not the case). To assess potential cutpoints for pain in the burn population, when measured using the VAT or GNRS, optimal combinations of highest sensitivity with lowest specificity [28] were examined for median 'unacceptable' pain scores reported by patients in this study, cutpoints reported in the literature, and cutpoints that are used as quality indicator in The Netherlands.

3. Results

A total of 192 patients participated in the study and yielded 5380 VAT assessments (of which 3648 for background pain and 1732 for procedural pain) and 4629 GNRS assessments (of which 3185 for background pain and 1454 for procedural pain) from post burn day 1 to 21.

3.1. *Patient baseline characteristics*

The majority of the patients was male (67%), mean age was 40.1 years (SD 15), mean TBSA was 9.0% (SD 8.7), mean TBSA deep dermal 3.4% (SD 7.5), mean length of hospital stay 17.1 days (SD 13.1) and mean number of surgical operations was 0.8 (SD 1.4). The median extent of pain, divided in the first, second and third week of admission, when measured with the individual scales, is presented in Fig. 3. Patients showed a large variation in pain scores: ranges between 0 and 10 were found for both instruments and both types of pain.

3.2. *Comparison of self-reports*

Spearman's rho was 0.64 for morning background pain, 0.51 for procedural pain, 0.55 for afternoon background pain, 0.59 for morning and afternoon background pain together and 0.59 for all types of pain together ($p < 0.01$). The correlations for background pain were higher than the correlation for procedural pain. Wilcoxon signed ranks tests indicated that the VAT scores were statistically significantly lower than GNRS scores (mean morning background pain 1.9 and 2.4, respectively ($z = -10.79$, $p < 0.01$), mean procedural pain 3.1 and 3.8, respectively ($z = -7.5$, $p < 0.01$), and mean afternoon background pain 1.9 and 2.5, respectively ($z = -10.70$, $p < 0.01$)).

3.3. *Comparison of ability to differentiate types of pain*

Wilcoxon signed ranks tests also indicated that procedural pain (mean 3.2 for VAT, 3.5 for GNRS), when measured by the VAT or GNRS, was statistically significantly higher than morning background pain (mean 2.2 ($z = -24.19$, $p < 0.01$) and 2.4 ($z = -18.44$, $p < 0.01$), respectively) and afternoon background pain (mean 2.1, ($z = -20.47$, $p < 0.01$) and 2.4 ($z = -19.95$, $p < 0.01$), respectively). The ability of the scales to differentiate background from procedural pain, expressed in SRM, was 0.518 for the VAT and 0.571 for the GNRS and can be considered as a moderate effect.

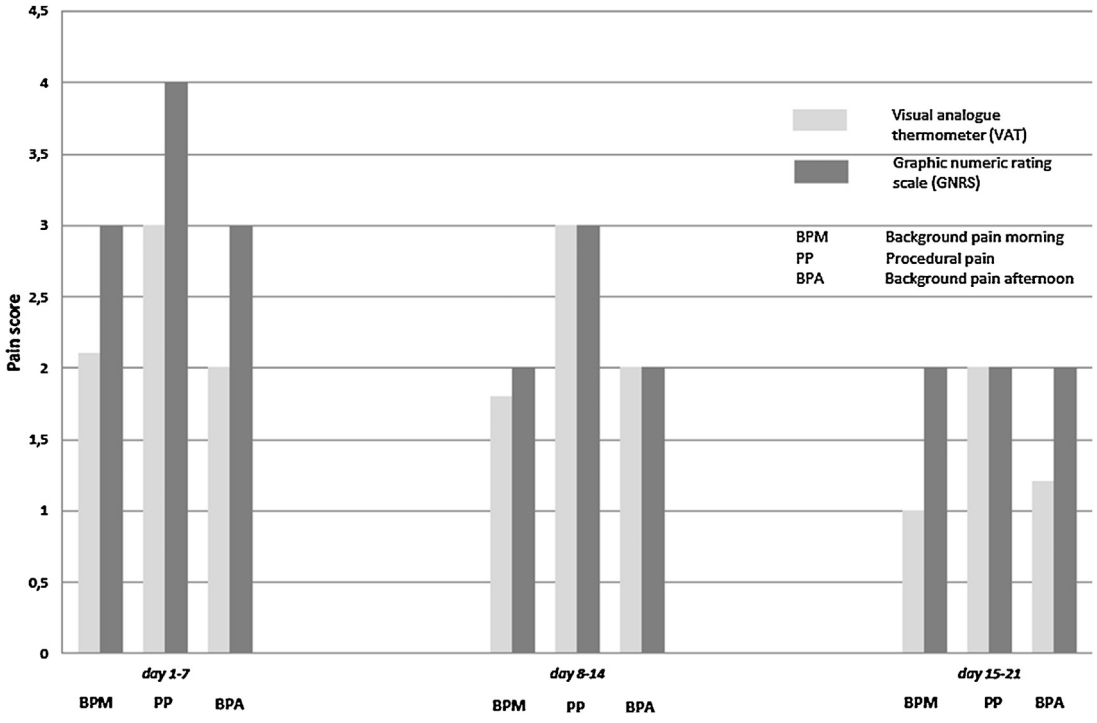

Fig. 3 – Median pain scores by VAT and GNRS.

3.4. *Comparison of cutpoints*

Not all pain scores were accompanied with the patients' classification of their pain scores into the adjective 'unacceptable'. Concerning the VAT, the classification was assessed twice a week only. With regard to the GNRS, patients were asked to report their classification daily, but they did not always complete it on the form. Medians of the patients' classification of their pain scores into the adjective 'unacceptable', divided in week 1, 2 and 3 post burn, are presented in Fig. 4. Overall, when these classifications are taken together, medians for 'unacceptable' pain differed for the VAT and GNRS: 4 and 6 for procedural pain, 2.9 and 4 for background pain afternoon, respectively. On average, median GNRS 'unacceptable' scores were higher. Wilcoxon signed ranks tests indicated that the VAT scores for 'unacceptable' procedural pain were statistically significantly lower than GNRS scores (mean 4.6 and 5.7, respectively ($z = -3.99$, $p < 0.001$). Due to a lack of paired measurements, we were unable to calculate this for afternoon background pain.

For the ROC analyses, the overall classifications for 'unacceptable' pain on post burn day 1 to 21 were used. The quality of the VAT was fair (66 to 72%, depending on the type of pain, (confidence interval 63-75%, standard error 0.02), while the quality of the GNRS was good (86 to 88%, confidence interval 85–90%, standard error 0.01), indicating that GNRS had better qualities to detect 'unacceptable pain'. Sensitivity and specificity per potential cutpoint are presented in Table 2. Unfortunately, for both scales, none of the potential cutpoints seemed to show an optimal combination of high sensitivity with low specificity. However, where the patients' self-reported classification of 'unacceptable pain' differed per scale and per type of pain, in the ROC analyses the VAT and GNRS share score 2 as the score with the highest sensitivity, meaning that score 2 has the lowest probability that 'unacceptable' pain is not recognised.

4. Discussion

This study investigated the clinimetric properties and the potential cutpoints of the VAT and GNRS, in order to assess whether these scales can be used interchangeably. The results suggest that the instruments cannot be used interchangeably without taking their differences into account.

We expected the correlation coefficients to be higher, since higher correlations (0.86 and 0.94) between the GNRS and VAS were reported in other study populations [29,30]. Possibly, the study procedure, the patients and/or the scales may have influenced the results. First, VAT and GNRS scores may not always have been registered simultaneously. Often, GNRS scores were completed when it suited best in the patients' busy daily schedule, for example in the afternoon. Second, patients may split the GNRS as follows: 0 is 'no pain', 10 is 'unbearable pain' and therefore 5 is in the middle and corresponds to 'medium pain.' As patients may interpret 'medium pain' intensity as not being strong, this may contribute to inflation of GNRS scores [3]. Third, the GNRS, since this scale has no decimals, forces the patient to choose a whole number out of 11 possibilities, whereas the VAT allows for more possibilities. Patients may round up GNRS scores, which may result in higher pain levels. Finally, although we assume that the scales are easy to use, patients may have had difficulties in understanding how to complete a pain score. This is possibly due to a lack of receiving adequate instructions. Also, patients may have interchanged the anchor words

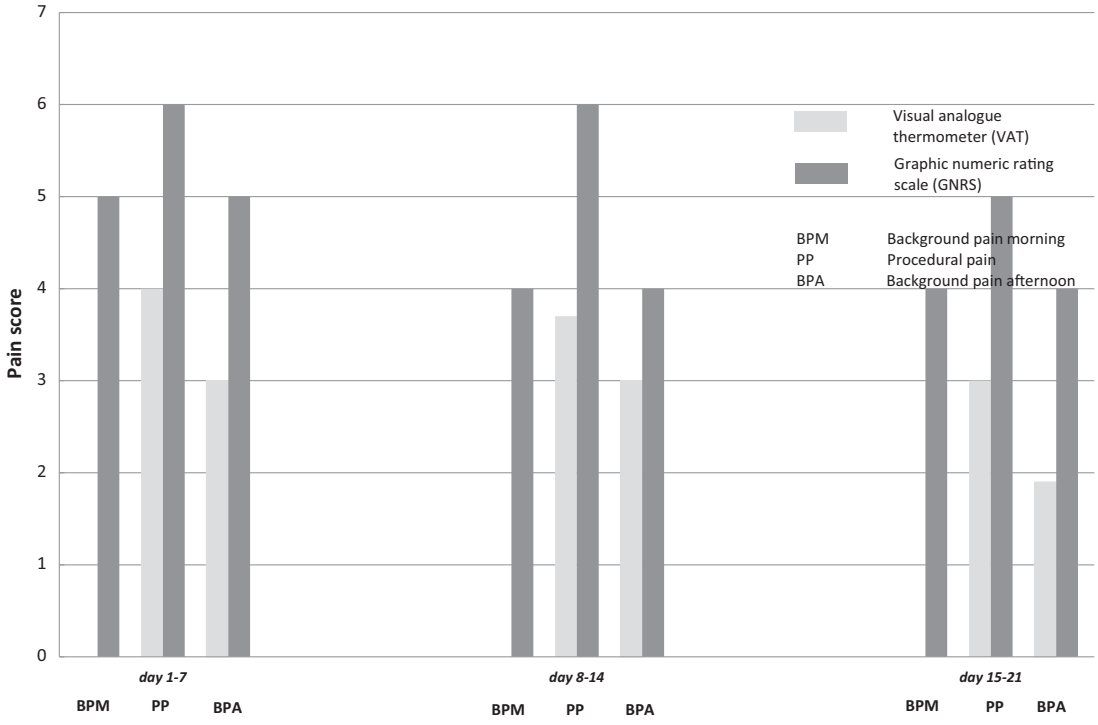

Fig. 4 – Median pain scores marked as 'unacceptable' by VAT and GNRS.

Table 2 – Sensitivity and specificity per possible cutpoint.

Type of pain	Visual analogue thermometer			Graphic numeric rating scale		
	Potential cutpoint	Sensitivity (%)	Specificity (%)	Potential cutpoint	Sensitivity (%)	Specificity (%)
Background morning	>2	60	70	>2[3]	91	67
	>3[1,2]	43	84	>3	73	84
	>4	27	91	>4[**,4,5]	47	94
	>5	16	95	>5	34	98
	>6	9	97	>6[4,5]	20	99
	>7	5	99	>7[**]	10	100
Procedural	>2	75	47	>2[3]	95	52
	>3	59	67	>3	83	71
	>4[*,2]	43	80	>4[**]	67	86
	>5	28	88	>5	55	93
	>6	19	94	>6[*]	39	97
	>7	10	96	>7[**]	22	99
Background afternoon	>2	64	70	>2[3]	94	67
	>3[*,1,2]	39	83	>3	76	85
	>4	22	93	>4[**,4,5]	47	93
	>5	12	97	>5	35	97
	>6	7	98	>6[4,5]	21	99
	>7	2	99	>7[**]	8	100

□ Highest sensitivity.
[*] Median classification 'unbearable pain' by patients in this sample.
[**] Considered as standard cutpoint in The Netherlands (4 = moderate, 7 = severe pain [34].
[1] Cutpoint according to Choinière et al. [3].
[2] Cutpoint according to Weinberg et al. [4].
[3] Cutpoint according to Carrougher et al. [15].
[4] Cutpoint according to Mendoza et al. [12].
[5] Cutpoint according to Jensen et al. [35].

since VAT scores of 9 points higher than GNRS scores were seen, as well as VAT scores of 9 points lower than GNRS scores.

GNRS scores in this study were higher than VAT scores. This is consistent with the literature, although it is based on results obtained with other, but comparable, instruments, on different descriptive statistics and on different settings. Choinière et al. [3] found that mean VNRS scores were 0.7 to 0.9 points higher than VAT scores ($p = 0.001$). Also, on average, GNRS scores were found 0.5 to 1.0 point higher than VAS scores [30]. Furthermore, for procedural pain, mean VAS scores of 4.9 and mean GNRS scores of 5.4 were reported [5]. In acute pain, a tendency towards higher pain intensity ratings on the GNRS when compared to the VAS was reported [29]. These results may be explained, as mentioned above, by the manner how patients used the scale and by the fact that only numbers without decimals can be chosen. Furthermore, the individual scales had the ability to differentiate background from procedural pain. Choinière et al. [3] also reported the ability of the VAT to detect change. Also, the GNRS was able to detect differences between treatments in acute pain [29].

Overall medians for 'unacceptable pain' in this study were 3 and 4 for background pain and 4 and 6 for procedural pain on the VAT and GNRS, respectively. The higher medians for 'unacceptable pain' associated with the GNRS are in accordance with the overall higher pain scores that were obtained with this scale. However, according to the ROC analyses, the most appropriate cutpoint for both scales was lower, namely 2. Score 2 had the highest probability to detect all patients suffering 'unacceptable pain'. At this point, the probability of undertreated pain is lowest, suggesting that patients reporting a pain score higher than 2 may need pain treatment evaluation. However, the higher medians for self-reported 'unacceptable pain' do reflect a large inter-individual variation and may indicate that a personal cutpoint may vary considerably across patients.

Although the most appropriate cutpoint did not differ across the scales, the GNRS had better properties to detect patients suffering 'unacceptable pain'. An explanation may be that patients find it easier to convert and remember pain in a rational number than in an amount of red colour when asked to give a personal cutpoint. Possibly, the VAT score may be determined more intuitively and may be more difficult to reproduce. Nevertheless, both scales did not show optimal performance on sensitivity and specificity. This may be related to the large variation of classification of the self-report ratings. Considerable variability in pain scores was previously reported between patients and for repeated measures from the same patient [6,29,31]. Also, variation in cutpoints was described, varying between 3 and 6 [2,17,24,32]. Although the latter studies involved other scales and different settings, it indicates the difficulty to determine cutpoints for 'unacceptable pain' due to large variability. In summary, we suggest to use cutpoint 2 for both scales when the aim is to decrease the probability of undertreating pain, indicating that cutpoint 2 may be the point that pain evaluation is required. With respect to pain treatment, individualized cutpoints are recommended to tailor pain treatment to personal needs.

Lastly, some limitations of this study should be mentioned. First, a considerable amount of data was missing. This may be due to flaws in the data collection procedure. Although

Table 3 – Properties of VAT and GNRS.

Properties	VAT	GNRS
Clinimetric properties	Appropriate clinimetric properties for the burn population (based on the literature and this study)	Appropriate clinimetric properties for the burn population (based on this study)
Clinical usability	Appropriate clinical usability, i.e. the speed and ease of use	Patients with burned hands may have difficulties using a pen
	Can be easily disinfected, enduring	Pen and paper may become filthy
	Patients may have difficulties in converting pain in an amount of red colour	Patients may find it easier to convert and remember pain in a rational number
	Pain score may be more difficult to reproduce	No decimals: rounding up score may result in higher score
	Pain may be determined more intuitively	Patient may consider 5 as medium pain: inflation of pain scores
Cost	Costly, handmade	Cheap

patients and nurses were instructed to complete the diary, this study was carried out with patients and nurses in a busy health care setting where we preferred to limit disturbing daily practice, we were unable to control if simultaneous measurements with both scales were completed. Since the results are in accordance with the literature, we assume that this did not cause bias. Second, although it concerned a small group, we did not analyze potential causes of the VAT scores of 9 points higher and 9 points lower than GNRS scores on an individual patient level. This may be helpful in detecting explanations for the reported differences between these instruments. Finally, all available data were analysed. In an earlier stage of the study however, we carried out preliminary analyses on a subset of our database, comprising paired measurements. The obtained results were similar when compared to analyses of the large dataset.

5. Conclusion

In this study, we compared self-reported pain scores obtained with the VAT and the GNRS, we compared their ability to differentiate background from procedural pain and we compared cutpoints. An overview of the properties of both scales is presented in Table 3. The results suggest, in accordance with previous findings [33], that the instruments cannot be used interchangeably as such without taking their differences into account. Self-reports obtained with the VAT turned out to be statistically significantly lower than when obtained with the GNRS. However, both scales were comparable in their ability to differentiate background from procedural pain. Furthermore, although median 'unacceptable pain' ratings differed across the scales and per type of pain, cutpoint 2 showed to have the highest sensitivity irrespectively of type of pain or scale. This suggests that to decrease the probability of undertreating pain, patients reporting pain scores exceeding 2 may need adjustment of pain treatment, which is in accordance with previous findings [15]. However, because of the large variability in 'unacceptable pain' scores on individual level, nurses may not only ask the patient about the extent of pain, but may also ask if that specific pain score is acceptable or not, before adapting pain treatment [24]. When using protocols, the choice is to the user: either not missing any patient suffering 'unacceptable' pain and risking to overtreat patients, or to miss patients suffering 'unacceptable' pain and thus undertreat them. Both options could be obviated by asking the patient his personal, individual cutpoint per obtained pain score.

Disclosures

This study was supported by grant 0901-057 from Fonds NutsOhra zorgsubsidies, Amsterdam, The Netherlands. There are no financial or other relationships that can lead to a conflict of interest.

Conflict of interest statement

The authors state that there are no financial or other relationships that can lead to a conflict of interest.

Acknowledgements

The authors would like to thank all of nurses from the Dutch burn centres for their participation, and Anita Boekelaar and Anneke van de Steenoven for the data collection.

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