Interhemispheric EEG Coherence Before and After Partial Callosotomy

Jacques Montplaisir, Toré Nielsen, Jean Côté, Diane Boivin, Isabelle Rouleau and Guy Lapierre

Key Words

Callosotomy
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Seizures, Intractable
Sleep

INTRODUCTION

The extent to which interhemispheric brain processes mediate the functions of human sleep remain unclear, in part, due to a lack of valid, noninvasive measures of the interhemispheric transfer and integration of information. In the present study, we explored EEG coherence in sleep as a measure of interhemispheric integration before and after surgical section of the corpus callosum. Specifically, we compared EEG coherence from homologous electrode sites in two epileptic patients on whom partial callosotomy was performed to alleviate intractable seizures.[1-4]

The EEG coherence function has previously been used to examine interhemispheric processes during waking cognitive tasks[5] and during sleep[6-9] even though its status as an index of interhemispheric integration in either state has not been validated. Since EEG coherence is a correlation spectrum, i.e., a measure of the extent of correlation between pairs of signals as a function of the frequency components which they contain,[10,11] coherence could be viewed as an index of functional connectivity between different brain regions. Surgical section of the corpus callosum — the major pathway of interhemispheric information transfer in the normal brain — should thus result in a lowering of EEG coherence relative to pre-surgery levels. To assess this possibility, we examined EEG coherence between homologous right and left brain regions before and after callosotomy in two patients. We examined whether EEG coherences following partial anterior callosotomy would decrease over posterior regions (especially the occipital), and whether EEG coherences following partial posterior callosotomy would decrease over anterior regions (especially the frontal).

To the extent that EEG coherence accurately reflects the anatomical disconnection produced by surgery in this small sample, its further investigation as a non-invasive index of interhemispheric integration would seem warranted. Such a measure would be particularly useful in assessing interhemispheric processes in cases of partial callosotomy and callosal agenesis.[12-15]

METHOD

Participants

Two epileptic patients were recorded polygraphically in the sleep laboratory before and after surgical section of the corpus callosum. These patients had frequent seizures that could not be controlled with anticonvulsive medications and, because of their multiple foci, could not be alleviated with lobectomy. Patient 1 (L.T.) underwent anterior callosotomy; patient 2 (F.P.), posterior callosotomy.

Procedures

Both patients were recorded polygraphically for 7 consecutive nights 2 weeks prior to surgery and an additional 7 nights 6 months after surgery. Their sleep was not interrupted during nights 1-3 of each recording period, but during nights 4-7 they were awakened during REM and NREM sleep to report dreams. An analysis of the dream content of these patients was reported previously.[16]

From the Centre D'étude du Sommeil, Hôpital du Sacré-Coeur, and Université de Montréal, Québec, Canada. Isabelle Rouleau is with the Service de neurologie, Hôpital Notre-Dame, Montréal, Québec, Canada.

Requests for reprints should be addressed to Dr. Jacques Montplaisir, Centre D'étude du Sommeil, Hôpital du Sacré-Coeur, 5400 boul. Gouin Ouest, Montréal (Québec), Canada H4J 1C5.

Table 1

Pre- and post-surgery EEG coherence means (and standard deviations) for anterior callosotomy patient L.T.

		Stage 2			Stage REM		
		pre	post	p	pre	post	p
Frontal	Delta	56.0 (10.1)	35.5 (7.3)	*	57.8 (12.0)	45.6 (12.9)	.06
	Theta	52.2 (9.2)	30.8 (9.9)	*	54.8 (10.9)	29.6 (6.3)	***
	Alpha	39.0 (3.3)	27.0 (5.9)	*	36.5 (12.4)	26.0 (6.5)	*
	Beta	16.5 (6.0)	18.2 (8.8)	ns	23.3 (10.2)	15.8 (4.9)	.06
Central	Delta	50.8 (9.8)	36.8 (10.1)	ns	38.8 (9.3)	34.7 (2.1)	ns
	Theta	45.2 (15.3)	33.2 (8.5)	ns	45.8 (7.7)	35.7 (1.1)	
	Alpha	25.0 (11.2)	26.2 (11.0)	ns	29.0 (8.4)	23.3 (2.3)	ns
	Beta	13.8 (7.5)	20.2 (17.8)	ns	15.0 (6.7)	14.0 (1.0)	ns
Parietal	Delta	39.5 (7.4)	14.8 (9.2)	*	42.7 (6.0)	33.4 (6.6)	
	Theta	39.2 (8.5)	20.8 (9.3)	*	38.6 (5.7)	32.4 (6.6)	
	Alpha	29.2 (5.0)	16.5 (5.1)	*	28.7 (5.5)	20.2 (3.4)	
	Beta	10.5 (3.4)	12.5 (5.0)	ns	15.2 (3.7)	10.0 (3.3)	
Occipital	Delta	54.4 (3.4)	13.5 (5.5)	***	35.2 (14.3)	14.8 (6.7)	**
	Theta	60.6 (7.8)	23.2 (4.5)	***	37.3 (14.5)	14.5 (7.0)	***
	Alpha	44.4 (6.2)	20.0 (5.0)	***	32.2 (11.6)	20.1 (6.5)	*
	Beta	22.4 (5.7)	11.8 (3.0)	*	19.0 (6.2)	10.9 (6.2)	*

*$p < .05$ **$p < .01$ ***$p < .001$

location, the observed decrements were least robust for beta.

Posterior Callosotomy

Surgical section of the posterior corpus callosum (F.P.) also led to marked overall decrements in coherence in REM and NREM stages of sleep (Table 2). In this case, the magnitude of decrease appeared equivalent for both stages of sleep, with decreases found in 10/16 frequency bands sampled in stage 2 NREM and 9/16 bands sampled in stage REM. Decreases were statistically significant or nearly significant for most frequency bands over the central (7/8), parietal (7/8), and occipital (5/8) regions, but not for frequency bands over the frontal (0/8) region.

Results reported above were obtained for electrode placements in the parasagittal mon-

Table 2

Pre- and post-surgery EEG coherence means (and standard deviations) for posterior callosotomy patient F.P.

		Stage 2			Stage REM		
		pre	post	p	pre	post	p
Frontal	Delta	62.3 (11.6)	55.8 (10.1)	ns	65.1 (10.2)	69.7 (10.4)	ns
	Theta	58.9 (6.3)	50.8 (13.1)	ns	56.1 (11.9)	59.8 (7.0)	ns
	Alpha	52.3 (1.9)	51.2 (9.6)	ns	46.6 (8.3)	48.4 (9.0)	ns
	Beta	28.0 (16.0)	30.0 (8.0)	ns	40.6 (12.6)	40.9 (7.5)	ns
Central	Delta	46.3 (1.5)	26.6 (7.4)	**	34.3 (12.6)	27.5 (8.3)	ns
	Theta	43.3 (8.6)	19.2 (1.8)	***	41.6 (5.0)	16.0 (5.1)	***
	Alpha	28.8 (6.8)	13.8 (4.7)	*	25.1 (7.4)	6.0 (2.4)	***
	Beta	20.8 (13.1)	6.6 (2.9)	**	30.4 (7.5)	9.2 (3.9)	***
Parietal	Delta	39.3 (3.9)	25.0 (7.7)		40.3 (10.1)	40.8 (6.2)	ns
	Theta	41.5 (9.5)	22.6 (8.2)		47.3 (5.4)	33.7 (6.7)	
	Alpha	28.8 (7.4)	19.6 (5.5)	.09	34.4 (4.3)	20.7 (6.2)	***
	Beta	28.3 (11.0)	12.0 (4.9)		33.0 (7.2)	15.0 (5.4)	***
Occipital	Delta	37.8 (8.1)	23.0 (6.3)	*	30.0 (9.8)	24.0 (11.6)	ns
	Theta	38.5 (9.2)	33.0 (2.7)	ns	36.1 (12.9)	24.2 (8.4)	*
	Alpha	32.3 (10.1)	19.8 (1.9)	*	22.9 (7.9)	15.4 (5.7)	*
	Beta	19.8 (9.4)	12.8 (2.2)	ns	22.7 (10.2)	10.4 (4.4)	**

$^{*}p < .05$ $^{**}p < .01$ $^{***}p < .001$

tage; however, similar results were also obtained for placements in the Queen Square montage, even though the EEG coherence values for these sites were much lower overall.

DISCUSSION

The present results lend some validity to the use of the [illegible] coherence function to quantify [illegible] integration. The present [illegible] surgical section of the corpus callosum results in a generalized decrease in EEG coherence in most frequency bands and over most brain regions sampled, suggests that the measure does indeed reflect processes of callosal transfer in the intact brain. Moreover, these results suggest that EEG coherence changes measured from individual placements reflect the anatomical loci of specific interhemispheric functions.

Specifically, in patient F.P., for whom surgical section was restricted to the posterior half of the corpus callosum, a topographically specific and marked reduction in EEG coherence occurred over the posterior regions while high coherence values persisted over the frontal regions. EEG coherence over occipital regions decreased less than over central and parietal regions, likely reflecting the fact that a portion of the splenium was spared during surgery.

Results for patient L.T., for whom a large anterior portion of the corpus callosum was sectioned, indicated marked reductions in EEG coherence over all brain regions except the central. Thus, changes of large magnitude were seen over posterior regions where, presumably, callosal fibres remained connected, and no changes were seen over central regions where, presumably, underlying fibres were sectioned. These discrepancies are not easily explained, but may be related to the extensiveness of the surgical section (almost 65% of the commissure), to the definition of our electrode montage, or to the fact that epileptic foci were located in the supplementary motor areas of each hemisphere in this patient.

The decreases in coherence after callosotomy seen in our patients may thus indicate that the corpus callosum contributes to interhemispheric coherence in the intact brain. However, other interpretations of these data are possible. One possibility is that the decreases in coherence after callosotomy reflect a decrease in epileptic activity — an activity that is, in many patients, synchronized over the two hemispheres prior to surgery and partially alleviated by surgical section. However, if epileptic activity is a major contributor to the coherence index, one would expect to observe high coherence values in epileptic patients prior to surgery. In fact, coherence values slightly lower than the normal range[8] were measured prior to surgery. Specifically, the range of coherence values in normal subjects reported by Dumermuth's group was between 35 and 85, whereas in our two patients values ranged only between 9 and 65. These differences suggest that epileptic activity had no major synchronizing effect on the two hemispheres prior to surgery. Also, our patients had rather normal background EEG activity, low interictal spike frequencies, and no recorded seizures during the 8 nights of the pre-surgery experimental procedure.

A second alternative explanation of our results is that the observed decreases in coherence reflect generalized brain damage secondary to surgery. However, this possibility is unlikely given the topographical specificity of our findings. High coherence values were maintained in the anterior regions in the patient with posterior callosotomy, suggesting that the drop in coherence occurred primarily over the anatomical locus of surgery.

SUMMARY

Measures of interhemispheric EEG coherence during REM and NREM sleep reflect the functional connectivity of the right and left hemispheres mediated by the corpus callosum. Surface recordings of interhemispheric coherence in two patients reflected fairly accurately the degree of anatomical section produced by partial callosotomy. With further development, EEG coherence may prove useful as a noninvasive method for assessing interhemispheric integration under different physiological and experimental conditions.

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Key Words
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