Acta Orthop. Belg., 2007, **73**, 31-37

ORIGINAL STUDY

Reliability of observer assessment of thermographic images in Complex Regional Pain Syndrome type 1

Sjoerd P. NIEHOF, Frank J.P.M. HUYGEN, Dirk L. STRONKS, Jan KLEIN, Freek J. ZIJLSTRA

From the Erasmus Medical Center, Rotterdam, The Netherlands

This study aimed at evaluating the sensitivity, specificity, reliability and repeatability of observer assessment of thermographic images taken from Complex Regional Pain Syndrome (CRPS) type 1. A computer program was developed to let observers rate the difference between randomly presented thermographic images of pairs of hands of individuals. The sensitivity and specificity, and potential learning effects were measured. Effects of the colours and rank number of the images were analysed.

The sensitivity was 71% and the specificity 85%. The repeatability was 0.5267 and the reliability was 0.4967. No significant relation was found between the rank number and the rating. There was a significant correlation between the colour pallet and the rating (r = 0.76).

Although the colour pallet used partly explained the variance in the rating scores, this study shows that observer assessment of thermographic images may distinguish between CRPS1 patients and healthy controls. However, the reliability and repeatability of this assessment was rather low.

Keywords : complex regional pain syndrome ; video-thermography ; observer-dependent.

INTRODUCTION

Complex regional pain syndrome type 1 (CRPS1) is a complication occurring after surgery or trauma, although spontaneous development has also been described. CRPS1 is characterised by signs and symptoms of inflammation and central sensitisation. The diagnosis can be made using several different criteria sets, the most popular of which are the International Association of Pain (IASP) and the Bruehl *et al* (*4*) criteria sets. The IASP criteria have a high sensitivity but a lower specificity, whereas the Bruehl criteria have a high specificity but a lower sensitivity. The IASP criteria are useful for clinical aims and the Bruehl criteria appear to be more useful in research. New IASP criteria are under discussion (*10*) and attempts have been made to obtain a less subjective diagnosis by using diagnostic tools such as 3-phase bone scan, X-ray, MRI, fMRI and temperature measurement devices (*1*). Until now, however, none of these

■ Sjoerd P. Niehof, BSc, PhD Student.
■ Frank J.P.M. Huygen MD, PhD, Head of Pain Center.
Department of Anaesthesiology, Division Pain Treatment Center, Erasmus MC, Rotterdam, The Netherlands.
■ Dirk L. Stronks, PhD, Statistician.
Pain Knowledge Center, Erasmus MC, Rotterdam, The Netherlands.
■ Jan Klein, PhD, Chairman.
■ Freek J. Zijlstra, PhD, Coordinator clinical research.
Department of Anaesthesiology, Erasmus MC, Rotterdam, The Netherlands.
Correspondence : Sjoerd P. Niehof, Department of Anaesthesiology, Pain Treatment Center, Erasmus Medisch Centrum, Dr. Molewaterplein 40, 3015 GD, Rotterdam, The Netherlands. E-mail : s.niehof@erasmusmc.nl.

This study was supported by a Dutch government grant (BSIK 03016)

methods has been accepted as a gold standard. Due to the limited validity of clinical diagnoses, it may be difficult to differentiate CRPS1 from other diseases, e.g. from functional disorders with disuse. We have the impression that a false-positive diagnosis for CRPS1 is still made too often, especially in patients with complaints for which no clear explanation can be obtained about the onset of the symptoms.

There are several reports on the use of videothermography as a diagnostic tool in CRPS1 (*2, 6, 11, 15*). Temperature is one of the criteria used in diagnosing CRPS, whereby temperature at the surface of an extremity reflects the result of a complex combination of central and local regulation systems. Sherman *et al* (*15*) assessed the clinical usefulness of skin temperature patterns in diagnosing CRPS, by observing long-term relationships between changes in pain due to CRPS and patterns of near-surface blood flow. Bruehl *et al* (*5*) examined the validity of thermogram derived indices of autonomic functioning in the diagnosis of CRPS ; they found that temperature asymmetry accurately discriminated between CRPS and non-CRPS patients. Wasner *et al* (*17*) evaluated the diagnostic value of side differences in skin temperature as an index of induced disturbance to the sympathetic nervous system ; they showed that skin temperature differences in the distal limbs proved useful to distinguish CRPS1 from other extremity pain syndromes with a sensitivity of 76% and specificity of 93%. Gulevich *et al* (*6*) showed a high sensitivity (93%) and specificity (89%) for stress infrared thermography in the diagnosis of CRPS ; based on an estimation of 50% prior probability, the positive predictive value was 90% and the negative predictive value was 94%. In an earlier study we described a calculation method to examine the difference between videothermographic pictures of CRPS1 patients and healthy controls (*9*). The mathematical method does not use the arbitrary conversion of temperature into colour, but merely the temperature data alone. Mathematical methods described in the literature used the contralateral extremity as a comparison, a method which cannot be utilised when both sides are affected. Mathematical methods used to assess thermographic images generally use point estimates to describe the temperature of the various regions and do not deal with all the available data contained in the images. A common use of thermography involves the search for thermal spots which do not fit well into the surrounding temperature (e.g. hot spot, cold spot) ; these spots are then given a rating by observers, according to their size and shift in temperature. Using observers to rate these thermographic images may result in subjective assessment of the colours in the images. These colours in the image can range from black to grey, red to blue, green to yellow, etc. and can also vary in their intensity, resulting in subjective rating (*7*). For example, the colour red might be associated with danger (*8*) which could affect differences between the observers with respect to their ratings. To our knowledge the validity of observers' assessments of thermographic images in discriminating between patient and controls has not been studied before. However the advantages of using observers to rate thermographic pictures include, for example, the ability to only rate the affected extremity and to incorporate the wide range of temperature patterns that can exist in thermographic data.

The aim of the present study was to assess the ability of independent observers to differentiate between patients with CRPS1 and healthy controls based on videothermographic images. In addition, to explore a possible learning effect and to ascertain the influence of the colour pallet used. We also hypothesised that there would be a relation between the ISS of CRPS1 patients and the observers' rating of their thermographic pictures.

MATERIALS AND METHODS

This controlled study was approved by the Medical Ethical committee of the Erasmus MC (MEC n° 198.780/2001/24), and all participants gave informed consent. Thirteen patients with CRPS1 in one upper extremity were sequentially included. The diagnosis for CRPS1 was based on the Bruehl criteria (*3, 4*). Thermographic images with visual signs of abnormality (e.g. visual oedema and visual limited range of motion) were excluded.

We measured a Visual Analog pain Score (VAS), the McGill Pain Questionnaire, the difference in active range of motion (AROM), and the difference in volume average temperature between the uninvolved and involved hand. The ISS was calculated according to Oerlemans *et al* (14). The control group consisted of 13 healthy volunteers without any history of vascular abnormality.

Measurement procedure

Videothermographic images were recorded following a standard protocol. Patients were acclimatised in a room with a mean temperature of 23°C (range : 22.5 to 23.5) and a relative humidity of 50% (range : 45 to 55) during 15 minutes.

Measurements of the involved and uninvolved extremity were made with the hands placed in a plexiglas frame. Plexiglas has a high emission factor (0.92) and is a bad conductor of heat. The frame has positioning points between digit 1 and digit 2, and between digit 3 and digit 4, which allows to record comparable parts of the extremity in different patients. The plexiglas frame is placed in a box of the same material to minimise the influence of airflow.

Skin temperature of both hands was registered with a computer-assisted infrared thermograph (ThermaCAM SC2000, Flir Systems, Berchem, Belgium). The thermal sensitivity is 0.05°C at 30°C, the spectral range 7.5 to 13 µm, and the built-in digital video has 320×240 pixels (total 76.800 pixels). Data were obtained through a high speed (50 Hz) analysis and recording system (ThermaCAM Researcher 2001 HS, Berchem, Belgium) coupled with a desktop-PC. Thermograms were stored on hard disk (14-bit resolution) awaiting further analysis. With an interval of -40°C to 120°C this results in a resolution of 9.8×10^{-3} °C per bit, which fits well in the range of the thermal sensitivity. The thermograph camera produces a matrix of temperature values. Each temperature value represents a pixel in the picture measured. The distance between the camera and the hand being measured was adjusted to 68 cm ; thereby the resolving capacity on the hand was 0.8×0.8 mm^2. To obtain only those pixels that represent the hand, the data were filtered by a threshold. On average one hand was represented by 23.540 pixels.

Measurements

A total of 35 independent observers (anaesthesia residents, Erasmus MC) were asked to assess the thermographic images. To become accustomed to the interpretation of thermographic images, the observers first received an explanation about the technique (table I). Examples of images with obvious differences in typical characteristics between a normal and a CRPS extremity were shown, and instruction was given about assessment with a Computerised Visual Analog Scale (COVAS). A COVAS is a slider with a scale ranging from zero to ten. In this study zero represented no CRPS and ten the full-blown CRPS. A computer program was developed to present at random the individual hands from a pair simultaneously. So the left and right hand of either a patient or of a healthy control was shown at the same time. The observers where asked to rate the difference between the images on the COVAS scale. In order to measure the intra-rater reliability, the raters had to rate each picture twice on the covas ; they were not informed that all images would be shown twice. The influence of a possible learning effect was ascertained using the rank number in which the individual images were presented. To measure the impact of the colour red on the rating of the images, the difference in the percentage of the amount of red between the involved and uninvolved extremity was calculated.

Table I. — Explanation given to the observers before they rated the thermographic images

	Contents of explanation
1	Explanation of the technique of thermography : how it works, what it records.
2	Look for patterns that you think are not normal, e.g., not a gradual decline but a sudden increase/decrease in temperature, so-called “hot spots” or “cold spots”.
3	Look for a difference in temperature between the two hands.
4	Explanation about how the rater scale works (COVAS).
5	Random presentation of the thermographic images.

Statistical analyses

The analyses were performed with SPSS 12.01. The sensitivity and specificity of the ratings were calculated with receiver operative characteristics (ROC) curve analysis. Statistical comparison of the ROC curves was performed using the software program ROCkit 0.9, which incorporates a method developed by Metz *et al* (13) to compare correlated ROC curves (16). Intra- and interobserver reliability were estimated by calculation of the intraclass correlation (ICC) based on the two-way random model of either absolute agreement or consistency. In this analysis both the observers as well as the

Table II. — Demographic data and percentage of total score for patients with complex regional pain syndrome type 1 (CRPS1)

subject no.	Age (years/sex)	Disease duration (Months)[a]	VAS (0-10)[b]	MPQ (0-10)[c]	AROM (0-10)[d]	Vol.Diff (0-10)[e]	Temp. Diff. (0-10)[f]	Total ISS (%)[g]	Score (average/sd)[h]	Score rep. (average/sd)[i]
1	35/f	3	7	4	9	2	1	46	5.7(2.3)	6.5(1.6)
2	24/f	6	3	6	2	3	10	48	8.1(1.8)	8.0(1.8)
3	40/f	12	8	7	9	3	4	62	1.7(1.7)	2.2(2.0)
4	42/f	4	5	9	6	10	3	66	5.4(2.5)	5.1(2.5)
5	48/f	5	6	9	9	5	1	60	4.8(2.6)	5.1(2.7)
6	35/f	3	7	8	10	1	2	56	0.7(1.4)	1.8(2.5)
7	72/f	2	4	7	8	8	10	74	7.3(1.9)	7.3(2.2)
8	50/m	13	3	6	9	3	9	60	5.2(2.7)	4.7(2.9)
9	32/f	6	6	5	6	1	1	38	2.9(2.6)	2.4(2.0)
10	56/f	3	2	7	9	3	4	50	4.5(1.5)	5.4(1.7)
11	26/f	12	8	7	1	4	7	54	2.2(2.6)	2.6(2.0)
12	51/f	6	5	3	3	4	3	36	6.9(1.9)	6.3(2.0)
13	44/f	3	2	3	9	7	7	56	7.1(1.8)	7.1(2.1)
Mean	42.7	6	5.1	6.2	6.9	4.2	4.8	54.3	4.8	4.9
SD	13.1	3.9	2.1	2	3.1	2.7	3.4	10.7	2.3	2.1
Mean Controls	28	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1.5	1.4
SD Controls	12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1.1	1.1

VAS : Visual analogue pain score ; *MPQ :* McGill Pain Questionnaire ; *AROM* active range of motion ; *Vol. diff. :* volume difference between the uninvolved hand and the involved hand ; *Temp. diff. :* Temperature difference between average temperature measured with tympanometer in the uninvolved and the involved hand ; *ISS :* impairment level sum score based on Oerlemans *et al* (*14*).

[a]Duration in months from CRPS1 on the day of measurement.

[b]Pain score with 0 representing no pain and 10 representing the maximum pain, rated on the day of measurement.

[c]McGill Pain Questionnaire, the number of words chosen from the list (maximum 20) are categorised as following : 0-2 words chosen equals 1, each subsequent ascending block is given a higher score.

[d]Active Range Of Motion, a score of 1 represents no limitation in motion, a score of 10 represents a maximum limitation in movement.

[e]Difference in volume between the uninvolved hand and the involved hand, minimum difference gives a score of 1, a maximum difference a score of 10.

[f]Difference in average temperature measured with a tympanometer between the uninvolved hand and the involved hand, minimum difference gives a score of 1, a maximum difference a score of 10.

[g]Percentage of total score is calculated by dividing the total of VAS, MPQ, AROM, Volume and Temp difference by the maximum score of 50.

[h,i] Average score on the images scored by 35 observers (and the standard deviation), maximum of 10 indicating the most difference.

images were considered as a random sample. A possible relationship between colour red and the obtained score was analysed with a MANOVA for repeated measurements analysis using the scores as a within-subjects effect, the images as between-subject factor, and the percentage of the colour red as a covariate. The following definition was used to describe the colour red, in the RGB colour channels the value of the red channel varied between 30 and 255 and the green and blue channels were both set to zero. The percentage of the total amount of red present in the picture was calculated. A potential effect of rank number of the images on the rating was analysed with a MANOVA for repeated measurements, using the above-mentioned model. A level of $p < 0.05$ was considered to be statistically significant.

RESULTS

Thirteen patients were included in the study, 11 women and 2 men (mean age : 44 years, SD 13.1, range : 33 to 58) ; table II presents demographic data of these patients. Thirteen healthy volunteers,

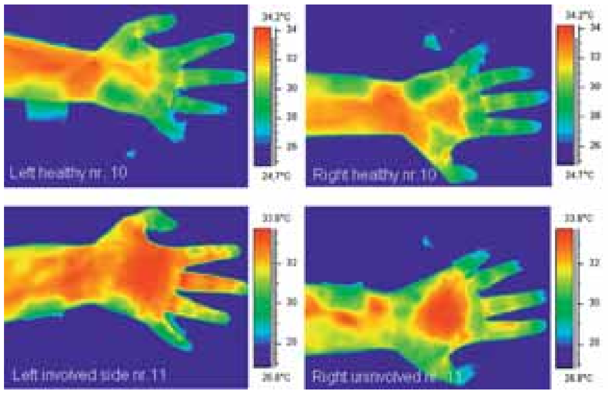

Fig. 1. — Examples of thermographic images of a healthy individual and a CRPS1 patient. Top left : thermographic image of palmar left extremity of a healthy individual (nr. 10) ; top right : thermographic image of palmar right extremity of the same healthy individual (nr. 10). Bottom left : thermographic image of palmar left extremity of a CRPS1 patient (nr. 11) ; bottom right : thermographic image of palmar right extremity of the same CRPS1 patient (nr. 11).

10 women and 3 men (mean age 28 years, range : 22 to 44) comprised the control group. The independent raters were residents in anaesthesia who were not experienced in the assessment of thermographic images. Figure 1 presents a typical recording of a healthy subject and a CRPS1 patient. The ISS of the patient presented in fig 1 (nr. 11) is 54% (see table II). The average difference score of the raters of these thermographic images of the patient were the first time 4.8 (SD 2.3) and the second time 4.9 (SD 2.1). The average difference score of the raters of these thermographic images of the patient were the first time 1.5 (SD 1.1) and the second time 1.4 (SD 1.1). No significant correlation was found between the ISS and the average ratings of the images. The first ratings had a sensitivity of 71% and a specificity of 85%, resulting in an overall correct classification of 81% ; the second score yielded a sensitivity of 74% and a specificity of 84%, with an overall correct classification of 79%. The sensitivity and specificity for different cut-points are presented in table III. Comparison of the ROC curves of the first and second score (fig 2) showed no significant differences in the area under the curve (AUC of 0.86 and 0.87 respectively).

Table III. — Sensitivity and specificity for different cut-off points at first and second rating

Cut-off points	Sensitivity first rating	Sensitivity second rating	Specificity first rating	Specificity second rating
> = 0	100	100	0	0
> 0	84.5	86.4	62.4	58
> 1	76.7	82.4	74.4	73.3
> 2 *	70.5	74.3	84.5	83.9
> 3	64.5	65.7	86.9	89
> 4	52.4	56	88.6	90.6
> 5	42.4	44.8	91.2	92.7
> 6	32.9	33.6	93.7	94.1
> 7	20	19.8	97.1	96.3
> 8	11.9	9.8	98.1	99
> 9	4.5	4.8	99.4	99.2

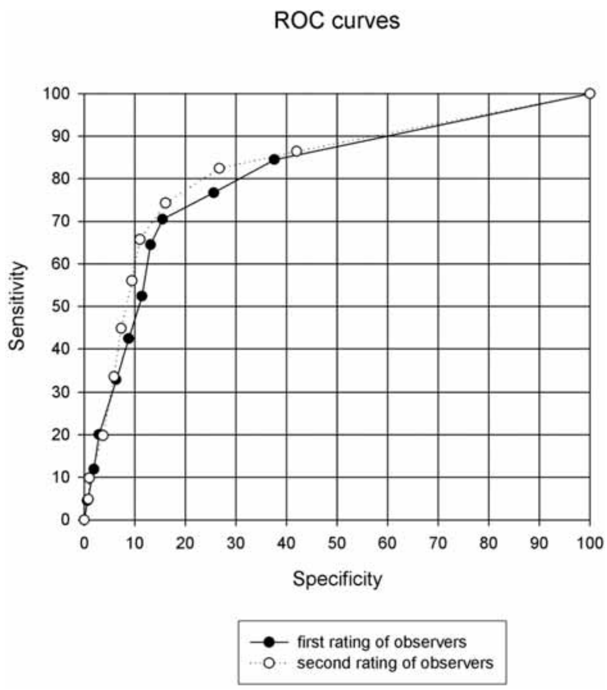

Fig. 2. — Sensitivity and specificity of the first rating and the second ratings of the observers. The first rating had an AUC of 0.86 with a cut-off point > 2, a sensitivity of 72% and a specificity of 90%. The second rating had an AUC of 0.87, a cut-off point > 2 and a sensitivity of 76% and specificity of 90%.

The inter-observer repeatability of the ratings of the images of the CRPS patients was 0.53 ($p < 0.001$), that of the healthy controls was 0.12 ($p < 0.001$), and that of the CRPS patients and healthy controls combined was 0.49 ($p < 0.001$).

Table IV. — Data on the reliability and repeatability of the scoring of the observers

	CRPS images	Control images	CRPS and Control images combined
Repeatability	0.5**	0.1**	0.5**
Reliability	0.5**	0.1**	0.7**

** significant at $p < 0.001$ level.

The intra-observer reliability of the ratings of the patients' images was 0.50 ($p < 0.001$), that of the healthy controls was 0.12 ($p < 0.001$), and that of the patients and the healthy controls combined was 0.68 ($p < 0.001$) (table IV).

The red colour was significantly associated with the rating ($r = 0.86$; $p < 0.001$), although the red colour on average only comprised 37% of the total colour pallet. The presentation rank number of the images was not significantly related to their ratings.

DISCUSSION

In this study, the Bruehl criteria for CRPS were used as a gold standard. A lack of consensus before 1994 regarding standardised diagnostic criteria resulted in serious problems in comparing patient samples across studies addressing the diagnosis and treatment of the disorder. The publication of the standardised criteria for CRPS type 1 and type 2 by the IASP was a step forward. However, in a validation study Bruehl *et al* (*4*) showed that the sensitivity of the Bruehl criteria was high (0.98) but specificity was poor (0.36). For clinical purposes sensitivity is extremely important, whereas for research the specificity is important. Especially for research, Bruehl *et al* (*4*) proposed modified research diagnostic criteria, which resulted in a lower sensitivity (0.70) but higher specificity (0.94).

The use of videothermography as a diagnostic tool in diseases other than CRPS1 has been studied extensively. Sherman *et al* (*15*) studied the usefulness of videothermography as a predictor of repetitive stress-induced lower limb pain disorders among American army soldiers. It was not possible from any thermographic measurement to predict those soldiers most likely to develop lower limb pain. However, the findings of the above mentioned studies are not consistent with regard to sensitivity, specificity and reliability, probably because different methods were used to analyse the thermographic data.

The present study shows that the sensitivity and specificity of the ratings of thermographic images of CRPS using independent observers, is reasonably high.

There was no significant difference between the ROC curves of the initial and repeated ratings, and no significant relation between the rank number and the obtained ratings.

The intra-observer reliability of the actual difference scores in the combined healthy and CRPS images, as well as in the separate assessments of the ICC in healthy and CRPS images was moderate, particularly when considering the short time interval between the two ratings. A similar level of reliability was found between the observers.

It is generally assumed that the choice of colour used in the images (representing the range of temperature of the presented extremities) can influence the rating ; particularly the colour red can be associated with abnormality. The present study confirmed this hypothesis. In a previous study we described a calculation method to differentiate between videothermographic images of patients with CRPS1 and healthy controls (*9*). We found a sensitivity of 92% and a specificity of 94% with an AUC of 0.97 ; the repeatability was 0.87 and the reliability 0.96. In that study the colour pallet could not influence the ratings because only the underlying temperature values were used for the calculation.

The ability of the observer to validly assess hot and cold spots on thermographic images without the need for a comparison picture is of advantage when two extremities are involved. Table II shows that there is no relation between the ratings and the ISS scores of the patients. Furthermore, compared with the calculation method employed by our group in an earlier study (*9*), the reliability and repeatability of the scores of the raters are low. It is expected that further training, the development of a standard colour pallet and a better scale to rate the thermographic images, can address these problems (*12*). Although there is no indication to use raters in the assessment of thermographic images in diagnosing CRPS1, in other types of diseases these images may produce more valid results. The results of the present study show that the observers may be able to discriminate between CRPS patients and healthy subjects, using thermographic pictures of extremities. While the slightly larger AUC of the repeated score may reflect a possible learning effect, this remains unproven.

In conclusion, the differences between thermographic images as assessed by observers did distinguish between CRPS1 patients and healthy subjects with a reasonable high sensitivity and specificity, however, the reliability and repeatability of this assessment was rather low. It is reasonable to assume that further improvement in assessment on thermographic images using observers can be achieved, for example by standardizing and optimizing the colour pallet. However, there is some doubt if a high enough degree of accuracy can be reached using observers. Therefore, further studying of the effect of training and the choice of colour pallet is necessary. As a start, to obtain repeatable and consistent ratings, we suggest that the colour pallet should be standardised and the raters should be trained.

Acknowledgments

In the pilot phase the expertise of Dr. R. van Hulst, MD, PhD (Diving Medical Center, Den Helder) and the initial thermographic images taken by Ronald Braaf and Ed Vos (Den Helder) were of great importance. The authors thank the Diving Medical Center and Laraine Visser-Isles for correcting the paper. This study was performed within TREND (Trauma Related Neuronal Dysfunction), a knowledge consortium that integrates research on Complex Regional Pain Syndrome type 1. The project is supported by a Dutch Government grant (BSIK03016).

REFERENCES

1. **Baron R, Janig W.** Complex regional pain syndromes : how do we escape the diagnostic trap ? *Lancet* 2004 ; 364 : 1739-1741.
2. **Birklein F, Riedl B, Neundorfer B *et al.*** Sympathetic vasoconstrictor reflex pattern in patients with complex regional pain syndrome. *Pain* 1998 ; 75 : 93-100.
3. **Bruehl S, Harden RN, Galer BS *et al.*** Complex regional pain syndrome : are there distinct subtypes and sequential stages of the syndrome ? *Pain* 2002 ; 95 : 119-124.
4. **Bruehl S, Harden RN, Galer BS *et al.*** External validation of IASP diagnostic criteria for Complex Regional Pain Syndrome and proposed research diagnostic criteria. International Association for the Study of Pain. *Pain* 1999 ; 81 : 147-154.
5. **Bruehl S, Lubenow TR, Nath H *et al.*** Validation of thermography in the diagnosis of reflex sympathetic dystrophy. *Clin J Pain* 1996 ; 12 : 316-325.
6. **Gulevich SJ, Conwell TD, Lane J *et al.*** Stress infrared telethermography is useful in the diagnosis of complex regional pain syndrome, type I (formerly reflex sympathetic dystrophy). *Clin J Pain* 1997 ; 13 : 50-59.
7. **Herry CL, Frize M.** Quantitative assessment of pain-related thermal dysfunction through clinical digital infrared thermal imaging. *Biomed Eng Online* 2004 ; 3 : 19.
8. **Hill RA, Barton RA.** Psychology : Red enhances human performance in contests. *Nature* 2005 ; 435 : 293.
9. **Huygen FJ, Niehof S, Klein J *et al.*** Computer-assisted skin videothermography is a highly sensitive quality tool in the diagnosis and monitoring of complex regional pain syndrome type I. *Eur J Appl Physiol* 2004 ; 91 : 516-524.
10. **Janig W, Baron R.** Complex regional pain syndrome is a disease of the central nervous system. *Clin Auton Res* 2002 ; 12 : 150-164.
11. **Kent P, Wilkinson D, Parkin A *et al.*** Comparing subjective and objective assessments of the severity of vibration induced white finger. *J Biomed Eng* 1991 ; 13 : 260-262.
12. **London RS, Murphy L, Reynolds M *et al.*** Reliability of contact-thermogram reading services. *J Reprod Med* 1984 ; 29 : 686-688.
13. **Metz CE, Herman BA, Roe CA.** Statistical comparison of two ROC-curve estimates obtained from partially-paired datasets. *Med Decis Making* 1998 ; 18 : 110-121.
14. **Oerlemans HM, Goris RJ, Oostendorp RA.** Impairment level sumscore in reflex sympathetic dystrophy of one upper extremity. *Arch Phys Med Rehabil* 1998 ; 79 : 979-990.
15. **Sherman RA, Karstetter KW, Damiano M *et al.*** Stability of temperature asymmetries in reflex sympathetic dystrophy over time and changes in pain. *Clin J Pain* 1994 ; 10 : 71-77.
16. **Stephan C, Wesseling S, Schink T *et al.*** Comparison of eight computer programs for receiver-operating characteristic analysis. *Clin Chem* 2003 ; 49 : 433-439.
17. **Wasner G, Schattschneider J Baron R.** Skin temperature side differences : a diagnostic tool for CRPS ? *Pain* 2002 ; 98 : 19-26.