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Use of Digital Infrared Thermography on Experimental Spinal Cord Compression in Dogs

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Abstract : This study was performed to examine the absolute skin temperature and temperature difference (ΔT) between the left and the right, the upper and the lower parts on the back of dog and to investigate the clinical usefulness of infrared thermography as diagnostic or prognostic aid on experimental spinal cord compression by using Digital Infrared Imaging System. In normal dogs, symmetrical and contouring patterns were observed in thermogram. The skin temperature difference was not significant between the left and the right, the upper and the lower parts on the back. In spinal cord compressed dog, there was symmetrical temperature reduction pattern around lesion. Patterns of ΔT between thoracic and lumbar portions were remarkable and showed the tendency to return to normal after 4 weeks of operation. It is considered that infrared thermography is a useful diagnostic and prognostic aid for spinal cord injury in dogs.

Key words **:** Infrared thermography, spinal cord injury, skin temperature difference, dog.

Introduction

Assessment of spinal cord injury has largely been dominated by the clinical neurological examination in combination with the imaging study. Spinal cord imaging modalities include radiographs, myelography, scintigraphy, computed tomography (CT) and magnetic resonance imaging (MRI). All of them provide anatomic information about the spinal cord and surrounding structures, not the physiologic and functional abnormalities. Therefore, new techniques such as infrared thermography and evoked potentials have been introduced to confirm the physiologic and functional abnormalities[9,14]. Infrared thermography is the pictorial representation of the surface temperature in an object. A medical thermogram represents the heat emitted from the skin surface of a patient. Variations in skin temperature result from changes in tissue perfusion and blood flow in superficial veins. The circulatory pattern and relative blood flow dictate the thermal pattern which is the basis for thermographic interpretation. Infrared thermography has several advantages including non-invasive, painless, safe (because it does not use radiation) and improving understandability to owner of the patient by showing the colored images[13,18]. However, thermography has been criticized for its possible lack of objectivity, arising from interpretation of the colored thermogram. To minimize its subjectivity, it is proposed to use computer-calculated temperature difference (ΔT) between homo-logous sections of the body[24].

In the human medicine, infrared thermography has been used for the diagnosis or prognosis of many problems such as the lumbar disc herniations, the peripheral neuropathy, the cardiovascular disease and the musculo-skeletal diseases[16]. Nowadays, infrared thermography has been widely used to quarantine infectious diseases[10]. In horses, infrared thermography has been applied for the examination of lameness, back pain, intervertebral disk problem, muscle tears, strain, tendonitis, fractures, neuritis and peritonitis[23,27]. In dogs, infrared thermography has been experimentally introduced to detect the cardiac ischemia, coronary artery attenuation and intestinal infarction[1-3]. Nevertheless, thermography on the canine spinal cord injury has not been reported yet.

This study was performed to examine the absolute normal skin temperature and ΔT between the left and right, the upper and the lower parts on the back in dogs and to investigate the usefulness of infrared thermography on spinal cord compression by using Digital Infrared Imaging System.

Materials and Methods

Experimental animals

Healthy 33 beagle dogs (10-16 kg and 2-5 years) were used regardless of sex. To take thermograph, the dorsal aspect of the trunk was clipped. This study adhered to the strict guideline of the "Guide for care and use of laboratory animals" of Seoul National University. Thirty three dogs were used to investigate the infrared thermography of normal dogs. To assess the infrared thermography of spinal cord compression study, we used the 7 healthy dogs.

Used apparatus

This study was carried out using Digital Infrared Imaging System (IRIS-5000, Medicore Co., Ltd., Korea). It is possible to calculate the average temperature of specified regions of the body that are identified for the computer. These specific regions are referred to as regions of interest (ROI) and temperature difference are calculated by subtracting right side value from left side value. The estimation distance was about 80 cm from scan device to the back of dog.

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Induction of spinal cord compression

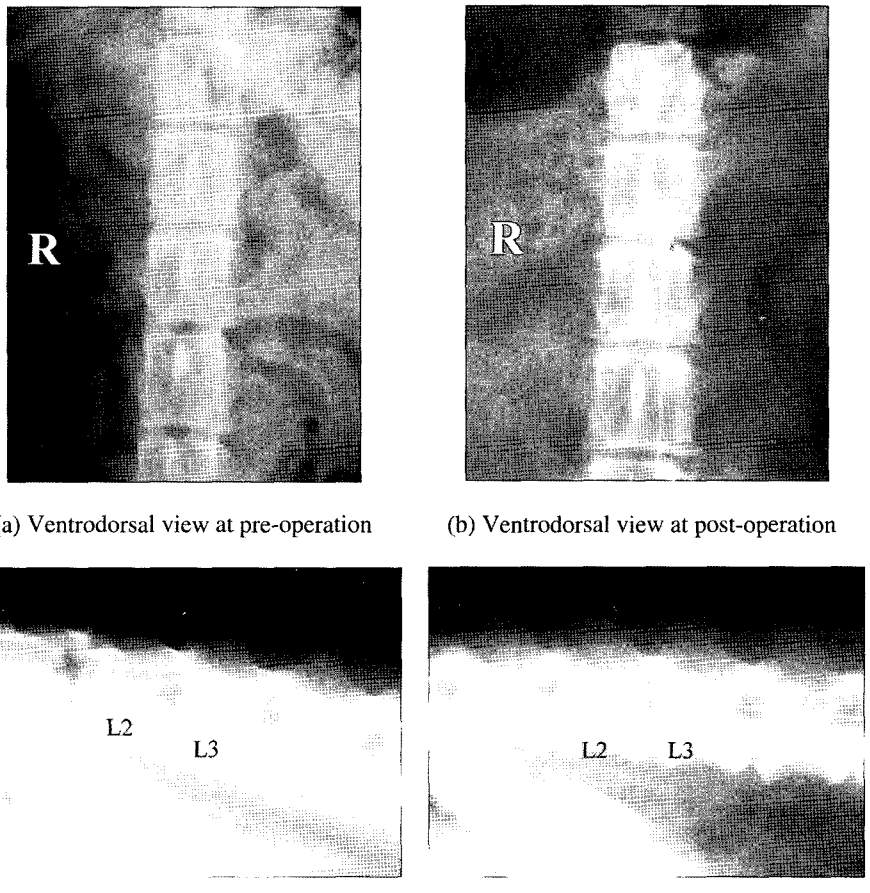
Before surgery, plain radiograph was taken to know the size of spinal canal. According to the radiograph, the degree of compression was determined. Acepromazine hydrochloride (0.1 mg/kg; Sedaject®, Samu median co., LTD, Seoul, Korea) and ketamine hydrochloride (10 mg/kg; Keiran®, Korea Unite co., LTD, Seoul, Korea) were injected intramuscularly for anesthesia. Dogs were placed on sternal recumbency. Midline skin incision was made between the seventh lumbar vertebra and the first sacral vertebra. The 6F balloon Foley catheter (Sewoon Medical Co., Ltd., Korea) was inserted from L_7-S_1 to L_2-L_3 through the epidural space. After placement of catheter, the skin incision was closed. Contrast media was infused to assess the position of balloon of catheter at L_2-L_5 intervertebral disk point by fluoroscopy. Spinal cord compression was induced by inflating the balloon with contrast media about 30% of spinal canal. Forty-eight hours after spinal compression, the balloon catheter was removed. Infrared thermography was conducted weekly for 4 weeks (Fig 1).

Neurological examination

On neurological examination, responses of superficial and deep pain perception were normal until 4 weeks after spinal cord compression. Just after spinal cord compression, there was severe back pain, decrease or absence of conscious proprioception on both hindlimbs, and mild urinary dysfunction of all dogs. After removing the balloon catheter, these neurological symptoms were gradually improved. Normal activity was observed after 2~3 weeks of operation.

Assessment of the thermogram on the back

All procedures were performed in a closed environment with constant room temperature (22-24°C), humidity (45-60%) and air-flow restriction. Experimental dogs were allowed enough time (>20 min) to adopt imaging atmosphere in accordance with recognized thermographic guidelines. Sixteen-color spectrum was used orderly from high to low temperature and the pattern was selected in this study (Fig 2). The areas under investigation were subdivided into six different regions (Lt.T=left thoracic portion (T3-T10); Rt.T=right thoracic portion (T3-T10); Lt.L=left lumbar portion (T11-L5); Rt.L= right lumbar portion (T11-L5); Lt.P=left pelvic portion (L6-S3); Rt.P=right pelvic portion (L6-S3)) for more precise description of the regional differences in the thermogram of



(a) Ventrodorsal view at pre-operation (b) Ventrodorsal view at post-operation

(c) Lateral view at pre-operation (d) Lateral view at post-operation

Fig 1. Ventrodorsal views of lumbar 2 and lumbar 3 spine. Spinal cord compression was induced by inflating the balloon with contrast media about 30% of spinal canal.

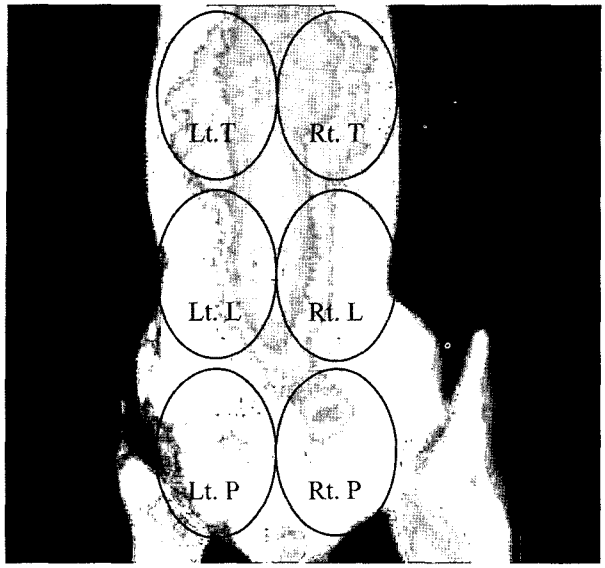


Fig 2. Subdivision of the back thermogram into six different regions according to anatomical features in normal dog. blue for colder areas and red for warmer areas.

Table 1. Normal absolute skin temperature and temperature difference (ΔT) in dogs (n=33)

Region	Skin temperature (°C)		
	Left	Right	ΔT
Thoracic	28.66 ± 0.73^{a}	28.65 ± 0.71^{a}	0.14 ± 0.11
Lumbar	28.48 ± 0.74^{a}	28.47 ± 0.73^{a}	0.14 ± 0.11
Pelvic	28.09 ± 0.81^{b}	28.09 ± 0.80^{b}	0.16 ± 0.13

[a-b)]Different superscripts were significantly different ($P<0.05$).

Table 2. Skin temperature difference in the unilateral side of the body of dog (n=33).

Region	Skin temperature difference (ΔT)	
	Left	Right
Thoracic-Lumbar*	0.17 ± 0.25	0.18 ± 0.29
Lumbar-Pelvic**	0.39 ± 0.25	0.38 ± 0.28
Thoracic-Pelvic***	0.57 ± 0.32	0.55 ± 0.38

* Temperature difference from thoracic to lumbar portion
** Temperature difference from lumbar to pelvic portion
*** Temperature difference from thoracic to pelvic portion

the back. Each portion represented a ROI identified on the computer for analysis. Upper portion means the higher position than the based portion. Lower portion mean the lower position than the based portion.

Statistical analysis

Parametric analysis of the means between two or among more population was analyzed by a one-way ANOVA followed by multiple pair-wise comparisons using the Duncans test; $p<0.05$ was considered significant.

Results

Normal thermogram on the back

Symmetrical and contouring pattern was observed (Fig 2). The color of thoracic portion was redder in contrast to that of pelvic portion. This consistency was observed in different dogs and different measurements in the same dog. The normal absolute skin temperature on the back is listed in Table 1. Generally, the skin temperature decreased from thoracic to pelvic portion. The temperature of pelvic portion was significantly ($P<0.05$) lower than those of thoracic and lumbar portion. However, there was no significant difference in temperature of left to right on the back. The ÄT from one side of the body to the other was extremely low and very stable (Table 1).

Temperature difference between upper and lower parts on the back of dog

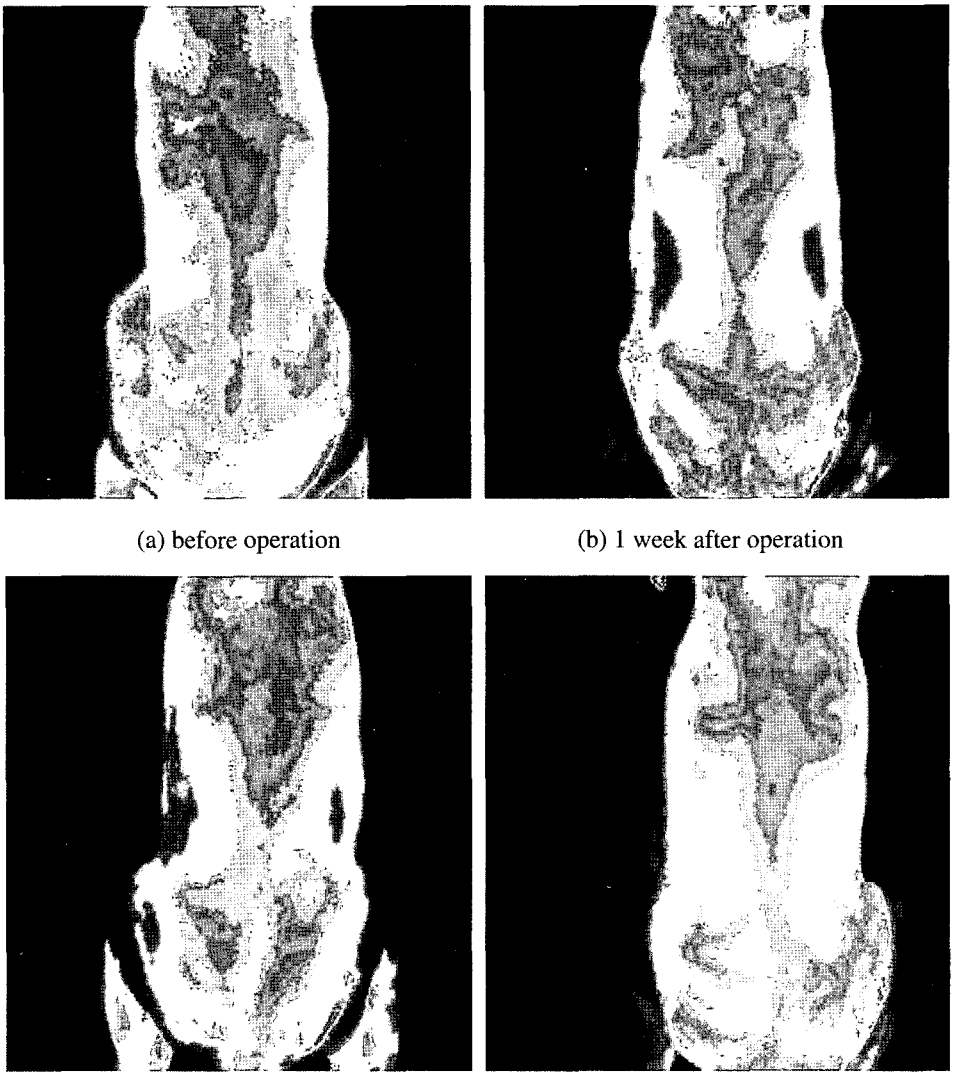
No significant difference was observed between the temperatures of the upper and the lower parts on the back (Table 2). The similar parameters were displayed regardless of both sides of the body. There was absolutely unchanged ΔT in thoracic-lumbar segment.

Temperature difference change on spinal cord compressed dog

Symmetrical and contouring pattern was still observed through experimental period (Fig. 3). The color spectrum around spinal cord injury region was changed from red to blue at the 1st week. There were abrupt temperature change and cold spot on the back. Infrared thermogram around L_2-L_3 region showed the tendency to return to normal after 4 weeks. Patterns of skin temperature after spinal cord injury are listed in Table 3. ΔT between the left and the right sides was low and very stable before and after spinal cord injury. There was no significant difference in skin temperatures between the left and the right sides (Table 4). Patterns of ΔT between thoracic and lumbar portion were remarkable and significant ($P<0.05$) until 3rd week (Table 5). After 1 week of spinal cord compression, the differences in skin temperature difference between upper and lower parts was highest (1.26±0.56) but gradually decreased. After 4 weeks of operation, the differences in skin temperature difference almost returned to normal regardless of both sides.

Discussion

Infrared thermography represents the skin temperature like a contour map and measures the emitted infrared-ray from the body non-invasively[19,22]. Hot spot indicates that there is inflammation and increased circulation of blood. On the contrary, when the cold spot is shown, there is edema, thrombus, scar or decreased circulation of blood[7]. In this study, cold spot



(a) before operation (b) 1 week after operation

(c) 2 weeks after operation (d) 4 weeks after operation

Fig 3. Patterns of thermogram (a) thermogram before surgery, (b) thermogram 1 week after operation, (c) thermogram 2 weeks after operation and (d) thermogram 4 weeks after operation

Table 3. Change of skin temperature after spinal cord compression by balloon catheter in dogs

		Skin temperature (°C)					
		Thoracic		Lumbar		Pelvic	
		Left	Right	Left	Right	Left	Right
Pre-op		28.85 ± 1.73	28.81 ± 1.73	28.61 ± 1.76	28.59 ± 1.77	28.22 ± 1.76	28.18 ± 1.76
Post- op (Week)	1	26.73 ± 2.25	26.79 ± 2.27	25.48 ± 2.61	25.49 ± 2.56	25.84 ± 2.00	25.83 ± 1.98
	2	26.32 ± 1.77	26.36 ± 1.69	25.39 ± 1.80	25.39 ± 1.81	25.72 ± 1.90	25.70 ± 1.88
	3	26.31 ± 1.16	26.31 ± 1.20	25.63 ± 1.24	25.56 ± 1.26	25.36 ± 1.02	25.37 ± 1.04
	4	27.30 ± 1.90	27.32 ± 1.91	26.84 ± 1.89	26.87 ± 1.87	26.52 ± 1.77	26.56 ± 1.76

Data were expressed as mean ± SD (n=7)

was found around the spinal cord injury region remarkably and hot spot was shown at skin incision site. In veterinary medicine, infrared thermography has been applied for neural, cardiovascular and musculoskeletal diseases[23,26]. Experiments on the spinal cord injury model had been carried out in monkey, rat, dog, and cat[4,6,12,21]. The interpretation of infrared images has been usually done by comparing physiologic and functional symmetry of the body. Literatures revealed that

Table 4. Change of skin temperature difference between left and right sides after spinal cord compression in dogs

		Skin temperature difference (ΔT)		
		Thoracic	Lumbar	Pelvic
Pre-op		0.09 ± 0.04	0.05 ± 0.03	0.05 ± 0.03
Post-op (Week)	1	0.12 ± 0.05	0.10 ± 0.07	0.03 ± 0.03
	2	0.07 ± 0.09	0.09 ± 0.04	0.13 ± 0.08
	3	0.10 ± 0.07	0.09 ± 0.06	0.05 ± 0.03
	4	0.07 ± 0.04	0.05 ± 0.02	0.05 ± 0.06

Data were expressed as mean ± SD (n=7).

temperature difference of anatomically symmetrical sides was in exceeding 0.3, in the presence of unilateral spinal cord involvement[5,25]. Most researchers used temperature difference ranges of 0.30.5 as diagnostic standpoint[15,25]. In bilateral lesions, as the skin temperature changes are bilaterally symmetrical, the interpretation of thermogram is difficult[17]. In the present study, there was constant symmetrical pattern like contour map in normal dogs. The outer contours of the back were readily detected and the color was changed from red to blue according to the skin temperature. Moreover, the thoracic portion had more red color but the pelvic portion had more blue color. ÄT between the left and the right sides was extremely low and very stable, even though there were estimation errors. In the present study, normal ΔT between the left and the right sides on the back of dog was within the limits of human. Also, the skin temperature difference between the upper and the lower portions was still low in normal dogs.

Various techniques, weight dropping, aneurysm clip compression and epidural balloon compression method were applied to induce the experimental spinal cord injuries in dogs[12]. Among them, epidural balloon compression method was known to create reproducible graded compression of the spinal cord. The epidural balloon compression method was used in this study and the degree of spinal cord injury was induced at the level of ambulatory paraparesis. Symmetrical pattern like normal thermogram was observed continuously through the entire experimental period. The color around the spinal cord injury region changed completely from red to blue at the 1st week. There were abrupt temperature changes and cold spots on the back. In the time progress, the color around L_2-L_3 region showed a tendency to return to normal. Many researchers reported that the typical thermographic findings included the decrease of skin temperature under spinal cord injury, disruption of central heat continuity, cold spot / belt on spinal cord level and hyperthermia in distal part of extremities[14,17,20]. They also pointed out that infrared thermography might be the first choice for useful estimation and identification of the location and extent of a spinal cord lesion. In the present experiment, the location of spinal cord injury region was not found exactly.

It is well known that the worsening of neurological findings after spinal cord injury is due to the secondary progression of pathological changes, which may be caused by spinal cord blood flow disturbance[8,11]. Focal decreases in spinal cord blood flow in white and gray matter are founded at the considerable distances of proximal and distal to the injury site. It is concluded that acute compression injury of the spinal cord is associated with long-lasting ischemia in the cord that increases the degree of injury. Before and after spinal cord injury, ÄT between the left and the right sides was extremely low and very stable throughout the body in this investigation. There was no significant skin temperature difference between the left and the right sides. It was coincide with ΔT of normal group. However, patterns of ÄT between thoracic and lumbar portion were remarkable and significant ($P<0.05$) except that of the 4th week. After the 1st week of spinal cord compression, skin temperature difference between the upper and the lower parts was the highest (1.26±0.56) but gradually decreased as time goes by. After 4 weeks, skin temperature difference returned to almost normal in both side. Kawata[11] reported that the worsening of neurological signs after spinal cord injury was coincided with spinal cord blood flow disturbance. Also, Hebert[7] documented that as spinal cord improved, there was increased circulation of blood. As the data was calculated using computer, it is possible to minimize the subjectivity of interpretation.

Conclusion

The present study suggests that infrared thermography is a useful diagnostic and prognostic aid for spinal cord injury in

Table 5. Change of skin temperature difference between upper and lower parts after spinal cord compression in dogs

		Skin temperature difference (ΔT)					
		Thoracic-Lumbar		Lumbar-Pelvic		Thoracic-Pelvic	
		Left	Right	Left	Right	Left	Right
Pre-op		0.24 ± 0.07[a]	0.22 ± 0.10[a]	0.39 ± 0.22	0.42 ± 0.23	0.63 ± 0.18	0.63 ± 0.23
Post-op (Week)	1	1.26 ± 0.56[b]	1.30 ± 0.53[b]	0.36 ± 0.67	0.34 ± 0.62	0.89 ± 0.62	0.96 ± 0.60
	2	0.93 ± 0.40[bc]	0.97 ± 0.37[bc]	0.33 ± 1.28	0.31 ± 1.28	0.60 ± 1.04	0.66 ± 1.07
	3	0.68 ± 0.26[cd]	0.75 ± 0.25[cd]	0.27 ± 0.70	0.18 ± 0.70	0.95 ± 0.60	0.94 ± 0.67
	4	0.46 ± 0.14[ad]	0.45 ± 0.21[ad]	0.33 ± 0.28	0.31 ± 0.24	0.79 ± 0.33	0.76 ± 0.30

Data were expressed as mean ± SD (n=7).
[a-d]Different superscripts were significantly different ($P<0.05$).

dogs. Normal skin ΔT between the left and the right, the upper and the lower parts is very useful to find out the abnormal region. In bilateral lesions, comparison of upper to lower parts is a more acceptable method after injury. Further studies should be undertaken to know the clinical efficacy of infrared thermography on spinal cord injury in dogs.

Acknowledgement

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개에서 실험적으로 유발한 척수압박에 대한 적외선 체열촬영술의 적용

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요 약 : 적외선 체열촬영술은 생리적, 기능적 이상유무를 평가하기 위해 수의와 인의에서 최근 사용되고 있다. 이 연구에서는 디지털 적외선 이미지 시스템을 사용하여 개의 등에서 피부의 절대온도와 상하 그리고 좌우 온도차를 알아보고, 실험적으로 유발한 척수 손상 시 적외선 체열촬영술의 임상적 유용성을 조사하기 위하여 실시되었다. 33마리의 건강한 비글견에서 등쪽 부분을 삭모한 후 정상체열상을 촬영하였으며, 7마리의 건강한 암컷에서 경막외 풍선카테터를 이용하여 척수손상을 유발하였다. 정상군은 체열영상에서 등고선과 같은 일정하면서도 대칭적인 양상을 보였으며, 상하, 좌우에 관계없이 유의적인 피부 온도차가 관찰되지 않았다. 이와는 달리, 척수 손상군의 경우 척수손상부위 주위로 대칭적인 온도 감소가 있었다. 좌우의 온도차는 거의 없었으며 매우 안정적인 경향을 보였다. 특이한 점은 상하의 온도차 중에서 흉추부와 요추부 사이의 온도차가 현저하게 나타났으며, 수술 후 4주가 경과 했을 때 거의 정상으로 회복되는 경향이 있었다. 이상의 결과로 보아 적외선 체열촬영술은 개의 척수 손상 시 진단 및 예후 평가를 위한 유용한 진단기법이며, 비정상 부위를 찾아내는 데 상하좌우의 정상 피부 온도차가 매우 유용할 것으로 사료된다. 또한 병변이 양측성인 경우, 좌우의 비교보다는 인접한 부위의 상하 온도차를 비교하는 것이 더 적절한 방법일 것으로 사료된다.

주요어 : 적외선체열촬영술, 척수손상, 경막외풍선카테터, 피부온도차, 개