

# 가토에서 심박수 변이율에 대한 전정기관의 자극 효과

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## Alterations of Heart Rate Variability by Vestibular Stimulation in Rabbits

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### ABSTRACT

**Background :** There is a substantial evidence that anatomical connections and functional interactions exist between vestibular and autonomic systems. The nature of these interactions, however, is complex and has not been fully defined. Heart rate variability (HRV) was used to investigate the physiological role of the vestibular system on control of heart rate. **Methods :** HRV including mean, standard deviation, coefficient of variation (CV), power spectrum was analyzed from R-R intervals of ECG during vestibular stimulation in rabbits. **Results :** Urethane anesthesia increased heart rate and maintained regular R-R intervals, however, low frequency region/high frequency region (LF/HF) was not changed. In anesthetized rabbits, electrical stimulation of the vagus nerve decreased heart rate and decreased LF/HF by increasing HF. On the contrary, electrical stimulation of the cervical sympathetic nerve increased heart rate and increased LF/HF by increasing LF. Atropine, cholinergic blocker, increased heart rate and increased LF/HF by reducing HF, and propranolol,  $\beta$ -adrenergic blocker, decreased heart rate and decreased LF/HF by reducing LF. In unanesthetized rabbits, stimulation of the vestibular system induced by rotation or caloric increased heart rate and increased LF/HF by increasing LF. Also electrical stimulation of the vestibular nerve produced the same effects as rotation or caloric in anesthetized rabbits. **Conclusion :** These results suggest that stimulation of the vestibular system increased heart rate not by inhibiting the parasympathetic nerve but by activating the sympathetic nerve. (**Korean Circulation J 1999; 29(7):722-730**)

**KEY WORDS :** Heart rate variability · Autonomic nervous system · Vestibular system.

### 서 론

가 , 가

1)

2)

3)

4)5)

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가 4-6)

R-R

가 21-23)

가

7-9)

가 R-R R-R

R-R 24)

10)

가 ,

11-14)

15)

16)

가

0.01 0.08 Hz

, 0.15 0.5 Hz

, 0.08 0.15 Hz

실 험 방 법

실험동물

2.0 2.5 kg 가 17

17)

가

7 가

McCraty 18)

가 가 10 가 1.0 g/kg

urethane

가

, Warren 19)

가

가

가

(Grass 7E) 1

KHz sampling rate

2가 가

가

5

20)

Money 21)

R - R .

(zero - crossing) R , 3 5 V, 1 ms, 100 Hz

, R R - R , R - 가 .

R , .

(power spectrum) . (coefficient of variation : CV) 교감신경, 부교감신경 차단제의 투여

R ,

R - R .

FFT (fast Fourier transform) propranolol 1 mg/kg

<sup>25)</sup> 0.01 0.15 Hz , atropine 2

, 0.15 0.40 Hz mg/kg .

, <sup>17)</sup> 10 20 , 가 atropine

2 propranolol pro -

pranolol 2 atropine .

(LF)

(HF) (LF/HF) .

통계처리

2

2

전정기관의 회전자극 또는 온도자극 R - R , , ,

Student t - test p

30 ° 0.05

<sup>26)</sup> , mean ± SE .

DC servo - motor , 0.01 0.64 Hz

가

실 험 성 적

<sup>27)</sup> 30 ° 마취가 심박수 변이율에 미치는 영향

0.04 Hz 60 %s R - R 가

가

4 2 ml . 가

미주신경, 경부교감신경 및 전정신경의 전기자극 R - R 0.230 ± 0.003 sec 260

Urethane /min , 0.006 ± 0.001,

0.027 ± 0.003 .

(LF) 4.96 ± 1.32 (beats/min)<sup>2</sup>/Hz,

(HF) 6.24 ± 2.39 (beats/min)<sup>2</sup>/Hz, LF/HF

0.80 ± 0.25 . kg 1 g urethane

R - R 0.205 ± 0.003

1 3 V, 1 ms, 20 Hz 가 sec

( $p < 0.01$ ), 292 /min 가

( $p < 0.01$ ) 가

( $p < 0.01$ )

( $p < 0.05$ ) LF/HF

(Table 1).

0.15 Hz

HF 1.0 (Fig. 1).

자율신경의 전기자극이 심박수 변이율에 미치는 영향

가 가

가

2

R - R 가

0.801  $\pm$  0.170 sec

( $p < 0.01$ ), 75 /min 가

(Fig. 2).

가 가 가 ( $p < 0.01$ )

가 ( $p < 0.01$ ),

가

가 LF/HF 0.32  $\pm$  0.25

( $p < 0.05$ )

가

R - R 0.195  $\pm$  0.003

sec ( $p < 0.05$ )

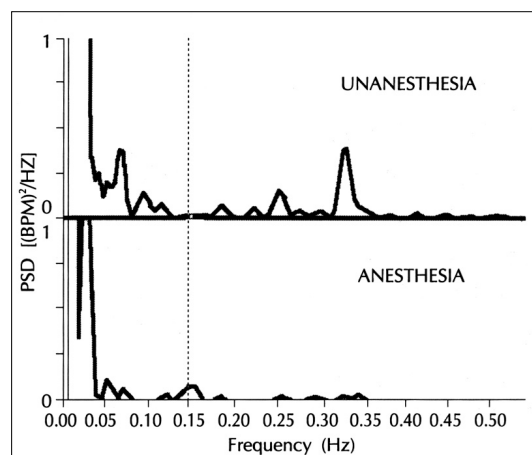
308 /min 가

가 가

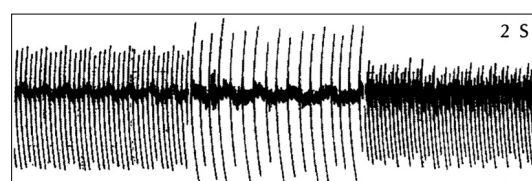
**Table 1.** Indexes of heart rate variability at unanesthetized and anesthetized rabbits

	UNANESTHETIZED	ANESTHETIZED
MEAN	0.230 $\pm$ 0.003	0.205 $\pm$ 0.003**
SD	0.006 $\pm$ 0.001	0.001 $\pm$ 0**
CV	0.027 $\pm$ 0.003	0.005 $\pm$ 0.001**
LF	4.96 $\pm$ 1.32	0.22 $\pm$ 0.04**
HF	6.24 $\pm$ 2.39	0.38 $\pm$ 0.11*
LF/HF	0.80 $\pm$ 0.25	0.62 $\pm$ 0.26

MEAN, SD and CV were obtained from R-R interval. SD, standard deviation ; CV, Coefficient of variation ; LF, Low frequency region ; HF, High frequency region. \*compared with UNANESTHETIZED (\* $p < 0.05$ , \*\* $p < 0.01$ )



**Fig. 1.** Power spectrum in unanesthetized and anesthetized rabbits. Dotted vertical line is a border between low frequency and high frequency region. LF/HF was 0.922 in unanesthetized and 0.685 in anesthetized. PSD, power spectrum density [(beats /min)<sup>2</sup>/Hz]. Real value of vertical scale should be multiplied by 10<sup>-6</sup>.



**Fig. 2.** ECG in control, vagus and sympathetic stimulation of anesthetized rabbit. A, control ; B, electrical stimulation of the right vagus nerve at 2.0 V, 1.0 ms, 20 Hz ; C, electrical stimulation of the right sympathetic nerve at 2.5 V, 1.0 ms, 20 Hz.

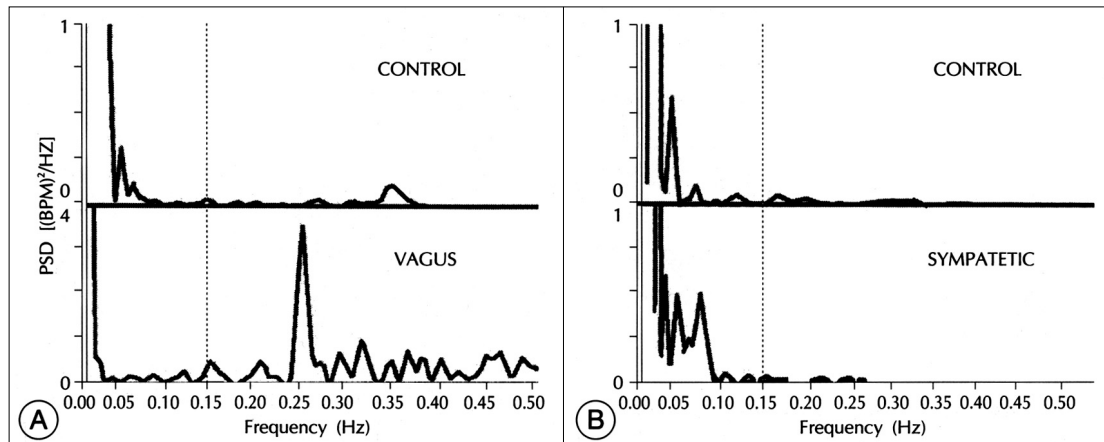
가 ( $p < 0.05$ ),

LF/HF 2.50  $\pm$

0.78 가 ( $p < 0.05$ ).

LF/HF 가

가 (Table 2 and Fig. 3).



**Fig. 3.** Changes of power spectrum by electrical stimulation of vagus (A) and sympathetic (B) nerves. LF/HF was 0.718 in control before vagus stimulation, 0.086 in stimulation of the vagus nerve at 2.0 V, 1.0 ms and 20 Hz, 0.737 in control before sympathetic stimulation, 6.821 in stimulation of the sympathetic nerve at 2.5 V, 1.0 ms and 20 Hz. Real value of vertical scale should be multiplied by  $10^{-3}$  in lower pannel of A and  $10^{-6}$  in others. Notations are as in Fig. 1.

**Table 2.** Alterations of HRV indexes by electrical stimulation of autonomic nerves in anesthetized rabbits

	CONTROL	VAGUS	SYMPATHETIC
MEAN	$0.205 \pm 0.003$	$0.801 \pm 0.170^{**}$	$0.195 \pm 0.003^{*}$
SD	$0.001 \pm 0$	$0.168 \pm 0.049^{**}$	$0.003 \pm 0.001^{**}$
CV	$0.005 \pm 0.001$	$0.203 \pm 0.057^{**}$	$0.015 \pm 0.003^{**}$
LF	$0.20 \pm 0.04$	$1354.70 \pm 683.32^{**}$	$0.49 \pm 0.09^{*}$
HF	$0.32 \pm 0.10$	$4196.14 \pm 2118.08^{**}$	$0.21 \pm 0.08$
LF/HF	$0.65 \pm 0.27$	$0.32 \pm 0.25^{*}$	$2.5 \pm 0.68^{*}$

VAGUS, electrical stimulation of the vagus nerve ; SYMPATHETIC, electrical stimulation of the sympathetic nerve. No-tations are as in Table 1.

**Table 3.** Effects of autonomic blockers on HRV indexes in anesthetized rabbits

	CONTROL	ATROPINE	PROPRANOLOL
MEAN	$0.205 \pm 0.003$	$0.187 \pm 0.009^{*}$	$0.287 \pm 0.006^{**}$
SD	$0.001 \pm 0$	$0.002 \pm 0$	$0.003 \pm 0.001^{*}$
CV	$0.005 \pm 0.001$	$0.010 \pm 0.001^{**}$	$0.010 \pm 0.004^{*}$
LF	$0.20 \pm 0.04$	$0.22 \pm 0.12$	$0.10 \pm 0.02^{**}$
HF	$0.32 \pm 0.10$	$0.03 \pm 0.01^{**}$	$0.20 \pm 0.05$
LF/HF	$0.65 \pm 0.27$	$7.36 \pm 1.66^{**}$	$0.48 \pm 0.05^{*}$

ATROPINE, after injection of atropine ; PROPRANOLOL, after injection of propranolol. Notations are as in Table 1

**Fig. 2**

가  
가  
자율신경계 차단제가 심박수 변이율에 미치는 영향  
atropine -  
propranolol  
Atropine R - R  
 $0.187 \pm 0.009$  sec  
( $p < 0.05$ ), 320 /min 가

( $p < 0.01$ ) LF/HF 가  
( $p < 0.01$ ). atropine

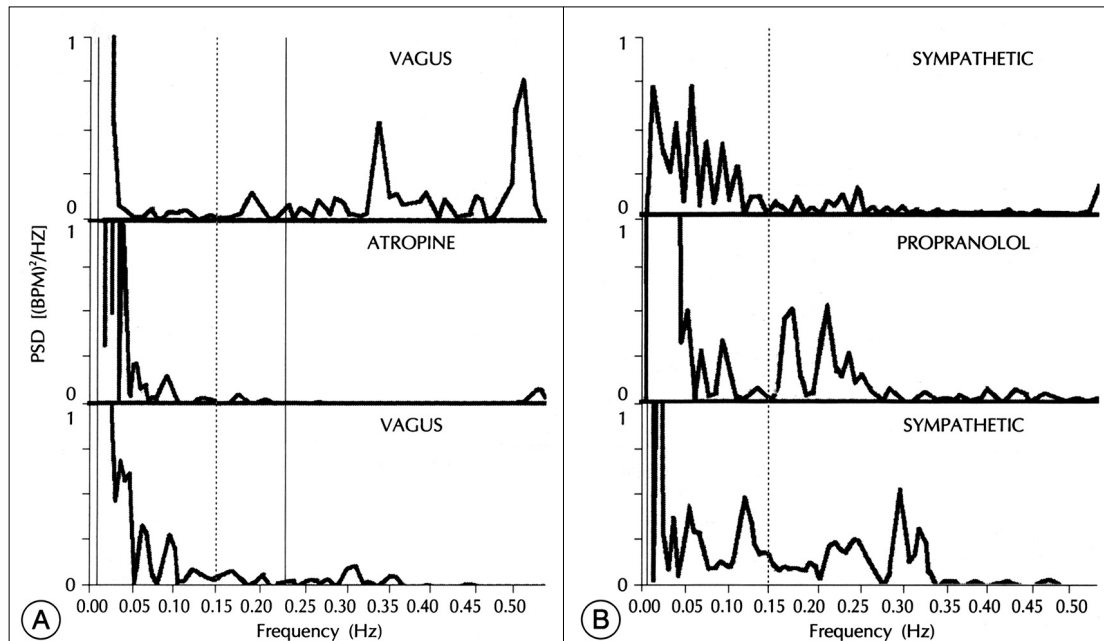
가  
propranolol R - R  $0.287 \pm 0.006$  sec  
가 ( $p < 0.01$ ) 209 /min  
( $p < 0.01$ )

propranolol LF/HF  $0.48 \pm 0.05$   
( $p < 0.05$ )

propranolol  
(Table 3).

**Fig. 4**

atropine  
가가 , propranolol



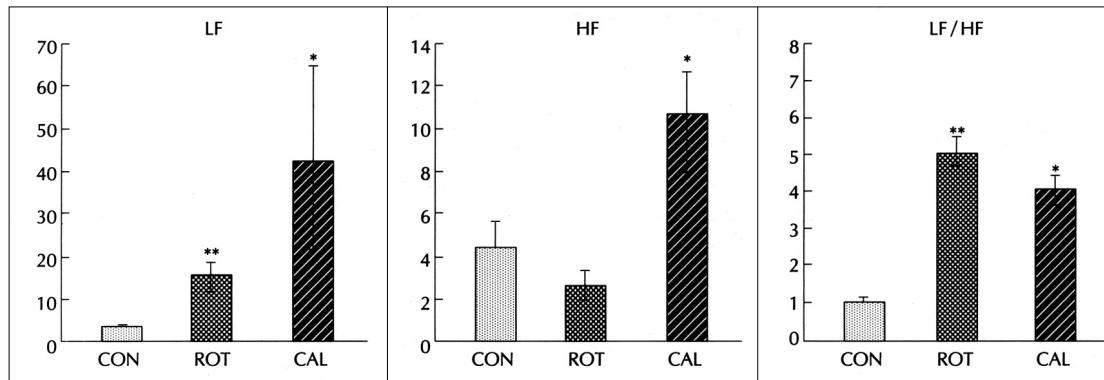
**Fig. 4.** Effects of autonomic blockers on power spectrum induced by electrical stimulation of autonomic nerves. A : effects of atropine on power spectrum induced by vagus stimulation. LF/HF was 0.066 in vagus stimulation before atropine treatment (upper), 5.503 in atropine treatment (middle), 1.250 in vagus stimulation under atropine treatment (lower). B : effects of propranolol on power spectrum induced by sympathetic stimulation. LF/HF was 2.178 in sympathetic stimulation before propranolol treatment, 0.434 in propranolol treatment, 0.689 in sympathetic stimulation under propranolol treatment. Real value of vertical scale should be multiplied by  $10^{-3}$  in upper pannel of A and  $10^{-6}$  in others. Notations are as in Fig. 1.

**Table 4.** Alterations of HRV indexes by vestibular stimulation in unanesthetized and anesthetized rabbit

	UNANESTHETIZED			ANESTHETIZED	
	CONTROL	ROTATION	CALORIC	CONTROL	ELECTRIC
MEAN	0.226 $\pm$ 0.008	0.201 $\pm$ 0.005*	0.209 $\pm$ 0.009*	0.205 $\pm$ 0.003	0.192 $\pm$ 0.003*
SD	0.005 $\pm$ 0.001	0.008 $\pm$ 0.001*	0.010 $\pm$ 0.001**	0.001 $\pm$ 0	0.001 $\pm$ 0**
CV	0.020 $\pm$ 0.002	0.039 $\pm$ 0.004*	0.046 $\pm$ 0.003**	0.005 $\pm$ 0.001	0.005 $\pm$ 0
LF	3.35 $\pm$ 1.03	14.97 $\pm$ 4.03**	42.43 $\pm$ 20.14*	0.20 $\pm$ 0.04	0.72 $\pm$ 0.10**
HF	4.25 $\pm$ 1.68	2.96 $\pm$ 0.58	10.40 $\pm$ 2.09*	0.32 $\pm$ 0.10	0.20 $\pm$ 0.09
LF/HF	0.79 $\pm$ 0.25	4.97 $\pm$ 0.72**	4.02 $\pm$ 0.92**	0.65 $\pm$ 0.27	3.80 $\pm$ 0.27**

ROTATION, sinusoidal rotation of the whole body at 0.04 Hz ; CALORIC, cold irrigation into the external auditory canal ; ELECTRIC, electrical stimulation of the vestibular nerve. Notations are as in Table 1

가 0.201  $\pm$  0.005 sec  
(p<0.05) 299 /min 가  
14.97  
전정기관 자극이 심박수 변이율에 미치는 영향  $\pm 4.03$ (beats/min) 2/Hz 가  
(p<0.05) LF/HF가 4.97  $\pm$  0.72 가  
(p<0.01). R - R  
가 0.209  $\pm$  0.009 sec 가  
(p<0.05),  
R - R 가 (p<0.05),



**Fig. 5.** Effects of vestibular stimulation on power spectrum in unanesthetized rabbits. LF, low frequency area ; HF, high frequency area ; CON, control ; ROT, sinusoidal rotation of the whole body ; CAL, cold water irrigation into external auditory canal. \* ; compared with control. Vertical scale is an arbitrary number.

가 LF/HF 4.02± thane epinephrine  
0.92 가 (p<0.01). 가 ,<sup>28)</sup> R-R  
가 가  
가 가  
가 (p<0.05), LF/HF  
가 (p<0.01) LF/  
HF가 3.80±0.27 가 (p<0.01).  
가 가  
(Table 4 and Fig. 5). 가  
고 안 가 가  
가 R-R R-R , 가 ,  
R-R ,<sup>10)</sup>  
,<sup>10)</sup> 가  
,<sup>11)12)</sup> R-R LF/HF가  
0.15 Hz , 가 LF/HF가 가 가  
가 ,<sup>17)18)</sup> Atropine  
LF/HF 가  
, propranolol LF/HF  
Urethane 가 가 ure-<sup>10)19)</sup>

Money <sup>21)</sup>

, , 가

Doweck <sup>22)</sup>

. Yates <sup>29)</sup> Lee <sup>5)</sup>

가 가

. Koch <sup>31)</sup>

, Yates <sup>30)</sup>  
(n. tractus solitarius)

phrine 가 가 epinephrine norepine -  
, Gordon <sup>32)</sup>  
가

가

가  
<sup>6)</sup>

가 LF/HF가 가

가 가

## 요 약

<sup>26)</sup>  
가 LF/HF가 가 ,  
가 가 LF/HF  
가 가

연구배경 :

가  
가

가

방 법 :

가 가

R - R , R - R ,

가

가

결 과 :

Urethane R - R 가  
가 가

⊢ LF/HF

가

R - R 가 가

Doweck <sup>22)</sup>

가 LF/HF가

R - R

가 가 ,

가 LF/HF가 가 . atro -  
pine 가 LF/  
HF 가 , propranolol  
LF/HF  
가 .  
R - R  
가 가 , 가  
LF/HF가 가 .  
가 가  
LF/HF가 가 .  
결 론 :

가 가 .

중심 단어 : . . .

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